PUGET SOUND NEARSHORE ECOSYSTEM RESTORATION

FINAL INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT

July 2016

Prepared In Support of

US Army Corps of Engineers
Seattle District

PUGET SOUND NEARSHORE
ECOSYSTEM RESTORATION PROJECT

Washington Department of
FISH and WILDLIFE

This page was intentionally left blank to facilitate double sided copying.

EXECUTIVE SUMMARY

The Seattle District Corps of Engineers (Corps), collaborating with the Washington Department of Fish and Wildlife (WDFW) as local sponsor, along with many other regional partners, has conducted a General Investigation (GI) to evaluate problems and potential solutions to ecosystem degradation and habitat loss in Puget Sound, Washington. The Puget Sound Nearshore Study (Nearshore Study) is authorized under Section 209 of the River and Harbor Act of 1962 (Pub. L. 87–874). The Corps and local sponsor are recommending implementation of restoration actions at three sites throughout the study area as the outcome of the Nearshore Study. The estimated project first cost to restore these sites is $451,627,000 (March 2016 price level).

The Puget Sound region is characterized by steep glacially carved terrain with high mountainous regions transitioning rapidly to deep marine waters. The nearshore zone is the narrow area at the interface of terrestrial, freshwater, and marine ecosystem types that rings the Puget Sound. The nearshore zone is composed of features such as beaches, embayments, and deltas that are shaped by the interaction of coastal geomorphology and local environmental conditions (e.g., wave energy, salinity) and provides important ecological services. Due to the significant impact of human-caused changes to the nearshore zone, the zone is a strategic focus for initiatives that improve the health of Puget Sound, including this Puget Sound Nearshore Study. Analysis of this complex zone was based on guidance provided by the Nearshore Study's interdisciplinary team of scientists. The Nearshore Science Team (NST) has overseen the delivery of a series of peer-reviewed technical reports that provide the foundation of the Nearshore Study. These analyses formed the basis for identification of a problem of national significance and to planning objectives necessary to address identified issues.

Six major changes to the physical characteristics of the nearshore have been identified:

1. Large river deltas have significantly reduced in size (27% decrease in shoreline length due to tidal barriers and armoring).
2. 35% of historical coastal embayments have been lost by being filled in or disconnected by tidal barriers.
3. Sediment input has been disconnected at beaches and bluffs (over 25% of the shoreline is armored)
4. 74% of tidal wetlands surrounding the shores of Puget Sound have been lost.
5. The Puget Sound shoreline has become shorter and more artificial, decreasing in length by 15%.
6. Many shorelines are experiencing multiple stressors and cumulative impacts.

As of 2016, 13 fish and marine mammal species in Puget Sound are listed as threatened or endangered species under the Endangered Species Act (ESA). Within the study area, there are three listed endangered species and 10 threatened species. Recovery plans for eight of the ESA-listed species have been, or are being, developed by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service. Actions proposed by the Nearshore Study support recovery of ESA-listed salmon consistent with NMFS's salmon recovery plans.

Local, State, Tribal, and Federal agencies, along with concerned citizens, nonprofit organizations, ports, and businesses recognize the need to identify nearshore ecosystem problems, evaluate potential solutions, and to restore and protect the critical ecosystem functions of the nearshore zone. The proposed actions in the Nearshore Study are integral to this comprehensive effort.

The Federal and state plan to accomplish Puget Sound recovery is the Puget Sound Action Agenda. The Action Agenda is prepared by the Puget Sound Partnership (PSP), a state agency, and is endorsed by the U.S. Environmental Protection Agency for this estuary of national significance under the National Estuary Program. In consultation with other Federal and state agencies, tribal governments, industry representatives, and others, the PSP has documented priorities for Puget Sound recovery and implementing the restoration actions proposed by the Nearshore Study is identified in the Action Agenda as a near-term priority for Puget Sound recovery. In addition, authorization and implementation of the sites included in the recommended plan would significantly contribute to the Action Agenda target of restoring over 2,100 acres of estuarine habitat by 2020. The Action Agenda has a total of 21 ecosystem recovery targets, one of which is estuarine habitat. Other Federal, state, local, Tribal, and non-governmental organizations each have a role in meeting those targets. The Corps' authorities are best suited to the restoration of aquatic habitat and therefore the nearshore zone is where the Corps is identified as having a role.

The Nearshore Study is highlighted in the Puget Sound Federal Agency Action Plan, which addresses the protection and restoration of Puget Sound and the Washington coast. The Action Plan responds to recent concerns raised by The Treaty Tribes of Western Washington about continued habitat losses and associated diminishment of treaty-protected fishery resources.

Based on principles of landscape ecology and ecological restoration, and consistent with Corps planning guidance, the Nearshore Study has identified principles for nearshore restoration that support a process-based approach. Process-based restoration includes intentional changes made to an ecosystem to allow natural processes, including unconstrained tidal hydrology, natural sediment erosion and accretion, and accumulation of driftwood, to occur. Restoration typically involves actions supporting or restoring the dynamic processes that generate and sustain desirable nearshore ecosystem structure (e.g., eelgrass beds) and functions (e.g., salmon production, bivalve production, and clean water). In most cases, this involves removing or modifying human-built structures that have interfered with essential ecosystem processes. Process-based restoration is distinguished from species-based restoration, which aims to improve habitat conditions for a single species or group of species. Nearshore Study objectives seek to benefit the entire ecosystem, with associated improvements in the delivery of broader ecosystem functions and qualities.

The results of the Nearshore Study are based on a comprehensive analysis of historical and current conditions in the Puget Sound nearshore zone. Technical reports characterize the impacts of shoreline and watershed alterations on nearshore ecosystem processes, identify the fundamental causes of the observed ecosystem degradation, and assess which of the causes most need to be addressed through restoration. The *Change Analysis* (Simenstad et al. 2011) "is a comprehensive, spatially-explicit assessment of the extent of change over Puget Sound's shorelines, estuaries, and deltas". The Change Analysis quantified structural and physical change between historical (1850s to 1890s) and current (2000 to 2006) conditions. Building on the results of Change Analysis, the *Strategic Needs Assessment* (Schlenger et al. 2011a) developed a complementary evaluation tool to investigate the degree of degradation to nearshore ecosystem processes. Evaluation of the Change Analysis and Strategic Needs Assessment results led to identification of six major changes to the physical characteristics of nearshore ecosystems of Puget Sound. These changes can be grouped into two broad categories: 1) significant direct changes to the nearshore ecosystems of Puget Sound; and 2) widespread and pervasive changes. These observations support a science-based *problem statement* (Fresh et al. 2011), providing the basis for Nearshore Study planning objectives.

The planning objectives articulate the Nearshore Study's goal to restore the physiographic processes that sustain the Puget Sound nearshore ecosystem and associated diverse nationally and regionally significant resources. The planning objectives include the following:

- Restore the size and quality of large river delta estuaries
- Restore the number and quality of coastal embayments
- Restore the size and quality of beaches

To identify the "right places" for achieving planning objectives, the Study team developed a *strategy* for determining where process-based restoration would have the greatest likelihood of protecting and restoring ecosystem functions (Cereghino et al. 2012). The Study team has undertaken a comprehensive plan formulation process; over 500 potential restoration sites initially identified by a diverse group of restoration practitioners were systematically evaluated using habitat modeling, cost-effectiveness and incremental cost analysis, and design and cost evaluations.

After a coordinated effort to evaluate the overall ecosystem restoration strategy for Puget Sound, a tiered implementation approach was developed for 36 sites identified across Puget Sound deemed critical to restore the connectivity and size of large river delta estuaries, restore the number and quality of coastal embayments, and restore the size and quality of beaches and bluffs. The tiered strategy allows for a more diversified scope of projects to be implemented under various restoration authorities and partners.

Of the 36 sites, three are recommended for construction authorization under this Corps feasibility study and are presented as the recommended plan in this report. Nine additional sites are recommended for additional study, 12 sites will be investigated by the Corps using construction authorities (Continuing Authorities Program or Puget Sound and Adjacent Waters Program), and 12 sites may be completed without Corps involvement. The figure below shows the geographical location of the 36 sites and the implementation approach for each.

Sites in the recommended plan for this feasibility report include the following:

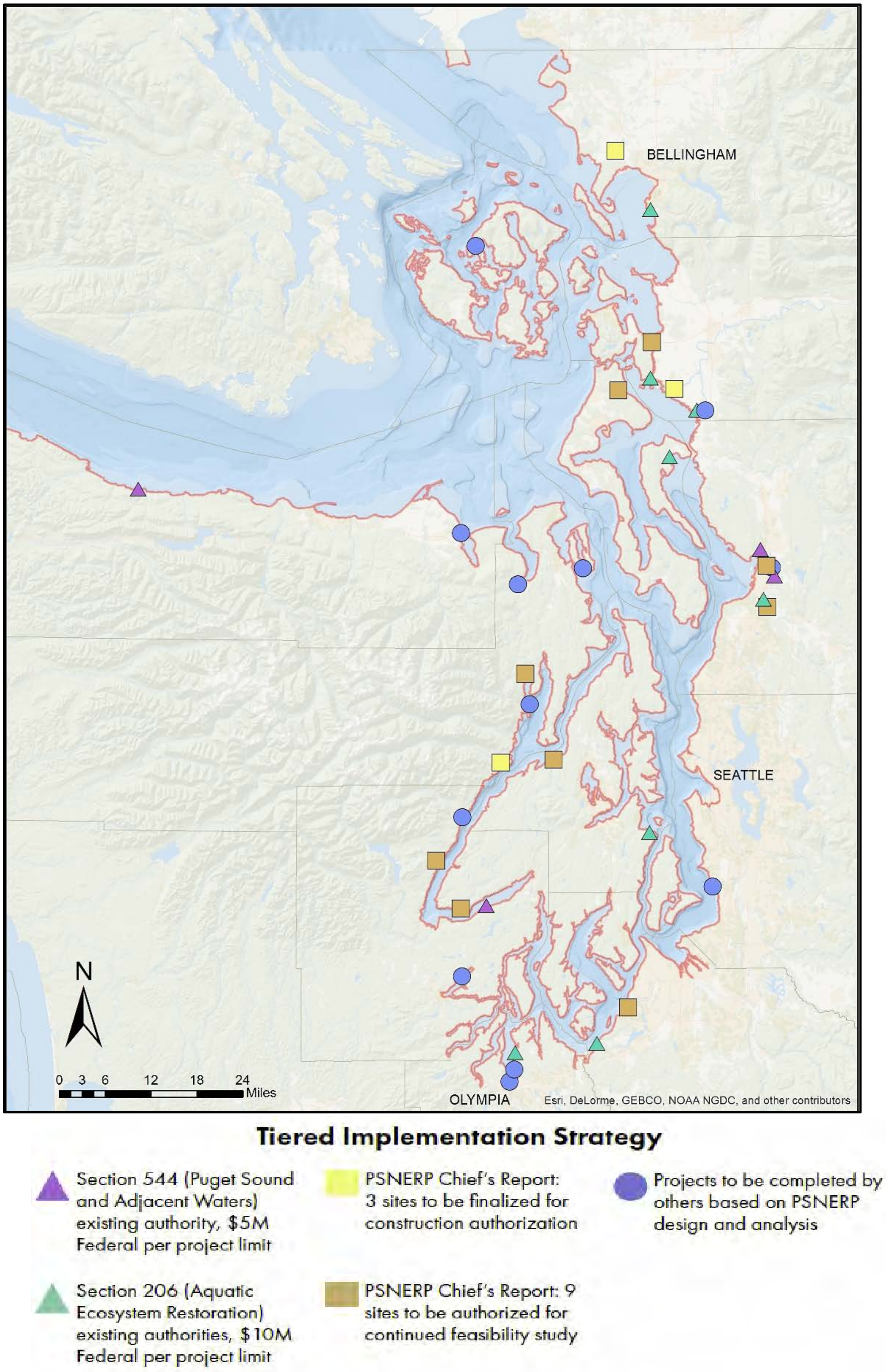
- Duckabush River Estuary
- Nooksack River Delta
- North Fork Skagit River Delta

The three sites included in the recommended plan for construction authorization range from 38 to 1,800 acres; total acreage of wetland restoration at the proposed sites is 2,101 acres. Costs, including final engineering design, environmental compliance, real estate, construction, and post-project monitoring, range from $91 million to $262 million per site.

Benefits from this recommended plan would derive from removing nearly 28,860 linear feet of shoreline stressors (including tidal barriers, nearshore fill, and shoreline armoring); thereby restoring processes that would restore 2,101 acres of tidally influenced wetlands in river deltas. These actions would restore wetlands that have either been lost due to fill or blocked by tidal barriers and lack sediment transport and delivery to beaches and embayments.

Restoration at the Duckabush River Estuary would address habitat constraints in Hood Canal, which is a partially isolated geographic section of Puget Sound. Restoration at the Nooksack River Delta would provide 25 percent of Puget Sound Action Agenda’s 2020 estuarine habitat recovery goal in a single project. Inclusion of North Fork Skagit River Delta would restore floodplain and tidal connectivity in the estuary of the Skagit River, the largest and most productive river in Puget Sound.

Restoration of these three sites would support major portions of multiple recovery plans including, but not limited to the Puget Sound Chinook Salmon Recovery Plan of 2005, the Washington Comprehensive Wildlife Conservation Strategy of 2005, the Northern Pacific Coast Regional Shorebird Management Plan of 2000, and the Pacific Coast Joint Venture of 1996, and the Summer Chum Salmon Conservation Initiative. Restoration would also benefit State of Washington Priority Habitats and Species categories of wintering waterfowl, bald eagle, and native amphibians.



Tiered Implementation Master Plan Puget Sound Nearshore Study

TABLE OF CONTENTS

*Headings and all sub-sections with an asterick therein are required by the National Environmental Policy Act.

List of Appendices

Table of Figures

Table of Tables

1 INTRODUCTION

This report documents the planning process for ecosystem restoration of the Puget Sound nearshore zone, to demonstrate consistency with U. S. Army Corps of Engineers (Corps) planning policy and to meet National Environmental Policy Act (NEPA) requirements (40 CFR 1500-1508). The study documented herein has been conducted jointly by the Corps and the Washington Department of Fish and Wildlife (WDFW). The study is named Puget Sound Nearshore Marine Habitat Restoration, Washington (WA), in annual Energy and Water Appropriation Acts. Hereinafter, the study is called the Puget Sound Nearshore Study (Nearshore Study).

1.1 STUDY AUTHORITY*

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

This Puget Sound Nearshore Study is authorized under Section 209 of the River and Harbor Act of 1962 (Pub. L. 87–874), which states, "The Secretary of the Army is hereby authorized and directed to cause surveys for flood control and allied purposes, including channel and major drainage improvements, and floods aggravated by or due to wind or tidal effects, to be made under the direction of the Chief of Engineers, in drainage areas of the United States and its territorial possessions, which include the following named localities: . . . Puget Sound, Washington, and adjacent waters, including tributaries, in the interest of flood control, navigation, and other water uses and related land resources." Per this authority, a number of changed physical conditions warrant additional study of Puget Sound, Washington, and adjacent waters. A summary of these changed physical conditions is presented in section 1.8.3.

1.2 STUDY BACKGROUND

The reconnaissance phase of the study, initiated on September 29, 1999, found that there was a Federal interest in continuing the study to the feasibility phase, in accordance with guidelines in Section 905(b) of the Water Resources Development Act (WRDA) of 1986. WDFW as the non-Federal sponsor and the Corps initiated the feasibility phase of the study on September 25, 2001 through execution of a feasibility cost sharing agreement. The feasibility phase cost was shared equally between the Corps and sponsor.

1.3 STUDY AREA AND LOCATION

The waters of Puget Sound receive all of the drainage from surrounding watersheds that cover more than 16,988 square miles, collectively referred to as the Puget Sound Basin. This basin is bordered on the east by the Cascade Mountains and on the west by the Olympic Mountains. The Puget Sound Nearshore Study area consists of the nearshore zone of the Puget Sound Basin including the Puget Sound, the Strait of Juan de Fuca, and southern portions of the Strait of Georgia that occur within the borders of the United States (Figure 1-1). While the basin occurs largely within northwestern Washington State, two of its headwater drainages originate in

Canada. The study area shoreline has a length of approximately 2,500 miles. The basin is roughly 80 percent land and 20 percent water. The total water area covers nearly 3,090 square miles at mean high water.

The study area has been divided into seven sub-basins based on geographic features including oceanographic sills and bathymetry, common issues and interests of the entities in these areas, and the water flow patterns. These sub-basins are Strait of Juan de Fuca; San Juan Islands – Georgia Strait; Hood Canal; Whidbey; and North Central, South Central, and South Puget Sound (Figure 1-1). Within these sub-basins, the study area consists of the entire nearshore zone, which includes beaches and the adjacent tops of coastal banks or bluffs, the shallow waters in estuarine deltas, and tidal waters from the head of tide to a depth of approximately 10 meters relative to the mean lower low water level (Figure 1-2). This contiguous band around the shoreline of the entire study area hosts diverse ecosystems that are shaped by coastal geomorphology and local environmental conditions, such as wave energy and salinity.

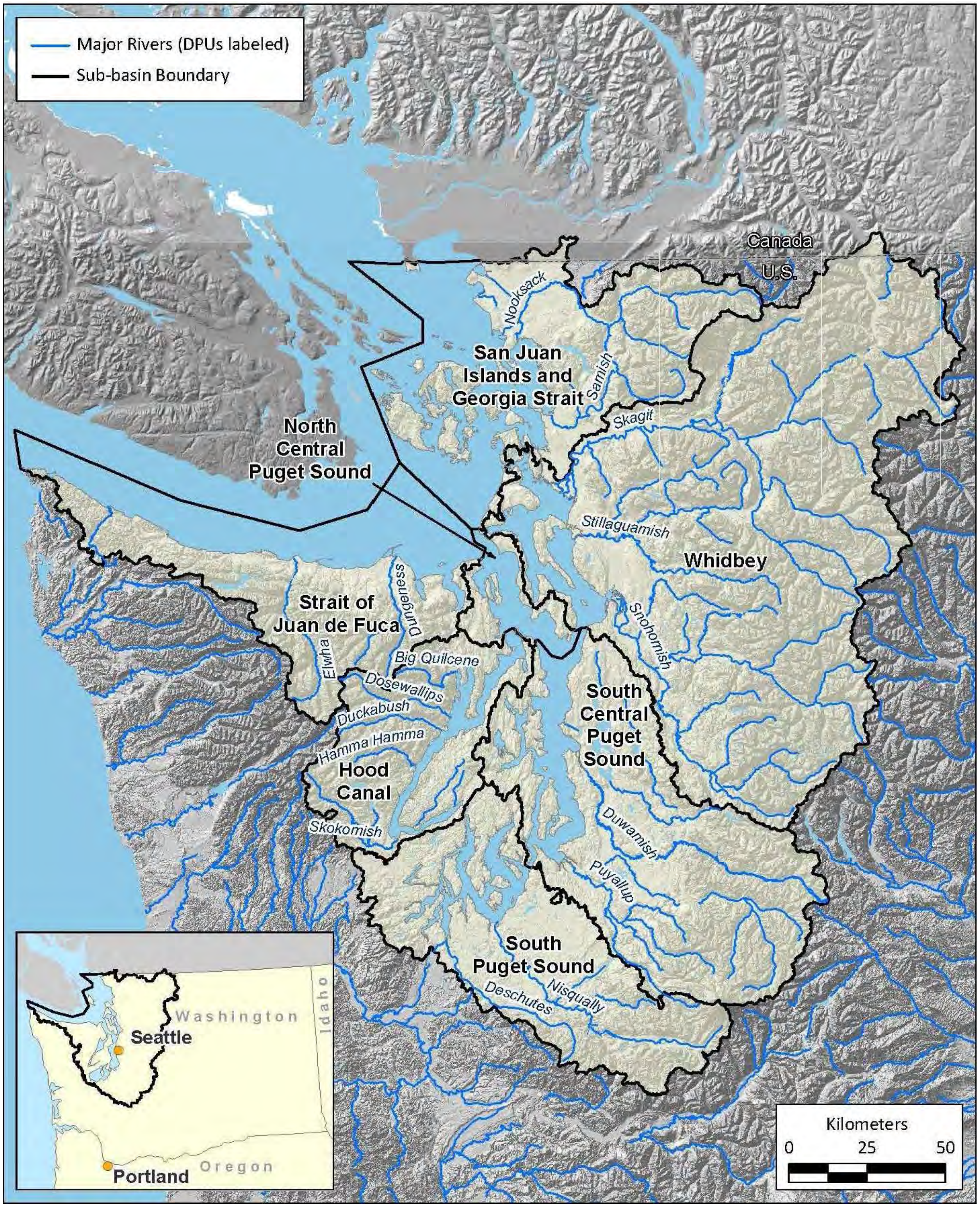


Figure 1-1. Puget Sound Nearshore Study Area with Delineated Sub-basins

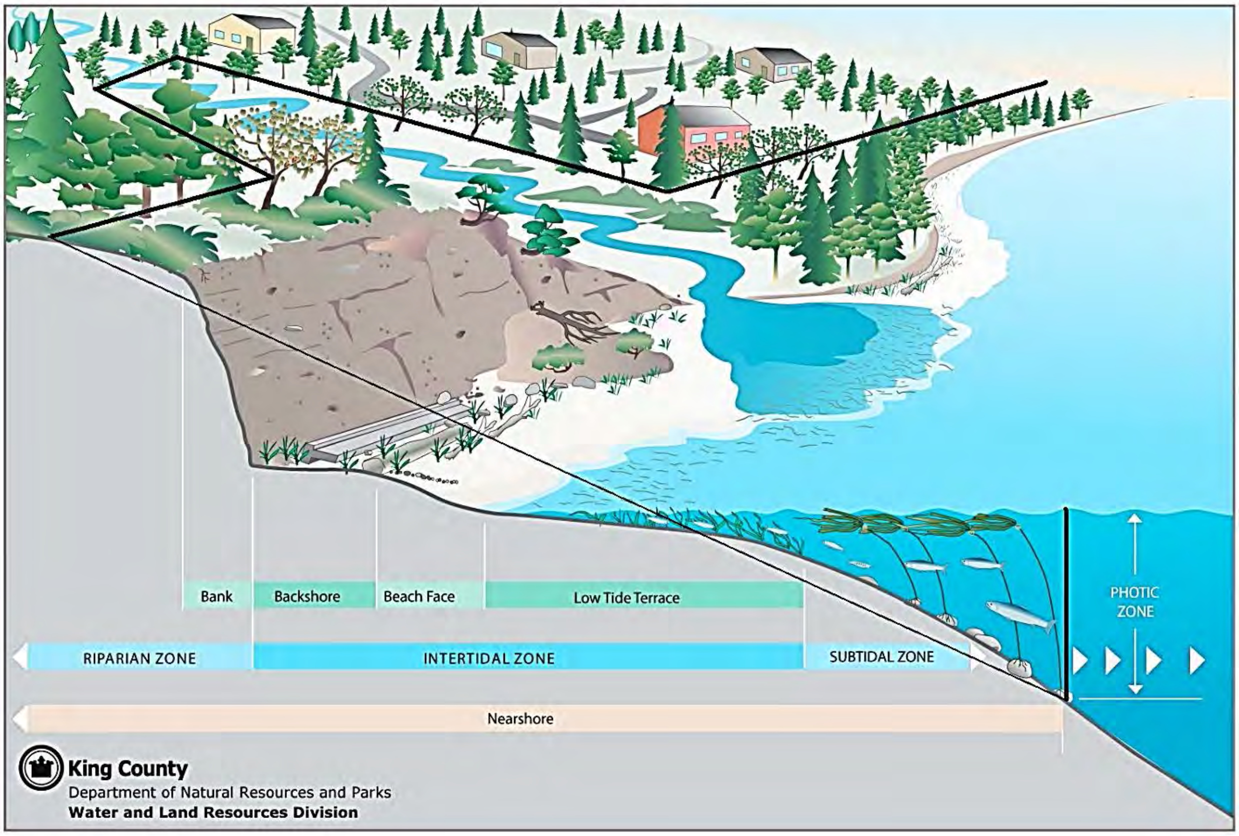


Figure 1-2. Boundaries of Nearshore Ecosystem between Riparian and Sub tidal Zones

1.4 STUDY FOCUS AND SCOPE

The focus of this study is the Puget Sound nearshore zone, the transitional zone between major ecosystem types: terrestrial, freshwater, and marine. Many of the important and unique characteristics of Puget Sound depend upon the nearshore zone, including its high biological productivity, complex food webs, diverse habitats, and large numbers of plants and animals that occupy these habitats (Kozloff 1973; Sound Science 2007). The purpose of the Puget Sound Nearshore Study is to evaluate ecosystem degradation in the Puget Sound Basin; to formulate, evaluate, and screen potential solutions to these problems; and to recommend sites that have a Federal interest and the support of a local entity willing to provide necessary local cooperation. Collectively, these restoration actions will be the recommended plan (referred to as the agency preferred alternative for NEPA compliance).

The Puget Sound Nearshore Study aims to address the continuing degradation of nearshore ecosystems through restoration of natural processes (e.g., sediment movement and tidal hydrodynamics) and restoration and/or re-creation of coastal wetlands and embayments. Scientists have extensively studied the historical character of the marine shoreline to understand the natural processes that sustain the ecosystem. Restoration projects will be designed to advance the natural processes that occur at specific sites working within the constraints of their adjacent landscape. The Puget Sound Nearshore Study does not formally consider other types of environmental concerns in Puget Sound, such as those related to water quality, contaminants, storm water, or land use management. These concerns are taken into consideration during the evaluation of alternatives, as they may affect the success or failure of projects proposed as part of the Nearshore Study, but they are being formally addressed outside of this study through other federal and state initiatives. The Project Delivery Team (PDT) is a multi-disciplinary, multi-agency team responsible for the successful development and execution of all aspects of the study. Composition of the PDT also referred to as the study team appears in Chapter 8.

1.5 PURPOSE AND NEED FOR PROPOSED ACTION*

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

The purpose of the proposed action is to restore the natural processes in the nearshore zone that sustain the biological, economic, and aesthetic resources important to the people of the Puget Sound region and the nation in a cost-effective and socially feasible manner with minimal risks, and to facilitate effective monitoring and adaptive management to maximize attainment of restoration objectives.

The Puget Sound region is home to approximately 4.3 million people, about 70 percent of Washington State's population, and has become the economic hub of the northwestern United States and an American global trade center on the Pacific Rim. Many of the region's natural resources play a major role in the economic well-being and standard of living in the area. A healthy Puget Sound is integral to the regional economy. Chapter 3 of this report provides a detailed account of nearshore ecosystem problems that have given rise to the need for a comprehensive restoration effort requiring the assistance of the Federal Government.

The need for the proposed action comes from recognizing that valuable natural resources in Puget Sound have declined to a point that the ecosystem may no longer be self-sustaining without immediate intervention to curtail significant ecological degradation. Impairment of nearshore processes and degradation of ecosystem functions are critical factors in the declining health of Puget Sound. Anthropogenic stressors causing this impairment and degradation include the direct effects of physical alterations to the landscape that have eliminated large expanses of habitat and have disrupted the major ecological processes that create and sustain habitats (see section 1.8.4 for more information on stressors). The degradation and loss of nearshore ecosystems is of critical importance because the nearshore zone serves as the connection between terrestrial, freshwater, and marine ecosystems. This means that the nearshore zone vitality, resilience, and productivity influence the productivity of the entire Puget Sound Basin. The alterations to the physiographic processes of the nearshore zone directly affect the ecosystem functions upon which humans depend such as fisheries, aquaculture, and recreation.

As of 2016, 13 species in Puget Sound are listed as threatened or endangered species under the Endangered Species Act (ESA). Within the study area, there are three endangered and 10 threatened species. Many of the ESA-listed species in Puget Sound impacted by habitat loss or degradation would benefit from restoration actions, either directly by using the restored habitat (as is the case for listed salmonids) or indirectly via reliance of their prey on the habitat (as is the case for killer whales and murrelets).

Local, state, tribal, and Federal agencies, along with concerned citizens, nonprofit organizations, port authorities, and other entities recognize the need to identify nearshore ecosystem problems, evaluate potential solutions, and restore and protect the critical ecosystem biodiversity and productivity of the nearshore zone. Because of the inherent complexities associated with the Puget Sound nearshore zone (i.e., varied ownership, mixed land use), large-scale ecosystem restoration options are beyond the capabilities of private entities, non-governmental organizations, or local governments and are more suited to Federal interests playing a key role in a coordinated restoration effort. The Corps is well suited to take the lead on this large-scale restoration effort and has the ability to use expertise in water-related resource problems to seek construction authority on restoration efforts in the nearshore zone.

1.6 PROPOSAL FOR FEDERAL ACTION

The Federal government's proposal to authorize, fund, and implement ecosystem restoration at sites in the Puget Sound Basin triggered the NEPA process recorded in this document (40 CFR 1501.2). The Corps is proposing a suite of ecosystem restoration sites around the Puget Sound nearshore zone. The Nearshore Study has identified principles for nearshore restoration that support a process-based approach. Process-based restoration typically involves actions supporting or restoring the dynamic processes that generate and sustain desirable nearshore ecosystem structure (e.g., eelgrass beds) and functions (e.g., biological productivity and clean water). In most cases, this involves removing or modifying human-built structures that have interfered with essential ecosystem processes. The types of nearshore features identified for restoration include freshwater and tidal wetlands, coastal embayments, intertidal mudflats, reconnection of estuarine tidal channels, and sediment delivery from bluff-backed beaches. Restoration of these features and natural processes requires construction work to remove human-built structures that have reduced ecosystem functions in the nearshore zone. Alternatives are presented and analyzed in section 4.6 (40 CFR 1502.14). In addition to the proposed construction projects, the Corps created a plan to ensure that monitoring and adaptive management are applied appropriately and efficiently. The monitoring and adaptive management plan is described in section 6.4.

1.7 PRIOR STUDIES, REPORTS, AND EXISTING WATER PROJECTS

The Corps' Seattle District has conducted other general investigations and has implemented other ecosystem restoration projects around Puget Sound prior to initiating the Puget Sound Nearshore Study. Lessons learned and data from these studies have been incorporated into the Puget Sound Nearshore Study where appropriate.

1.7.1 Corps Studies in the Puget Sound Area

General investigation studies underway in the Puget Sound region are listed in Table 1-1.

Table 1-1. General Investigations Underway in the Puget Sound Area

Study Name	Purpose	Description
Skokomish River General Investigation (Chief's Report signed Dec. 2015)	Ecosystem Restoration	Investigate restoration measures along the Skokomish River, which drains to Hood Canal, a naturally formed fjord of the Puget Sound Basin.
Puyallup River General Investigation	Flood Risk Management	Investigate flood risk management measures along the Puyallup River, which drains to Commencement Bay, Puget Sound.
Seattle Harbor General Investigation	Deep Draft Navigation	Investigate navigation improvements to the East and West Waterways of Seattle Harbor.

1.7.2 Corps Ecosystem Restoration Projects in the Puget Sound Area

Authorized and/or completed restoration projects in the Puget Sound area appear in Table 1-2.

Table 1-2. Corps Ecosystem Restoration Projects in the Puget Sound Area

Project Name	Authorization	Description
Puget Sound and Adjacent Waters Restoration Program (PSAW)	PSAW - WRDA[a] 2000	Restoration studies underway include a Dungeness River ecosystem restoration site.
Qwuloolt Ecosystem Restoration	PSAW - WRDA 2000	Restored tidal processes to 400 acres of previously diked pasturelands.
Seahurst Beach Restoration Phases 1 and 2	PSAW - WRDA 2000	Phase 1 construction was complete in 2005. Phase 2 construction was complete in August 2014. This restored approximately 1 mile of nearshore habitat through removal of shoreline armoring.
Stillaguamish River Ecosystem Restoration Project	WRDA 2000	Restoration of 10 sites along the Stillaguamish River including three estuary sites.
Green-Duwamish Ecosystem Restoration Project	WRDA 2000	Authorizes 45 site-specific (including 3 estuary sites) and programmatic restoration sites throughout the Green-Duwamish River Basin. Six projects have been completed, one is currently under construction, and one more is nearing the construction phase.
Deepwater Slough Estuarine Restoration Project – Phase I	Section 1135 [b]	Deepwater Slough was the largest estuarine restoration project in Puget Sound when it was implemented, opening 230 acres of intertidal and tidal channel habitat.
Carpenter Creek Estuarine Restoration Project	Section 206 [c]	The project was authorized to improve tidal flushing at two undersized culverts, reduce tidal velocities, remove fish passage barriers, and reduce habitat fragmentation restoring 22 acres of estuarine and salt marsh habitat. The local sponsor constructed this project.

Project Name	Authorization	Description
Green/Duwamish River (at Codiga Farms site) Restoration Project	Section 1135	This project created 830 linear feet of side-channel rearing habitat for juvenile salmon, a half-acre estuarine marsh, and 1.6 acres of riparian and upland planting to support wildlife.
Green/Duwamish River Turning Basin (at Hamm Creek) Restoration Project	Section 1135	The project restored a highly degraded tributary to the Duwamish River including a new 1,000-foot channel with soil amendments and plantings.
Lake Washington Ship Canal Smolt Passage Project	Section 1135	The project implemented numerous measures to minimize abrasion injury and mortality to juvenile salmon including installation of smolt flumes over the dam.
Union Slough Restoration Project	Section 1135	The project breached levees and opened 35 acres to tidal influence in the Snohomish River Estuary.

a. WRDA – Water Resources Development Act
b. Section 1135 of the Water Resources Development Act of 1986
c. Section 206 of the Water Resources Development Act of 1996

1.8 PUGET SOUND NEARSHORE STUDY SYSTEMS APPROACH

Corps guidance (Engineer Pamphlet [EP] 1165-2-502 [USACE 1999a]) states, "ecosystem restoration is a primary mission of the [Corps] Civil Works program. … the purpose of Civil Works ecosystem restoration activities is to restore significant ecosystem function, structure, and dynamic processes that have been degraded. Improving the long-term survival of self-sustaining systems delivers improved conditions for fish and wildlife resources."

The Puget Sound Nearshore Study approach is consistent with Corps policies on ecosystem restoration planning. The study bases its investigation on numerous scientific studies and findings that recognize ecosystem processes as key system drivers that, if degraded, have long-lasting, spatially extensive effects on biological communities. While difficult to assess directly, ecosystem processes are manifested in the natural landforms that they create and maintain. By completing detailed characterizations of marine landforms using historical and current data, and projections of future conditions, the Puget Sound Nearshore Study team has been able to infer the state of natural process degradation within Puget Sound. These findings serve as the condition that can be expected in Puget Sound if a project is not authorized and implemented. Figure 1-3 shows the major documents associated with plan formulation of the Nearshore Study. These technical reports are available for download at *www.pugetsoundnearshore.org*.

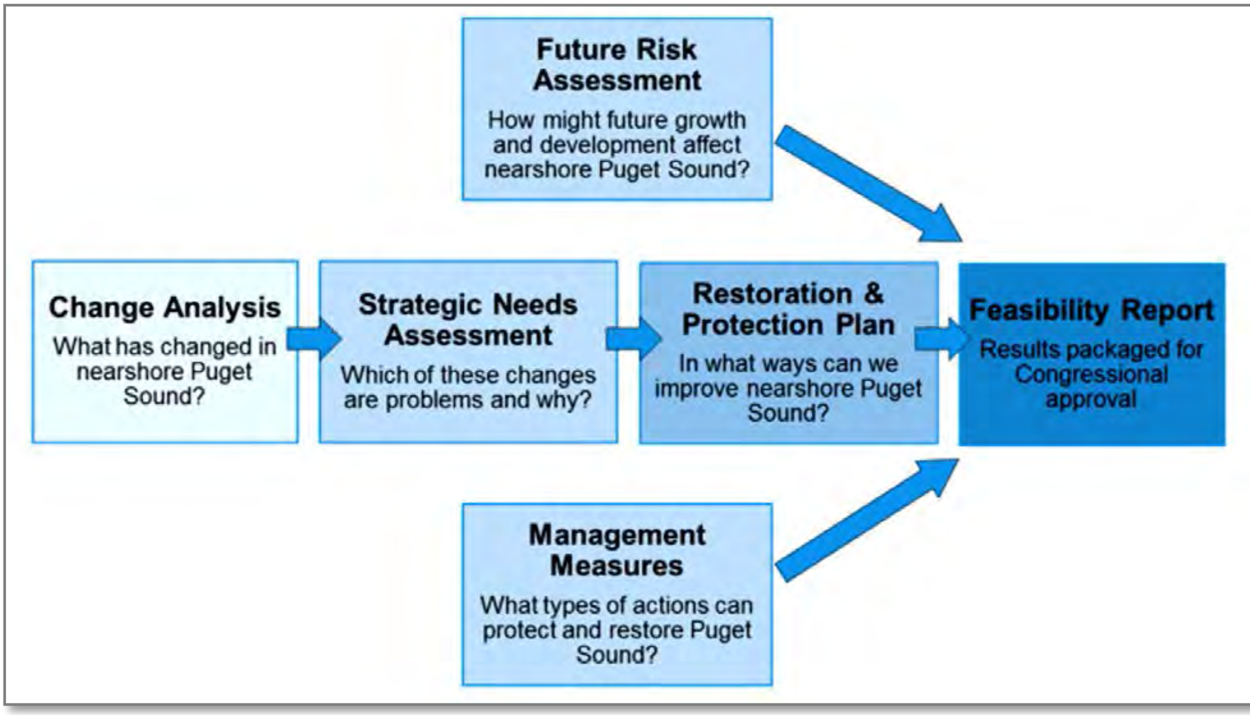


Figure 1-3. Supporting Documents in the Nearshore Study Planning Process

1.8.1 Process-based Restoration

Ecosystem processes are the interactions among physiochemical and biological elements of an ecosystem that change in character or state over time (Fresh et al. 2004). Processes operate at naturally occurring rates, frequencies, durations, and magnitudes that are controlled by human and natural factors (Goetz et al. 2004). Human attempts to control dynamic coastal systems (such as beaches, bluffs, floodplains, and river deltas) using structural approaches (such as groins, bulkheads, dikes, and levees) disrupt the natural processes and degrade nearshore ecosystems. Restoration actions aimed at restoring damaged processes enable the ecosystem to be naturally productive, self-sustaining, and diverse (Goetz et al. 2004).

The Puget Sound Nearshore Study has identified guiding principles for nearshore ecosystem restoration that favor process-based restoration over species-based restoration (see sidebar). Key physical processes such as tidal hydrology and sediment supply are understood to be essential to biotic function. The study identifies three main reasons for favoring process-based restoration (Simenstad et al. 2006):

- Without restored processes, the long-term maintenance of the structure and its associated ecological functions is highly uncertain.
- The processes are inherently involved in the functions to be recovered.
- Incorporating or accepting natural ecosystem dynamics is less likely when considering only the function an ecosystem provides to a single species.

A detailed discussion of a process-based restoration approach, as applied by the Puget Sound Nearshore Study, is provided in "Introduction and Background" of the Management Measures Technical Report (Clancy et al. 2009).

> **Process-based restoration** includes intentional changes made to an ecosystem to allow natural processes (such as erosion, accretion, accumulation of wood debris, etc.) to occur. This restoration typically involves actions supporting or restoring the dynamic processes that generate and sustain desirable nearshore ecosystem structure (e.g., eelgrass beds) and functions (e.g., salmon production, bivalve production, and clean water). Process-based restoration is distinguished from species-based restoration, which aims to improve the services an ecosystem provides to a single species or group of species as opposed to improving elements that support the entire ecosystem.

Alterations to natural processes alter nearshore ecosystem habitats (e.g. river deltas, beaches, and coastal embayments) that provide ecosystem biological and geochemical functions. These functions can be largely categorized as biodiversity, plant and animal productivity, soil fertility, water quality, and many other local and global environmental conditions. Human alterations of structures and functions affect these life-supporting components.

1.8.2 Conceptual Model Used to Support Process-Based Restoration

The Puget Sound Nearshore Study approach to process-based restoration relies upon conceptual models explaining the linkages between nearshore ecosystem processes, structures/systems, habitats, and ecological functions. These linkages, depicted in Figure 1-4 for Puget Sound beaches, are based on the Puget Sound Nearshore Study's underlying scientific hypothesis that "alterations of natural hydrologic, geomorphologic (i.e., pertaining to geological structure), and ecological processes impair important nearshore ecosystem structure and functions" (Simenstad et al. 2006).

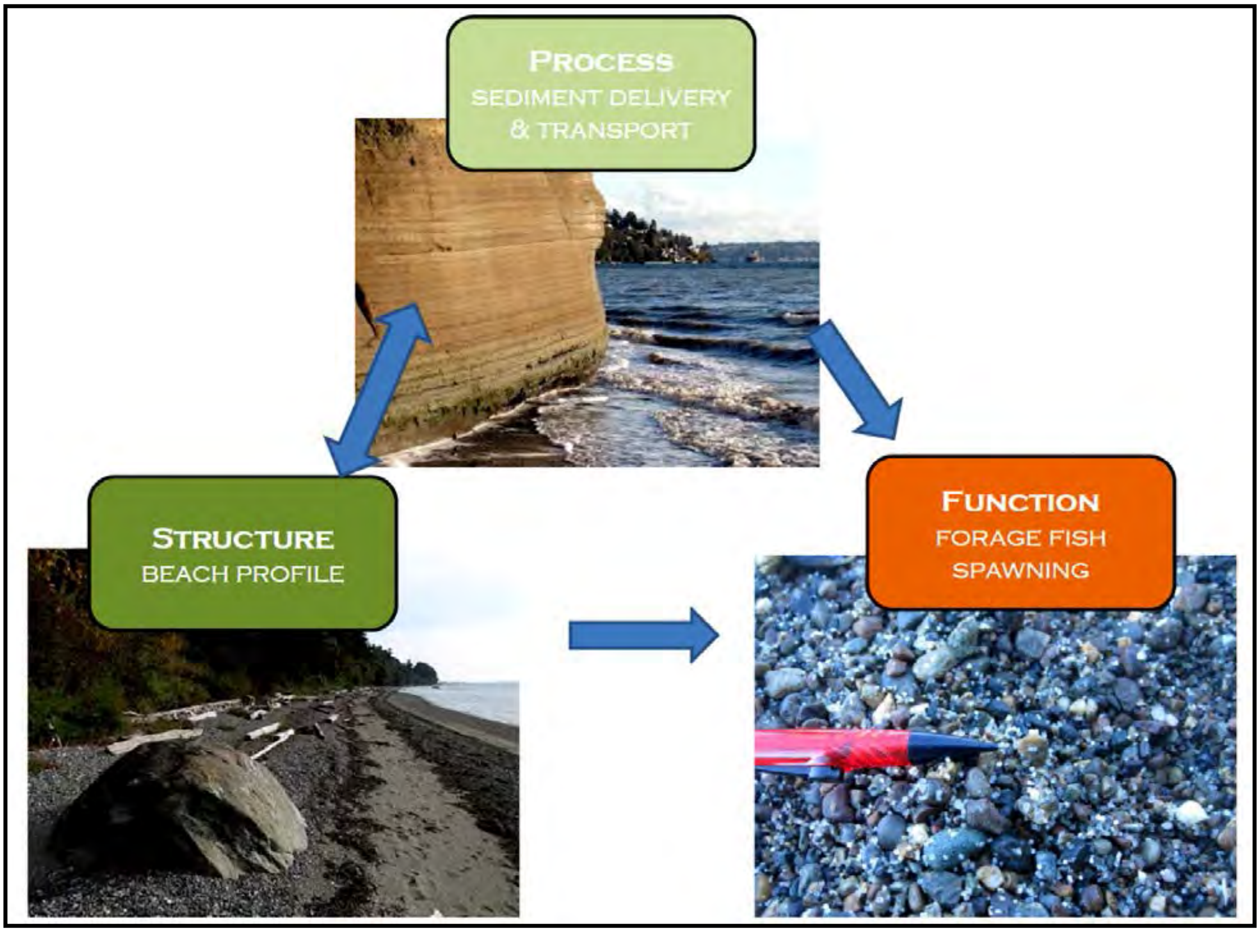


Figure 1-4. Beach Conceptual Model of Relationship of Process, Structure, and Function

1.8.3 Change Analysis

The change analysis of the Puget Sound nearshore zone (Change Analysis; Simenstad et al. 2011) serves as ". . . a comprehensive, spatially explicit assessment of the extent of change over Puget Sound's shorelines, estuaries and deltas." The change analysis report provides a detailed discussion of the Study team's approach and results in assessing change between historical and current conditions. The report provides detail on data structure and components for the Puget Sound-wide geodatabase assembled for this analysis (Simenstad et al. 2011).

The Change Analysis quantified structural and physical change between historical (ca. 1850s – 1890s) and current (ca. 2000 – 2006) conditions. This analysis correlates the location, occurrence, and amount of stressor impacts on nearshore ecosystems in the context of dominant ecosystem processes. Finally, the analysis interpreted the spatially explicit significance of the various changes and stressors in terms of impairment to ecosystem functions.

To provide a spatially explicit accounting of nearshore ecosystem process changes, the Puget Sound shoreline was delineated into geomorphically similar segments (landforms) based on the adopted geomorphic classification system (Shipman 2008). This classification provided the basis for independently classifying both historical and current landforms that reflect varying sedimentation processes (beaches) and freshwater inflow and tidal mixing (estuaries/deltas) as the dominant controlling factors.

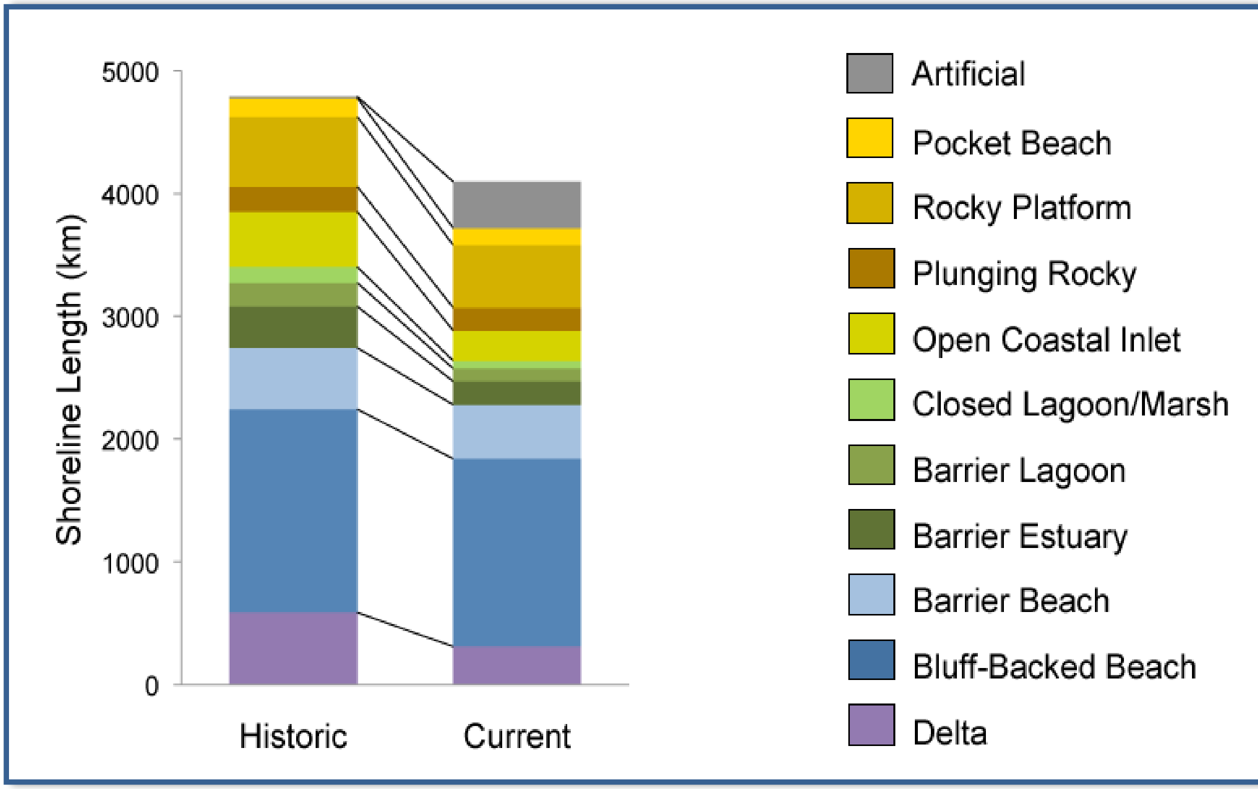


Figure 1-5. Puget Sound-wide Landform Transitions (from Simenstad et al. 2011)

The resulting change analysis geodatabase documents changes over the (current) approximately 2,466 miles of Puget Sound shoreline and corresponding 13,930 square miles of drainage area. Historical change was analyzed for each identified process unit (shoreline reach associated with a littoral drift cell) in Puget Sound, as well as in each sub-basin. Change data is tabulated and mapped in a variety of analytical outputs at the individual process unit level and summarized within Puget Sound sub-basins, among sub-basins, and Sound-wide. An example graph showing landform transition from historic to current at the Puget Sound-wide scale appears in Figure 1-5.

1.8.4 Strategic Needs Assessment

The purposes of the strategic needs assessment (Schlenger et al. 2011a) were to characterize the impacts of shoreline and watershed alterations on nearshore ecosystem processes, identify the fundamental causes of the observed ecosystem degradation, and assess which of the causes most need to be addressed in this feasibility study through restoration and protection alternatives. Specifically, the assessment does the following:

- Explains the impacts of stressors (human alterations) along shorelines and in watersheds on the nearshore processes that create and sustain the ecosystems.
- Explains the resulting effects of the impacted nearshore processes on nearshore habitat structures and functions.
- Presents a spatial analysis that applies a set of rules to assess nearshore ecosystem process degradation resulting from human alterations to physical conditions along the shoreline and throughout the watershed.
- Uses spatial analysis outputs to identify and characterize locations and magnitudes of degradation of nearshore ecosystem processes Sound-wide and in each of the sub-basins.
- Presents a discussion of the major physical changes and problems affecting the overall function of the Puget Sound nearshore ecosystems.
- Identifies recommended priorities for locations and nearshore processes to be addressed through restoration and conservation.

While the change analysis results identify ecosystem impairment, Schlenger et al. (2011a) developed a complementary methodology to investigate the degree of degradation to nearshore ecosystem processes as part of the strategic needs assessment. To develop this tool, the Study team documented scientific understanding of the impacts that shoreline and upland stressors (human alterations) have on nearshore ecosystem processes, habitat structures, and functions. For each stressor, a separate section of the strategic needs assessment report was prepared, using available scientific literature to explain the linkages among stressors, processes, structures, and functions. In addition, each section described the impacts of the stressors on socially important biota and habitats, and the distribution of the stressor throughout Puget Sound and its sub-basins.

Table 1-3. Nearshore Stressors

Stressor	Description
Tidal barriers	Structures (e.g., dikes and levees) designed to impede tidal flow
Nearshore fill	Material placed below the ordinary high water mark (OHWM) to create upland area
Shoreline armoring	Shore-parallel erosion control structures, such as bulkheads and rock revetments
Nearshore railroads	Active and abandoned railroads within 25 meters of the shoreline
Nearshore roads	Roads along the shoreline and within 25 meters of the shoreline
Marinas	Temporary and permanent boat slips, and associated in-water facilities to accommodate vessel moorage and upland support facilities
Breakwaters and jetties	Structures designed to mitigate the impact of wave energy
Overwater structures	Large industrial/commercial docks, single-family residence docks, floating docks, fixed piers, bridges, floating breakwaters, moored vessels
Dams	Barriers that block the flow of water in a stream or river channel
Stream crossings	Places where transportation corridors (i.e., roads and railroads) cross rivers, streams, and estuaries
Impervious surfaces	Pavement, buildings, and other largely impermeable areas
Developed land cover	Type of human feature present on the surface of the earth

The 12 stressors considered in the Nearshore Study (Table 1-3) were limited to those physical stressors for which sufficient Sound-wide data were available. Some of these stressors lie directly along the nearshore zone, while some are features within the contributing watershed.

The strategic needs assessment presents a process evaluation framework used to assess the degree of degradation for each of the nearshore ecosystem processes. This framework assesses co-occurrence of stressors that degrade ecosystem processes along the portions of the nearshore zone that support these important processes. An overall characterization combining the observed degradation of all 12 processes was presented for shoreline and delta process units (Figure 1-6).

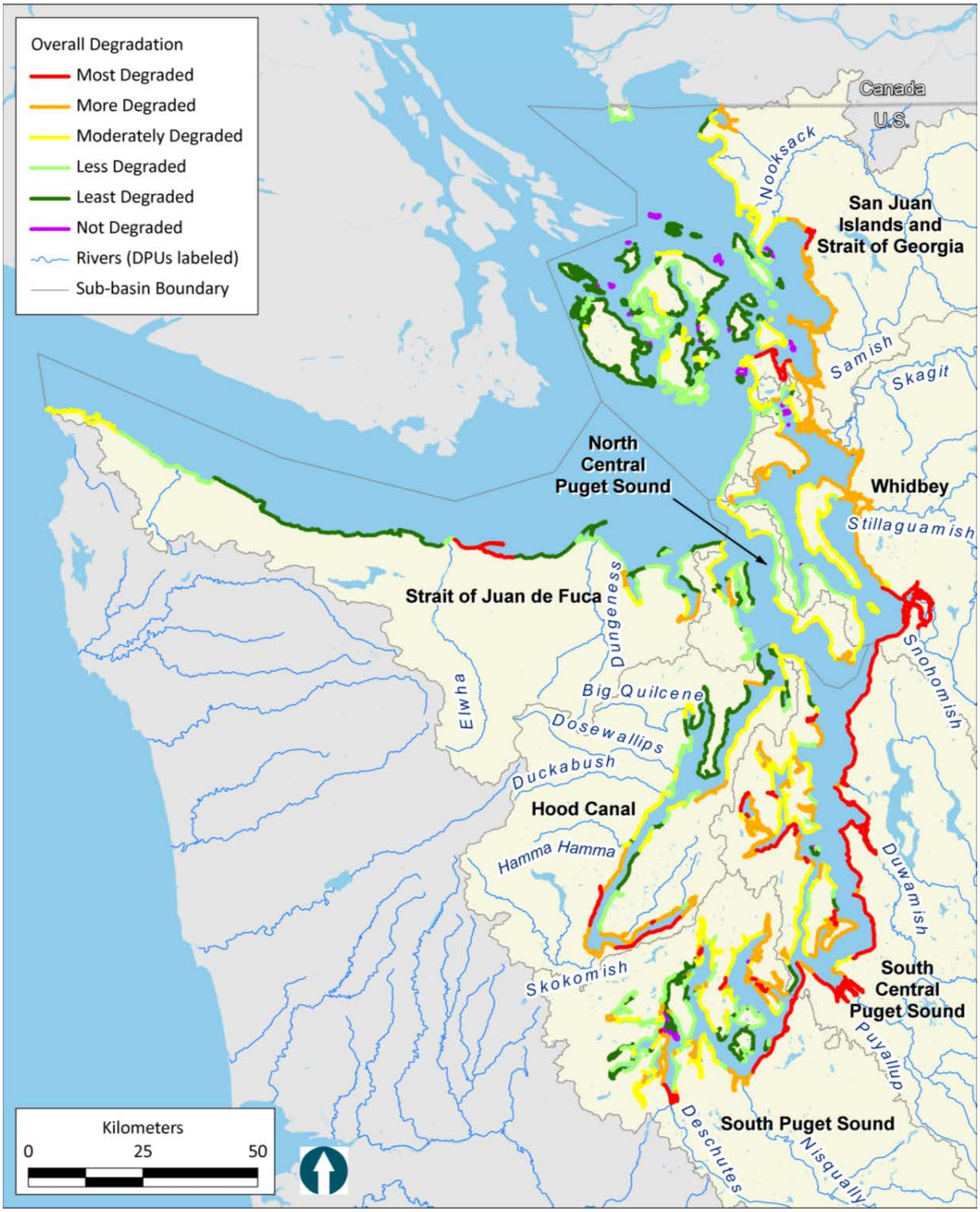


Figure 1-6. Puget Sound-wide Current Degree of Process Degradation (from Schlenger et al. 2011a)

1.8.5 Problem Statement

The Nearshore Science Team (NST; see section 8.1.3 for a description) identified six major changes to the physical characteristics of the nearshore ecosystems of Puget Sound, based on the team's evaluation of findings in the change analysis and the strategic needs assessment. These changes are described in a comprehensive document referred to as "the problem statement" (Fresh et al. 2011). Changes have two broad categories: 1) direct changes to nearshore ecosystems; and 2) widespread and pervasive changes. These observations support a science-based problem, providing a focus for evaluating restoration alternatives and formulating a plan.

Significant direct changes to nearshore ecosystems include the following:

- Large river deltas have been widely impacted by multiple alterations that significantly limit the size of the estuaries and degrade the nearshore ecosystem processes that support them. For the 16 largest river deltas in Puget Sound combined, shoreline length has declined nearly 27% from historical conditions (Fresh et al. 2011).
- Many coastal embayments, including open coastal inlets, barrier estuaries, barrier lagoons, and closed lagoons/marshes, have been eliminated or disconnected from Puget Sound by the placement of fill, tidal barriers, and other stressors. Puget Sound has experienced a loss of 305 embayment landforms (from 884 under historical conditions to 579 currently). The length of embayment shoreline in Puget Sound declined nearly 46% (Fresh et al. 2011).
- Stressors along beaches and bluffs have disconnected sediment inputs and altered sediment transport and accretion along long sections of the Puget Sound shoreline. Approximately 27% of the shoreline of Puget Sound is armored; 59% of divergent zones (a major source of sediment to Puget Sound beaches) have some armoring associated with them (Fresh et al. 2011).
- Estuarine wetlands have been extensively lost throughout Puget Sound, including a loss of 56% in the 16 largest river deltas. In particular, oligohaline (i.e. low saltwater concentration) and freshwater tidal wetlands have been almost completely eliminated (loss of 93%) in Puget Sound (Fresh et al. 2011).

Widespread and pervasive changes include the following:

- The shoreline of Puget Sound has become much shorter and simpler, as well as more artificial. Since Europeans began settling the region, Puget Sound's shoreline has had a net decline of 15% in length due to hardening the shoreline, as well as closing off bays and estuaries for development of homes and businesses. Artificial landforms now represent 10% of the shoreline of Puget Sound (Fresh et al. 2011).
- Large portions of Puget Sound have been altered by multiple types of changes that may cumulatively combine to severely degrade nearshore ecosystem processes. Approximately 40% of the shoreline of Puget Sound has been altered by a stressor (e.g., overwater

structures, roads, marinas, etc.). Only 112 of 828 shoreline segments (encompassing all of Puget Sound's shoreline with the exception of large deltas) have no stressor associated with them (Fresh et al. 2011).

The cumulative effects of these multiple human-induced stressors threaten to overwhelm the ability of naturally occurring ecosystem processes to maintain structures, biological resources, and ultimately, the biodiversity and productivity provided by the ecosystem. Thus, the synergistic efforts of restoring the nearshore processes, structures, and functions must be thoroughly coordinated and pursued simultaneously with other restoration efforts, such as the protection of water quality, freshwater resources, good land use practices, and human health.

The effects of ecosystem degradation and potential restoration opportunities are illustrated in Figure 1-7 and Figure 1-8. These images show a typical Puget Sound nearshore site not included in this study, Seahurst Beach, as a reference condition for similar sites under consideration in the Nearshore Study. These figures illustrate the site in a formally degraded condition followed by restoration of approximately 2 miles of nearshore habitat through removal of shoreline armoring. These images depict the typical types of degraded processes in the nearshore zone as well as a reference condition for a site that has undergone process-based restoration.

Figure 1-7. Reference Condition: Seahurst Beach "Before" Process-Based Restoration

Figure 1-8. Reference Condition: Seahurst Beach "After" Process-Based Restoration

1.8.6 Restoration and Protection Strategies

To inform restoration and protection strategies so that actions are directed toward "sites where we can best protect and restore nearshore ecosystem services", Cereghino et al. (2012) have further evaluated the results of the change analysis and the strategic needs assessment. This evaluation seeks to answer the following questions about nearshore ecosystem restoration and protection:

1. Where should we try to recover the ecosystem services we have lost?
2. How should our approach respond to the variable conditions found in the landscape?
3. How should we consider an individual project as part of a cohesive landscape strategy?
4. What kinds of opportunities and risks should we keep in mind as we work in different settings?

By applying principles proposed by Goetz et al. (2004) and ecosystem restoration theory reviewed by Greiner (2010), river deltas, beaches, barrier embayments, and coastal inlets were categorized based on attributes of opportunity, degradation, and risk. Statistical treatment of these attributes suggests organizing sites into groups in which management strategies of protection, restoration, or enhancement are most likely to be successful (Figure 1-9). These recommendations are identified for each landform type (e.g., beaches or embayments), but not across types. The authors (Cereghino et al. 2012) explain, "Our strategies do not attempt to compare deltas to beaches or beaches to inlets. We need deltas, beaches, embayments, and inlets to restore historical ecosystem services in the nearshore zone. The physical structure of the landscape defines landform, and the potential for a landscape to provide these services."

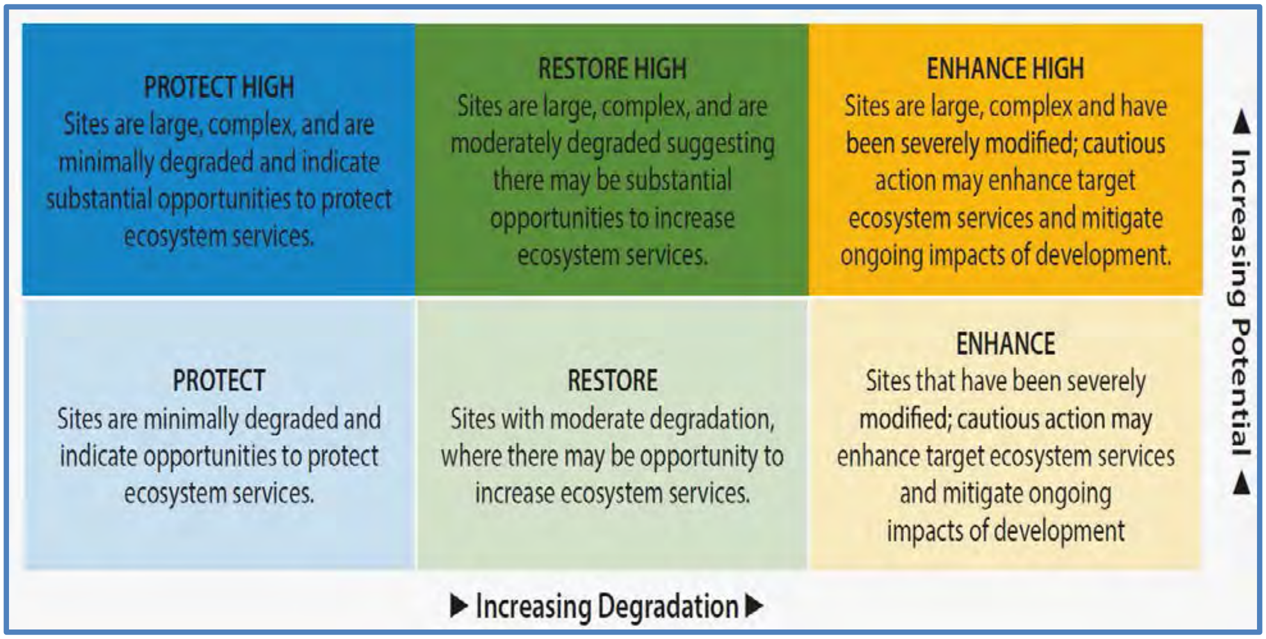


Figure 1-9. Strategic Recommendations Based on Site Potential and Degradation

In evaluating potential restoration actions, the Study team used preliminary results from the Restoration and Protection Strategies evaluation, hereafter called the “Strategies Report” (Cereghino et al. 2012), to determine whether each proposal could support restoration objectives with the “right action in the right place.” Please note that Figure 1-3 refers to this Strategies Report as the “Restoration and protection Plan”. The Corps focuses on areas of high restoration potential while other entities may choose to focus on addressing areas of high protection potential and/or high enhancement potential. More detail on this concept is provided in section 4.1.

1.9 REPORT ORGANIZATION: INTEGRATION OF NEPA COMPLIANCE & THE PLANNING PROCESS

This document is an integrated Feasibility Report and Environmental Impact Statement (FR/EIS). The purpose of the feasibility report is to identify the plan that reasonably maximizes ecosystem restoration benefits, is technically feasible, and preserves environmental and cultural values. The purpose of the EIS portion of the report is to identify and present information about any potentially significant adverse environmental effects of the alternatives and to incorporate environmental concerns into the decision-making process.

1.9.1 The 6-Step Corps Planning Process and NEPA Requirements

The six steps of the Corps planning process each align with a NEPA requirement. The planning steps are listed below followed by the document chapter and NEPA element to which they relate:

Planning Step	Analogous NEPA Requirement & Document Chapter:
Step One: **Problems and Opportunities**	Purpose and Need for Action; Chapter 2
Step Two: **Inventory and Forecast of Conditions**	Affected Environment; Chapter 3
Step Three: **Formulate Alternative Plans**	Alternatives including Proposed Action; Chapter 4
Step Four: **Evaluate Effects of Alternative Plans**	Environmental Consequences; Chapter 3
Step Five: **Compare Alternative Plans**	Alternatives including Proposed Action; Chapter 4 and 5
Step Six: **Select Recommended Plan**	Agency Preferred Alternative; Chapter 6

1.9.2 NEPA Scoping and Identification of Issues*

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

Scoping took several forms for this study. The various committees of the Nearshore Study consist of regional experts in natural resources and ecosystem restoration programs; these individuals and committees have been discussing the significance of issues related to the project throughout the life of the Study, and those concepts are captured within this document. Additionally, the primary project delivery team consulted natural resource agencies such as NMFS and USFWS, and held internal meetings to discuss the scope of issues included in this report. Furthermore, the Corps and WDFW hosted public meetings to solicit comments about this project. The comprehensive list of activities is detailed in section 8.3. The significant resources identified for detailed analysis are described in Chapter 3 and the effects of the alternatives on these resources are compared in Chapter 5.

2 NEED FOR AND OBJECTIVES OF ACTION

This chapter lays out the objectives for this ecosystem restoration project and explains their importance. The chapter begins with a statement of the Federal objective that underlies Corps ecosystem restoration efforts. Next, this chapter addresses how the resources that comprise the ecosystem are recognized as significant institutionally, technically, and publicly. The Problems and Opportunities section explains how the ecosystem has been affected, and describes opportunities the Nearshore Study has identified to address those problems. Finally, this chapter identifies planning objectives and constraints that guide plan formulation described in Chapter 4.

2.1 THE FEDERAL OBJECTIVE

The purpose of Civil Works ecosystem restoration activities is to restore significant ecosystem function, structure, and dynamic processes that have been degraded. The intent of ecosystem restoration is to partially or fully reestablish the attributes of a naturalistic, functioning, and self-regulating system.

2.2 SIGNIFICANCE OF RESOURCES: TECHNICAL, INSTITUTIONAL, PUBLIC

The Puget Sound and its nearshore zone include resources that are technically, institutionally, and publicly significant as summarized below and described in the following sub-sections:

- Puget Sound and its adjacent waters support the largest area of remaining estuarine wetlands on the West Coast, exceeding the combined total area of Columbia River and San Francisco Bay estuarine wetlands by over 30%. Because of its size, tidal exchange, and freshwater inputs, Puget Sound supports more than twice the primary productivity of Chesapeake and San Francisco bays combined, supporting a corresponding biodiversity and secondary productivity of flora and fauna (Emmett 2000, USACE 2004).

- Recognizing its uniqueness, the U.S. Environmental Protection Agency (EPA) designated Puget Sound as an "Estuary of National Significance" in 1988. To date, 28 estuaries have this designation. According to EPA, one of the many benefits of the National Estuary Program (NEP) is that they "share information about their successful approaches to environmental challenges with each other and other coastal watershed managers". That exchange is critical to the effective restoration and protection of estuarine health across all the NEPs.

- The Puget Sound Action Agenda is the Federal and state roadmap for restoring the health of Puget Sound by 2020. Proposed restoration by PSNERP is an integral component to achieving Action Agenda recovery targets. The Action Agenda has been approved by EPA as the Comprehensive Conservation and Management Plan for Puget Sound under the EPA's NEP and has been endorsed by the Puget Sound Federal Caucus (which includes the Corps of Engineers). The Action Agenda has a total of 21 ecosystem recovery targets, one of which is estuarine habitat. Other Federal, state, local, Tribal, and non-governmental organizations each have a role in meeting those targets. The Corps' authorities are best suited to the restoration of aquatic habitat and therefore the nearshore zone is where the Corps is identified as having a role.

- Nearshore restoration actions that improve habitat function are critical to the recovery and protection of tribal treaty right resources, such as fish and shellfish, in Puget Sound. *US v. State of Washington* and sub-proceedings guaranteed Treaty Tribes 50% of harvestable salmon (Boldt decision) and shellfish resources (Rafeedie decision), and confirmed the value of habitat to maintain harvestable populations.

- Over a dozen species including fish, mammals, birds, and plants that are listed as endangered or threatened under the Endangered Species Act are dependent on the ecosystems of Puget Sound and either directly or indirectly on the Puget Sound nearshore zone.

The following sections describe the technical, institutional, and public significance of Puget Sound resources. Chapter 6 also includes expanded discussions of significance for each of the sites included in the recommended plan.

2.2.1 Technical Significance

The Nearshore Science Team (NST) consists of experts representing various technical disciplines to support and inform the Study in aspects of Puget Sound including biology, geology, and sociology. The NST has collaborated or authored several pivotal publications, which emphasize the technical significance of the Puget Sound including the following:

- Strategies for Nearshore Protection and Restoration in Puget Sound (Cereghino et al. 2012)
- Implications of Observed Anthropogenic Changes to the Nearshore Ecosystem in Puget Sound (Fresh et al. 2011)
- Historical Change and Impairment of Puget Sound Shoreline (Simenstad et al. 2011)
- A Geomorphic Classification of Puget Sound Shorelines (Shipman 2008)
- Valuing Puget Sound's Valued Ecosystem Components (Leschine and Petersen 2007)
- Conceptual Model for Assessing Restoration of Puget Sound Nearshore Ecosystems (Simenstad et al. 2006)

These peer-reviewed technical reports have informed local ecosystem restoration projects and local regulatory approaches.

2.2.2 Institutional Significance

Laws, adopted plans, and other policy statements of public agencies, tribes, or private groups all show institutional recognition of environmental significance. Following enactment of the ESA in 1973, the Federal Government began to address the decline of individual species with the listing of endangered species and the subsequent development of recovery plans. As of 2016, 13 fish and marine mammal species in Puget Sound are listed under the ESA as threatened or endangered. The responsible agencies have developed or are working on recovery plans for eight of the listed species. State efforts to address the decline of Puget Sound have been underway for many years, focusing on addressing water pollution. In 2007, the Puget Sound Partnership (PSP) replaced previous water quality agencies, and began integrating the work of State, local, and Federal Government entities, as well as local watershed planning and salmon recovery efforts. The PSP created the Puget Sound Action Agenda in 2008 and works to revise the plan through research and many collaborative partnerships (PSP 2008, 2012). The Action Agenda serves as a statement of common purpose across Puget Sound and forms the basis for cooperation and collaboration among implementing partners. The Nearshore Study is the nearshore ecosystem component of PSP's set of actions identified to protect and restore Puget Sound.

The Nearshore Study is a critical aspect to the various mission areas and agency interests outlined below. The proposed actions in the Nearshore Study are integral to a comprehensive restoration effort of institutionally significant resources within Puget Sound. Specific examples of institutional recognition of the significance of the resources being addressed by this study include the following:

A. *Puget Sound Partnership (PSP)* - The State of Washington has invested in the health of Puget Sound by creating specific agencies including the former Puget Sound Action Team, since replaced by PSP. PSP has developed an Action Agenda that addresses restoration and protection of Puget Sound, and uses "indicators" and "recovery targets" to help measure success. These include habitat features such as estuaries, floodplains, and eelgrass, and species including birds, herring, killer whales, and salmon (PSP 2012).
B. *Environmental Protection Agency (EPA)* - Puget Sound has been designated an estuary of National Significance under §320 of the Clean Water Act. The goal of the Puget Sound National Estuary Program is to restore and maintain the Puget Sound Estuary's estuarine environment so that it will support balanced indigenous populations of shellfish, fish, and wildlife, and support the extensive list of recognized uses of Puget Sound. In 2009, the EPA adopted the PSP Action Agenda as the Comprehensive Conservation and Management Plan of the Puget Sound National Estuary Program.
C. *Council on Environmental Quality (CEQ)* - President Obama established the Interagency Ocean Policy Task Force in 2009 to develop recommendations to enhance the nation's ability to maintain healthy, resilient, and sustainable oceans, coasts, and Great Lakes resources (CEQ 2010b). The task force established a new National Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes that set nine national priority objectives. The Nearshore Study aligns well with these objectives, especially the recommendation to "establish and implement an integrated ecosystem protection and restoration strategy that is science-based and aligns conservation and restoration goals at the Federal, State, tribal, local,

and regional levels." These recommendations target Puget Sound as one of the prioritized regions for restoration effort.

2.2.3 Public Significance

Public recognition of the significance of a resource may involve memberships in a conservation organization, financial contributions to resource-related efforts, volunteer labor, and correspondence regarding the importance of the resource. Public concerns with the health of the Puget Sound ecosystem have been evident for decades. As early as the 1920s, shellfish growers pointed to pollution from pulp mills as an issue, and in 1945 the State formed the Pollution Control Commission (The Olympian 2007). More recently, several large non-profit organizations have indicated interest in improving the ecosystem quality and function of the Puget Sound (e.g., Ducks Unlimited, Seattle Audubon Society, and The Nature Conservancy [TNC]). Reflecting the concerns of a range of people nearby, a large number of local groups have formed around improving conditions in the Puget Sound within the project area, including the following:

- Marine Resource Committees
- Regional Fisheries Enhancement Groups
- Orca Network
- Puget Sound Restoration Fund (Olympia Oysters)
- Pacific Coast Joint Venture
- Friends of the San Juans
- Puget Soundkeeper Alliance
- The Mountaineers
- Volunteers for Outdoor Washington
- Washington Council of Trout Unlimited
- Washington Water Trails Association
- Wild Fish Conservancy
- People for Puget Sound
- Washington Environmental Council

Public significance is further highlighted by the State of Washington's multi-million-dollar restoration budget, support from municipalities, NGOs, and other non-Federal partners in the cost-sharing of restoration efforts, as well as implementing millions of dollars' worth of generally smaller scale restoration work in Puget Sound without Corps involvement. These investments are important aspects of public significance of the resources within Puget Sound.

2.3 PROBLEMS AND OPPORTUNITIES

This section documents the identification of problems and opportunities in Puget Sound's nearshore zone, which is the first step in the Corps' six-step planning process (ER 1105-2-100; USACE 2000a). From the planning perspective, a problem can be thought of as an undesirable condition, while an opportunity offers a chance for progress or improvement. The identification of problems and opportunities gives focus to the planning effort and aids in the development of planning objectives. The problems identified in the Puget Sound nearshore area are listed here and discussed below.

- Degradation of large river deltas
- Loss of coastal embayments
- Disconnection between beaches and bluffs
- Loss of estuarine wetlands
- Shortening and simplification of the shoreline
- Accumulation of multiple stressors

The Nearshore Study identified "valued ecosystem components" (VECs) that share the three characteristics described in "Valuing Puget Sound's Valued Ecosystem Components" (Leschine and Petersen 2007). First, each is judged likely to be enhanced by nearshore zone restoration. Second, each VEC has direct or indirect value to humans socially, culturally, or environmentally. Third, many people recognize each component as emblematic of a "healthy" Puget Sound. The Nearshore Study identified the following nine VECs:

- Coastal forests (marine riparian vegetation)
- Beaches and bluffs
- Eelgrass and kelp
- Forage fish
- Juvenile salmon (including three ESA-listed species)
- Killer (orca) whales (ESA-listed)
- Native shellfish (includes one state candidate species)
- Great blue herons
- Nearshore birds

The problems described below affect these VECs directly or indirectly as detailed in a series of white papers available at *www.pugetsoundnearshore.org/technical_reports*. For example, forage fish rely directly on suitable beach habitat for spawning, and juvenile salmon rely directly on suitable delta habitat for rearing and on embayments for migration, while orcas benefit indirectly through increased availability of salmon as prey and through the water quality improvements that healthy deltas with abundant wetlands provide.

2.3.1 Sound-wide Problems

In their 2009 State of the Sound Report, the PSP's Science Panel evaluated ecosystem status indicators including human health, human well-being, species and food webs, habitats, water quantity, and water quality. The report concludes that "compared to historical conditions, the

Puget Sound ecosystem shows signs of stress and degradation from human activity." About half of the indicators in the report provide evidence of continuing decline in the Puget Sound ecosystem, while several other indicators show evidence of improving conditions. The remaining few indicators describe ecosystem aspects for which no clear trend was apparent. Declining indicators include three of the VECs that the Nearshore Study evaluated: killer whales, eelgrass, and forage fish (herring). Shellfish harvest shows signs of improvement, and Chinook salmon run size has slightly increased since their ESA listing in 1999; however, Chinook populations remain substantially below recovery targets (PSP 2009). In a subsequent report, the PSP adopted a set of 21 indicators for assessing Puget Sound health. Data on status and trends of these "vital signs" are under development. Many of these overlap with the VECs that the Nearshore Study identified, including Chinook salmon, killer whales, herring, birds, eelgrass, estuaries, and functioning beaches (without shoreline armoring) (PSP 2012).

2.3.2 Nearshore Ecosystem Problems

Impairment of nearshore processes and degradation of ecosystem functions are critical factors in the declining health of Puget Sound. The alterations to the physiographic processes of the nearshore zone directly and indirectly affect the ecosystem functions upon which humans depend. Watersheds comprising a mere 0.2% of the Puget Sound shoreline length and 0.003% of the Puget Sound watershed area have not encountered any degradation of nearshore ecosystem processes (Schlenger et al. 2011a). The problems of the other 99.8% of the shoreline and 99.997% of the watershed area are summarized in this section. The problems described below directly affect many plants and animals in Puget Sound and the ecosystem as a whole. Sections 2.3.2.1 through 2.3.2.6 below are excerpted from Fresh et al. (2011).

2.3.2.1 *Effects to Large River Deltas*

Barriers to tidal hydrology have affected large river deltas.

2.3.2.1.1 *Physical Changes*

All of the 16 largest deltas of Puget Sound have been extensively modified. Combining all 16 deltas, the total length of their shoreline has decreased by 109 miles or 26.6% from historical conditions. The two primary anthropogenic stressors in large deltas are tidal barriers, which account for nearly 200 miles of the current delta shoreline, and armoring, which accounts for 108 miles of the current delta shoreline. Changes to the wetlands of the large deltas have been especially dramatic. In aggregate, 55.5% of the historical wetlands (57,823 acres) in the 16 largest deltas of Puget Sound have been eliminated (Simenstad et al. 2011).

Watershed changes can affect deltas in ways that were not directly detected in the Change Analysis. For instance, water diversions can alter the equilibrium between sediment transport to deltas and sediment transport within them. Half of the watersheds associated with the large deltas of Puget Sound have at least one significant water diversion. In one case, Jay and Simenstad

(1996) suggested that the effects of a 40% reduction in the average annual discharge of the Skokomish River due to a hydropower diversion could be responsible for a 15 to 19% loss of low intertidal area and a 17% loss of sub tidal eelgrass on the outer delta.

Bolte and Vache (2010) project that by the year 2060, population growth will introduce development and stressors to five of the six large river deltas that do not yet have significant development at their mouths; the forecast for all 16 large river deltas represents an overall loss of 59% of historical tidal wetlands. In addition to wetlands protection under the Corps' regulatory program, Executive Order 11990 dictates no net loss of wetland functions and values; however, Corps enforcement of this policy when unauthorized fill occurs is discretionary. The wetland-fill permitting process may prevent a net loss of total wetland area, but mitigation measures may cause the type and location of wetlands to shift toward wetland banks and areas protected from development, and away from desirable nearshore zone development locations such as private waterfront properties. Furthermore, mitigation ratios are intended to account for potential loss of in-kind functions and temporal impacts, but there are risks and uncertainties that may hamper the success of mitigation projects, and monitoring is not always performed consistently enough or long enough to ensure full replacement of functions and values.

2.3.2.1.2 *Implications*

One significant implication of changes to deltas is that much less native habitat is available for plants and animals. In particular, diking and filling of deltas have eliminated most of the channels that historically cut through deltas and have thus restricted fish and wildlife to smaller areas. River deltas that have been simplified to a single channel, such as the Puyallup and Duwamish, which are now the Port of Tacoma and the Port of Seattle, respectively, concentrate fish into a smaller area thereby limiting their ability to avoid predators or stressful environmental conditions and significantly reducing the overall habitat carrying capacity. Loss of delta area has affected the quantity and quality of habitats available for birds for feeding, roosting, and reproduction. At least 30 species of shorebirds use estuarine tide flats associated with Puget Sound's deltas (Buchanan 2006).

The loss of tidal prism (volume of water exchanged by tides) can have ramifications to the local flooding regime by increasing freshwater flood peaks. In addition, tidal prism loss can cause the simplification and loss of volume of tidal channel networks outside the area enclosed by tidal barriers (Hood 2004). The loss of tidal prism in the delta and the addition of dams and diversions within the watershed can alter estuarine salinity structure, shifting the area and location of wetland types sensitive to certain salinity regimes.

2.3.2.2 *Disconnection or Loss of Coastal Embayments*

Small coastal embayments have been eliminated throughout Puget Sound or had their connections to the Sound severed.

2.3.2.2.1 *Physical Changes*

Puget Sound has experienced a significant loss in the numbers of small, coastal embayment landforms. Overall, 884 historical (1850s-1890s) embayment landforms were mapped, and 579 were mapped in current conditions (2006) representing a loss of 305 embayments (Simenstad et al. 2011).

Embayments historically accounted for 689 miles of Puget Sound shoreline (23.2%) but now account for 375 miles of shoreline (15.0%); this represents a decline in length of 45.5%. Historically and currently, the embayment landform type that represents the greatest proportion of Puget Sound's shoreline is the open coastal inlet. Of the embayments that remain along Puget Sound, many have been extensively modified. Armoring is the main modification, with 18% of the shoreline length of embayments armored. Changes to embayments vary considerably among the seven sub-basins (see section 1.2 for sub-basins).

Based on land cover projections from Bolte and Vache (2010), losses of tidal wetlands are expected to continue. They project these losses to occur in embayments and large river deltas. Modeling the effects of increased regional population and associated development leads to a projected loss of 17%, or 1,013 acres, of the current extent of tidal wetlands by 2060. This forecast represents an overall loss of 75% of historical tidal wetlands in embayments. Mitigation required through wetland-fill permitting could create new wetlands in other locations such as wetland banks to maintain no net loss; however, wetlands upstream from the nearshore zone have different benefits than the marine and estuarine types with their associated species assemblages.

2.3.2.2.2 *Implications*

The sheltered condition of embayments makes them important habitat for native shellfish, fish, and shorebirds. For example, embayments can provide a sheltered, food-rich environment for several species of juvenile fish during certain times of the year. Recent evidence from the Whidbey Sub-basin shows that large numbers of post-larval and juvenile surf smelt rear in some of the "pocket estuaries" found there (Beamer et al. 2006). In addition, during late winter and early spring, large numbers of juvenile Chinook and chum salmon rear in pocket estuaries of the Whidbey Sub-basin. The juvenile Chinook salmon are part of federally protected populations and are considered to be one of the life history types that support viability of the species (Beamer et al. 2005).

2.3.2.3 *Disconnection or Loss of Beaches and Bluffs*

Changes to beaches and bluffs have resulted in the loss of sediment supply and the interruption of sediment transport processes.

2.3.2.3.1 *Physical Changes*

As with other Puget Sound landforms, the amount of beach shoreline has declined from historical conditions, but the magnitude of changes was less pronounced than for embayments and large deltas. Historically, 38.5% of Puget Sound's shoreline (950 miles) was composed of bluff-backed beach; it was (and remains) the dominant landform in Puget Sound. Barrier beaches (i.e. depositional features that form across bays or small estuaries) were the fourth dominant landform, accounting for 273 miles (11.1%) of the shoreline. From historical to current conditions, bluff-backed beach and barrier beach length declined by 80 miles and 37 miles, respectively. Changes to beaches varied greatly between sub-basins (Simenstad et al. 2011).

Puget Sound beaches have seen many modifications. Armoring (seawalls and revetments) is the most pervasive direct alteration. Armoring occurs along 33.4% of bluff-backed beaches and 27.2% of barrier beaches; 34.0% of all bluff-backed beaches are armored along more than half of their length. Only 25.0% of all bluff-backed beaches are completely unarmored. The distribution of armoring associated with beaches varies greatly among sub-basins. Other than armoring, roads and nearshore fill are the most significant stressors affecting beaches in Puget Sound. For example, roads and nearshore fill each affect about 10% of the length of bluff-backed beaches.

2.3.2.3.2 *Implications*

One of the most important physical processes occurring along beaches and bluffs is the erosion, transport, and distribution of sediment. Sediment processes are dynamic and driven by storms, wave action, and tides. They vary significantly along shore and from one part of Puget Sound to another, due to variability in wave action, geology, and the shape of the inherited glacial landscape (Finlayson 2006). Sediment processes, in combination with other factors, such as disturbance regimes, directly affect characteristics of beaches fed by those sediments and the composition, abundance, and diversity of plant and animal communities associated with them (Turner et al. 1995; Farina 2000).

Disruption of sediment processes can result from anthropogenic stressors such as structures placed either along (parallel to) or across (perpendicular to) the shoreline, which can affect the amount and size (grain size) of sediment delivered to the beach, and how and where it is transported. One of the most apparent human-caused changes to a beach is placement of structures (e.g. nearshore fill or armoring) parallel to the shore that cuts off or isolates bluffs that are sediment sources (so-called feeder bluffs) (Shipman et al. 2010). This is because the primary source of sediment to the non-delta landforms of Puget Sound is the feeder bluffs associated with bluff-backed beaches. Downing (1983) estimated that erosion of coastal bluffs supplies 90% of the sediment to Puget Sound beaches, and shoreline armoring occurs along approximately 33% of those bluffs (Schlenger et al. 2011a). Disruptions in sediment processes can change the physical characteristics of a beach, including changes in sediment composition (e.g., coarsening of the material), beach slope, and beach width (Pilkey and Wright 1988; Shipman et al. 2010). Down-drift beaches in the vicinity can disappear, and beach width can decline (Griggs 2005).

Various biological effects can result from changes in sediment processes including changes in invertebrate communities, loss of forage fish spawning habitat, and loss of feeding and migration habitat for juvenile salmon and forage fish (Shipman et al. 2010). Armoring can affect benthic and epibenthic invertebrates due to a loss of beach area, changes in beach slope, and changes in substrate characteristics. Because the composition of intertidal invertebrate communities is strongly linked to substrate characteristics (Dethier and Schoch 2005), changes in local sediment characteristics due to armoring (e.g., caused by wave reflection or blocked sediment sources) can alter the abundance and composition of infaunal and epifaunal organisms, including shellfish.

Armoring can affect reproduction of forage fish in several ways. First, armoring low in the intertidal zone can displace the spawning habitat of several species (e.g. surf smelt and sand lance) that spawn on fine-grained substrates on the upper beach (Penttila 2007). Second, by blocking sediment input to the beach, armoring can cause spawning areas to convert from the fine-grained material that the fish need for spawning to coarser materials such as gravel and cobble that are unsuitable for spawning. Third, armoring can negatively affect forage fish populations by increasing sediment temperatures on the upper beach, where shading by natural shoreline vegetation has been removed; this reduces survival of incubating embryos (Rice 2006). In addition to effects on reproduction of forage fish, armoring can affect feeding behavior of juvenile forage fish (as well as juvenile Pacific salmon) that often feed in shallow water at high tide. When shoreline modifications extend lower on the shore, the truncation of intertidal shallow water habitat by armoring reduces foraging by juvenile fish on riparian insects (Toft et al. 2007).

Projected sea-level change and increased storm frequency and magnitude are expected to cause the base of the coastal bluffs along bluff-backed beaches to be more frequently inundated by waves. This increased wave action on the base of the bluffs is expected to cause additional bluff erosion and increase sediment inputs to the nearshore zone. It is expected, however, that shoreline property owners may respond by constructing additional armoring to reduce bluff-backed beach erosion. Expected increases in shoreline armoring related to sea-level change are unquantified and are not included in the Bolte and Vache (2010) projections.

2.3.2.4 *Loss of Estuarine Wetlands*

Extensive losses of tidal/estuarine wetlands have occurred throughout Puget Sound. There are four types of tidal/estuarine wetlands: euryhaline (i.e. high saltwater concentration) unvegetated, estuarine mixing, oligohaline transition, and tidal freshwater.

2.3.2.4.1 *Physical Changes*

Puget Sound has experienced a dramatic loss of tidal/estuarine wetlands. Most Puget Sound tidal/estuarine wetlands are associated with the 16 large deltas. These delta systems historically contained nearly 103,000 acres of tidal/estuarine wetlands (all four types combined), compared to the current 45,220 acres, a decline of 56%. For landforms other than large deltas (mostly embayments), the estimated 25,205 acres of historical wetlands has declined to 8,229 acres, a loss of 69% (because data on the amount of euryhaline unvegetated wetland is only reliable for the large deltas, the estimated 25,205 acres of historical wetlands does not include that type).

Considering just the estuarine mixing, oligohaline transition, and tidal freshwater (i.e. vegetated) tidal/estuarine wetland types, 74.2% of wetlands that historically surrounded the shores of Puget Sound have been lost. Tidal freshwater and oligohaline transitional wetlands have been nearly eliminated. Combining all landforms, 93.1% of these two wetland types have been lost throughout Puget Sound. Of the 15,815 acres of historical oligohaline transition marsh, only 371 acres remain. The loss of tidal wetlands has been especially dramatic in several sub-basins and in several large deltas in particular. In the Duwamish and Puyallup river deltas, almost no wetlands remain of any type as these deltas have been developed into the Port of Seattle and Port of Tacoma, respectively. In the Whidbey Basin, the amount of oligohaline transition and tidal freshwater wetlands declined from 14,826 acres to 148 acres and from 21,745 acres to 2,224 acres, respectively. Most of this loss was in the three large deltas found in this sub-basin.

Based on land cover projections from Bolte and Vache (2010), losses of tidal wetlands are expected to continue. These losses are projected to occur in embayments and large river deltas. In addition to previously cited projected future losses of coastal embayment wetlands, (17%), large river deltas are projected to lose 3% (1,606 acres) of their current extent of tidal wetlands between now and the year 2060. While new wetlands can be created through the permitting process to prevent a net loss of total wetland area, the use of mitigation banking is rare in estuarine areas, so mitigation may cause a shift in wetland types from estuarine to other types.

The projected increases in armoring paired with the projected sea-level change will likely cause further wetland losses beyond those projected by Bolte and Vache (2010). Some of the current tidal wetlands occur at elevations that will be inundated too deeply and/or too frequently as the sea-level changes. In a natural setting, many of these wetlands might shift to colonize higher elevations that would provide suitable conditions; however, the presence of barriers to tidal inundation (e.g., armoring) will limit the ability of estuarine wetlands to migrate landward.

2.3.2.4.2 *Implications*

Wetlands are one of the most important ecosystem types, wherever they occur, because they provide a wide variety of functions, including primary production; nutrient cycling; biophysical mediation of contaminants; fish and wildlife habitat, particularly for reproduction and feeding; and support of coastal fisheries species (Boesch and Turner 1984; Mitsch and Gosselink 2007).

Throughout the Pacific Northwest, one of the most prominent functions of estuarine wetlands, especially those associated with large deltas, is that they support extended rearing of several species of juvenile salmon (Healey 1982; Levy and Northcote 1982; Simenstad et al. 1982; Bottom et al. 2005a, 2005b; Henning et al. 2006). Studies have demonstrated that particular "life history types" are those that use delta wetland habitats for extended periods and depend on this habitat for initial, early growth (Fresh 2006). The production of these life history types is important to maintaining population resilience and supporting efforts to rebuild salmon populations (Bottom et al. 2005a). Because there is a strong relationship between juvenile salmon size and their survival to the next life phase (Duffy 2009), high growth rates in juvenile salmon during their residency in estuarine areas are critical to the survival of these life history types and their contribution to population resilience.

2.3.2.5 *Shortening and Simplification of Shoreline*

The shoreline has become shorter, simpler, and more artificial.

2.3.2.5.1 *Physical Changes*

In addition to the types of structural changes (i.e., stressors) described previously (e.g., construction of bulkheads, roads, and overwater structures), the basic character of the shoreline has changed. In particular, the shoreline of Puget Sound has become shorter and simpler over the past 150 years. Over all of Puget Sound, the net loss of shoreline length has been 431 miles, meaning the current shoreline is about 15% shorter than the historical length of the shoreline, as shown in Figure 1-5. While more than 600 miles of natural shoreline was eliminated, 229 miles of artificial shoreline was added (herein, artificial means human-made landforms such as seawalls backed by fill). Although the length of shoreline classified as artificial was negligible historically, artificial shoreline now represents about 9.5% of the length of shoreline in Puget Sound. There was a strong association between fill placed in the nearshore zone and the artificial landform type, with fill occurring along 62% of the length of artificial landforms.

Although available land cover projections from Bolte and Vache (2010) do not provide estimates of shortening and simplification of the shoreline, it is anticipated that the projected addition of nearly 100 miles of shoreline armoring between now and 2060 will continue a long trend of shortening and simplifying the shoreline through development. In those areas where armoring is added, the shoreline loses its natural complexity and heterogeneity; in those areas, the shoreline will be converted from a mix of landforms and habitats to straightened and simplified reaches within which the connection between terrestrial and aquatic habitats and resources is interrupted.

2.3.2.5.2 *Implications*

Although some of the changes in shoreline length and in landform were clearly due to natural processes such as erosion, waves, and floods, many are due to anthropogenic influences. The simplification and shortening of Puget Sound's shoreline has altered the fundamental way that nearshore ecosystems function. The way an ecosystem works depends in part upon characteristics of surrounding ecosystems and the spatial arrangement of their components, sizes, shape, and location (Forman and Godron 1986; Turner 1989; Fahrig and Merriam 1994; Bell et al. 1997; Wiens 2002; Bilkovic and Roggero 2008; Partyka and Peterson 2008). Simply by changing how Puget Sound's parts are arranged, people have changed how water and sediment move around, where and how much sediment is deposited, and how detritus and nutrients are processed and cycled (Farina 2000; Lourie and Vincent 2004). Furthermore, people have modified the behavior and survival of species and altered the composition of plant and animal communities (Bell et al. 1997; Farina 2000; Wiens et al. 2002; Lourie and Vincent 2004).

Changes to shoreline complexity and the loss of shoreline length have affected the rate, magnitude, and effectiveness of many ecosystem processes that depend on the amount of space available. The loss of shoreline length has reduced the amount of space in Puget Sound for fish and wildlife to reproduce, feed, and grow (Dethier 2006; Coen et al. 2007). In particular, juvenile salmon, which are closely associated with nearshore ecosystems during their migration to the ocean, now have less space to feed, grow, and evade predators; such impacts have reduced their survival (Beamer and Larsen 2004). The loss in shoreline length has likely affected other habitats as well, such as eelgrass beds, although historical data is insufficient to quantify this change.

2.3.2.6 *Cumulative Effects of Multiple Stressors*

Many nearshore places have experienced multiple types of stressors (cumulative effects).

2.3.2.6.1 *Physical Changes*

Many of the altered shoreline segments around Puget Sound have not just one, but multiple types of human-caused alterations. Of the 812 shoreline segments (not including deltas) in Puget Sound, only 112 (14%) have no shoreline stressor (e.g., a dock, a marina, armoring, or fill). Segments with only one stressor make up 5% of the count, and 60% of shoreline segments have two to four stressors. Although no shoreline segments contain all nine stressors, 81% of segments have more than one type of stressor, suggesting a high potential for cumulative effects. Of the nine shoreline stressors considered in the Nearshore Study, armoring is clearly the dominant stressor, occurring in 78% of all shoreline segments. When calculating length of changes rather than number of segments, armoring occurs along 27% of the shoreline of Puget Sound. Other stressors often co-occur with armoring. Of the 2,466 miles of shoreline in Puget Sound, 23% of the length has one stressor, 12% has two stressors, and 6% has three or more.

2.3.2.6.2 *Implications*

It is highly likely that cumulative effects are negatively affecting nearshore ecosystem functions. Cumulative effects refer to the combined, incremental effects of human activities on the environment (EPA 1999). Cumulative effects may be synergistic, in that the overall effect is more than the sum of the individual effects (Williams and Faber 2001; Peterson and Lowe 2009). While a small-scale alteration may be insignificant (and not even noticed) by itself, cumulative effects from one or more sources often accumulate over time and space (Jordan et al. 2008;

Peterson and Lowe 2009). Such changes to ecosystems are usually small-scale and can occur through persistent additions or losses of the same resources and through the compounding effects of two or more stressors (Reeves et al. 1993; May 1996). In the nearshore ecosystems of Puget Sound, cumulative effects include not only the physical changes upon which the Nearshore Study has focused, but other effects as well, such as changes to water and sediment quality.

2.3.3 Opportunities

Opportunities exist to address problems in Puget Sound nearshore ecosystems and thereby contribute to the health of species that depend on that habitat, directly or indirectly, for survival.

2.3.3.1 *Restoration Opportunities*

Puget Sound deltas have opportunities to increase the quantity and quality of valuable habitat for a variety of fish, wildlife, and plants. For example, restoration of estuarine habitat would benefit salmonids that depend on such habitat as they transition from freshwater to saltwater and back. Restored estuarine wetlands would benefit over 30 species of shorebirds found in Puget Sound deltas. There are opportunities to improve the overall water quality of Puget Sound through restoring some of the deltas that have historically provided that function.

At degraded coastal embayments around Puget Sound, opportunities exist to improve conditions for native shellfish, fish, and shorebirds. In particular, there are opportunities to benefit juvenile Chinook salmon populations that depend on the protected nature of coastal embayments for rearing habitat, and there are opportunities to improve conditions for surf smelt, a forage fish species that is an important part of the diet of Chinook salmon. There are also opportunities to restore degraded wetlands associated with coastal embayments, re-establishing diminished habitat, and contributing to improved water quality in Puget Sound.

Through restoration of beaches and the bluffs that provide the sediment that beaches depend on, there are opportunities to improve conditions for the fish and wildlife that inhabit or use Puget Sound beaches; and to contribute to the sustainability of barrier embayments that are made up of accreted sediment from eroding bluffs, providing habitat for migrating salmonids, native shellfish, and shorebirds. Such restoration represents opportunities to improve conditions for organisms at many levels of the food chain, including invertebrates, forage fish, and salmonids.

An additional consideration for restoration is the potential for sea level change. Although it is often seen as a limiting condition, it can also be viewed as an opportunity to enact managed retreat from altered coastal conditions. In the situation where it is not feasible to preserve historic infrastructure while restoring habitat under conditions of sea level change, artificial shorelines may be restored to natural function by removal of the threatened structures.

In summary, through addressing the problems observed in Puget Sound's deltas, embayments, beaches, and bluffs, there are opportunities to restore some of the historic structural complexity to the shoreline, increasing the area available for habitat as well as the diversity of ecological niches required to support Puget Sound's rich natural heritage.

2.3.3.2 *Protection Opportunities*

A critical part of a comprehensive approach to ecosystem recovery is to protect healthy, functioning portions of the nearshore zone. Considering that restoration often requires protecting lands, and full function of restored lands may be delayed while systems reestablish, protection is often a more cost-effective approach to ensuring delivery of ecosystem functions. The Strategies Report (Cereghino et al. 2012) identifies intact sites with high potential for protection; however, because protection is not a Corps mission, it is not included in the planning objectives for this study. However, because the Corps restoration mission is to implement and restore where the Corps expertise is needed to restore function and quality, acquisition for protection is not a planning objective.

2.3.3.3 *Learning Opportunities*

Restoration efforts offer opportunities for further learning, research, and education. Specifically, learning opportunities include the following:

- Increased institutional capability and capacity will arise as ecosystem restoration provides a setting for learning.
- Improvement in the performance of projects will provide feedback that can help reduce the uncertainty in implementing new projects and in applying adaptive management measures to constructed projects.

2.4 PLANNING OBJECTIVES

The Study team developed three broad planning objectives with associated sub-objectives to guide the formulation of alternative plans aimed at addressing the problems and opportunities described in section 2.3. The planning objectives articulate the Study's goal to restore the physiographic processes that sustain the Puget Sound nearshore ecosystem and its broad array of nationally and regionally significant resources. Through process restoration, the project aims to sustainably address impairment to the nearshore zone's ability to deliver ecosystem structures, functions, and processes, and to support valued ecosystem components. The planning objectives appear in Table 2-1, along with associated problems, opportunities, and affected species. Chapter 6 includes site-specific planning objectives for the sites included in the recommended plan.

In the following sections, each planning objective is briefly described along with sub-objectives that more fully detail the planning objective's intent. Sub-objectives refer to removal of stressors that impact physiographic processes that sustain the nearshore ecosystem; in all cases the Nearshore Study's intent is to remove all stressors within the footprint of a given restoration site, except where constraints limit that goal. The degree to which proposed solutions achieve objectives was calculated by the ecosystem output model developed for the Nearshore Study.

Table 2-1. Planning Objectives

Planning Objectives[1]	Sub-objectives	Problems	Representative Species Affected
1. Restore connectivity and size of large river delta estuaries in the Puget Sound Nearshore for the 50-year period of analysis.	Restore tidal flow and inundation area in river deltas Restore quality and quantity of tidal wetlands in river deltas with emphasis on oligohaline and tidal freshwater wetlands Improve connectivity between the nearshore zone and adjacent uplands/ watershed Increase the shoreline length of large river deltas	• Large River Delta Impacts • Estuarine Wetland Loss • Shortening and Simplification of Shoreline Multiple Stressors	• Puget Sound Chinook salmon and other salmonids Great blue herons Peregrine falcons • Shorebirds (>30 species) Killer whales
2. Restore the number and quality of coastal embayments in the Puget Sound Nearshore for the 50-year period of analysis.	Restore embayment shoreline length that has been reduced through fill placement Restore embayments that have transitioned to an artificial landform or have been lost through conversion to uplands Restore degraded embayments Restore quality and quantity of tidal wetlands in coastal embayments	• Coastal Embayment Loss or Disconnection • Estuarine Wetland Loss • Shortening and Simplification of Shoreline Multiple Stressors	• Puget Sound Chinook salmon and other salmonids Shellfish Olympia oysters Forage fish Kelp and Eelgrass
3. Restore the size and quality of beaches in the Puget Sound Nearshore for the 50-year period of analysis.	Restore sediment input processes at bluff-backed beaches in divergence zones and transport zones of sediment drift cells Improve sediment transport and accretion processes by removing sub tidal and intertidal stressors contributing to shoreline degradation	• Beaches and Bluffs Disconnection Multiple Stressors • Shortening and Simplification of Shoreline	• Puget Sound Chinook salmon and other salmonids Forage fish Shellfish Olympia oysters

Notes: 1. All objectives cover the 50-year period of analysis.

2.4.1 Objective 1 – Restore Connectivity and Size of Large River Deltas

The 16 large river deltas distributed throughout Puget Sound vitally contribute to the overall health of Puget Sound ecosystems. These delta areas support a broad set of nearshore ecosystem processes in different ways than shoreline areas, and their contributions extend far beyond their delineated boundaries. Opportunities to restore processes should be identified and developed in areas with consideration for restoring "stepping stones of healthy patches" to increase landscape connectivity, as described in Principles for Strategic Conservation and Restoration (Greiner 2010). This objective has the following four sub-objectives:

- Restore tidal flow in river deltas
- Restore wetland quality and quantity with emphasis on oligohaline and tidal freshwater
- Improve connectivity between the nearshore zone and adjacent uplands/watershed
- Increase the shoreline length of large river deltas
- Increase riparian areas in river deltas

2.4.2 Objective 2 - Restore the Number and Quality of Coastal Embayments

Embayments are significant landscape features that contribute to the complexity and heterogeneity of the Puget Sound shoreline. Embayments between the large deltas and in areas where deltas are absent provide important habitats for a variety of valued species including several species of salmon, more than 30 species of shorebirds, and migratory waterfowl. Many of the remaining embayments have been reduced in size, complexity, and function through stressors such as fill, armoring, stream crossings, roads, and railroads. Restoration can recover the historical footprint (size and shape) and associated functions of the embayment. Embayments can also be restored at sites where, due to fill and other stressors, they no longer exist. This objective is broken into the following four sub-objectives:

- Restore shoreline length reduced through fill placement and other stressors
- Restore embayments that have transitioned to artificial or have been lost
- Restore degraded embayments
- Restore quality and quantity of tidal wetlands in coastal embayments

2.4.3 Objective 3 – Restore the Size and Quality of Beaches

The nearshore ecosystem processes of sediment input, transport, and accretion are vital to supporting many of the unique and important characteristics of Puget Sound, such as shallow beach slopes, woody debris and algae accumulation, migration corridors for wildlife, beach spits, and other habitat features critical to the survival of Puget Sound biota. Results of historical change analysis indicate that there is a widespread need for the restoration of these processes of sediment movement throughout Puget Sound. While restored sediment supply at the site of an historic bluff-backed beach will support the reestablishment of the intertidal habitat, the benefits of restoring processes extend far beyond the site of restoration. Reconnecting a sediment source to the intertidal area at the up drift end of a non-degraded longshore sediment drift cell can contribute to maintenance of barrier beaches miles down drift. The following two sub-objectives are included in this objective:

- Restore sediment input processes by reducing degradation of bluff-backed beaches in divergence zones and transport zones of sediment drift cells
- Improve sediment transport and accretion processes by removing sub tidal and intertidal stressors contributing to shoreline degradation

2.5 PLANNING CONSTRAINTS

Unlike planning objectives, which represent desired positive changes, planning constraints represent restrictions. A planning constraint is any technical, legal, departmental, or operational restriction that limits the extent of the planning process or scope.

The planning constraints identified in this study are as follows:

- No restoration action will be considered in locations with known hazardous, toxic, and radioactive waste (HTRW) issues; all known HTRW sites will be avoided.
- The restoration plan should not induce flooding of existing structures to the maximum extent practical.
- The restoration actions should not impact transportation infrastructure that directly supports life safety or economic viability.
- International boundaries constrain project opportunities. Puget Sound, as defined for this study, is the U.S. portion of the larger Salish Sea that extends into Canada. The study area is limited to Puget Sound, and does not include Canadian portions of the Salish Sea.
- The recommended set of restoration actions should be sized so as to expect them to be funded and implemented within the next 10 to 20 years.
- The development of restoration projects should be sensitive to the Corps Trust responsibilities to Federally recognized Tribes and when sited, should not negatively impact Tribal resources. Tribal resources may include but are not limited to: Usual and Accustomed (U&A) treaty reserved fishing, hunting, and gathering areas within the project area.

Chapter 6 also includes site-specific planning constraints for the sites included in the recommended plan.

3 AFFECTED ENVIRONMENT*

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

This chapter describes the existing conditions and future without-project conditions used for analysis. Existing conditions are the physical, chemical, biological, and sociological characteristics of the study area, which is the Puget Sound nearshore zone as defined in Figure 1-2 and covering all seven sub-basins as identified in section 1.3. Characterizing resource conditions is critical for estimating their future condition (the without-project condition) and for defining problems and opportunities. Scoping required by NEPA was introduced in section 1.9; all related activities appear in section 8.3.6. During the scoping process, agencies and the public identified topics of interest for analysis. Resources that would be affected by proposed actions are described here and project effects are analyzed in Chapter 5. Other resources, as described in section 3.5, did not receive a detailed analysis because the agencies determined the project would not have significant effects on these resources, and the public did not raise concerns. This chapter serves as a baseline of without-project conditions for analyzing the effects of different alternatives framed around the analysis of ecosystem processes, structures, and functions.

3.1 PHYSICAL ENVIRONMENT: NEARSHORE PROCESSES AND STRUCTURES

As discussed in section 1.8, the linkages between nearshore ecosystem processes, structures, and functions provide the analytical framework of the Nearshore Study. This framework derives from the hypothesis that “alterations of natural hydrologic, geomorphologic, and ecological processes impair important nearshore ecosystem structures and functions” (Simenstad et al. 2006). These relationships are important because ecosystem structure, a fundamental component of habitat, sustains socially relevant functions, including support for fish, wildlife, and plants, which in turn provide ecosystem functions in a dynamic relationship.

3.1.1 Nearshore Ecosystem Processes

Ecosystem processes are interactions among physical, chemical, and biological attributes of an ecosystem that cause change in character of the ecosystem and its components. The nearshore ecosystem processes that influence the marine and estuarine shorelines of Puget Sound occur and vary over diverse spatial and temporal scales. The processes are classified into three scales of influence on nearshore ecosystems: regional influences, broad physiographic processes, and local geochemical and ecological processes. *Regional influences* include factors such as climate, wave exposure, geology, inherited physiography, sea-level history, and tidal regime. The *broad physiographic processes* are considered landscape-forming processes, and are embedded within regional influences but vary considerably on scales of kilometers or smaller. Examples include sediment input to beaches and distributary channel formation. The *local geochemical and ecological processes* that occur within a given landscape structure, and vary within the local structure of nearshore ecosystems, are shaped by the combined effects of the regional influences and broad physiographic processes. They vary on the order of meters within the local structures and, thus, are spatially and temporally complex. Examples include geochemical reactions that lead to nutrient cycling, primary production of plants, and food web interactions. The Nearshore Study assessment of ecosystem conditions focuses on the broad physiographic processes because they are responsible for creation and maintenance of the different complexes of landforms that characterize Puget Sound's shorelines. Eleven broad physiographic processes have been identified as most essential to the creation, maintenance, and function of Puget Sound's shoreline ecosystems; they are listed in Table 3-1.

Table 3-1. Nearshore Ecosystem Processes

Nearshore Ecosystem Process	Process Description
Sediment Input	Flux of sediments from bluff, stream, river, and marine sources Depending on landscape setting, scale can vary from acute, low frequency (hill slope mass wasting from bluffs) to chronic, high frequency (some streams and rivers)
Sediment Transport	Bed load and suspended sediment transport of sediments and other matter by water and wind along (long shore) and across (cross-shore) the shoreline as well as riverine transport in estuaries.
Erosion and Accretion of Sediments	Erosion (coastal retreat) of coastal bluffs, shorelines and estuarine river banks Deposition (dune formation, delta building, spits, and bars) of non-suspended (e.g., bed load) sediments and mineral particulate material by water, wind, and other forces Settling (accretion) of suspended sediments and organic matter on intertidal surfaces
Tidal Flow	Localized tidal effects on water elevation and currents, differing significantly from regional tidal regime mostly in tidal freshwater and estuarine ecosystems
Distributary Channel Migration	Change of distributary channel form and location caused by combined freshwater and tidal flow
Tidal Channel Formation and Maintenance	Geomorphic processes, primarily tidally driven, that form and maintain tidal channel geometry Natural levee formation
Freshwater Input	Freshwater inflow from surface (stream flow) and groundwater (seepage)
Detritus Import and Export	Import and deposition of particulate (dead) organic matter Soil formation Recruitment, disturbance, and export of large wood
Exchange of Aquatic Organisms	Organism transport and movement driven predominantly by water (tidal, fluvial) movement
Physical Disturbance	Change of shoreline shape or character caused by exposure to local wind, wave energy, and currents Localized disturbance such as large wood movement, scour, and over wash
Solar Incidence	Exposure, absorption, and reflectance of solar radiation and resulting effects

3.1.2 Geologic and Physiographic Setting

Puget Sound's striking terrain is a complex mixture of beaches, bluffs, deltas, mudflats, rocky archipelagos, and wetlands. Extensive glacial and tectonic activities caused many of the geomorphological features that characterize Puget Sound’s shoreline. Other geologic processes, including weathering, erosion, and sedimentation, have further defined landforms and physical characteristics of the Puget Sound basin. At the peak of the Pleistocene epoch, a one-mile thick sheet of glacial ice covered the region and reached the southern extent of Puget Sound. The repeated advance and retreat of glaciers over many ice ages carved Puget Sound into its present form and reworked the till deposits. The region’s soils are characterized as immature, being less than 10,000 years old. As is typical of fjords, water depths in Puget Sound increase rapidly from shore, with an average depth of 200 feet and a maximum depth of more than 1,200 feet.

Erosion, weathering, and alluvial deposition processes since retreat of the last glaciers have contributed to the mix of substrates of Puget Sound’s nearshore zone. Studies show tremendous variability in substrate grain size along the shoreline. Puget Sound beaches have mixed sand and gravel sediments derived primarily from glacial till and outwash material that eroded from coastal bluffs (Downing 1983, Finlayson 2006). Sandy and muddy sediments from fluvial sources make up the large river deltas. The complexity and variability in Puget Sound shoreline substrates is mirrored in the geomorphology, diversity of the biota of the nearshore zone, and ecosystem functions provided. These relationships between process, structure, and function and the resulting biodiversity are the primary reasons the Nearshore Study chose to focus on restoration of the natural processes that supply and transport natural sediment sources.

The structures and habitats of Puget Sound are a complex mosaic of beaches and bluffs, estuaries, lagoons, river deltas, and rocky coastlines. Shipman (2008) defines a classification of Puget Sound nearshore landforms that reflects the primary role of geomorphic processes in shaping the landscape. This classification system identifies four geomorphic systems (structures) that form the foundation of this shoreline classification. Three of these systems (beaches, embayments, and river deltas) reflect differences in the roles of waves, tides, and rivers in transporting sediment and shaping the coastline. The most common Puget Sound shoreline type consists of mixed sand and gravel beaches backed by high coastal bluffs. Other sediment-dominated shoreline environments include large river deltas, tidal flats, salt marshes, and estuaries. A fourth system, rocky coasts, has limited availability of mobile sediment and a lack of major depositional landforms. Rocky-bottom habitat is less common than soft-bottom habitat and is confined mostly to northern Puget Sound.

Within each of these geomorphic systems, there can be a variety of smaller landforms. These can be complex features, their configuration determined by the shoreline, availability of sediment, and local influence of waves, tides, and stream-related processes. Figure 3-1 shows typical shapes and relationships of landform types. Table 3-2 summarizes the geomorphic systems and natural landforms described in detail by Shipman (2008). In addition to the natural landform types defined by this classification system, the Nearshore Study mapped "artificial" areas, which are areas that have been fundamentally altered by dredging and filling. Artificial landforms often support biotic communities not present in natural shorelines. Approximately 240 miles (10%) of the shoreline in the study area is classified as artificial (Simenstad et al. 2011).

Figure 3-1. Coastal landforms typical of Puget Sound

Table 3-2. Summary of Geomorphic Classification System (Shipman 2008)

<table>
<tr><th>System</th><th>Landform</th></tr>
<tr><td rowspan="4">River Deltas
Long-term deposition of fluvial sediment at river mouths
</td><td>River-dominated deltas
Extensive alluvial valleys with multiple distributaries and significant upstream tidal influence</td></tr>
<tr><td>Wave-dominated deltas
Deltas heavily influenced by wave action, typically with barrier beaches defining their shoreline</td></tr>
<tr><td>Tide-dominated deltas
At heads of bays where tidal influence is more significant than fluvial factors, typically with a wedge-shaped estuary</td></tr>
<tr><td>Fan deltas
Steep, often coarse-grained deltas with limited upstream tidal influence</td></tr>
<tr><td rowspan="3">Rocky Coast
Resistant bedrock with limited upland erosion
</td><td>Plunging
Rocky shores with minimal erosion/ deposition and no erosional bench or platform</td></tr>
<tr><td>Platform
Wave-eroded platform/ramp, but no beaches</td></tr>
<tr><td>Pocket beaches
Isolated beaches contained by rocky headlands</td></tr>
</table>

System	Landform
Beaches Shorelines consisting of loose sediment and under the influence of wave action 	**Coastal Bluffs** Formed by landward retreat of the shoreline **Barrier Beaches** Formed where sediment accumulates seaward of earlier shoreline
Embayments Protected from wave action by small size and sheltered configuration 	**Open coastal inlets** Small inlets protected from wave action by their small size or shape, but not significantly enclosed by barrier beaches **Barrier estuaries** Tidal inlets largely isolated by barrier beaches and with significant inputs of freshwater from streams or upland drainage **Barrier lagoons** Tidal inlets largely isolated by barrier beaches and with no significant input of freshwater **Closed lagoons and marshes** Back-barrier wetlands with no surface connection to Puget Sound

3.1.3 Oceanography

Puget Sound is the second largest estuary in the United States, composed of many smaller estuarine components with a total shoreline length of more than 2,466 miles. An estuary is a semi-enclosed body of water in which saltwater from a nearby ocean mixes with freshwater runoff from the surrounding watershed. In estuaries, denser saltwater sinks deeper and moves toward the land with tides, while freshwater moves seaward as a surface layer. Shallow sills (submerged ridges that separate basins of water) in Puget Sound’s sea floor disrupt tidal movements and promote mixing of the water layers. Exchange of water between estuarine Puget

Sound and saline Pacific Ocean primarily occurs through the Strait of Juan de Fuca, northwest of Puget Sound. Limited exchange occurs through a more obstructed pathway along the eastern side of Vancouver Island, through the Georgia and Johnstone Straits north of Puget Sound. Oceanography of Puget Sound is important to the Nearshore Study because it is a significant factor in the creation and maintenance of landforms (see section 3.1.2). It is a part of the natural processes that contribute to ecosystem structure and function.

Tides

Tides of Puget Sound are mixed-semidiurnal with significant biweekly spring-neap modulation (Mofjeld and Larsen 1984). Thus, twice each day, the shorelines are alternately underwater and exposed to the air, rain, or sun. Beaches can be delineated into zones based on the length of time the substrate is underwater or exposed to air. The *intertidal* zone is between the limits of the tidal highs and lows and is inundated and exposed during each tidal cycle. The *sub tidal* zone is under water except during extreme low tides. The *supratidal* zone, or splash zone, is not frequently inundated except during extreme high tides. Each tidal zone hosts unique assemblages of species. The tidal range around Puget Sound varies depending on location, the geomorphological characteristics, and the distance from the Pacific Ocean. In the mid-sound, the mean tidal range is 7.66 feet and the maximum is 14.4 feet of difference between the lower low and higher high tide. Muted and restricted tidal flows are a problem throughout Puget Sound, particularly in estuaries where the mouth is restricted by causeways and/or much of the adjacent wetlands are cut-off due to levees. Armoring along beaches limits the tidal inundation of higher beach elevations, creating deeper water along the shoreline. Restricted tidal flow affects sediment transport and delivery, detritus import and export, and exchange of aquatic organisms. Shoreline modifications inhibit the habitat quantity, quality, and species diversity of these tidal zones.

Currents

A large volume of water, roughly 1.25 cubic miles, continually moves in and out of Puget Sound with each tidal cycle (Lincoln 2000). The twice-daily exchange of this water produces strong tidal currents through the narrow passages and over the seafloor sills that constrict flows. In addition to the saline water of the Pacific Ocean, freshwater discharge volumes within the Puget Sound watershed contribute to the volume. More than 10,000 rivers and streams drain into the Puget Sound system (WDFW 1975), providing highly seasonal freshwater discharges originating in the Olympic and Cascade Mountain watersheds. The total river discharges range seasonally from a minimum of about 141,000 cubic feet per second (cfs) to a maximum of 3.7 million cfs with a yearly mean of 410,000 cfs. The range in volume of water discharged from the rivers can influence local currents around the deltas. Figure 1-1 (page 3) shows the basins and rivers included within the Nearshore Study area. Levees, jetties, and groins interfere with current patterns that deliver sediment and detritus, and exchange of aquatic organisms within and adjacent to river deltas, as well as along drift cells that run parallel to beaches, which affects habitat quality and quantity.

Waves

Climatic conditions (e.g. storms, wind, etc.) contribute to the wave environment that influences shorelines. Broad regional differences occur in wind patterns and directions within the Puget Sound region, which affect wave energy and its influence on erosion and sediment transport rates within the study area. Exposure to wave action depends on the relative location of the individual shorelines around Puget Sound. The orientation of shorelines to open water is another significant factor. Shorelines that are exposed to considerable expanses of open water, particularly from a northwesterly direction, allow winds to blow unobstructed, creating wave climates having greater amplitudes and frequencies. Long-term exposure of shorelines to these energy conditions influences their physical features, substrate conditions, and susceptibility to erosion.

In Puget Sound, waves are primarily limited by fetch (the distance over water the wind blows), resulting in waves with small to moderate heights and short periods (Downing 1983). An exception is along the Strait of Juan de Fuca and the western side of Whidbey Island, where long-period swell waves can enter from the Pacific Ocean. The irregular shape of Puget Sound, combined with the relatively smaller sizes of its interconnecting basins, produces a fetch-limited environment with significant local variability in wave energy, orientation to winds, and exposure to waves. Prevailing winds come from the south during the winter and from the northwest during the summer; the strongest winds come from the south when winter storms move inland from the eastern Pacific (Mass 2008). The ability of waves to erode the shoreline, particularly feeder bluffs, is severely limited in Puget Sound as much of the shoreline is armored. Wave erosion of bluffs is an essential source of sediment for Puget Sound beaches that are critical spawning habitat for forage fish and migration corridor for salmon among other essential habitat attributes.

3.1.4 Sedimentation and Erosion

Puget Sound beaches are primarily defined by sediment movement driven by wave action, which includes erosion, transport, and deposition of material (Downing 1983, Woodroffe 2002). Sediment movement perpendicular to the shoreline, cross-shore transport, creates the characteristic beach profile. Movement parallel to the shoreline, or longshore transport, redistributes coastal sediment over many miles. Longshore transport is significant in shaping and forming other nearshore ecosystems, including barrier embayments and closed lagoons, which are maintained by spits or other depositional features. Puget Sound sedimentation and erosion is highly episodic. It relies heavily on the sources of sediments and the frequency of the strong storms that contribute sediments to the Sound and redistribute them in the coastal zone. The benefits sought by restoration actions will likely depend on the nature of episodic storm events as well as the quantity of available sediments.

Most beaches of Puget Sound lie within littoral cells (drift cells), which have a net transport of substrate from sediment sources to deposition areas. Beaches can generally be assigned to one of two fundamental geomorphic types: coastal bluffs or barrier beaches. Coastal bluffs occur where the coastline has eroded landward, into upland terrain. Barrier beaches are formed where beach sediment has accumulated seaward of the original coastline, forming a barrier beach (Shipman 2008). The spatial pattern of bluffs and barriers along Puget Sound's shoreline is complex, reflecting the irregular shape of the shoreline and accompanying local changes in wave energy and orientation, differences in the abundance and texture of sediment sources, and the redistribution of coastal sediment by longshore transport (Finlayson and Shipman 2003). As discussed in the previous section, erosion and sedimentation is severely limited along Puget Sound beaches due to the presence of shoreline armoring and jetties and groins. This armoring restricts the erosion of feeder bluffs that provide a source of sediment input, and groins and jetties interrupt sediment transport to beaches that are down drift.

While coastal embayments of different sizes derive from various geologic origins associated with glaciations, stream channel formation, spatial orientation to wind and waves, and other processes, sediment delivery and transport play a vital role in their geomorphology and functions. Embayments with the same geologic origins and initial morphology can have widely varying geomorphology and functioning due to effects of more recent nearshore processes. The influx of fluvial sediment from contributing watersheds, coastal sediments from adjacent shorelines, volume of sediment relative to embayment size and depth, and the extent of isolation from wave energy and associated sediment transport forces define the complex mosaic of embayment landforms in Puget Sound. Sediment delivery and transport are fundamental shaping processes used to distinguish embayment landforms, including open coastal inlets, barrier estuaries, barrier lagoons, and closed marsh lagoons. In short, these systems are distinguished by the extent to which sediment supply supports depositional features (spits, bars, beaches) that enclose embayments completely, partially, or insignificantly.

River delta systems are dominated by tidal and fluvial processes, and are typically not strongly influenced by littoral (beach) sediment transport and delivery. However, sediment erosion and accretion are still important in delta ecosystem functions. The shape and size of a delta is largely determined by amount and type of sediment available, as well as the configuration of the shoreline near the river mouth. Wave and tidal action redistribute deltaic sediments delivered from the watershed (Wright 1985, Bird 2000, Woodroffe 2002), defining each delta's dynamic shape and size. Upstream of a delta, estuarine wetlands develop where sediment accretion exceeds erosion and subsidence rates. Changes in this balance can lead to erosion of salt marsh and changes to tidal channel morphology (Grossman 2005). Over many decades, this can lead to great differences in geomorphic as well as ecological processes among large portions of a delta.

Sediment input and transport are limited due to causeways and levees that inhibit the erosive forces of tidal hydrology and freshwater input. Jetties and groins at the mouths of large rivers and streams limit the delivery of riverine sediment to adjacent beaches and marine submerged vegetation. Stressors that restrict erosion and sediment dynamics in deltas and embayments also inhibit distributary and tidal channel formation and migration that aid in the delivery of detritus and exchange of aquatic organisms and provide important habitat for aquatic species.

3.1.5 Hazardous, Toxic, and Radioactive Waste (HTRW)

Hazardous, toxic, and radioactive waste (HTRW) sites in the Puget Sound basin are regulated primarily by the EPA and the Washington State Department of Ecology (WDOE) through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, with amendments), and the Washington State Model Toxics Control Act (MTCA). HTRW is defined in ER 1165-2-132 as “any material listed as a "hazardous substance" under 42 U.S.C. 9601 et seq. (CERCLA). (See 42 U.S.C. 9601(14). Hazardous substances regulated under CERCLA include "hazardous wastes" under Sec. 3001 of the Resource Conservation and Recovery Act, 42 U.S.C. 6921 et seq; "hazardous substances" identified under Section 311 of the Clean Air Act, 33 U.S.C. 1321, "toxic pollutants" designated under Section 307 of the Clean Water Act, 33 U.S.C. 1317, "hazardous air pollutants" designated under Section 112 of the Clean Air Act, 42 U.S.C. 7412; and "imminently hazardous chemical substances or mixtures" on which EPA has taken action under Section 7 of the Toxic Substance Control Act, 15 U.S.C. 2606; these do not include petroleum or natural gas unless already included in the above categories.” Contamination at a site caused by a spill or other uncontrolled release or an abandoned hazardous waste site meets the definition of HTRW in ER 1165-2-132. If a substance is used for its intended purpose (application of pesticides per labeled directions) or released via a permitted structure (storm water pipe), the substance would not meet the definition as HTRW.

The project sponsor commissioned a Phase 1 Environmental Site Assessment for the sites under initial consideration (USFWS 2012). This report is incorporated by reference.

3.1.6 Water Quality

Water quality is generally defined as the chemical, physical, and biological characteristics of water in a particular area. In Puget Sound, water quality is expressed by a set of parameters that shows the relative health and quality of that water. To determine overall water quality, parameters such as temperature, dissolved oxygen (DO), total dissolved gas, pH, turbidity, and nutrient content are measured.

Puget Sound, as in most large water bodies, has a great deal of variability with respect to water quality parameters across different parts of the water body. Additionally, water quality is influenced a great deal by natural variability, and discerning natural changes from anthropogenic changes is an ongoing challenge. The most recent monitoring data from the Puget Sound Partnership indicates that marine water quality as a whole continues to decrease relative to the baseline. Recent favorable ocean conditions have slowed this apparent decline in areas such as Admiralty Reach and the Georgia Basin, but areas such as Elliot Bay and Budd Inlet continue to decline unabated. The most recent data show the top 50 meters water layer to be warmer than usual from about January to June and cooler than normal in the latter part of the calendar year. Surface temperatures (0-2 meters) in the Central Basin were at or slightly below the long-term average. Water bodies were measured to be slightly saltier than the previous 3 years, although these values did not approach the values observed in the mid-2000s. Salinities in the Central Basin specifically were typical compared to the long-term average except in May through July, when increased freshwater inputs from snowmelt decrease the overall salinity.

There is a wealth of monitoring data that provide further insight into the existing condition of water quality for Puget Sound. The Puget Sound Ecosystem Monitoring Program (PSEMP) Marine Waters Workgroup releases annual overviews of Puget Sound water quality, as well as quantitative monitoring data for specific basins and water quality parameters. WDOE, along with the PSP, maintains the Marine Water Quality Index, which compares recent parameter data with previous years to create an overall temporal picture of changes in water quality across Washington. Finally, the PSP annually publishes the State of the Sound, which assesses data related to the health of the Puget Sound, including water quality.

3.1.7 Greenhouse Gas Emissions

The Earth's atmosphere is changing, the climate system is warming, and the changes are likely due in part to human activities that produce greenhouse gases (GHGs). GHGs can be produced both naturally and by non-natural human activities such as the combustion of fossil fuels and production of cement. Water vapor is the most abundant of the GHGs and carbon dioxide (CO_2) is the second most-abundant. CO_2 is naturally absorbed during some physicochemical and biological processes, but human activities can also affect these processes. For example, deforestation reduces the amount of CO_2 absorbed by plants via photosynthesis. After CO_2, the most abundant GHGs in the atmosphere are methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). These compounds are produced through both natural processes and human activities. Of the GHGs, water vapor and carbon dioxide have the most significant impact on the greenhouse effect, contributing 36 to 72% and 9 to 26%, respectively (Kiehl and Trenberth 1997).

As a primary contributor to the greenhouse effect and with production and absorption sources closely linked to human activity, CO_2 is typically the focus of GHG discussion. According to NOAA's Earth Systems Research Laboratory, the concentration of CO_2 in the atmosphere increased by 36% from 280 parts per million (ppm) in pre-industrial times to 382 ppm in 2006. The current annual increase in CO_2 concentration is 1.9 ppm/year. Projections for future emissions vary greatly based on the assumptions made about trends in human activities related to CO_2 production and absorption. Generally, however, the scientific community agrees that without significant changes to current policies and practices, CO_2 concentrations in the atmosphere will continue to increase.

3.1.8 Underwater Noise

Anthropogenic activities have increased the ambient sound levels throughout Puget Sound. To analyze the proposed action's potential effects of underwater noise on aquatic resources, some fundamental characteristics of sound and the existing conditions (i.e., the status of underwater noise in Puget Sound) are laid out here for a basic understanding for the analysis in section 5.1.8. Underwater noise was raised as a concern due to potential construction impacts.

Sources of Sound

Ambient noise is the combination of all sound sources, which creates a steady background noise. Underwater sound source categories are biological (caused by marine life), hydrodynamic (caused by wind, waves, and rain), marine vessel traffic, and seismically produced such as during earthquakes or seismic surveys for oil exploration. Ambient noise conditions underwater in Puget Sound have many contributors including shipping traffic to the Ports of Everett, Seattle, and Tacoma, U.S. Navy activities, the Washington State ferry routes across Puget Sound with up to 23 vessels operating at a time, cruise ships, commercial fishing vessels, and recreational boats. As one example location, permanent ambient underwater noise in Admiralty Inlet, a major route for shipping traffic near Port Townsend, is around 98 decibels (dB) (1 µPa @ 1 m; Bassett 2010). Mean ambient level in most marine waters is 80 to 100 dB (Richardson et al. 1995).

Sources of sound are intermittent as well as ambient. Some temporarily occurring noises include dredging, ships passing nearby, naval sonar testing, and pile driving or other construction-related activities. For example, in addition to the ambient noise in Admiralty Inlet, the Washington state ferry vessel in the Port Townsend-Coupeville route emits roughly 179 dB (1 µPa @ 1 m; Bassett 2010). Small ships around 100 to 150 feet long are common in Puget Sound and their engines emit broadband sound (20 Hz to 1 kHz) at 150 to 170 dB (1 µPa @ 1 m; Richardson et al. 1995). Larger commercial vessels emit lower frequency noise as loud as 170 to nearly 200 dB (1 µPa @ 1 m). Naval active sonar testing is likely the loudest sound produced emitting 230 dB (1 µPa @ 1 m) in the range of 2 to 5 kHz.

Animals in Puget Sound Potentially Affected by Underwater Noise

The major groups of animals in Puget Sound that can be affected by underwater noise are fish, diving birds, pinnipeds (seals, sea lions, and sea otters), and the two types of whales, mysticetes (baleen whales) and odontocetes (toothed whales). The species of focus for this analysis are identified as significant biological resources in section 3.2 or are otherwise protected by the Marine Mammal Protection Act.

Fish can be harmed in different ways, particularly through their swim bladder because of the large difference in impedance between the gas-filled bladder and the surrounding water-filled body tissues (Nedwell et al. 2004). Intense sound pressure waves can cause physical harm and mortality. Fishes' sensitivity to hearing varies, but most exhibit a response to sounds in the range of 50 Hz to 2 kHz, with a minimum threshold around 70 dB (Hastings 1995). Herring, a forage fish with declining populations, have high sensitivity to sound due to their specialization of pressure-sensing mechanisms (Blaxter and Hoss 1981); this is in contrast to Cottids, which have no swim bladder and are therefore not sensitive to sound waves (Nedwell et al. 2004).

Diving birds, such as marbled murrelets, are vulnerable to excessive underwater noise because it affects their ability to catch prey while diving, and can cause disorientation and injury. Excessive noise can cause a range of problems including aborted feeding attempts, disorientation, and even injury if the sound pressure wave is strong enough.

Marine mammals use vocalizations to identify themselves, their location, territory, or reproductive status and communicate with each other about presence of prey, another animal, or danger. Loudness, frequency, duration, and types of sounds vary widely among the species, and can be compared to the audiogram for the species if one has been developed. Audiograms are the graphic display of hearing sensitivity, which plot frequency against hearing threshold. Available data show that whales' auditory thresholds can extend as low as 10Hz for the mysticetes and as high as 500 kHz for some odontocetes (Gordon and Moscrop 1996). California Sea lions are most sensitive to sounds between 1 kHz and 28 kHz with peak sensitivity around 16 kHz (Schusterman et al. 1972). Harbor seals have a slightly broader range with ability to hear up to about 50 kHz for sounds over 60 dB (1 µPa @ 1 m; Richardson et al. 1995). The Steller sea lion hearing range is 500 Hz to 32 kHz with less sensitivity at the low and high frequencies.

Killer whales rely on their highly developed acoustic sensory system for navigating, locating prey, and communicating with other individuals (Ford 1989). Noise pollution from marine vessel traffic is one of the main concerns with decline in the endangered Southern Resident killer whale population because of how it may affect their vocalizations and hearing. Excessive noise levels may mask echolocation and other signals the species use, as well as temporarily or permanently damage hearing sensitivity (NMFS 2005a). Vessel traffic negatively affects foraging behavior of the Southern Resident killer whales, which can have biologically significant consequences and is likely a factor in their low population level (Lusseau et al. 2009).

3.2 BIOLOGICAL ENVIRONMENT: NEARSHORE FUNCTIONS

Puget Sound is home to approximately 100 species of shorebirds, 200 species of fish (regular inhabitants), 15 species of marine mammals, hundreds of plant species, and thousands of invertebrate species (Sound Science 2007). Many of these species rely in some way on Puget Sound nearshore ecosystems utilizing productive and complex food webs that derive from interactions among terrestrial, nearshore, and deep water/pelagic ecosystems. The following sections of this chapter provide an overview of biota that occupies the nearshore ecosystem, with a focus on the biota of embayments, beaches, and river deltas. Rocky shorelines have unique species assemblages but are not specifically addressed by the Nearshore Study. The results of the change analysis (Simenstad et al. 2011) indicated that from a geomorphic perspective, rocky coast systems are largely unchanged from historic conditions and therefore have not been identified as a restoration priority in Puget Sound (Fresh et al. 2011). Appendix F has more information on the biota of the rocky shorelines. Table 3-3 lists common names for nearshore biota found in the four landforms.

Table 3-3. Nearshore Biota

	Rocky Coast	Beaches	Embayments	Large River Deltas
Vegetation	See Table 1 in Appendix F	Eelgrass and variety of marine macro-algae.	Eelgrass, marine macro-algae, and salt-water and estuarine wetland species.	Eelgrass, estuarine wetland species.
Macro-Invert-ebrates	See Table 2 in Appendix F	Beachhoppers, isopods, amphipods, cancer crabs, barnacles, polychaetes, sea cucumbers, sea stars, shrimp species, sand dollars, Lewis's moon snail, mussels, cockles, and horse, macoma, and geoduck clams.	Amphipods, isopods, copepods, geoduck, horse, and macoma clams, cockles, Olympia and Japanese oysters, cancer crabs, shore crabs, polychaetes, sea slugs, burrowing anemones, and sea and brittle stars.	Crab, shrimp, mussels, anemones, and sea cucumbers in higher salinity marine portions. Isopods, amphipods, oligochaete and polychaete worms, and fly larvae in brackish marshes.
Fish	Rockfish, kelp greenlings, pricklebacks, wolf eels, perch, many sculpin species such as cabezon and red Irish lord.	Flatfish (sole and flounder), sculpin species, juvenile salmonids, forage fish, and perch.	Flatfish (sole and flounder), sculpin species, stickleback, juvenile salmonids, sturgeon. At high tides in eelgrass beds: bay pipefish, gunnels, shiner perch, and surf smelt.	Flatfish, shiner perch, surf smelt, bay pipefish, salmonids (juvenile and adult), sturgeon, lamprey, longfin smelt, and eulachon.
Marine Mammals	Harbor seals, sea lions, sea otters, killer whales, and northern elephant seals.	Harbor seals, occasionally sea lions (California and Steller), and killer whales.	Harbor seals, occasionally sea lions (California and Steller), and killer whales in larger embayments.	Harbor seals.
Birds	Oystercatchers, harlequin ducks, turnstones, surfbirds, pigeon guillemots, auklets, and belted kingfishers.	Surf scoters, buffleheads, a variety of gulls, mergansers, loons, brants, Canada geese, cormorants, and sandpipers.	Snow geese, brants, gadwalls, American wigeons, teals, plovers, dowitchers, and great blue heron.	Brants, plovers, gadwalls, sandpipers, dowitchers, and great blue herons on mudflats and in estuaries. Mallards, pintails, wigeons, teals, and snow geese in floodplains.

Note: This table is intended to be a *general* rather than comprehensive list of species representative of different Puget Sound landforms. In many cases, species are not endemic to a particular landform, and numerous species that occur in Puget Sound have not been included. (Sources: Kozloff 1973 and 1993, and Dethier 1990)

To relate the benefits of process-based restoration to ecological outcomes, the Nearshore Study team identified a subset of Puget Sound species, species guilds, and habitats, termed "valued ecosystem components" (VECs), that depend on nearshore ecosystems and have social significance to the region's human inhabitants. The relationships between VECs and nearshore ecosystems, documented in peer-reviewed literature, appear in a series of white papers (Buchanan 2006, Dethier 2006, Fresh 2006, Brennan 2007, Eissinger 2007, Johannessen and

MacLennan 2007, Kriete 2007, Leschine and Petersen 2007, Penttila 2007). Conceptual models, restoration objectives, and outreach materials often reference VECs and these documented relationships to nearshore ecosystem process and structures. While not intended to be inclusive of all socially important ecosystem functions, the VEC list does represent a useful cross section of diverse ecological attributes supported by the nearshore zone, including the following:

- Kelp and eelgrass
- Marine riparian vegetation
- Native shellfish
- Forage fish
- Juvenile salmon
- Beaches and bluffs
- Orca whales
- Nearshore birds
- Great blue herons

Species and guilds identified by the Nearshore Study team as VECs that have been used to relate project benefits to ecological outcomes are denoted in this section with an asterisk (*).

3.2.1 Vegetation

Marine Submerged Vegetation

Two main types of submerged marine vegetation inhabit the nearshore zone of Puget Sound: marine algae (which includes kelp and a variety of other seaweeds) and eelgrass. Most marine macroalgae require solid substrate to attach to, but exposure to waves, currents, and sedimentation affect distribution. The highest diversity and abundance of seaweeds in greater Puget Sound occurs in the San Juan Islands and Strait of Juan de Fuca, largely due to the heterogeneity of habitat, exposure to waves and currents, and timing of the tides (Mumford and Dethier, pers. comm., 2010). Native eelgrass generally occurs in intertidal and shallow sub tidal areas throughout Puget Sound (Mumford 2007). The larger perennial species of kelp, bull kelp (*Nereocystis luetkeana*) and giant kelp (*Macrocystis integrifolia*), need consolidated substrate such as bedrock and boulders, and therefore tend to grow more continuously along the rocky shorelines, but kelp beds are not necessarily unique to rocky landforms. Almost all of the 625 marine algal species of Washington can occur on the unconsolidated (boulder/cobble) substrate that is more characteristic of beaches and, in some cases, embayments (Mumford, pers. comm., 2010). Once these kelp and algae detach from their substrate, they typically wash onto Puget Sound beaches providing important nutrients to the upper beach community.

Kelp* plays a critical role in nearshore ecology by providing three-dimensional structure and refuge for a variety of organisms. It has an important role in primary production, directly by serving as a food source for grazers such as urchins and abalone and by providing drift kelp to the shoreline for scavengers, and indirectly by providing a source of carbon for phytoplankton as the kelp decomposes. Floating kelp forests occur primarily along the Strait of Juan de Fuca and the rocky shores of the San Juan Islands, and Puget Sound proper has patchily distributed beds. Non-floating kelp occurs throughout Puget Sound (Mumford 2007). Recent studies have shown that the floating kelp canopy is increasing along the Puget Sound and Strait of Juan de Fuca shoreline (Berry et al. 2005); however, losses in certain areas such as Bainbridge and Marrowstone Islands and small beds in southern Puget Sound are of concern (Mumford 2007).

Eelgrass* (*Zostera marina*) is the most common native vegetation in intertidal and sub tidal beach habitats of Puget Sound, as well as in embayments with minimal freshwater influence. Large eelgrass beds can grow on the fringes of large river deltas where the salinity is high enough and sediment supply is sufficient. Eelgrass meadow size varies throughout Puget Sound, ranging from a few to several hundred square meters. Biological diversity of eelgrass beds is much higher than that of surrounding areas because the three dimensional structure provides cover and foraging habitat. A variety of epiphytic algae, a critical food source at lower trophic levels, can be associated with eelgrass. Lack of data hinders ability to judge trends in eelgrass populations in Washington (Mumford 2007), although evidence suggests major losses in several large embayments such as Bellingham Bay and the Snohomish River delta and a set of small embayments in the San Juan Islands. Hypotheses for the loss of eelgrass in the San Juan Islands include increases in sediment load, hypoxia, eutrophication, shading by overwater structures, overgrowth by macroalgae, and presence of toxic contaminants (Mumford 2007).

Wetland Vegetation

Wetlands are present in the shallows of many landforms in Puget Sound including barrier estuaries, barrier lagoons, closed marshes and lagoons, and large river deltas. Many of these wetlands have severely declined or been lost due to anthropogenic stressors (see Appendix F for information on wetland trends). Wetlands provide foraging and rearing habitat to a variety of organisms in Puget Sound. Some species use coastal wetlands year-round, and others use the habitat during their transition from freshwater to saltwater. Along the fringes of lagoons (which are typically high salinity marine water), pickleweed (*Salicornia virginica*) and jaumea (*Jaumea canosa*) typically dominate the vegetation communities. Where freshwater is present, as in barrier estuaries, closed marshes, and large river deltas, three types of vegetated wetland classes are present: estuarine mixing, oligohaline transition, and tidal freshwater. These classes transition from more saline to freshwater as one moves upstream. In the estuarine mixing and oligohaline transition wetlands, salt marsh vegetation such as saltgrasses (*Distichlis spicata*) and pickleweed dominate. As the marsh transitions from oligohaline transition to freshwater tidal, Lyngby's sedge (*Carex lyngbyei*), tufted hairgrass (*Deschampsia caespitosa*), bulrush (*Schoenoplectus* spp.), and hooker willow (*Salix hookerii*) become more prevalent. Other vegetation tolerant of the higher salinities in estuaries and lagoons includes arrowgrass (*Triglochin maritima*), saltwort (*Glaux maritima*), seaside plantain (*Plantago maritima*), sea-spurrey (*Spergularia* spp.), gumweed (*Grindelia integrifolia*), and saltbrush (*Atriplex patula*) (Dethier 1990, Cummins pers. comm. 2009). Another class of wetland in Puget Sound is euryhaline unvegetated, commonly called tidal flats. Little vegetation other than diatoms inhabits this wetland type.

Estuarine wetlands have a special regulatory status within Western Washington such that they receive high levels of protection regardless of their size or condition (Hruby 2004). Even so, much of the salt marsh and wetland habitat has been lost due to the diking and filling of small embayments and tidally influenced portions of the delta and floodplain for the development of pastures, cropland, industry, and urban centers. Some large river deltas have suffered more than others have. For example, the Skagit River delta has lost 74 percent of its historical wetlands (mostly at the upstream area of the estuary), whereas the Duwamish River, which no longer has a recognizable delta, has lost nearly 100 percent of its historical wetlands (Simenstad et al. 2011).

Riparian Vegetation*

Riparian vegetation characteristic of Puget Sound lowlands includes coniferous trees such as western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga menziesii*), and western red cedar (*Thuja plicata*). Pacific madrone (*Arbutus menziesii*) occurs in drier areas. Native deciduous trees such as red alder (*Alnus rubra*), big leaf maple (*Acer macrophylla*), and vine maple (*Acer circinatum*) are present if there is disturbance, minimal soil development, and a local seed source to facilitate colonization. Shrubs and understory plants such as ocean spray (*Holodiscus discolor*), Oregon grape (*Mahonia spp.*), Indian plum (*Oemlaria cerasiformis*), and sword ferns (*Polystichum munitum*) are common in riparian areas (Brennan 2007). In addition to regionally common upland plant communities, the nearshore zone is the only location of the wetland communities described above, sand spit vegetation such as dune grass, and coastal bluff prairies (see “Rare Communities” in Appendix F).

Colonization of Puget Sound has resulted in large-scale changes to terrestrial vegetation patterns as a result of agriculture, timber harvest, and industrial and residential development. These disruptions and conversions interfere with natural forest processes, structure, and functions, setting the stage for invasions of non-native species (Brennan 2007). Invasive shrubby species such as Himalayan blackberry (*Rubus armenicus*), butterfly bush (*Buddleja davidii*), reed canary grass (*Phalaris arundinacea*), and Japanese knotweed (*Polygonum* spp.) commonly invade disturbed areas, often so aggressively that they inhibit establishment of native vegetation. In large river deltas, the majority of the forested wetlands and riparian zones are entirely devoid of trees or consist of sparse, narrow, and patchy strips of small- to medium-sized cottonwood (*Populus balsamifera*), willow (*Salix* spp.), and alder. River channelization and bank stabilization with levees have required vegetation removal, which results in the majority of the stabilized banks being covered with grasses and invasive species (e.g., blackberry, knotweed, and reed canary grass) of low value to the native fish and wildlife.

3.2.2 Shellfish and Other Macroinvertebrates

Invertebrates on beaches, embayments, and large river deltas assemble largely according to extent of tidal inundation. In river deltas, invertebrate communities may differ among rivers depending on factors such as the extent of freshwater influence and chemical contamination. Benthic macroinvertebrates in brackish and saline conditions include amphipods, isopods, oligochaete and polychaete worms, and copepods (Cordell et al. 1998). Insect larvae are more prevalent in freshwater. Other invertebrates found in more saline conditions include cancer crabs, polychaetes, sea cucumbers, sea stars, many shrimp species, and sand dollars (Dethier 1990). Native and introduced oysters can reside in the protected intertidal zones of embayments. Lewis's moon snail and sunflower sea stars are common predators in intertidal and sub tidal zones. Occasionally, giant Pacific and red octopi dwell in the lower intertidal and sub tidal zones (Harbo 2006). Beach hoppers live underneath driftwood in the upper tidal elevations of beaches (Kozloff 1993). In eelgrass meadows and kelp beds, diversity and density of invertebrates increase tremendously with nudibranchs, jellyfish, decorator crabs, sea urchins, sea pens, and a variety of bivalves, shrimp, crabs, and echinoderms.

Shellfish*, mainly clams and oysters, are an important part of the Puget Sound ecosystem and regional economy, and have cultural significance for Native American tribes. Geoduck clams are the largest of the bivalve species in Puget Sound, ranging from the lowest intertidal elevations to depths of 100 meters (Harbo 2006). These large clams can reach over 80 years old. Native Americans and recreational users harvest wild geoduck. Geoduck aquaculture is increasing along beaches and embayments of south Puget Sound and Hood Canal, as demand for overseas export increases. Another shellfish, the native Olympia oyster (see section 3.2.7) has declined dramatically over the past century mainly due to overharvest (Dethier 2006). The Pacific oyster, introduced from Japan, is artificially propagated throughout Puget Sound. Pacific oysters could not sustain themselves as a population without aquaculture efforts as they require higher temperature for reproduction; however, they occasionally reproduce successfully in the wild.

Artificial landforms often attract unique benthic communities. Although many pilings and docks are treated with preservatives to prevent bio-fouling, hardier species move in first, then others follow. Invertebrates commonly found on floats, docks, and pilings include plumose anemones, ochre and sunflower sea stars, tubeworms, and breadcrumb sponges (*Halichondria* spp.) (Kozloff 1993). Other invertebrates may be present, such as sabellid worms, bryozoans, barnacles, mussels, several types of snails, crabs, and shrimp, and native and invasive ascidians.

3.2.3 Fishes

Widely varying fish communities use the nearshore zone where individuals spend all or just portions of their lives. Three general groupings are demersal/reef fish, forage fish, and anadromous fish, although some nearshore species may not fit neatly into a single category. Fish diversity is higher in kelp and eelgrass beds due to the refuge and feeding opportunities provided. At high tide, the diversity of fish species in the nearshore zone increases significantly, especially in eelgrass meadows (Dethier 1990). Information on the three categories of fish follows.

Demersal/Benthic Fish

The demersal/benthic (associated with and located on the bottom) fish category includes fish that use a wide spectrum of habitats including rocky shores, submerged vegetation, and sandy bottoms. Fish found in the rocky/boulder habitat are referred to as reef-dwelling fish; however, they may use areas with softer substrate, particularly if there is structure to hover over, such as vegetation, sunken boats, riprap, or old pilings. Lingcod is the typical top predator in reef-like habitats. Juvenile rockfish often hide in understory kelp and rocky crevices (Hayden-Spear and Gunderson 2007), and certain species use areas as shallow as tide pools (Love et al. 2002). A few rockfish species forage in shallow areas as adults. A variety of sculpin use reef habitats to rest on the bottom and feed on the abundance of invertebrates indicative of rocky substrates. Kelp greenlings, pricklebacks, wolf eels, gunnels, and shiner perch forage in and around rocky substrates and their associated kelp forests. Demersal fish more typical of softer substrate include flatfish such as sole and flounder, certain sculpin species, and the occasional rockfish species. Occasionally, deepwater fish such as spiny dogfish, ratfish, eelpout, Pacific tomcod, and hake may enter the shallows of the nearshore zone to feed.

Forage Fish*

The three species of small schooling fish that are most highly dependent on the nearshore zone are Pacific herring, Pacific sand lance, and surf smelt. Collectively referred to as “forage fish”, their sheer abundance makes them a primary food source for a many marine fish and birds, particularly salmonids. These three species are highly dependent on nearshore habitats and substrate for spawning (Penttila 2007). Sand lance and surf smelt spawn in the upper intertidal zone of sand/gravel beaches leaving their eggs to incubate in the substrate. Their spawning areas are common throughout Puget Sound. Pacific herring spawn almost exclusively in the shallow sub tidal and lower intertidal zones, mainly on eelgrass and kelp. Other forage fish species, such as longfin smelt and eulachon, use river deltas for spawning (see Appendix F).

Anadromous Fish

Fifteen native species of anadromous fish use marine and freshwater of the Puget Sound area. These include all five species of Pacific salmon (pink, Coho, chum, Chinook, and sockeye), two species of native char (bull trout and Dolly Varden), steelhead and coastal cutthroat trout, longfin smelt, eulachon, white and green sturgeon, and two species of lamprey. Salmon are discussed in more detail because of their ecological, cultural, and economic importance in Puget Sound. For detailed information on other anadromous fish that occur in Puget Sound, see Appendix F.

<u>Salmonids:</u> The most well-known anadromous fish in Puget Sound are salmonids (salmon, trout, and char). Several agencies monitor salmonid populations due to the ecological and economic importance and declining numbers (warranting the listing of several species on the Endangered Species List). Pacific salmon, in particular, have a critical role in Puget Sound’s ecosystem dynamics. Known as a keystone species (Willson and Halupka 1995), Pacific salmon are a food source for many marine, freshwater, and land animals and provide marine nutrients to freshwater environments post-spawning (Cederholm et al. 1999). All salmonids spawn in freshwater gravel substrates where the eggs incubate and hatch.

Although most species and life history stages of salmonids can be observed in nearshore areas, juvenile salmonids* typically use these ecosystems extensively as a migration corridor and foraging habitat; however, not all species or runs within a species use the nearshore zone in the same way (Fresh 2006). For example, Chinook and chum use coastal embayments and non-natal estuaries from other rivers whereas steelhead do not. As the juveniles grow, they expand their range into deeper water before migrating to the North Pacific Ocean, with the exception of a few runs that are Puget Sound residents (Fresh 2006). As adults, large salmonids such as steelhead and Chinook typically only use the larger rivers for spawning, but pink, chum, and Coho salmon adults can transit small embayments en route to their spawning grounds in smaller streams that flow into Puget Sound. Adult bull trout use the nearshore areas along beaches and at the entrances of embayments and large river deltas as foraging habitats.

Salmonid use of the nearshore zone depends on the species, the particular run of a species, and environmental conditions. Dendritic tidal channels in large river deltas are an important feature for juvenile rearing and smoltification (Beamer et al. 2005, Fresh 2006); however, much of this off-channel habitat has been lost in large river deltas due to diking of rivers for development of floodplains. See Appendix F for information on population trends of salmonids in Puget Sound.

3.2.4 Birds

Approximately 100 bird species utilize Puget Sound nearshore ecosystems. Shorebirds* forage along the beaches at the tide line in search of benthic invertebrates that are close to the surface; representative species include spotted sandpipers, surf scoters, dunlins, Western sandpipers, yellowlegs, and turnstones. Embayments and river deltas host a variety of birds that are attracted to abundant eelgrass beds, salt marshes, and mudflats. Birds associated with tide flats include snow geese, brants, gadwalls, American widgeons, mallards, pintails, teal, plovers, sandpipers, and dowitchers (Buchanan 2006). Great blue herons* forage on a variety of fish and invertebrates in shallow pools, mudflats, and eelgrass beds during low tides (Eissinger 2007). American bitterns, Virginia rails, marsh wrens, savannah wrens, song sparrows, and common yellow throats nest and forage in and around salt and freshwater marshes.

In fall and winter, the more agriculturally developed river deltas, such as Skagit and Snohomish, host large numbers of snow geese and trumpeter swans that feed on vegetation in shallows and agricultural fields. The trumpeter swan, once an endangered species, has increased in numbers in Skagit County from a 1963 population of 20 to several thousand today. Other shorebirds, such as dunlin and black bellied plover, use flooded agricultural fields and estuaries mainly during migration and in winter. Several species of raptors appear throughout Puget Sound including bald eagle, red-tailed hawk, rough-legged hawk (winter only), northern harrier, gyrfalcon (winter only), peregrine falcon, merlin, Cooper’s hawk, sharp-shinned hawk, and osprey. The Skagit Delta hosts one of the largest wintering populations of raptors in the contiguous United States. In heavily urbanized river deltas such as the Duwamish River estuary, abundance of birds is much lower due to lack of foraging and nesting habitat.

More widely distributed birds throughout Puget Sound include cormorants, grebes, loons, crows, geese, and a variety of gulls. Some of these, such as cormorants and gulls, take advantage of human-made shoreline structures for nesting and foraging. A variety of passerines, also known as song and/or perching birds, nest and forage in riparian areas of rivers and along the shoreline.

3.2.5 Mammals

Marine

Harbor seals are the most common marine mammal, found throughout Puget Sound, often seen basking on rocky outcroppings, beaches, and occasionally human-made structures. They occasionally enter rivers and may travel several miles upstream. Steller sea lions visit the San Juan Islands every fall to rest and forage before they go to coastal rookeries to mate. California sea lions, northern elephant seals, and sea otters visit Puget Sound, though not in large numbers. Killer whales*, also known as orcas, are top predators in Puget Sound. These whales appear most frequently around the San Juan Islands; however, they occasionally explore other areas of Puget Sound. Of the four types of killer whales in the northeastern Pacific, only the Transients and Southern Residents are common in the San Juan Islands and greater Puget Sound region; the Offshores and Northern Residents rarely enter Puget Sound (Kriete 2007). Transient killer whales feed on marine mammals such as harbor seals, sea lions, and porpoises, and their presence is rather unpredictable. The Southern Residents regularly occur among the San Juan Islands and occasionally in Puget Sound; they feed almost exclusively on fish, primarily Chinook and chum salmon. The Southern Residents are ESA-listed as endangered (see section 3.2.7).

Freshwater and Terrestrial

If freshwater is present or a stream is nearby, river otters may forage and play in embayments and at the mouth of rivers. Beaver, muskrat, and mink inhabit upstream portions of the many streams and rivers that flow into Puget Sound. Terrestrial mammals such as black tail deer, raccoon, weasels, opossum, coyote, and a variety of small mammals inhabit riparian areas and occasionally browse the shoreline. Carlton and Hodder (2003) introduced the term “maritime mammal” and have documented many predation events by terrestrial mammals that forage specifically in marine intertidal areas; the majority of records involved raccoon, mink, and black bear on shores of the Eastern North Pacific Ocean. Habitat areas have significantly decreased due to urbanization and industrialization around Puget Sound.

3.2.6 Aquatic Invasive Species

Biological monitoring of Puget Sound in the last 20 years has identified many exotic species that have invaded the region. At least 52 non-indigenous marine species inhabit Puget Sound based on a comparison of listings by WDFW and researchers (Cohen 2004). Ray (2005) found 125 non-indigenous marine and estuarine animal species in the State of Washington by querying lists maintained by the Smithsonian Institution (*www.nisbase.org*). In Ray’s (2005) report sponsored by the Corps’ Engineer Research and Development Center, there are 12 invasive marine animal species deemed most threatening to Corps habitat restoration efforts in Washington. These include several species of clams and mussels as well as Atlantic salmon and green crab. In addition, the Washington State Aquatic Nuisance Species Management Plan (Meacham 2001) identifies nine marine plant species as present in Washington, including *Pseudo-nitzchia australis*, the algae linked to domoic acid and shellfish poisoning in humans. Shipping imports for aquaculture and fisheries provide the dominant pathways for marine invasion within this region (Wonham and Carlton 2005); however, human modification of shorelines, including marina development, can increase the likelihood of spread as exotic species fill voids following native habitat loss. See Appendix F for more specific information on aquatic invasive species.

3.2.7 Rare, Threatened, and Endangered Species

Puget Sound supports numerous rare, threatened, and endangered species. Many of these have specific ecological niches that are vulnerable to multiple anthropogenic pressures including habitat loss, overharvest, and pollution. Some have protection under the ESA; others are recognized at the state level, and some have no formal protection status but have been identified as rare by the conservation community. Plants discussed herein have been identified as rare on the Washington Department of Natural Resources (WDNR) Natural Heritage website. Species discussed below use nearshore ecosystems either **directly** as habitat (exclusively or intermittently), **indirectly** by foraging for species that have a strong dependence on the nearshore zone, or **intermittently** by occasionally using the nearshore habitats, including use as migratory corridors. Details on distribution, population status, and threats to each of these species appear in the following sections. Appendix F provides additional information on life history and population status on rare, threatened and endangered species.

Southern Resident Killer Whale (Orca)

Due to the low numbers and potential threats, Southern Resident killer whales are ESA-listed as endangered (NMFS 2005a). Critical habitat is designated as marine water more than 20 feet deep in Puget Sound, San Juan Islands, and Strait of Juan de Fuca (NMFS 2006b). Southern Resident killer whales (*Orcinus orca*) occur in Puget Sound from early spring to late fall until they move to the coast for the winter. Southern Resident killer whales eat a variety of fish and squid, but have a strong feeding preference for chum and Chinook salmon, which rely heavily on the nearshore zone for juvenile rearing. Southern Resident killer whales are often around the San Juan and Gulf Islands, the surrounding straits, and the eastern end of the Strait of Juan de Fuca, sometimes playing and foraging in shallow kelp beds adjacent to rocky shorelines (Kriete 2007). In the fall, the whales may expand their range in Puget Sound to the south in pursuit of local salmon runs before leaving for their winter habitat outside of Puget Sound (Kriete 2007).

Three matrilineal pods of Southern Resident killer whales frequent Puget Sound, named J, K, and L pods, numbered at 82 individuals for all three pods in 2015. Threats to this population include decline in prey abundance, presence of toxic substances, and whale-watching vessel traffic. Concentrations of contaminants in Southern Resident killer whale are some of the highest of any marine mammal in the world (Kriete 2007). In addition, the Southern Resident pods are relatively small, reproductively isolated, and face the risk of population decline through inbreeding effects. Currently, these pods have few reproductive males and females, and the loss of a key reproductive male or female could stunt population growth for years until another individual reaches maturity, which typically occurs at 10 to 15 years of age (Perrin and Reilly 1984). The social cohesion within pods concentrates individuals within a relatively close extent; this can lead to large population declines resulting from one catastrophic event.

Humpback Whale

Due to past commercial exploitation, humpback whales are ESA-listed as endangered. Although humpbacks were one of the more common cetacean species in Puget Sound in the early 1900s, they are now sighted only intermittently (Calambokidis and Steiger 1990). Humpback whales (*Megaptera novaeangliae*) have at least three different populations in the North Pacific Ocean. This population winters in coastal Central America and Mexico and migrates to areas ranging from the coast of California to southern British Columbia in summer/fall (NMFS 2013). The California/Oregon/Washington stock is relevant to this project. Humpbacks are increasing in abundance in much of their range. In the North Pacific, humpback abundance was fewer than 1,400 whales in 1966 after heavy commercial exploitation. The current abundance estimate for the North Pacific is about 20,000 whales. Recent increases in the population have resulted in more frequent sightings in Puget Sound and along the Strait of Juan de Fuca. Humpbacks observed in Puget Sound do not remain for long periods and are considered stragglers. Threats to humpbacks include entanglement in fishing gear, boat strikes, whale watch harassment, and habitat degradation (NMFS 2013).

Sea Otter

Sea otters (*Enhydra lutris*) range from Southern California to the Aleutian Islands in Alaska, in non-contiguous patches. The Washington population is listed as endangered by the State of Washington due to its small size, restricted distribution, and vulnerability. The southern population, in California, and the northern population, in Alaska, are each listed as a federally threatened species; however, the Washington and British Columbia populations are separate and not ESA-listed (USFWS 1977; USFWS 2004). Sea otters almost never leave the water where they inhabit the shallow kelp forests of the nearshore zone and prey on a variety of invertebrates (Haley 1986).

Historically, sea otters inhabited the entire west coast of North America, but harvest for pelts that began in the 1700s extirpated them from many areas, including Washington. In 1969 and 1970, sea otters were reintroduced to the Washington coast from Alaska. Surveys indicate that the sea otter population is gradually increasing in Washington State and in British Columbia off Vancouver Island. Most of the Washington population is on the northern coast and the western Strait of Juan de Fuca; however, sightings have occurred as far south as Olympia and more frequently in the San Juan Islands (Lance et al. 2004). Threats to sea otters in Washington include oil spills, infectious disease, and entanglement in fishing nets (WDFW 2012b).

Hood Canal Summer Chum Salmon

The Hood Canal Summer-Run chum salmon Evolutionarily Significant Unit (ESU) is ESA-listed as threatened (NMFS 2005b). Critical habitat exists throughout Hood Canal and its tributaries, which are all considered part of the Puget Sound Basin. Chum salmon (*Oncorhynchus keta*) range from Monterey, California to the Arctic coast and Beaufort Sea along the coast of North America. Juvenile chum salmon use small coastal embayments and eelgrass beds as foraging grounds and refuge from predators before migrating to the Pacific Ocean (Fresh 2006). Chum salmon use their natal estuaries extensively for rearing and foraging during outmigration to the ocean.

Six of the eight summer chum salmon stocks within the Hood Canal ESU have decreased in abundance with return stocks below viable replacement levels (Fresh 2006). The Hood Canal summer chum populations have been declining since 1978. The Strait of Juan de Fuca populations have been declining since 1988 and although they are not declining as rapidly as those in Hood Canal, these populations are at very low levels. Threats to Hood Canal summer-run chum include degradation of habitat, harvest, and low water flows in the Hood Canal watersheds (Johnson et al. 1997). The Duckabush estuary site will provide an opportunity to restore habitat and increase populations within Hood Canal for Summer Chum Salmon.

Puget Sound Chinook Salmon

The Puget Sound Chinook salmon ESU found east of the Elwha River is ESA-listed as threatened (NMFS 2005b). Critical habitat exists throughout Puget Sound and its tributaries. Chinook salmon (*Oncorhynchus tshawytscha*) range from central California to Kotzebue Sound, Alaska. Puget Sound populations are largely summer/fall runs, which are typically considered ocean-type fish (migrating to marine water within their first year). They are found in most river and tributaries in Puget Sound, Hood Canal, and Strait of Juan de Fuca. Like chum, juvenile Chinook, particularly ocean-type, have a have a strong dependence on their natal estuary during outmigration to the ocean and use small coastal embayments and nearshore areas while rearing along the shoreline before migrating to the North Pacific Ocean (Fresh 2006). Few Chinook salmon (called residents) reside year-round in Puget Sound (Pressey 1953, Brannon and Setter 1989).

Abundance estimates indicate that most populations are at a small fraction of their historic levels; several populations within the Nooksack, Lake Washington, mid-Hood Canal, Puyallup, and Dungeness basins have returns of fewer than 200 adult fish, signifying extinction risk. The Nooksack river delta site will provide a rare opportunity to restore a large river delta area that will increase severely degraded populations of salmon in this river system. Only the upper-Skagit stocks have returns of native (non-hatchery) fish in excess of 10,000 adults. The North Fork river delta site is located at the confluence of the Skagit River and is critical to these native fish returns by providing scarce river delta and estuary habitats that are necessary for life cycle requirements of these salmon. A 1998 status review indicated a decline of 1.1 percent per year; more recent calculations indicate a slower decline (Shared Strategy 2007). Threats to Puget Sound Chinook salmon include diking, draining, and filling of freshwater and estuarine wetlands; sedimentation of upper tributaries due to timber harvest; and blockages and altered hydraulic regimes from dams (Good et al. 2005).

Puget Sound/Strait of Georgia Coho Salmon

Coho salmon (*Oncorhynchus kisutch*) range from central California to the Bering Sea to along the coast of North America. NMFS (2009c) identified Puget Sound/Strait of Georgia Coho as a Federal Species of Concern. While in Puget Sound, juvenile and sub-adult Coho migrate and forage along the shoreline before migrating to the Pacific Ocean. A few coastal and inland Coho salmon stocks reside year-round (called residents) in Puget Sound (Weitkamp and Neely 2002).

Stocks in Puget Sound range from healthy to critical (WDFW 2002). Three stocks in Puget Sound/Strait of Georgia are at high risk of extinction and one as possibly extinct (Nooksack River) (Nehlsen et al. 1991). None of the stocks identified as healthy are strictly of wild origin. Bledsoe et al. (1989) reported an 85 percent decline of Coho salmon runs in South Puget Sound from 1896-1975. Hatchery production is a major threat to Puget Sound/Strait of Georgia Coho by way of genetic outbreeding and homogenization, as many hatchery strains are from out-of-basin sources. Other threats include loss of habitat and unfavorable ocean conditions (NMFS 2009c).

Coastal/Puget Sound Bull Trout

Bull trout (*Salvelinus confluentus*) are native char of Washington, Oregon, Idaho, Nevada, Montana, and western Canada. Puget Sound bull trout are ESA-listed as threatened (USFWS 1999). Critical habitat exists throughout much of Puget Sound and its tributaries. Unlike Pacific salmon, anadromous bull trout are year-round residents of the Puget Sound basin. In marine water, sub-adult and adult bull trout commonly forage in shallow nearshore habitat and natal and non-natal estuaries along the shoreline, but usually return to their natal estuary to migrate upstream to spawn.

Bull trout populations have declined throughout much of the species' range; some local populations are extinct, and many other stocks are isolated and may be at risk (Rieman and McIntyre 1993). Insufficient data exist to confidently estimate bull trout abundance for many core areas and for the entire management unit (Shared Strategy 2007). Combinations of factors including habitat degradation, expansion of exotic species, and exploitation have contributed to the decline and fragmentation of bull trout populations.

Puget Sound Steelhead
Steelhead (*Oncorhynchus mykiss*) range from Kamchatka in Asia, east to Alaska, and south along the Pacific Coast to about the U.S.-Mexico border (Busby et al. 1996). Puget Sound steelhead are ESA-listed as threatened (NMFS 2007b). Relative to the longer nearshore rearing periods of other juvenile salmonids, steelhead smolts outmigrate to offshore areas quickly and the transit time through the estuary is brief (days to weeks).

In the last 10 years, Puget Sound steelhead populations have decreased at a steady pace with marked decreases seen within the Strait of Juan de Fuca, Bellingham Bay, Hood Canal, and South Puget Sound. The more intense population declines since 1990 in Puget Sound mimic declines of steelhead in British Columbia along the Strait of Georgia and eastern Vancouver Island. Speculated causes of these declines include climate change, hatchery production, harvesting, and increased UV radiation (Hard et al. 2007).

Green Sturgeon
Green sturgeon (*Acipenser medirostris*) are a broadly distributed fish ranging from Mexico to Alaska along the coast of North America. The southern distinct population segment (DPS) of green sturgeon is ESA-listed as threatened (NMFS 2006a). No critical habitat is designated in Puget Sound proper (NMFS 2009a). Although no freshwater spawning habitat occurs in Puget Sound, green sturgeon use the nearshore zone as foraging habitat. Population declines of the southern DPS of green sturgeon are due to a reduction in spawning area to a limited number of rivers including the Sacramento, Rogue, and Klamath, and have little to do with Puget Sound. Other threats include insufficient freshwater flow rates, contaminants, bycatch, impassible barriers, and elevated water temperatures.

Rockfish (Bocaccio, Canary, Yelloweye)
Bocaccio (*Sebastes paucispinis*) range from northern British Columbia to central Baja California. Juveniles are the most abundant life stage occurring in the nearshore zone where they hover over rocky substrate with various understory kelps or sandy bottoms with eelgrass. Due to declining numbers, bocaccio are ESA-listed as endangered (NMFS 2009b). Threats to bocaccio include direct fishing and by-catch, which led to recruitment failure in the early 1990s (NMFS 2009b).

Canary rockfish (*Sebastes pinniger*) range from northern British Columbia to northern Baja California, potentially living to be 80+ years old. Juveniles are the most abundant life stage in the nearshore zone where they hover over rock-sand interfaces and sand flats. Due to declining numbers of canary rockfish in Puget Sound, they are ESA-listed as threatened (NMFS 2009b). Threats to canary rockfish are the same as those for bocaccio.

Yelloweye rockfish (*Sebastes ruberrimus*) range from the eastern Aleutian Islands to Northern California and can live up to 118 years. Due to declining numbers, they are ESA-listed as threatened (NMFS 2009b). Adults, sub-adults, and juveniles occupy the nearshore areas with rocky substrate. Threats to yelloweye rockfish are the same as those for the other rockfish.

Eulachon

Eulachon (*Thaleichthys pacificus*) are a small anadromous fish in the eastern Pacific Ocean that range from California to Vancouver Island, including northern Puget Sound. The southern DPS of eulachon is ESA-listed as threatened (NMFS 2010). No spawning areas are documented in Puget Sound. The only documented eulachon spawning near the project area is the Elwha River in the Strait of Juan de Fuca (designated as critical habitat) and the Fraser River in southern British Columbia (NMFS 2011); however, migrants from the northern population likely forage in areas of the Puget Sound nearshore zone that extend beyond their spawning range (Goetz pers. comm. 2009).

Eulachon abundance exhibits considerable year-to-year variability; however, nearly all spawning runs from California to southeastern Alaska have declined in the past 20 years, especially since the mid-1990s. From 1938 to 1992, the median commercial catch of eulachon in the Columbia River was approximately 2 million pounds (900,000 kg), but from 1993 to 2006, the median catch declined to approximately 43,000 pounds (19,500 kg), representing a nearly 98 percent reduction in catch from the prior period (Gustafson et al. 2010). Threats to eulachon include habitat loss and degradation of spawning grounds via dams, siltation, and dredging, and potentially chemical pollution (Gustafson et al. 2010).

Marbled Murrelet

Marbled murrelets (*Brachyramphus marmoratus*) are small marine diving birds that range from southern California to Alaska. They are ESA-listed as threatened (USFWS 1992). Critical habitat includes upland forested stands used for nesting, but does not include marine water. Murrelets are common winter residents of Puget Sound, especially the northern portions. Forage habitat is deeper water in entrance channels of rocky shores, estuaries, and protected bays where the birds can dive in pursuit of forage fish, which are dependent on nearshore habitat (Angell and Balcomb 1982).

Few data are available to interpret trends in population; however, there was an estimated 51 percent decline in north Puget Sound between 1978 and 2003 (Huff et al. 2006). Recent trends indicate a continued steady decline of marbled murrelets, with a decrease in population of 7.9 percent from 2000 to 2009 in Puget Sound and the Strait of Juan de Fuca (USFWS 2009). The marbled murrelet population estimate for Puget Sound and Strait of Juan de Fuca in 2010 was around 4,400 birds (Pearson et al. 2011a). Threats include habitat loss from timber harvest and windthrow in their terrestrial environment, and harmful algal blooms, declining prey availability (forage fish), and catastrophic events such as oil spills in their marine environment.

Northern Abalone

Northern, or pinto, abalone (*Haliotis kamtschatkana*) range from Alaska to Mexico. NMFS lists northern abalone as a Federal Species of Concern (NMFS 2007b). In Washington, they inhabit rocky shorelines with significant kelp cover around the San Juan Islands and the Strait of Juan de

Fuca. Although there has never been a commercial fishery for northern abalone in Washington State, sport harvests continued into the mid-1990s. Declining numbers triggered WDFW to close the recreational harvest in 1994; however, populations continue to decline (Puget Sound Restoration Fund 2009). Reasons for the continued decline include the Allee effect (in which individuals are too far from each other for successful fertilization), water quality conditions, and poaching.

Olympia Oysters

Olympia oysters (*Ostrea lurida*) historically ranged from southeast Alaska to Baja California. Olympia oysters are a State Candidate Species in Washington meaning they are under review for listing as State endangered, threatened, or sensitive. Oyster reefs often occur between eelgrass beds and mudflats, where they filter-feed on plankton and other matter (Dethier 2006). Although they were once abundant in shallow sub tidal zones of southern Puget Sound in wild and cultured forms, natural reproduction of Olympia oysters has nearly disappeared. Factors leading to the decline include overharvest, siltation, and domestic and industrial pollution of estuaries. Other stressors include predation from invasive drilling snails and flatworms, and displacement by culture of the hardier introduced Japanese oyster (*Crassostrea gigas*) (Dethier 2006).

California Buttercup

California buttercup (*Ranunculus californicus*) grows in open grassy areas, rocky slopes along the coast, and in rocky wooded areas from southern California to southern Vancouver Island. It is listed as a rare plant by the WDNR Natural Heritage Program (WDNR 2009). It tends to be associated with Sitka spruce, Douglas fir, and madrone, and dryer areas such as grasslands. Very few sites in Puget Sound still contain California buttercup and presently are only around the coastline of the San Juan Islands. Given the small range, any disturbance via grazing, development, or recreation can be a threat (WDNR 2009).

Sharpfruited Peppergrass

Sharpfruited peppergrass (*Lepidium oxycarpum*) grows in the salt spray zone from central California to Victoria, British Columbia. In Washington, it is listed as a rare plant by the WDNR Natural Heritage Program. This plant grows in moist cracks and vernal pools and in sand or saline soil in direct sunlight along the coastline. The only known occurrence of Sharpfruited peppergrass in Washington is on the coastline of the San Juan Islands. Given the small range, any disturbance via grazing, development, or recreation can be a threat (WDNR 2009).

Golden Paintbrush

Golden paintbrush (*Castilleja levisecta*) historically occurred at many sites in Puget Sound, British Columbia, and as far south as the Willamette Valley in Oregon. It has been extirpated from the majority of these sites, including all of Oregon, and it is ESA-listed as threatened (USFWS 1997). It occurs in open grasslands at low elevations around the perimeter of Puget Sound. Most remaining populations are in the San Juan Islands and on Whidbey Island. Loss of golden paintbrush is associated with the conversion of grasslands to agriculture, and residential and commercial development (WDNR 2009).

3.3 CULTURAL RESOURCES

Cultural resources encompass a wide range of historic and cultural places and property types. Buildings, structures, and sites; groups of buildings, structures, or sites forming historic districts; landscapes; and individual objects may be eligible for listing in the National Register of Historic Places (National Register) if they meet three main standards: age, significance, and integrity. Resources must be 50 years old or older for National Register consideration, although more recent properties may be determined eligible if they possess exceptional significance. To be significant, a property must have a demonstrated association with events, activities, or developments that were important in the past; with the lives of people who were important; or have potential to yield information through archaeological investigations. Integrity refers to the ability of a property to demonstrate significance through the retention of aspects of location, design, setting, materials, workmanship, feeling, and association. The term "historic properties" refers to cultural resources that are either eligible for or listed on the National Register.

Preliminary investigations to identify historic properties at all 36 proposed restoration sites included a records/literature review and reconnaissance-level survey work (see annotated bibliography). The records/literature search was designed to identify any known (previously recorded) potential cultural resources as well as the extent and location of previous cultural resource investigations. Materials reviewed included reports, field notes, and site forms at the Washington State Department of Archaeology and Historic Preservation and various historical, ethnographic, and environmental documents. The findings are summarized in a confidential report, restricted in distribution due to the sensitive nature of cultural resource information. Conceptual design reports prepared for restoration sites identified several additional buildings and structures potentially historic in age. Reconnaissance-level surveys occurred at 18 sites. Only areas where landowners granted access were considered for investigation. Pedestrian archaeological surveys were further limited to sample areas based on various environmental factors and extent of previous cultural resource investigation and site finds. Additionally, no "occupied" buildings were inventoried. The Corps considers the survey's findings and recommendations are considered baseline and further investigation at each of the proposed sites is needed to determine the presence/absence of unidentified archaeological resources and to evaluate the previously recorded sites. In addition, further inventory of historic structures is necessary.

Common archaeological sites found in the Puget Sound nearshore zone include the following types:

- Occupation sites such as prehistoric hunting camps, prehistoric and ethnohistoric villages, as well as early Euro-American cabins, and farms
- Prehistoric and Ethnohistoric Shell Middens

- Prehistoric and Ethnohistoric Lithic Assemblages/Scatters
- Cemeteries (both prehistoric and historic)
- Railroad camps associated with the construction of railroads and other transportation methods (roads, bridges)
- Logging camps

Common historic buildings and structures found in the Puget Sound nearshore zone include the following types:

- Levees and dike systems
- Canneries
- Early pioneer houses and farming complexes (barns, sheds, fences, and orchards)
- Roads and bridges
- Railroads
- Sawmills

3.4 SOCIOECONOMIC RESOURCES AND HUMAN ENVIRONMENT

The Puget Sound ecosystem is a cornerstone of the region's prosperity and quality of life. People from around the world are drawn to the Puget Sound region because of the dynamic economic opportunities and abundant natural assets the region offers. Puget Sound is bordered by 12 Washington counties and is home to 4.3 million people or over 70 percent of the State's total population (U.S. Census Bureau 2010). The Seattle Metropolitan Statistical Area (MSA) is the population center and economic engine of the Puget Sound Region. The Seattle MSA encompasses three of these 12 counties; with a total 2010 population of over 3.5 million, it is the 15th largest metro area in the U.S. (U.S. Census Bureau 2010).

Puget Sound serves as the major North American gateway for trade with Pacific Rim countries. Together the ports of Seattle and Tacoma make the Puget Sound the second largest U.S. harbor for container traffic. The Puget Sound ecosystem—among the most productive and ecologically diverse in the U.S.—supports one of the largest commercial shellfish fishing and aquaculture industries in the country. Visitors and local residents alike enjoy a thriving outdoor recreation industry including such water-related activities as sportfishing, whale watching, shellfishing, kayaking, and scuba diving. These commercial and recreational activities are dependent upon the ecosystem functions that come from the "natural capital" (i.e. ecosystem elements of geology, water and nutrient flow, native plants and animals, etc.) of the Puget Sound environment (Earth Economics 2008). The following sections describe the socioeconomic resources and human environment with a focus on how the natural capital of the Nearshore Study area benefits the socioeconomics of Washington State.

3.4.1 Shoreline Ownership and Land Use

Washington has an unusual patchwork of public and private tideland ownership along its shoreline. Unlike some coastal states, Washington's tidelands and beaches are not all in public ownership. Based on a public access study by WDOE (2009b), 62% of the State's marine waterfront property is privately owned (or 1,898 of 3,065 miles). The State Legislature elected to sell tidelands and beaches in 1889 and continued sales for many years. In 1971, the State ceased all sales of tidelands to private entities. The boundaries and ownership of tidelands are complex due to changes in the law.

Various entities hold adjacent upland ownership. Some areas are predominantly residential in private ownership, supporting vacation and retirement communities. Other areas are in state or local government ownership for public recreational use or for transportation features or infrastructure related to ports and harbors. Private industries, especially those that are water-dependent for production or distribution of goods, are another common owner of adjacent uplands. Size and density of adjacent upland parcels often reflect proximity to urban centers. Agriculture is a common land use type across many of the Puget Sound deltas due to their fertile soil and flat topography. In most cases, landowners and local governments have constructed levees and tidegates around agricultural land to prevent flooding and saltwater intrusion.

3.4.2 Public Access and Recreation

Many recreation opportunities associated with the nearshore zone are dependent on access. The Washington State Public Trust Doctrine states that the waters of the State are a public resource for use and owned by the public for purposes of navigation, fishing, and recreation. While the doctrine provides for public use of waters regardless of tideland ownership, it does not require property owners to provide access to these areas. The Washington Shoreline Management Act of 1971 acknowledges the need for public access by including it, along with shoreline use and environmental protection, as overarching policies of the Act. Table 3-4 provides a summary of shoreline access in Washington State by general geographic area (WDOE 2009b).

Recreational opportunities associated with the nearshore zone range from passive (e.g., viewing the nearshore zone and its associated wildlife or sunbathing on a beach) to active including fishing, swimming, scuba diving, and boating. The Puget Sound area attracts $9.5 billion in travel spending annually, including 88,000 tourism-related jobs and $3 billion in income (WDOE 2008). Based on a 2001 wildlife viewing survey completed for the USFWS, approximately 208,000 U.S. residents (over the age of 16) travel to Washington State annually to view killer whales and other marine mammals. This estimate for 2001 shows Washington's whale watching industry generated approximately $18.4 million in sales and 205 jobs in counties adjacent to the coastal habitat of killer whales (Industrial Economics, Inc. 2006). According to the 2006 Outdoor Recreation Survey (Clearwater Research, Inc. 2007), 34% of Washington's 6.5 million residents engaged in beach combing, 31% swam or waded at marine beaches, 7% fished from shore, and

9% collected shellfish. All of these recreational opportunities bring many visitors to the area; nearly 80% of the state's revenue from tourism is generated in the Puget Sound area (Earth Economics 2008).

Table 3-4. Shoreline public access summary Source: WDOE 2009b

Shoreline Location	Miles	Percent of total statewide shoreline miles	Number of public access sites
Puget Sound Shore	591	17%	821
Outer Coast of Pacific Ocean	363	11%	152
Strait of Juan de Fuca	102	3%	66
Hood Canal	39	1%	74
Total Shoreline Public Access	*1,095*	*32%*	*1,113*

Sportfishing for salmon and other marine fish is a popular activity in Puget Sound; however, the decrease in the availability of some salmon species for sportfishing has been dramatic. Nonetheless, the activity remains popular; marine recreational anglers in Washington State spent an estimated $126 million in 2004 including fishing equipment expenditures, but this figure does not include trip-related expenditures, which can be hundreds of dollars per trip and employ many individuals as captains and crew (Southwick 2006). Of all the salmon caught in freshwaters of Washington, 57% were caught in rivers that drain into Puget Sound, and of all salmon caught in marine waters, 60% of these fish are from Puget Sound stocks (TCW Economics 2012).

Shellfishing around Puget Sound includes Dungeness crabs, clams, oysters, and spot shrimp. Non-tribal recreational crabbers have been taking an average of 1.4 million Dungeness crabs each year since 2000, and treaty-reserved tribal collections amount to roughly 4 million per year (WDFW 2012a); the Puget Sound contribution to these figures is 85% (TCW Economics 2008). Non-tribal clam harvesting within Puget Sound produced nearly 350,000 pounds of clams in 2006; recreational harvesters collected over 650,000 oysters as well (TCW Economics 2012). Most of the spot shrimp in Washington (78%) comes from South Puget Sound areas, caught by recreational harvesters.

Expenditures for these activities go toward equipment, boat launching, fuel, and bait among other goods and activities. Economic effects of recreational fishing and shellfishing have direct benefits to food and beverage suppliers and establishments, lodging, gas stations, sporting goods suppliers, equipment rental suppliers, and guide services. Recreational anglers spent an estimated $905 million in Washington State in 2006 on fishing equipment and trip-related expenditures; approximately half of the net economic value of this figure is associated with species that rely on the nearshore zone for some part of their life history (TCW Economics 2008).

3.4.3 Commercial Fisheries and Aquaculture

Commercial fishing and aquaculture are key industries in the Puget Sound economy. In 2007, approximately $3.9 billion, or 2.1 percent of Washington's overall revenue for the year, was generated from industries directly and indirectly associated with the commercial fisheries of Washington State. The industry includes businesses that harvest, distribute, and process finfish and shellfish products, as well as those that provide supplies and services to them. Puget Sound salmon, groundfish, Pacific herring, shellfish, and Dungeness crab are commercially harvested, processed, and distributed from multiple ports throughout the region. Commercial aquaculture includes the production of farmed clams, oysters, mussels, and geoducks.

Commercial fisheries for finfish in Washington State harvest a wide variety of species; key examples are salmon, rockfish, lingcod, sablefish, and halibut. Landings of commercially harvested fish statewide were valued at $272 million in 2010 (NMFS 2012); Puget Sound ports account for about 52% percent of Washington commercial fishery landings (TRG 2008). Fourteen of the 19 commercial fishing ports in Washington State are located in Puget Sound. The highest grossing ports are located in Bellingham Bay, Seattle, Anacortes, and Blaine. Other commercial fishing ports adding substantial economic value to their local economies are located in Neah Bay, La Conner, Everett, Tacoma, Olympia, and Shelton. Over the past three decades, the combined total harvest of tribal and non-tribal commercial fisheries has decreased by 60%, ranging from approximately 70 down to 30 million pounds harvested annually (Plummer pers. comm. 2009). Figure 3-2 illustrates the historical trends for commercial finfish and shellfish harvest in Puget Sound from 1981 through 2008.

Commercial harvest of shellfish such as oysters, clams, and mussels has been occurring in Puget Sound for over a hundred years, leading to a robust aquaculture industry that is one of the largest shellfish producing regions in the U.S. Shellfish aquaculture in Puget Sound has shown significant growth since the early 1980s, including an increase in geoduck production, a shellfish species that was virtually unknown outside the Pacific Northwest 40 years ago. Today, Puget Sound commercial harvesters sell 1.7 million pounds of this species each year, primarily in overseas markets bringing in $20 million in yearly state revenues (PCSGA 2012). Puget Sound's commercial aquaculture industry has been relatively stable over the past several years. The most recent data available are for 2009, when the total weight of all oysters, clams, mussels, and geoducks was nearly 75 million pounds, with a sales value of $107 million (PCSGA 2012).

Harvested fisheries and seafood products are destined for domestic as well as foreign markets, creating a commerce system with many beneficiaries. The industry contributes to seafood and fisheries processing and other sectors of the state economy such as marine technology and vessel maintenance and repair. Fishing vessels, processors, and related support businesses provide many jobs and substantial economic benefits to the regional economy. As reported earlier in this section, in 2007 approximately $3.9 billion, or 2.1 percent of Washington's overall earnings for the year, was generated from industries directly and indirectly associated with commercial fisheries in Washington State (BEA 2010, as cited in Radtke 2011).

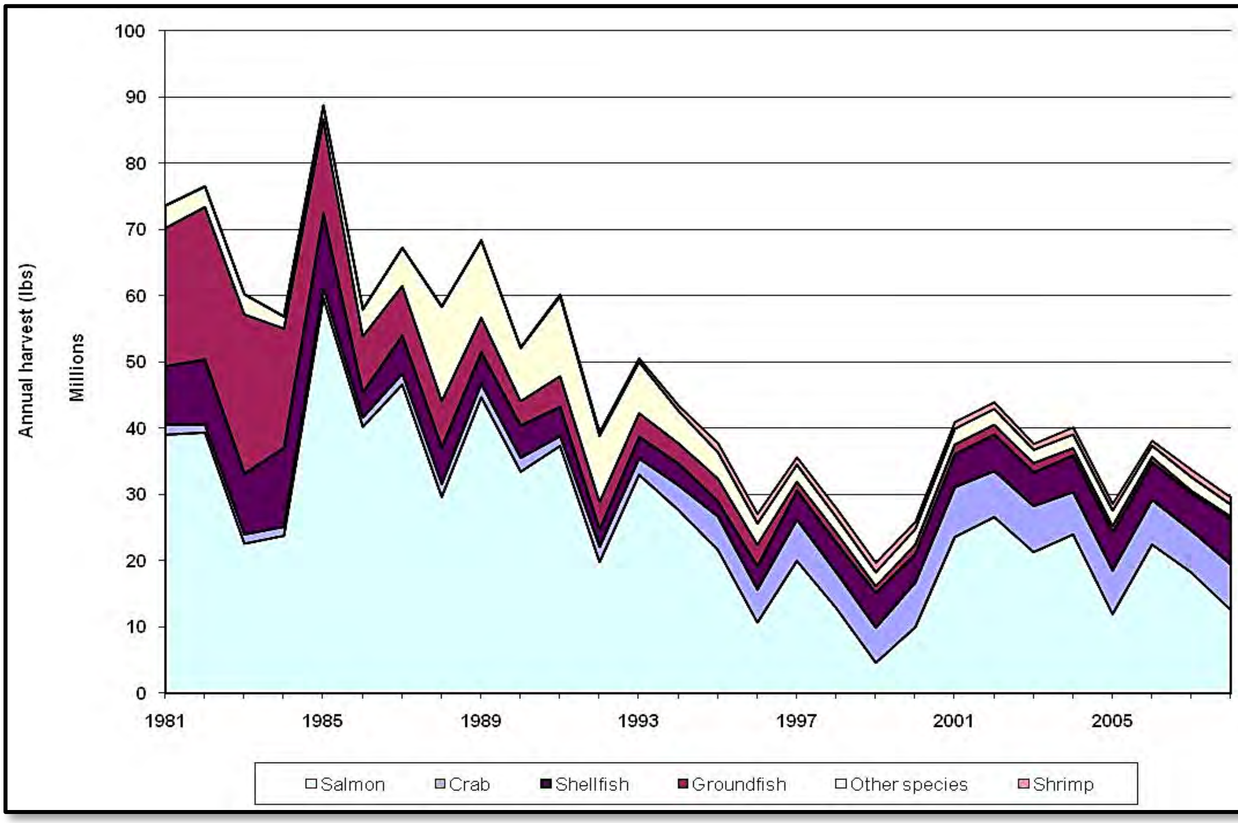


Figure 3-2. Puget Sound Commercial Fishery Harvest, 1981-2008 Source: Plummer (2009)

3.4.4 Transportation

The Puget Sound transportation system is a network of infrastructure moving people and goods within the region. In addition to the typical network of roads, highways, and railways, the system includes a fleet of vehicle and passenger ferries operated by the Washington State Department of Transportation. Puget Sound is home to the second largest U.S. harbor for container traffic, shipping over 62 million metric tons annually in recent years (WDOE 2008). The lucrative commerce industry located in Puget Sound has led to an expansive port and rail system.

Roadways within Puget Sound are commonly located along the shoreline to take advantage of the relatively flat and unobstructed terrain, avoiding the design challenges associated with hilly terrain. Roads along the shoreline are scenic and provide access to shoreline properties and public beach access points. By necessity, ferry terminals and international shipping port infrastructure are located in the nearshore zone. Terminals that allow for access to ferries and their associated vehicle holding areas (paved impervious surface) are located on wharves over the sub tidal and intertidal zones and extend into the adjacent upland area. The ports of Seattle, Tacoma, and Everett were built in historical river deltas to take advantage of flat real estate for upland storage and the easy access to deep water that allows large vessels to reach the wharves, cranes, storage yards, and rail lines for nationwide distribution of goods and commodities. Each port includes the terminus of a rail line, and much like the region's roads, rail corridors follow along the shoreline for efficient use of a flat right-of-way. Long stretches of rail lines extend along the eastern Puget Sound shoreline from Everett to Seattle and Tacoma to Nisqually. Shoreline roads and rail lines have contributed a significant amount of the degradation of the shoreline through fill, armoring, and stabilization of the Puget Sound nearshore zone.

3.4.5 Public Safety

Public safety is a primary concern for any Federal water resources project. The following features may be included in the proposed action and may have relevance for public safety: levees, tide gates and culverts for flood risk management, shoreline armoring for erosion protection, roads for access of emergency and police vehicles, vehicle and railroad bridges, and public utility infrastructure. The proposed action contains ecosystem restoration features that must be designed to maintain public safety, for example, proposed projects would at a minimum maintain the existing level of flood risk management.

Restoration of nearshore habitat requires balancing improved estuarine flow conditions with the need to maintain road and railway access in and across the project, especially during emergencies and high water conditions. Public utilities such as phone lines, sewer, fiber optic cabling, electrical transmission lines, and pipelines frequently follow the linear corridors already occupied by roads, highways, and railroads. These corridors often cross streams, rivers, and estuaries to deliver services to cities, towns, and developments of all sizes. Ecosystem restoration features that enhance the flow of water must consider and design for continued railway and vehicle access as well as delivery of all public utility services.

Airports near wetlands need to minimize risks from birds and wildlife. The Federal Aviation Administration provides an advisory circular regarding land uses that attract "hazardous wildlife" on or near public-use airports (FAA 2007); it references a 2003 Memorandum of Agreement on this topic signed by the Corps and other Federal agencies. This circular covers considerations for airports near wetlands and other wildlife habitat. In addition, the Navy has their Bird/Animal Aircraft Strike Hazard (BASH) (U.S. Navy 2010) program, which describes a variety of measures that help minimize risk to aircraft from bird and animal strikes.

3.5 NEPA SCOPING RESULTS

As stated in the introduction to Chapter 2, certain resources were not raised as significant issues during the NEPA scoping process and therefore were not analyzed in detail as they related to potential impacts of the proposed action. Resources not carried forward for detailed analysis are sediment quality, air quality, aesthetic resources, environmental justice, public utilities, and airborne noise. The following sections provide a summary of the existing conditions of these topics and brief rationale for exclusion from detailed analysis.

3.5.1 Sediment Quality

Glacial retreat left a mix of substrate types around the Puget Sound nearshore zone, which include mixed sand, gravel, and cobbles on the beaches, and sandy and muddy sediments around the large, fertile river deltas. Relatively recent human activities in the adjacent watersheds have contributed some of the finer sediments to the substrates. The primary characteristic of sediments is the vast variability in grain size distribution.

No sediments in Puget Sound are free from the contamination typical of urbanized and industrialized waterfronts in the United States. Under the No-Action Alternative, these sediments in Nearshore Study-identified sites would likely remain in place and may release contaminants for an extended period, whereas under the proposed action alternatives, any contaminated sediments identified during design or construction would be addressed in accordance with applicable laws and regulations. The result of construction would not reduce the quality of any sediment. Project features shall be designed to minimize post-project erosion of any identified areas of contaminated sediment. Some sediment of agricultural value may be lost to the aquatic environment as natural ecosystem processes are restored to the nearshore zone, which include sedimentation and erosion processes. Other aspects of sediment quality such as presence of toxic substances and invasive species seed sources are analyzed in their respective chapters in this document. The proposed ecosystem restoration activities would be expected to improve sediment quality at the site locations and would have no effect toward degradation of sediment quality; therefore, the proposed action would have no significant impact to sediment quality.

3.5.2 Air Quality

Under the provisions of the Clean Air Act (CAA), the EPA has established National Ambient Air Quality Standards (NAAQS). The standards specify maximum concentrations for carbon monoxide, particulate matter smaller than 10 micrometers, particulate matter smaller than 2.5 micrometers, ozone, sulfur dioxide, lead, and nitrogen dioxide. The EPA has published a list of all geographic areas with their NAAQS compliance status; for each NAAQS pollutant, each area is considered an “attainment” or “non-attainment” area. In a non-attainment area, the air pollutant concentration exceeds the NAAQS for one or more of these pollutants.

The proposed action may have temporary minor adverse impacts on highly localized air quality at the construction sites; construction may take months to years depending on the site. For all sites, best management practices would keep fugitive dust under control during land clearing activities. Heavy equipment would produce hydrocarbons in exhaust emissions although the incremental contribution would be extremely small compared to all sources of exhaust emissions in the region. Construction contractors would be required to keep all equipment in good working order to minimize emissions. Exhaust emissions would not be at a level that puts human health at risk, and the restoration sites would not have any permanent source of air pollutant emissions. A long-term effect of this ecosystem restoration project is that the increased area of vegetated wetlands could aid in removal of carbon dioxide and some other gaseous air pollutants. For these reasons, this project would have no significant impact to air quality in the Puget Sound area.

3.5.3 Aesthetic Resources

The visual character of the Puget Sound nearshore zone ranges from nearly pristine wilderness shorelines, to quaint waterfront towns such as Port Gamble and Port Townsend, to modern cityscapes like Tacoma and Seattle. While aesthetic value of a landscape can be highly subjective and vary widely depending on the viewer, the standard used for analysis for this project relies on values stated in the Washington State Shoreline Management Act (RCW 90.58.020). This Act protects the public interests of the natural character of the shoreline, resources and ecology of the shoreline, and public access and recreational opportunities.

The proposed project sites would have a temporary reduction of aesthetic quality for the duration of construction, which may take months to years per site. The long-term change, however, would be a return of the shoreline to a more natural configuration resembling the pre-settlement wilderness conditions. None of the stated values of the Shoreline Management Act would be precluded or degraded. The result of the proposed action would not degrade natural viewsheds, conflict with local guidelines or goals related to visual quality, reduce sunlight availability in residential areas, or obstruct views of valued resources. Therefore, the proposed action would have no significant impact on the visual quality and aesthetic resources in the Puget Sound area.

3.5.4 Environmental Justice

The purpose of Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" is to protect minority and low-income populations from disproportionately high and adverse human health or environmental effects from government programs, policies, and activities. Only one of the proposed sites is located in proximity to a qualifying stakeholder community, the Lummi Nation. The Lummi Nation has been a strong proponent of the Nearshore Study since the beginning of the General Investigation and has no opposition to an ecosystem restoration site proposed in proximity to their tribal lands and interests. The nature of the proposed action is such that it would have no adverse human health or environmental effects and would in fact benefit the stakeholder community identified. Therefore, the proposed action would have no significant impact on environmental justice or any identified minority or low-income population.

3.5.5 Public Utilities

Public utilities have rights-of-way in the Puget Sound nearshore zone that include natural gas pipelines, water supply pipelines, sanitary sewer collection lines, and phone, cable, and electric lines. In general, public utility services at the proposed restoration sites would be avoided, modified, relocated, upgraded, or abandoned in accordance with applicable regulations. Specific impacts to utility lines located within the project sites would be evaluated during the design phase and mitigated during construction. In most cases, the public utility infrastructure would benefit from upgrades and replacement, or relocation that reduces risk of inundation in predicted sea level change scenarios. There would be no or very minimal disruptions to services during construction and no long-term change to availability of the utilities; therefore, this project would have no significant impact on public utilities in the Puget Sound nearshore zone.

3.5.6 Airborne Noise

Urbanization and industrial development have affected the soundscape of many areas around Puget Sound. Anthropogenic noise reflected off hard surfaces such as buildings and pavement can affect the behavior of certain species that use sound for communication (Dowling et al. 2011). Typical noise sources around the Puget Sound nearshore zone consist of motorized traffic on shoreline roads; train traffic on the rail lines along the eastern shoreline of Puget Sound; aircraft noise from military, commercial, and private airplanes; and heavy industry at the major ports and developed waterfronts.

Airborne sound sources that would occur during restoration construction activities would mainly be from large vehicle traffic on local roads, and construction machinery operating at the sites. Machinery noise at the project sites as well as haul truck traffic during construction would cause unusually high noise levels at residences and businesses near the site and near roads that access the site. This engine noise, however, would only occur during regular working hours, and would only endure for the construction period. Most of the proposed sites are located away from residential areas, and the effects would certainly not be Sound-wide. Therefore, the proposed action would have no significant impact on airborne noise in the Puget Sound nearshore zone.

3.6 FUTURE WITHOUT-PROJECT CONDITIONS

This section describes the Study team’s approach to assessing the most likely future conditions in Puget Sound, and summarizes the findings. Characterizing expected future conditions informs strategic water resources planning by providing a baseline against which to evaluate the effects of proposed alternatives. While the Study team has collected and analyzed information that suggests Sound-wide trends of increased degradation, it is not possible to accurately predict the degree of future degradation of nearshore ecosystem processes and functions at the scale of a particular restoration action. The Corps defines the period of analysis as spanning 50 years beyond when benefits would commence once an authorized project is implemented. The Nearshore Study period of analysis is from 2015 to 2065. While the "future" for this project has been defined at 2065, future conditions are reported in the years for which resource documents report their data. The Nearshore Study sites are stand-alone project proposals with a footprint limited to only that area where no other restoration is planned as of release of the report. Some sites have completed projects adjacent to the Nearshore Study sites, but not within the proposed footprints. The Nearshore Study sites are complementary to, but independent from, any adjacent restoration sites.

3.6.1 Nearshore Ecosystem Processes

Ecosystem process degradation was measured using the process evaluation framework summarized in section 1.8 and described in detail in the Strategic Needs Assessment report (Schlenger et al. 2011a). The framework provides a method for quantifying the degradation of nearshore ecosystem processes associated with nearshore stressors. These results were used to characterize existing conditions and as an input into the ecosystem benefit model used for the cost-effectiveness analyses described in Chapter 4. To help depict future without-project conditions and to inform the Study team's understanding of where Nearshore Study objectives could best be achieved, authors completed an addendum to the Strategic Needs Assessment using development patterns forecasted as part of a future risk assessment conducted by Oregon State University researchers (Bolte and Vache 2010). This report describes the application of scenario-forecasting computer model called ENVISION. It is titled "Envisioning Puget Sound Alternative Futures" and is incorporated by reference (available online at *www.pugetsoundnearshore.org*.)

3.6.1.1 *Future Risk Assessment*

The Study team recognizes that projected population growth and associated development within the Puget Sound region pose a potential risk to the success of recommended restoration actions. To investigate this risk, the Study team forecasted regional development patterns associated with expected population growth. Future population estimates were computed based on a medium-growth projection from the Washington State Office of Financial Management (OFM) through 2030. By extrapolation of the OFM annual growth estimates, the Puget Sound region's population is expected to grow to 9.1 million residents by 2065.

To forecast land development patterns in Puget Sound, the Study team applied the scenario-forecasting computer model, ENVISION as mentioned above. Land development scenarios account for potential changes in land use policy and associated development patterns. See Appendix F for further information on the use of ENVISION.

3.6.1.2 *Projected Future Nearshore Ecosystem Process Degradation*

To forecast degradation of nearshore processes in the study area, the Bolte and Vache (2010) Status Quo scenario projections were used for the analyses in this section. These projections were applied to the same process evaluation framework as was used to evaluate existing conditions. Due to the limitations of the input data and the technology in supporting the modeling of spatially explicit projections for all of the stressors, Bolte and Vache (2010) provided projections on the distribution of a subset of the stressors. As a result, the assessment of forecasted process degradation used projections of future distributions of three stressors, and relied on present distribution data for the other nine stressors used for nearshore ecosystem process degradation calculations. The assumptions used in the forecast of process degradation and an explanation of the justification for accepting each assumption are detailed in Appendix F.

As reported in an addendum to the strategic needs assessment report (Schlenger et al. 2011b), many portions of the Sound are expected to encounter further degradation of nearshore ecosystem processes (Figure 3-3) well beyond current conditions (Figure 1-6). The evaluation suggests that the most concentrated increase of areas entering the more-degraded or most-degraded categories will be along the western shoreline of the South Central Puget Sound sub-basin, in an area that includes Bainbridge Island. As a result, much of the central portion of Puget Sound, which forms the only connection between South Puget Sound and the ocean, will be among the most degraded areas in the Sound. In fact, the forecast shows 55% of the South Central Puget Sound shoreline length will fall into the most-degraded category.

The most widespread increases in degradation among the currently less-degraded or least-degraded areas in Puget Sound are forecasted to occur in three sub-basins: the South Puget Sound, San Juan Islands, and Georgia Strait sub-basins. In addition, as suggested by the land use/land cover projections presented the in the Future Risk Assessment (Bolte and Vache 2010), process degradation will begin to appear in more remote portions of Puget Sound.

Another important factor to consider is that without restoration, the present stressors will still be in place in the year 2065. As such, the natural ecosystem setting and the processes that create and maintain it will have been impaired and will continue degrading for another 50 years. For example, for nearshore ecosystem processes related to sediment supply, transport, and accretion, the prolonged degraded condition can lead to significant lowering of the beach profile and coarsening of the shoreline substrate (i.e., much less sand and much more cobble). In addition, since these processes are vital to creating and maintaining barrier beach features such as spits, locations throughout Puget Sound could see some loss of these landforms and the embayments they protect. The reduced availability of fine-grained sediment to maintain features and functions would affect a large portion of the remainder of these landforms.

Figure 3-3 shows the projected future degradation of nearshore ecosystem processes throughout Puget Sound and this can be compared to Figure 1-6.

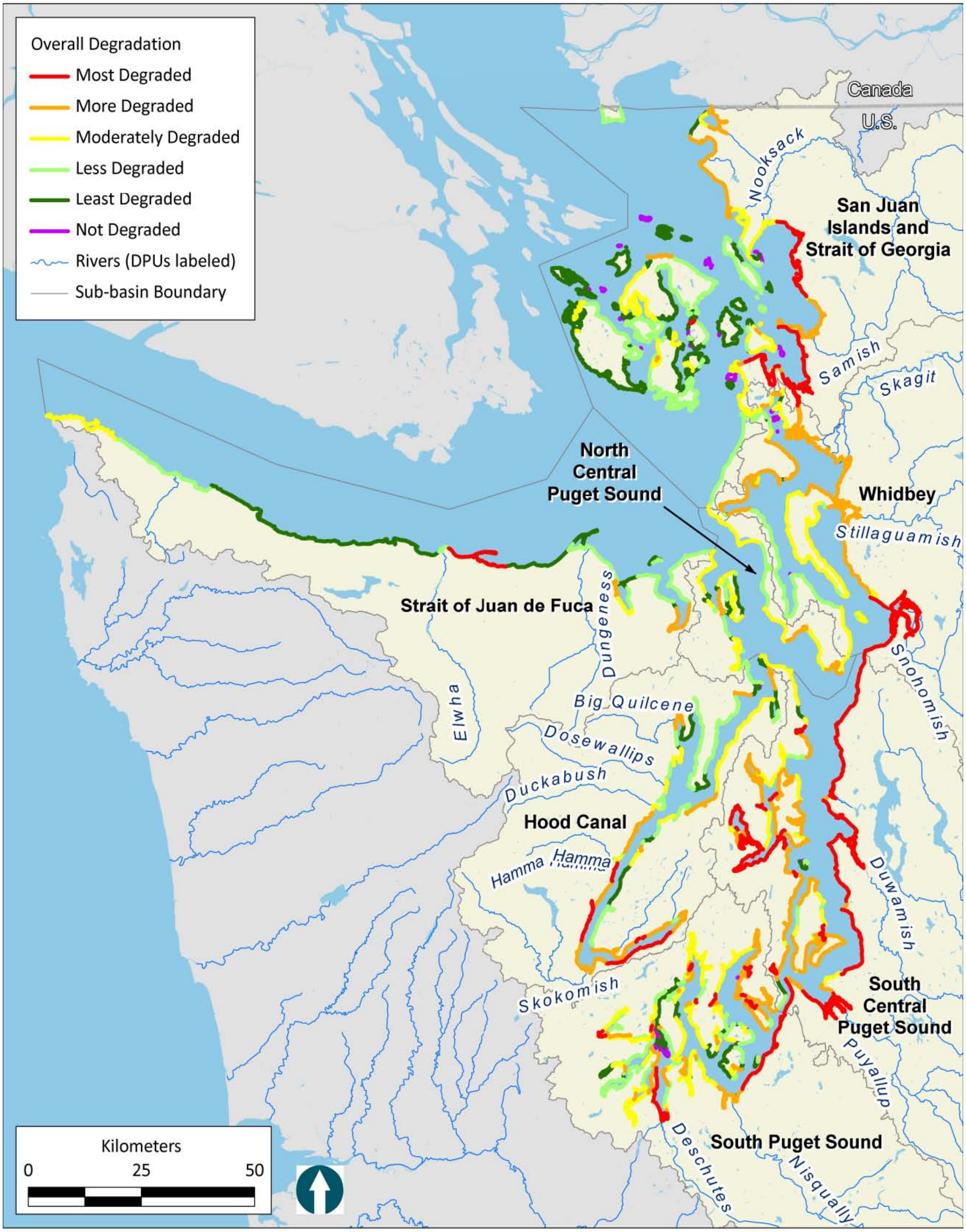


Figure 3-3. Projected Overall Process Degradation by Process Unit in the Year 2060

3.6.2 Biological Environment: Nearshore Zone Functions

Shoreline and watershed development are forecasted to continue expanding and will degrade the nearshore ecosystem processes that create and maintain Puget Sound ecosystems. The expanded footprint of degraded areas, combined with climate change and sea-level change, will further imperil the ecosystems that support diverse biological communities that inhabit or otherwise depend on Puget Sound. While evidence of the implications of this ecosystem degradation is apparent in the declines of many biological communities to date, forecasts show increases in degradation will greatly worsen the species declines. As summarized below, the declining conditions of Puget Sound ecosystems are expected to influence declines across all levels of the food web, from lower trophic levels like invertebrates to top predators such as killer whales. Forecasts show that without significant ecosystem restoration, species populations that are low now will move closer to extinction and additional species may become threatened.

3.6.2.1 *Vegetation*

Marine Submerged

Stressors that affect submerged aquatic vegetation (SAV) include those that affect the amount of light available to the plant, the direct and indirect effect of high or low nutrient levels, toxic substances, and physical disturbances (Mumford 2007). Decreased light levels often occur from an increase in suspended sediments (i.e., turbidity) or because of overwater structures such as piers, docks, and moored boats. Sedimentation from upland runoff or re-suspension can prevent kelp spores or zygotes from attaching and cause injury from smothering and light blockage (Schiel et al. 2006, Mumford 2007). Degraded water quality can cause kelp losses as well. The ENVISION model results show shoreline development, deforestation, and impervious surfaces increasing through 2060. Each of these increases could decrease water quality and increase turbidity to the degree that kelp populations will decline. The predicted construction of marinas and other over-water structures will likely contribute to the (potential) decline of kelp by 2065. Increased ocean temperatures associated with climate change could decrease kelp abundance as well, particularly in embayments already experiencing near-lethal temperatures.

A wide variety of factors adversely influence eelgrass meadows including dredging, marinas, increased storm intensity attributable to climate change, and a variety of human activities that reduce water quality and decrease light reaching plants. Water quality often deteriorates due to coastal development, land-based practices, dredging, and eutrophication. The decline in water quality from projected population growth and its associated land use practices paired with additional shading from docks and marinas may lead to declines in eelgrass bed size and abundance throughout Puget Sound.

Ulvoids (a type of green algae) tend to dominate nearshore algal blooms, which may result from nutrient loading and non-point source pollution. These blooms have the ability to deplete oxygen concentration in a process referred to as eutrophication, alter the structure and diversity of marine communities, and reduce eelgrass shoot density and fragment eelgrass meadows. Additions of shoreline development and impervious surfaces will likely contribute to an increase in the abundance of ulvoids due to nutrient loading, which could exacerbate hypoxia events as the ulvoids decay and consume oxygen. Water temperatures higher than 64 °F promote harmful algal blooms and since water temperatures in Puget Sound are expected to increase by 10 °F by 2100 (Climate Impacts Group 2009), there will likely be earlier and longer lasting blooms (Pearson et al. 2011b).

Climate change and sea-level change are likely to impact eelgrass meadows, but the exact effects are uncertain. Climate change stressors are related to water quality and light availability (sea level change and temperature rise, suspended sediment, nutrient-driven harmful algal blooms, contaminants, disease, and freshwater input) and physical changes from shoreline armoring. The resulting increased depth and light attenuation from sea level change may contribute to vulnerability of eelgrass and/or result in eelgrass decline at the lower edges of beds. Warmer water directly affects the productivity and respiration rates of eelgrass with extended periods of high temperatures reducing eelgrass growth and survival, which can affect large areas of the Sound. In places where the water warms substantially in the summer (e.g., poorly flushed shallow bays), small increases in temperature would cause loss of plants. In the case of climate change driven sea temperature increases, the reversibility would be low (Thom et al. 2011).

Increased frequency of El Niño conditions are an anticipated implication of climate change, and are known to affect growth patterns of SAV. El Niño conditions are associated with increased storminess that can stress eelgrass. Increased precipitation resulting from climate change will likely compound with the forecasted increase in deforestation, development, and impervious surfaces to further degrade water quality (e.g., increased suspended sediment and harmful algal blooms) with ensuing decline in eelgrass meadows. As sea level changes and beach profiles migrate landward, eelgrass meadows will recede inland. Armored shorelines constrain the shallow water edge of the eelgrass beds, which will not be able to move landward. Additional impacts to species distribution of all SAV types are likely to result from climate change, which may alter the competition between eelgrass species and algal populations (Short 1999).

Wetlands

Estimates of wetland loss over the past 150 years in Washington range from 20 to 39%, while other estimates are as high as 50% statewide and 70 to 100% in highly urbanized areas (Lane and Taylor 1997). Nearshore wetland loss and degradation in Puget Sound are most commonly the result of urban expansion, forestry, and agricultural practices (Canning and Stevens 1989; WDOE 1992a, b). Estimates of continuing wetland loss range from 700 to 2,000 acres per year with additional and significant degradation to remaining wetlands (WDOE 1992a, b); however, these estimates are statewide and not specific to the Puget Sound nearshore zone. Given previous trends of wetland loss in the nation, one could deduce that those trends would continue for Puget Sound. A few causes of continued loss, despite a national policy of no net loss, are that some wetlands are exempt from regulation based on small size or isolation, and required buffer widths are too small to provide protection. Ultimately, projections of wetland abundance in the nearshore zone depend on a variety of factors including land development and zoning, regulatory permitting and enforcement, mitigation requirements, sea-level change, and climate change.

Estuarine salt marshes and other wetlands potentially affected by sea-level change face new risks related to climate change. Modest sea-level change during the 20th century does not appear to have adversely affected the majority of the region's salt marshes. These systems were able to keep pace through accretion (accumulation of sediments), generally captured by vegetation structure (Thom 1992). Increasing rates of sea-level change may lead to substantial loss of salt marsh habitat, especially in areas that are subsiding and/or where sediment supply is reduced or where upland migration of marshes is prevented by shoreline armoring, coastal development, or natural bluffs. Projected changes in water temperature, water salinity, and soil salinity could change the mix of plant species in salt marshes and the viability of invertebrates that play a key role in the health of salt marsh systems (Snover et al. 2005). Furthermore, many freshwater marshes adjacent to marine waters are likely to convert to salt marshes or to transitional marshes that experience frequent saltwater inundation (NWF 2007). If coastal development occurs or if shoreline armoring continues to be used as a countermeasure for sea level change, the new salt marshes will also, in turn, disappear due to subsidence or lack of sediment supply.

Riparian Areas

Results of ENVISION modeling show loss of an additional 1,350 square miles (3,500 km^2) of forest due to new development in Puget Sound by 2060. Less than one percent of the forest loss is expected to occur within 200 feet of the shoreline. Shrub/scrub will likely see the greatest loss as a percentage of total natural area. The relative abundance of other terrestrial vegetation types appears in Table 3-5 (note these figures are for the Puget Sound watershed, not just shoreline).

Table 3-5. Projected Land Cover Distributions in 2060 (Source: Bolte and Vache 2010)

Natural land Cover Type	2010 (%)	2010 (km^2)	2060* (%)	2060 (km^2)	Change (km^2)
Barren land	3%	1,011.2	1%	920.1	-91.1
Deciduous forest	3%	945.7	2%	756.1	-189.6
Emergent Herb Wetlands	1%	329.5	1%	321.3	-8.3
Evergreen forest	62%	20,061.5	31%	17,512.8	-2,548.7
Herbaceous	3%	1,136.3	2%	921.7	-214.5
Mixed forest	9%	3,011.3	5%	2,491.8	-519.5
Open Water	2%	498.1	1%	472.7	-25.4
Snow/Ice	1%	380.2	1%	380.2	0.0
Shrub/Scrub	14%	4,499.7	4%	3,897.2	-602.4
Woody Wetlands	2%	637.0	1%	606.9	-30.1

*By 2060, 51% of the natural land cover types that occur in 2010 will have changed to some type of developed, non-natural land cover.

The influences of climate change and sea-level change will result in additional changes to the structure and composition of terrestrial vegetation throughout the region. Potential forest impacts are tied to changes in summer and winter temperature and precipitation, snow pack duration, and regional hydrology (Littell and Binder 2007). Sea-level change will result in the inland migration of the shoreline and halophytic vegetation assemblages will shift landward. Salt marshes are anticipated to expand at the expense of freshwater wetlands as saltwater inundates them. Exacerbated bluff and bank erosion associated with sea-level change and precipitation, stream flows, and flooding will reduce bluff and bank vegetation. Deciduous forest may increase in abundance along these disturbed areas, which might previously have been predominantly coniferous forest. The increase in disturbance combined with changes in climate zones could result in rapid shifts in species ranges (or in genetic variability within species). Increased risk of wildfires, vulnerability to insects, and a decrease in growth and regeneration are anticipated in drier, lower elevations (Littell and Binder 2007).

Forest Aggregation Index

According to the Regional Geographic Initiative, conducted by Urban Ecology Research Laboratory at the University of Washington from 1991 to 2001, most sub-watersheds of the Puget Sound area saw a significant decline in their forest aggregation index (an indicator of forest fragmentation). According to the Cascade Land Conservancy, the business-as-usual trends for this region will cause increased fragmentation. According to the Rural Forest Initiative, western Washington has been losing forestland at increasing rates in the last two decades.

3.6.2.2 *Invertebrate Assemblages*

Several invertebrate species are in decline due to loss or degradation of habitat. At least two species, Olympia oyster and Northern abalone, have undergone long-term declines with little evidence of potential for recovery. All native invertebrate populations are affected by habitat loss or pollution due to human development (Dethier 2006). Continued declines are anticipated with further habitat encroachment and the effects of development such as pollution. Changes in water quality conditions from increased temperature, ocean acidification, and more frequent episodes of low dissolved oxygen will exacerbate existing stressors on most invertebrate assemblages (Newton et al. 2008). Select species that have adapted to anthropogenic changes to the shoreline may flourish, potentially to the detriment of more sensitive species. The further transition of nearshore invertebrate communities to more tolerant species is anticipated.

3.6.2.3 *Fish Communities*

Demersal/Benthic Fish

Some groups of demersal/benthic fish, such as rockfish, are in depressed or critical condition, while others like English sole and Pacific halibut have seen increases (PSP 2009). While the overall trend of demersal/benthic fish population could remain stable, further declines are expected for long-lived and late maturing fishes, such as certain species of rockfish. Such species have been assessed as vulnerable to extinction warranting protection under the ESA.

Forage Fish

Pacific herring are the only forage fish species that has been monitored comprehensively in Puget Sound in the last 20 years. For the 2007-08 period, fewer than half (47%) of local herring stocks are classified as healthy or moderately healthy. This is the lowest percentage of individual stocks meeting these criteria since development of the stock status summary in 1994 (Stick and Lindquist 2009). Moreover, additional impacts could result from sea-level change potentially inundating intertidal spawning grounds on shoreline beaches, and projected development trends that could cause further habitat loss within the region. Sea-level change is likely to cause substantial loss of surf smelt spawning habitat on beaches with armored shorelines because armoring prevents beach migration inland (Griggs et al. 1994), thereby reducing the area of beach with elevations preferred for spawning. Estimates of sea-level change suggest that on beaches with armored shoreline, substantial surf smelt spawning habitat might be lost in the next few decades and most spawning habitat might be lost by 2100 (Krueger et al. 2010).

Anadromous Fish

Many anadromous fish species are in decline due to loss or degradation of habitat. Between the 1992 and 2002 salmon population inventories, the number of salmon stocks that were listed as depressed or critical increased by one-third (WDFW 1993 and 2002). Projections show it is likely that populations of anadromous fish, particularly salmonids, will continue to decline due to sub-optimal habitat for rearing and spawning that has been altered by armoring, filling, and diking of the shoreline, as well as development in the upper watersheds. The impacts of climate change will likely exacerbate degraded habitat conditions in nearshore areas and may affect populations of anadromous salmonids. For example, an 18- to 32-inch sea-level change in the Skagit Delta may reduce the rearing capacity in marshes for juvenile Chinook salmon by an estimated 211,000 and 530,000 fish respectively, which are substantial percentages of this population (Hood 2005). The projected changes are also likely to affect Coho and pink salmon, cutthroat trout, and bull trout, which depend on marshes and other nearshore habitats for parts of their life cycle (Williams and Thom 2001). If recovery efforts in the region are successful, they may eventually diminish these losses, but many other variables could influence population trends of salmonids including environmental contaminants, oceanic conditions, and other aspects of climate change such as increased water temperature and changes in stream flows. Population trends for certain anadromous species, such as green and white sturgeon, will depend more heavily on conditions outside of Puget Sound.

3.6.2.4 *Birds*

Species with significant declines in abundance included red-throated loon, numerous grebe species, canvasback, scaup, black scoter, common goldeneye, ruddy duck, Bonaparte's gull, glaucous-winged gull, common murre, and two murrelet species. Trends between 1992 and 1999 indicate a reduction of 58% for all three Puget Sound scoter populations. Great blue heron populations show an overall trend that indicates a slight to moderate increase; however, significant changes in colony dynamics were apparent as birds shifted from engagement with numerous small colonies to a consolidation of herons into fewer larger colonies. This trend is disturbing in that it increases the risk of large population loss through a single catastrophic event. Other species such as the common loon, double-crested and pelagic cormorants, bald eagle, and most notably the Canada goose showed significant increases (Bower 2009). Due to the likely continued loss of habitat and prey species, such as forage fish and juvenile salmonids, continued decline of many Puget Sound bird species is likely. Species like cormorants, crows, and gulls that have successfully adapted to development within the region may increase and may out-compete species that are more sensitive.

3.6.2.5 *Mammals*

Populations of terrestrial mammals that use the Puget Sound nearshore zone, such as raccoons and deer, will likely remain stable largely because they have adapted to the human environment. Likewise, harbor seal and California sea lion populations may remain stable due to their similar adaptability. However, declines of the more sensitive marine mammal species like killer whales are probable as they continue to be limited by prey abundance and environmental contaminants.

3.6.2.6 *Invasive and Introduced Species*

Human modification of shorelines, including marina and shoreline development, can increase the likelihood of spread of invasive species either by way of additional boat traffic or the opportunity for colonization by invasive species, which are often more tolerant of disturbance than native species. Increases in the densities and diversity of exotic species populations are anticipated, given existing conditions and trends.

3.6.2.7 *Rare, Threatened, and Endangered Species*

The future conditions of rare, threatened, and endangered species in Puget Sound depend on a variety of factors including habitat loss, climate change, environmental contaminants, and harvest and poaching, as well as whether or not there is a recovery plan and how well it is implemented. Species with population declines that are tied to habitat loss, such as salmonids, may recover to some extent due to habitat restoration efforts throughout Puget Sound. Marine mammal species that are adversely affected by environmental contaminants, such as Southern Resident killer whales, have more uncertainty associated with forecasts. Species that are vulnerable to fishing pressure may recover if fishing and poaching are halted (as is the case with some of the listed rockfish species). Acidification of Puget Sound marine waters will affect the persistence of shellfish and other calcifer species. Other species' populations are dependent on conditions outside of Puget Sound. Below are expected trends for Puget Sound populations of ESA-listed species. As stated above, a variety of factors will influence these trends, not just the physical condition of the Puget Sound shoreline.

Southern Resident Killer Whale (Orca)

The 2004 NMFS Status Review of the Southern Resident killer whales presented a population viability analysis. The most optimistic model (based on data from the last 30 years) predicted a relatively low extinction risk of less than 0.1 to 3% in 100 years and 2 to 42% in 300 years. However, the most pessimistic model (based on data from the last 10 years) predicted an extinction risk of 6 to 19% in 100 years and 68 to 94% in 300 years. When modeled to a quasi-extinction rate (fewer than 10 males or females) instead of actual extinction (less than one male or female), the model predicted a risk of extinction of 40 to 67% in 100 years and 76 to 98% in 300 years. The Southern Resident killer whale's dependence on salmon and the persistence of bioaccumulating environmental contaminants make significant population declines likely.

Sea Otter

A survey from 2008 indicates that sea otter populations have increased moderately along the Washington Coast with a count of approximately 1,073 otters. Populations reintroduced on the western side of Vancouver Island are also increasing and expanding their range within British Columbia. If kelp beds along the San Juan Islands and Strait of Juan de Fuca remain unaltered, this sea otter population may continue to increase. However, the predicted loss of kelp habitat and declining shellfish populations may keep the Puget Sound sea otter population low.

Hood Canal Summer Chum

NMFS concluded that the Hood Canal summer-run chum Evolutionarily Significant Unit (ESU) is in danger of extinction due to degradation of habitat, harvests, and low water flows in the Strait of Juan de Fuca and Hood Canal watershed (Johnson et al. 1997). Of the original 18 spawning aggregations, only 10 are extant. The overall abundance trend over the past 40 years is positive for natural origin spawners in the Strait of Fuca populations, but negative in the Hood Canal populations (Ford et al. 2010). Declines are possible given the latest population trends and continued loss of habitat in Hood Canal. Certain smaller stocks in decline may lead to regional extinction of non-hatchery populations. Populations in Strait of Juan de Fuca may continue to increase given dam removal and restoration efforts.

Puget Sound Chinook Salmon

Nine of 31 populations of Chinook salmon within the Puget Sound ESU are classified as extinct and eight of those were early run populations. Most of the remaining 22 Chinook populations are summer or fall runs with larger populations often supplemented through hatchery fish (Shared Strategy 2007). The 2005-2009 geometric mean of natural spawners ranges from 81 (Mid-Hood canal population) to 10,345 (upper Skagit population); most populations that contain natural spawners number in the high hundreds. Many populations have either declined or maintained numbers of wild fish over the past 30 to 40 years. The overall trend during this period for natural origin spawners in Puget Sound has declined, where 2009 showed the lowest returns since 1997 (Ford et al. 2010). This indicates a significant loss of genetic diversity. A continued decline in non-hatchery Chinook is anticipated given habitat loss trends; these declines will likely lead to extinction in basins that produce runs with fewer than 200 adults unless substantial habitat restoration occurs in the near future.

Puget Sound/Strait of Georgia Coho

Puget Sound/Strait of Georgia Coho salmon populations are stable; however, it is difficult to tell native stocks from hatchery stocks (Weitkamp et al. 1995). It is likely that native origin Coho will continue to decline in the Puget Sound basin due to decreases in genetic diversity via inter-breeding with hatchery origin fish, as well as factors like habitat loss and pollution that affect all salmonids in the region.

Puget Sound Bull Trout

Of all the bull trout sub-population areas in Puget Sound, only the Skokomish area, which is thought to be the most depressed core area within the Olympic Peninsula management unit, has abundance data and trends based on monitoring. The species status in this core area is depressed with fewer than 60 adults documented in the South Fork Skokomish and approximately 100 adults documented in the North Fork Skokomish (Shared Strategy 2007). Given current trends of habitat loss and fragmentation, fisheries managers expect significant declines within the Puget Sound region and even extinction within the most depressed basins such as the Skokomish. Increasing water temperatures and changes in hydrology associated with climate change will impact bull trout disproportionately as it is the most temperature-sensitive species in Washington. Increased marine water temperatures will restrict the distribution of bull trout in nearshore areas while decreased snowpack and higher temperatures in freshwater will limit spawning and rearing areas in all watersheds.

Puget Sound Steelhead

Population trends reported in 2007 indicated significantly declining abundance in natural escapement for the Puget Sound ESU (NMFS 2007). All but a few demographically independent populations of steelhead in Puget Sound are declining. Redd counts are declining 3 to 10% annually. From 2005-2009 the geometric mean of winter-run steelhead has been fewer than 250 fish annually for eight of the 15 populations evaluated. The extinction risk for most populations in the next 100 years is estimated to be moderate to high (Ford et al. 2010). NMFS concluded that substantially declining abundance and low productivity as well as a moderate loss of diversity and spatial structure indicate that steelhead are “likely to become at risk of extinction” in the foreseeable future (Hard et al. 2007). Thus, continued declines of steelhead are anticipated given habitat conditions and population trends.

Green Sturgeon

NMFS concluded that small population sizes, water temperature changes, harvest losses, loss of spawning habitat in areas outside of Puget Sound, predation by exotic species, and pollution are having a deleterious effect on the Southern DPS of green sturgeon. These populations are “likely to become extinct” in the foreseeable future (NMFS 2006).

Rockfish

NMFS estimated a 3% per year declining trend in the overall abundance of rockfish. Bocaccio is believed to be at high risk of extinction, and yelloweye and canary rockfish are rated at moderate risk of extinction (NMFS 2009b). Given continued trends, further declines in these species are expected due to their late-maturing nature and low reproductive success in any given year.

Eulachon

NMFS found that even with little monitoring of eulachon, almost all data available for the species indicate an abrupt decline. Their assessment returned a moderate risk of extinction within the southern DPS of eulachon. The continued loss of habitat, largely outside of Puget Sound, and likely overuse of the species as sturgeon bait will likely cause further declines.

Marbled Murrelet

Modeling indicates annual declines of 4 to 7% (Beissinger and Nur 1997 from Huff et al. 2006) with a 16% probability of extinction in 100 years within California and Oregon and only 45 birds remaining in Washington (Huff et al. 2006). Estimates based on four years (2000 to 2003) of at-sea monitoring indicate no declines and even moderate increases in densities within Puget Sound. However, for the entire Northwest Forest Plan study area (including Washington, Oregon, and California), the authors anticipate being able to estimate a 5% annual decline with 80% power after seven years of data collection and modeling (Huff et al. 2006). Declines in marbled murrelets can be expected due to declining prey abundance (forage fish) and development in the upper watersheds where they nest. If a catastrophic event occurred, steeper declines and possible extinction within the region is conceivable.

Northern Abalone

Abalone in the San Juan archipelago declined by 77% between 1992 and 2006, and resulting densities were well below the threshold required for successful reproduction (Rothaus et al. 2008). Growth trajectory models in Canada suggest continued abalone declines in northern British Columbia (Zhang et al. 2007); given the documented Allee effect for Washington populations, this trend is likely transferable to Puget Sound populations (Babcock and Keesing 1999). Continued declines after fishery closures indicate a lack of recovery from past overharvesting. The fact that this continued decline is in some cases reaching levels below a successful reproduction threshold indicates the likely extinction of abalone populations within the Puget Sound basin in the near future. Climate change effects from increased acidification will decrease calcification rates and could compromise the survival of abalone and other organisms.

Olympia Oysters

Given the status quo scenario leading to continued degraded water quality, and lack of oyster reef habitat for larval settlement, Olympia oyster populations are not expected to increase. Restoration efforts may result in temporary holds in population numbers, but without significant changes to water quality, they will likely not last. Ocean acidification has been implicated as a possible cause of recent large die-offs of cultured larval oysters, and will be an additional constraint to recovery efforts.

California Buttercup, Sharpfruited Peppergrass, and Golden Paintbrush

If the predicted rate of development and disturbance of the shoreline continues in areas where these species occur or could occur, then the likelihood of extirpation will increase.

3.6.3 Cultural Resources

Cultural resources within the Puget Sound nearshore zone will continue to be subject to both natural and human-made processes. Some natural processes negatively affect cultural resources through erosion, rising tides, landslides, or severe storms and less severe natural processes have little to no effect on cultural resources in the study area. Human-made processes such as shoreline development can have negative effects by destroying known and unknown cultural resources. Adverse effects from humans would likely be mitigated if the process is subject to Section 106 of the NHPA.

3.6.4 Socio-Economic Characteristics

Population growth and associated land development are key drivers shaping the future of Puget Sound. While development is also influenced by the economy, people will continue to build homes along the shore, conduct maritime activities, build roads and infrastructure, recreate, and consume food from the nearshore zone. Land and water use, release of pollutants, shoreline modifications, and other effects of population increase will be major drivers of ecosystem change, particularly without significant ecosystem restoration activities.

The human population in the Puget Sound Basin has increased rapidly over the last two decades. In 2005, approximately 4.4 million people inhabited the Puget Sound Basin, a 25% increase from 1991, with an average annual growth rate of 1.28%. The OFM forecasts population growth by looking at economic trends, migration, and natural growth (fertility and mortality). The Puget Sound population is expected to grow to 9.1 million residents by 2065, which is expected to lead to an expansion of developed areas in the Nearshore Study Area. The ways in which this development occurs to accommodate the forecasted growth will be a key driver affecting the future condition of Puget Sound.

3.6.4.1 *Shoreline Ownership*

Washington State shorelines and tidelands are a patchwork of public and private ownership. Today, an estimated 60 to 70% of Washington's tidelands are in private hands. Shoreline and tideland ownership patterns are not expected to change significantly from existing conditions. No forthcoming laws are anticipated to affect shoreline and tideland ownership. Therefore, it is expected that the current mix of private and state-owned tidelands will persist, and land development will occur according to predictions from the ENVISION analysis.

3.6.4.2 *Public Access and Recreation*

Given the largely private ownership of shoreline, public access is expected to remain similar to current conditions. Public access is recognized as an important component of shoreline activities as directed by the Shoreline Management Act, which strives to balance responsible shoreline development with environmental protection and public access (WDOE 2009c). The Interagency Committee for Outdoor Recreation (IAC) notes that projecting recreation participation into the future is at best a problematic exercise because participation in various outdoor activities is affected by a wide array of factors, including changes in population, available sites and infrastructure, lifestyles, economics, technology, and the politics of land use (IAC 2003). Nevertheless, the IAC used the best data available to forecast participation in outdoor recreation activities in Washington State over periods of 10 and 20 years. Figure 3-4 shows the forecast participation in water-related activities as the percent change in the number of people participating in the future compared to current (2003) levels.

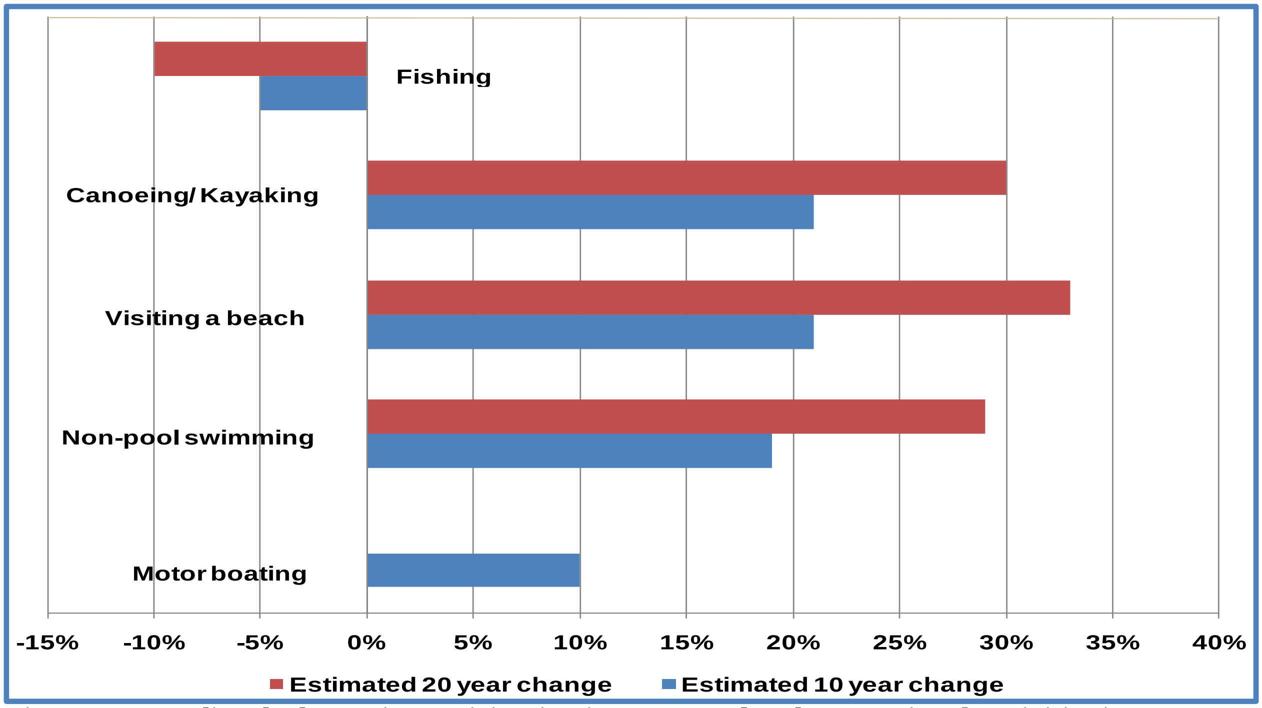


Figure 3-4. Predicted Change in Participation in Water-Related Recreational Activities in Washington State Source: IAC (2003)

Participation in some activities is predicted to be substantially higher—canoeing and kayaking, swimming, and beach visitation are all predicted to increase by around one-third over the next 20 years. However, other activities are anticipated to show slow growth or even a declining trend. The IAC states that new boat launch sites are rarely developed with proponents facing significant challenges in populated areas such as Puget Sound, where developable low bank waterfront property is at a premium. Slow expansion of the inventory of boating facilities will likely result in slow growth in motor boating.

The IAC notes that participation in motor boating appears to be linked closely to participation in recreational fishing, which is predicted to show negative growth. According to the IAC, the main reason for the expected decline in fishing is the perception of or actual decrease in the availability of fish for recreational harvest. While studies (e.g., Dawson and Wilkins 1980) show that the quality of a recreational fishing experience is not solely dependent on catching fish, but the prospect of catching at least some fish is an important factor motivating people to go fishing, and repeated poor catch during fishing trips undoubtedly diminishes angler satisfaction and discourages further participation. They conclude that unless there is considerable improvement in the numbers of fish available for recreational harvest, declines in fishing activity are expected.

Furthermore, the IAC suggests that the expected increases in the levels of other water-related activities may have to be adjusted downward if resource quality deteriorates. They observe that swimming, wading, surfing, SCUBA diving, and other water-contact activities are directly affected by water quality, including pollution and the presence of noxious weeds. Similarly, they note that photographing and observing wildlife depend on natural settings including habitat for species of interest. It is clear that the future of Puget Sound's whale-watching industry is contingent on robust populations of whales, which, in turn, is dependent on clean water and a healthy food source. The IAC draws the conclusion that, "For resource recreation to be sustained over time, resource protection must come first."

3.6.4.3 *Commercial Fisheries and Aquaculture*

Commercial fishing and shellfish production have long been important natural resource-based industries in the Puget Sound region that provide jobs, wages, profits, taxes, and a local food source. In addition, the commercial harvest of fish and shellfish is a significant part of the culture and heritage of the residents of the Puget Sound region.

The future viability of commercial finfish and shellfish harvesting is inexorably tied to specific species' populations and related policies developed for species protection including actions to restore the degraded ecosystems that finfish and shellfish depend upon. Section 3.4.3 describes past trends in finfish and shellfish fisheries, which may be instructional for predicting future commercial harvests. As discussed in the existing conditions section, over the past three decades, the combined tribal and non-tribal commercial fisheries harvest has decreased by 60%, from approximately 70 million down to 30 million pounds harvested annually. However, the rate of decline has lessened since the mid-1990s, although with significant annual variation. The state of Dungeness crab in Puget Sound appears to be healthy with an increasing trend in commercial harvest. In addition, shellfish aquaculture operations show steady growth in harvest levels, probably caused by increased acreage under production and improved culturing techniques.

Moreover, recent changes in management approaches suggest that some depressed commercial fisheries could improve. Although fish hatcheries did not prove to enhance fisheries as once predicted, and actually harmed wild salmon populations, improving hatchery practices represents an opportunity to help recover salmon. Puget Sound populations of rockfish, one type of groundfish, have potential for recovery. Of the 17 marine fish stocks in Puget Sound that have been petitioned for listing as threatened or endangered under the ESA, about half are rockfish. In 2009, WDFW prepared a draft plan that includes a range of policies, strategies, and actions that could rebuild rockfish stocks (WDFW 2009). It is uncertain whether the proposed conservation efforts are sufficient to protect rockfish and allow rebuilding given their late maturation and low reproductive success.

Washington State is now the top producer of farmed clams, oysters, and mussels in the United States. Along with ocean acidification associated with increasing atmospheric carbon dioxide, the most direct threat to continued shellfish production in the Puget Sound region is land development, which is likely a major contributor of reduced water quality. While aquaculture production will likely increase in the next 50 years, trends in human development patterns, increased impervious surfaces, and hardening of shorelines continue in the Puget Sound region. The ecological requirements of Dungeness crab and commercially important bivalve shellfish make them vulnerable to stressors associated with human population increases. In the absence of remedial actions, the resulting increases in toxins, nutrients, and degradation of habitat may offset this potential growth in the industry, leading to the loss of a traditional employment opportunity, revenue, and Northwesterners' strong sense of place.

3.6.4.4 *Transportation*

Puget Sound residents benefit from high connectivity at the local and regional level. Transportation infrastructure, such as roadway expansion, has served as a catalyst for development intrusion into natural lands. Over the last 30 years, the number of roads within the region has doubled (PSRC 2010). Major public investments will be required over the next 50 years to maintain and upgrade the transportation system in light of projected population increases. The Transportation 2040 Plan (PSRC 2010) anticipates a need to invest $189 billion to $225 billion over the next 30 years to accommodate projected increases in population, employment, and commerce. In general, regional transportation plans involve expansion of public transit options, state highways and other major roads, non-motorized transportation (bike and walk improvements), and ferry systems.

3.6.5 Predicted Effects of Climate Change and Sea-Level Change

There is consensus among international and regional scientists that global climate change and associated sea-level change (SLC) will result in widespread and far-reaching changes to Puget Sound nearshore ecosystems. Projections of the specific implications of climate change show that impacts will occur to climate, water resources, forests, and coastal areas with forthcoming impacts to salmon, economics, and human health. Climate change will affect several general types of processes in Puget Sound that in turn affect its structure and function. The processes affected include sea-level, weather and temperature, large- and local-scale atmospheric forcing, the water cycle, and ocean acidity (Pearson et al. 2011b). For the Puget Sound, climate change can be characterized by increased frequency of damaging storms and floods, lower riverine flows during summer, gradual inundation of low lying areas, increased erosion rates, loss or major shifts in nearshore habitats, escalating costs of maintaining and repairing infrastructure, effects on shellfish harvesting and agriculture, and seawater intrusion into coastal aquifers (Snover et al. 2005, Climate Impacts Group 2009).

Effects of SLC and weather patterns will vary by coastal area and landscape types. Along marine shorelines, increased erosion rates will increase frequency of landslides, larger erosional events may occur more often, and patterns of sediment transport on beaches will change, leading to complex, perhaps rapid shoreline changes. SLC will cause progressive loss of upper beach where the shoreline cannot retreat landward while other nearshore and estuary habitats may disappear if they cannot migrate landward (section 3.6.2 discusses impacts to vegetation types forming key habitats). SLC in river deltas will cause loss of nearshore habitats seaward of dikes, with increased intrusion of saltwater into the estuary, increased flooding, soil saturation, and potential changes in agricultural land use. Costs to maintain infrastructure including seawalls, levees, marinas, septic systems, and port facilities will increase. Costs to maintain land-based transportation systems such as roadways, bridges, and railways are also expected to increase.

The ecological changes associated with climate change and human responses to these changes are likely to affect ecosystem processes. In particular, physical processes will be affected by the forecasted SLC, changes in weather patterns including changing hydrology with increased winter flooding and lower summer flows, increased water temperature, and ocean acidification. SLC impacts include the loss of marsh habitat particularly if natural sedimentation is altered and cannot keep pace with the rate of change. All of these appear likely to significantly impact many of the ecosystem processes directly as well as indirectly through the actions people take to counteract the impacts of climate change. For example, SLC coupled with increased riverine flooding can directly affect nearly all of the nearshore ecosystem processes. Human response to SLC and changing inland hydrology can include the construction of structural countermeasures that put increased stress on ecosystems.

3.6.5.1 *Effects of Climate Change on Inland Hydrology*

The USACE Engineering and Construction Bulletin 2014-10 requires a qualitative analysis of climate change variability in hydrologic analysis for inland watersheds. In its climate change assessment for the Pacific Northwest region, the Corps of Engineers prepared a report synthesizing recent climate change and hydrology literature (USACE 2015).

The 2015 USACE literature review presents this summary of findings for the Pacific Northwest:

> "There is moderate consensus in the literature that annual average air temperatures will increase in the Pacific Northwest Region, and throughout the country, over the next century.

The largest increases are projected for the summer months. A strong consensus is also seen in the literature with respect to projected increases in extreme temperature events, including more frequent, longer, and more intense summer heat waves in the long-term future compared to the recent past.

Projections of precipitation and streamflow in the study basin are less certain than those associated with air temperature. Results of the studies reviewed here are roughly evenly split with respect to projected increases versus decreases in future annual precipitation. There is, however, a strong consensus among the reviewed studies that future storm events in the region will be more intense and more frequent compared to the recent past.

Similarly, clear consensus is lacking in the hydrologic projection literature. For example, projections generated by coupling GCMs [Global Climate Models] with macro-scale hydrologic models in some cases indicate little change in future streamflows but in other cases indicate a potential increase in runoff in the study region. This lack of consensus across the literature is likely due to the varied topography of the region and the current ability of GCMs and regional climate models to consistently resolve topographic effects from local climate forcings."

Figure 3-5, taken from the USACE report, presents a graphical summary of the projected climate trends for the Pacific Northwest.

By the end of this century, ambient air temperatures are expected to increase by 3.2 to 9.7 °F. Air temperature extremes are expected to increase 4.5 to 14.4 °F, with the number of heat wave days expected to increase by up to 75 days per year. Plankton are highly sensitive to changes in temperature, and temperature driven shifts in plankton species and abundance could affect the food web, changing the composition of invertebrates, fish, and mammal communities. Increased algal productivity in surface waters and changes in circulation and upwelling due to warmer marine temperatures could exacerbate low-oxygen events (Snover et al. 2005, Glick et al. 2007, Newton et al. 2008).

The literature review found uniform agreement that the frequency of extreme storm events would rise. Runoff may increase by up to 200 mm/year. Decreased snowpack and earlier snowmelt are expected to contribute to lower summer stream flows, higher winter stream flows, and a change in the timing and extent of freshwater inputs into marine waters. The combined effects of warming stream temperatures and altered stream flows will very likely reduce the reproductive success for many salmon populations (Mantua et al. 2010). Changes in temperature and stream flow can influence the spring bloom timing of algae and zooplankton with attendant impacts to other trophic levels timed to historical blooms (reduced growth and survival). Changes in timing of freshwater input may affect the circulation, stratification, and mixing of the Sound. In winter months, projected increases in stream flow would increase stratification in Puget Sound, which can affect upwelling of nutrient supplies to surface waters, phytoplankton growth, the availability of dissolved oxygen to waters at depth, and pollutant flushing (Newton et al. 2003).

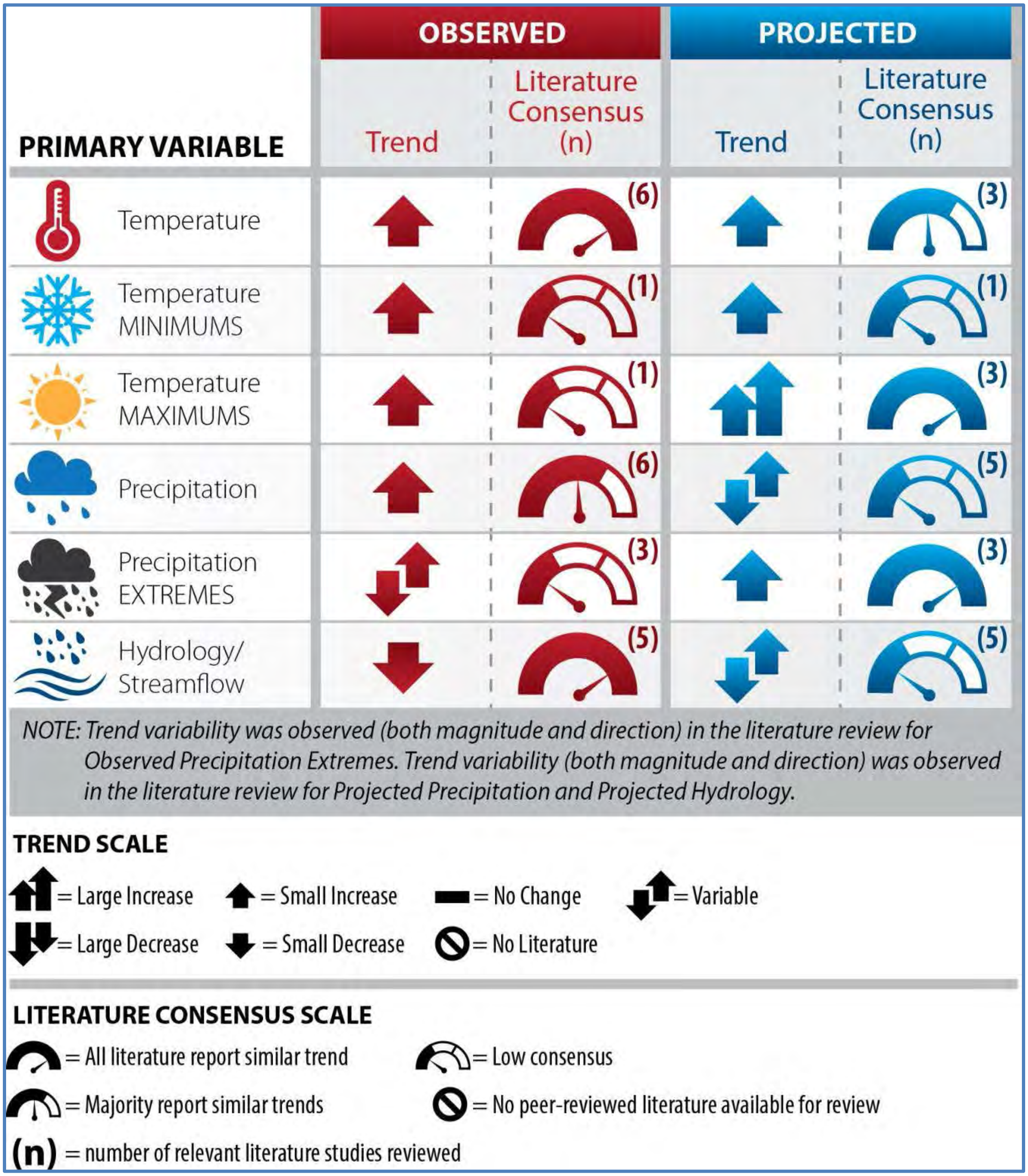


Figure 3-5. Summary matrix of observed and projected climate trends and literary consensus.

The increasing rate and amount of human-caused CO_2 emissions is progressively affecting the ocean system and linked estuaries such as Puget Sound, causing the acidity of seawater to increase. When CO_2 reacts with seawater it creates carbonic acid, lowering the pH level of the of the ocean water (acidifying). At the same time, the reduction in pH reduces the availability of carbonate ions, which play an important role in shell formation in a number of marine organisms. This acidification of ocean water is harming marine organisms that build calcium carbonate shells (calcifers) such as zooplankton, oysters, and mussels and can, in turn, affect higher trophic levels. In Puget Sound 30% of all species are calcifers. In the subsurface waters of Hood Canal, pH values as low as 7.4 have been observed; these values are more than 200% more acidic than open ocean surface waters (Feely et al. 2010). Recent declines and mass die-off of commercial oyster larvae are thought to have possible links to ocean acidification.

The design concept for the project focuses on removing human-made structures or features. Once the impediments are removed form a site, it is expected that the natural system will be dynamic and more resilient to climate change effects, including changes in inland hydrology. Although the project design establishes initial habitat types and channel configurations, the project is not constrained to maintain a specific combination of habitat types into the future. Site designs increase the area of tidal exchange and riverine inundation when compared to present conditions but do not prescribe a particular mix of habitat types. For example, increased channel complexity in levee setback areas will allow refuge for fish under a wider variety of conditions even when winters are wetter and summers are drier. The channels will be allowed to migrate and adapt to changing hydraulic conditions, which may result in shifts between saltwater, freshwater and upland vegetation, however benefits will still accrue in the restored areas. The project design also takes into account regional efforts by others for estuarine and riparian restoration that are being implemented independently in nearby areas.

3.6.5.2 *Sea Level Change Predictions*

The Intergovernmental Panel on Climate Change (IPCC 2007) indicates that, in the 20th century, the rate of global mean sea level (GMSL) change has been 1.7 ± 0.5 mm/year, or between five and nine inches. Vertical land movement (VLM) strongly influences sea-level change (SLC) in Puget Sound and affects local SLC differently in the various sub-basins. VLM varies from uplift on the Olympic Peninsula creating a net sea-level decline, to subsidence in the southern sub-basins resulting in net sea-level rise.

The Nearshore Study is required to consider the effects that SLC could have on the management, planning, design, construction, operation, and maintenance of projects (Corps Engineering Regulation [ER] 1100-2-8162 [USACE 2013] hereinafter referred to as SLC Regulation). The SLC Regulation requires feasibility studies to examine three scenarios to consider the sensitivity and adaptability of projects to sea level change. These scenarios include “low,” “intermediate,” and “high” forecasts of SLC. These scenarios correspond to the historical SLC trend computed from local, long-term, tidal stations and two National Research Council GMSL change acceleration curves (National Research Council 1987) modified by new data from the IPCC. The analysis requires combining local VLM with values from the three SLC scenarios to determine total SLC for each scenario forecast for the period of analysis, which extends 50 years beyond the year when the first project benefits can be expected. Figure 3-6 shows the three predicted sea level change curves for tide gauges at Seattle, Port Townsend and Friday Harbor, in or near Puget Sound near the project sites. The predictions are similar in magnitude around the Puget Sound, with a 100-year high sea level rise of about six to seven feet, a 100-year intermediate rise value of about two feet, and the 100-year low value of under one foot of rise.

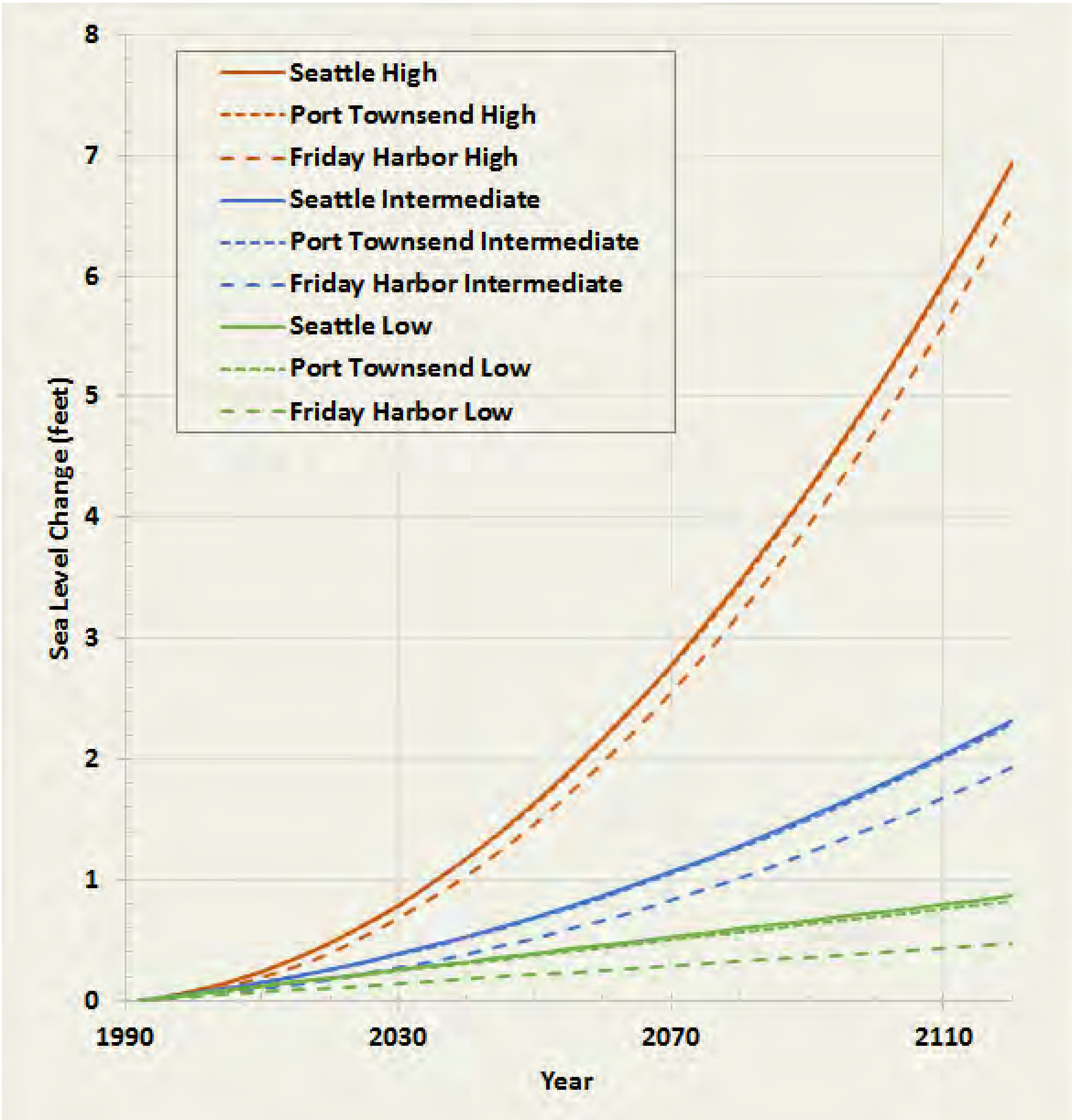


Figure 3-6. Sea level Change Predictions for Tidal Stations Affecting PSNERP Sites, per ER-1100-2-1862. Data from Seattle Gage 9447130 (VLM = -0.54 mm/yr), Port Townsend Gage 9444900 (VLM = -0.24 mm/yr) and Friday Harbor Gage 9449880 (VLM = 0.58 mm/yr). Source: USACE Sea-Level Change Curve Calculator (2015.46).

Local SLC estimates in the Hood Canal, South Puget Sound, and Whidbey sub-basins present the most uncertainty as no active tidal stations exist in these regions and estimates are based on the nearest available VLM correlated gage. Under ER 1100-2-8162, several options are available for feasibility level design. Design of the recommended plan opted to use the approach described in Paragraph 6.d (1) of the guidance - working within a single scenario and identifying the preferred alternative under that scenario. That alternative's performance was then evaluated under the other scenarios to determine its overall potential performance. This approach is best used when plan performance is not highly sensitive to sea level change.

From the ecosystem restoration standpoint, the project is not very sensitive to sea level change. The design concept focuses on removing human-made structures or features to allow natural processes to evolve freely in the absence of impediments. For example, tidal marshes can adapt to sea level change by building elevation to keep pace with the rising water levels, as long as an adequate supply of sediment and/or organic matter accumulation is available. Although the project design establishes initial habitat types and channel configurations, the project is not constrained to maintain a specific combination of habitat types into the future. By expanding freshwater and saltwater inundation area over present conditions through project actions, benefits can accrue in different types of habitat so the number of AAHUs is not strongly a function of sea level. This increase would occur under all sea level change scenarios. The project design takes into account other regional efforts for estuarine restoration and the possibility of managed coastal retreat to allow habitat to keep moving as sea level changes. For these reasons, all alternatives, i.e. all the sites considered in the plan formulation, are expected to perform equally under the different scenarios and the selection of recommended alternative is not sensitive to the rate of sea level change. Structural features within each site are designed to be resilient to sea level change or to allow OMRR&R cost contingency for sea level change but are not necessarily unaffected by sea level change. Levee design uses the existing level of flood risk as a formulation baseline so that future with-project risk is the same as future without-project risk.

This analysis of available scenarios and projections provides ranges of local SLC rates that the Nearshore Study can use to incorporate SLC considerations into the analysis and evaluation of alternatives. The study team will continue to evaluate sea-level change for site-specific project planning during the preconstruction engineering and design (PED) phase.

One consideration for coastal climate change is the effect of high winds on wave heights, storm surge and wave setup. While extreme precipitation events are expected to increase in the Pacific Northwest, recent literature indicates lower tropospheric winds are expected to change little (Warner et al. 2015, Cheng et al. 2015) so that high wind events are not expected to worsen in the near future. In fetch-limited areas, such as in most of Puget Sound, wave heights would not be expected to increase. In those areas which are depth-limited, however, sea level rise will lead to higher wave heights prior to wave breaking and correspondingly increased water levels.

4 PLAN FORMULATION

This chapter explains the process used to formulate, evaluate, and compare alternative plans. To develop restoration plans and a comprehensive restoration master plan for the Puget Sound nearshore, the Study team used the process illustrated in Figure 4-1. These steps are described in more detail throughout this chapter.

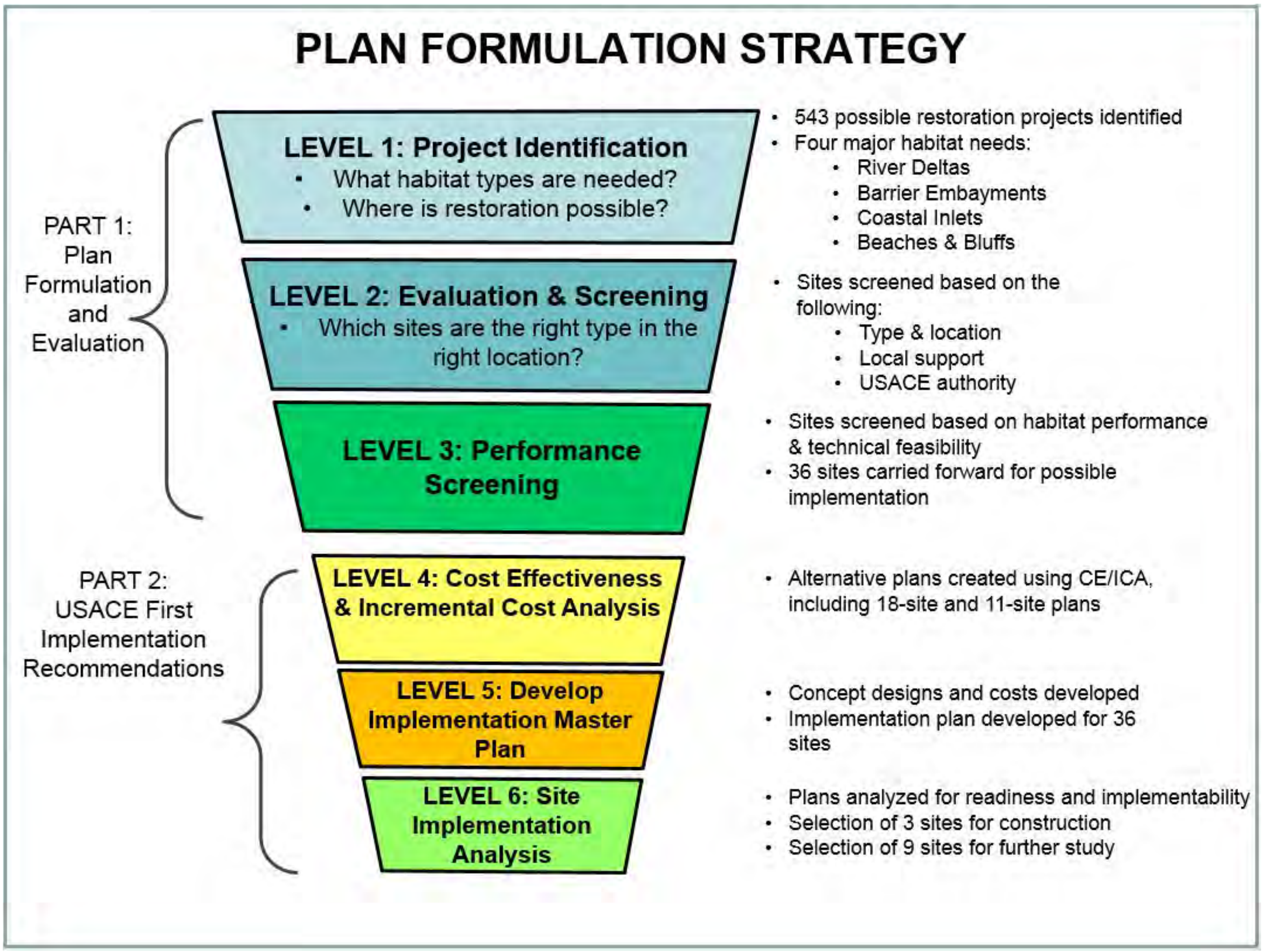


Figure 4-1. Summary of Plan Formulation Process

4.1 LEVEL 1: PROJECT IDENTIFICATION

Level 1 of the plan formulation strategy includes identification and screening of management measures as well as initial site identification for potential restoration projects across the nearshore zone based on the types of habitat to be restored in the most critical areas. The following sections summarize this first level of the plan formulation process.

4.1.1 Management Measures – “Right Action”

Management measures are features or activities that can be implemented at a specific geographic site to address one or more planning objectives. To determine the “right action” for potential restoration activities in the Puget Sound nearshore zone, the Study team identified 21 management measures that are outlined in a report titled, Management Measures for Protecting and Restoring Puget Sound Nearshore (Management Measures Technical Report, Clancy et al. 2009). Structural measures (e.g., armor removal, dike removal, channel rehabilitation, etc.) and non-structural measures (invasive species control, physical exclusion, public education, etc.) were identified and evaluated. A summary of the 21 management measures and their relationships to nearshore ecosystem processes are shown in Table 4-1. It should be noted that some of the management measures are not within the Corps’ ecosystem restoration authority. They are included in the table to capture a complete list of possible measures but were not carried forward for future consideration (these measures are shaded in gray Table 4-1). The process used to evaluate and screen measures is summarized in the following paragraphs.

Table 4-1. Potential of Management Measures to Influence Nearshore Processes

No. [1]	Management Measure [2]	Relationship to Puget Sound Nearshore Ecosystem Processes ● = strong effect; ◗ = weak effect; blank = no relationship									
		Sediment Supply and Transport	Beach Erosion and Accretion	Distributary Channel Migration	Tidal Channel Formation and Maintenance	Freshwater Input	Tidal Hydrology	Detritus Recruitment and	Exchange of Aquatic Organisms	Solar Radiation (Sunshine)	Wind and Waves
1	Armor (a) Removal	●	●			◗		●			●
	(b) Modification		◗			◗					
2	Beach Nourishment	●	●								
3	Berm or Dike (a) Removal	●		●	●	●	●	●	●		◗
	(b) Modification	◗			◗	◗	◗	◗	◗		
4	Channel (a) Rehabilitation	●		◗	◗	●	●	●	●		
	(b) Creation	◗			◗	●	◗	◗	◗		
5	Contaminant (a) Removal								◗		
	(b) Remediation								◗		
6	Debris Removal	◗	◗		◗						
7	Groin (a) Removal	●	●	◗	◗	●	◗	◗	●		●
	(b) Modification	◗	◗	◗	◗	◗	◗	◗	◗		◗
8	Habitat Protection Policy or Regulations[3]	◗	◗	◗	◗	◗		◗	◗		◗
9	Hydraulic Modification	◗				◗	◗	◗	◗		◗
10	Invasive Species Control	◗	◗		◗	◗	◗	◗	◗	◗	◗
11	Large Wood Placement	◗	◗	◗	◗			◗	◗		◗
12	Overwater Structure (a) Removal	◗	◗							●	◗
	(b) Modification									◗	◗

No.[1]	Management Measure[2]	Relationship to Puget Sound Nearshore Ecosystem Processes ● = strong effect; ◗ = weak effect; blank = no relationship									
		Sediment Supply and Transport	Beach Erosion and Accretion	Distributary Channel Migration	Tidal Channel Formation and Maintenance	Freshwater Input	Tidal Hydrology	Detritus Recruitment and	Exchange of Aquatic Organisms	Solar Radiation (Sunshine)	Wind and Waves
13	Physical Exclusion								◗		
14	Pollution Control								◗		
15	Property Acquisition and Conservation[4]	●	●	●	●	●	●	●	●	●	●
16	Public Education and Involvement[5]	◗	◗	◗	◗	◗	◗	◗	◗	◗	◗
17	Revegetation	◗	◗	◗		◗		◗		◗	◗
18	Species Habitat Enhancement								◗		
19	Reintroduction of Native Animals								●		
20	Substrate Modification	◗	◗		◗	◗			●		◗
21	Topography (a) Restoration	●	●	●	●	●	●	●	●		●
	(b) Creation	◗	◗			◗	◗	◗	◗		◗

Notes:

1 The following management measures are non-structural: 5, 8, 10, 13, 14, 15, 16, 17, 18, and 19.

2 Some management measures are separated into rows labeled (a) and (b) to distinguish variation in the degree of process restoration between full removal of a stressor and partial removal/modification of the stressor.

3 The Habitat Protection Policy or Regulations management measure influences process via specific regulations such as the Shoreline Management Act and the Growth Management Act (critical areas ordinances), which limit shoreline armoring, overwater structures, and removal of riparian vegetation; storm water regulations, which require management of runoff and infiltration; and other regulations that protect ecosystem processes.

4 The Property Acquisition and Conservation management measure has potential to influence all processes to some degree and is an essential measure for long-term protection of ecosystem processes.

5 Public Education and Involvement potentially influences most ecosystem processes, through indirect mechanisms with varying durability.

The 21 management measures can be classified into groups as follows:

- **Restorative Measures** – These measures exert long-lasting effects on ecosystem processes and will often provide the best opportunity of achieving complete restoration of processes. They primarily involve removal of human-made stressors that physically impede processes. This also includes structural measures that provide immediate benefits in terms of habitat structure. Sustainability of these measures requires intact ecosystem processes.
- **Prerequisite Measures** – Includes measures that are often required prior to or in conjunction with other measures.
- **Protective Measures** – Measures such as these are a critical part of an overall recovery strategy. While important, these types of measures would not be implemented by the Corps as they are typically not within the Corps' ecosystem restoration mission area and authorities; therefore, protective measures are not considered further in this study.

Restorative management measures are considered keystone elements of sustainable restoration because they directly address degradation of the processes that create and sustain nearshore ecosystems. Of the 21 management measures originally identified, nine management measures were classified as restorative and were carried forward in the formulation of alternative plans.

The nine restorative management measures and their relationships to the planning objectives appear in Table 4-2. An expanded discussion of the management measures carried forward for each site included in the recommended plan is presented in Chapter 6.

Table 4-2. Relationship between Objectives and Management Measures

Management Measures[1]	**Objectives**		
	Restore Deltas	**Restore Beaches**	**Restore Embayments**
Armor Removal or Modification	✓	✓	✓
Berm or Dike Removal or Modification	✓		
Channel Rehabilitation or Creation	✓		✓
Groin Removal or Modification		✓	✓
Hydraulic Modification	✓		✓
Overwater Structure Removal/ Modification		✓	✓
Topography Restoration	✓	✓	✓
Large Wood Placement	✓	✓	✓
Revegetation	✓	✓	

Notes: [1] Based on Management Measures Technical Report (Clancy et al. 2009)

4.1.2 Identification of Restoration Strategies – "Right Place"

To determine the "right places" for restoration in the Puget Sound nearshore zone, the Study team conducted an analysis to determine where process-based restoration would have the greatest likelihood of successfully achieving planning objectives. This analysis is documented in the Strategies Report (Cereghino et al. 2012). The analysis uses preexisting, Sound-wide, spatially explicit information on nearshore landforms, stressors, and land use.

As described in section 1.8.3, the Change Analysis quantified structural and physical change between historic (1850s-1890s) and current (2000-2006) conditions. This analysis correlates the location, occurrence, and amount of stressor impact on nearshore ecosystems in the context of dominant ecosystem processes. Based on the historic and current conditions, the report presents four restoration strategies intended to assist in achieving the three Nearshore Study planning objectives. These four strategies are the foundation of site identification, where the Study team identified potential locations where one or more measures can be implemented to restore river deltas, barrier embayments, coastal inlets, and beaches. In other words, the strategies define site-specific locations in the Puget Sound Region where the objectives can be directly addressed.

Table 4-3 shows the correlation between the planning objectives and the strategies. The resulting strategic recommendations are presented (in part) as maps indicating where the Study team recommends focusing efforts to implement one or more process-based ecosystem restoration measures for the four strategies. As an example, the map illustrating the recommended approach for the River Deltas strategy is displayed in Figure 4-2. The maps of the other three strategies can be found in the Engineering Appendix.

Table 4-3. Nearshore Planning Objectives and Strategies

Planning Objective	Strategy Name	Description
Restore connectivity and size of large river deltas	River Delta	Protect and restore fresh water input and tidal processes where major river floodplains meet marine waters.
Restore the number and quality of coastal embayments	Barrier Embayment	Protect and restore sediment input and transport processes to littoral drift cells where bluff erosion sustains barrier beaches that form barrier embayments and restore the tidal flow processes within these partially closed systems.
	Coastal Inlet	Protect and restore tidal inflow processes in coastal inlets, and protect and restore fresh water input and detritus transport processes within these open embayment systems.
Restore the size and quality of beaches	Beach	Protect and restore fresh water input and tidal processes to littoral drift cells where bluff erosion sustains beach structure.

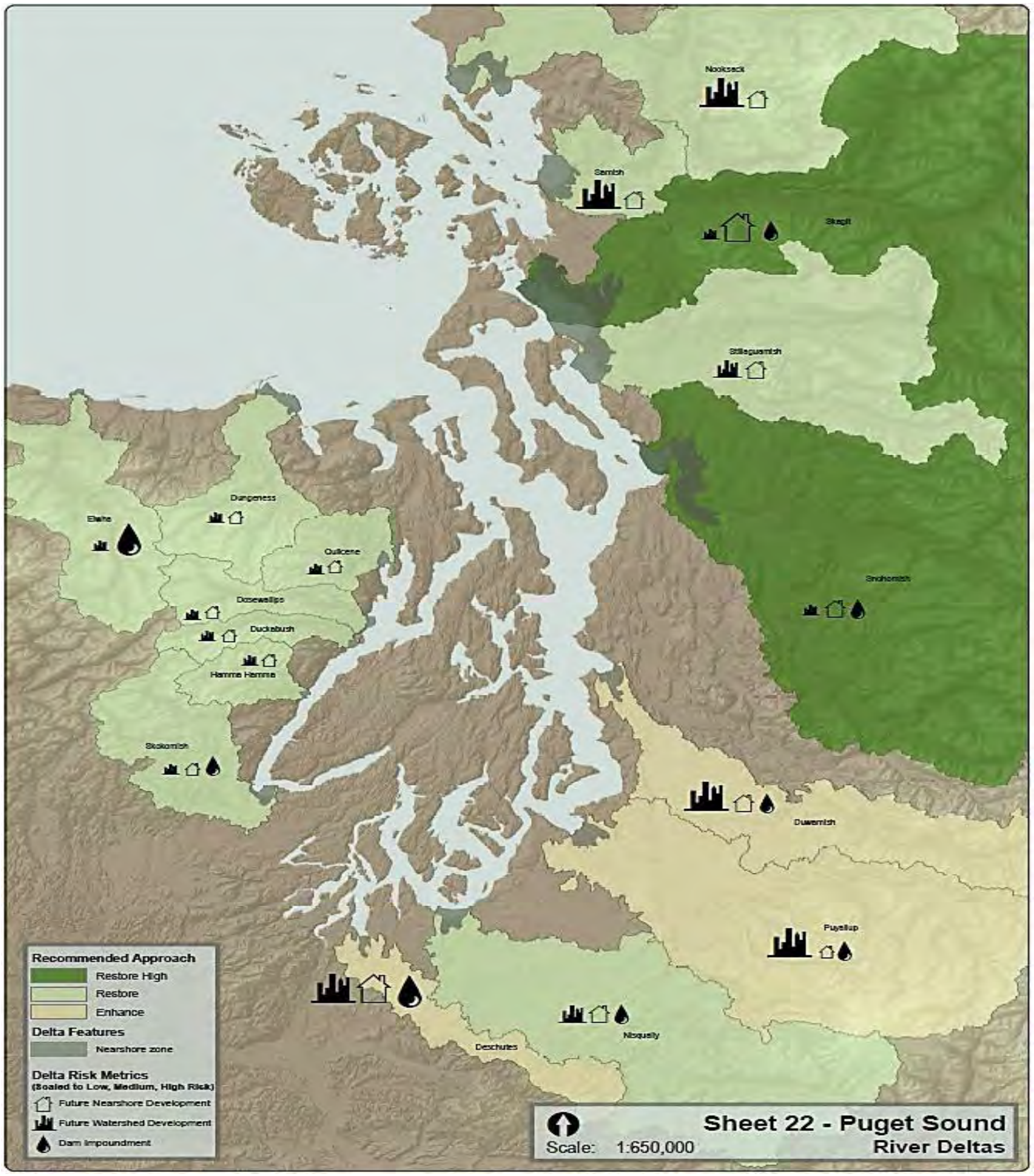


Figure 4-2. Map of Strategies Analysis for Deltas (from Cereghino et al. 2012)

4.1.3 Site Identification

To foster collaboration and maximize efficiency in creating an initial list of potential restoration sites where one or more measures could be implemented, the Nearshore Study used the knowledge base of local restoration practitioners and organizations and the extensive backlog of restoration ideas generated by these groups. Potential project ideas were generated by groups across the restoration community including Lead Entities, Marine Resource Committees, Salmon Enhancement Groups, tribes, etc. Information they provided was used to populate the Nearshore Database, which became a comprehensive list of restoration ideas throughout Puget Sound. The Nearshore Database was created by the Nearshore Study and has been maintained by the Study team since then. In addition to serving as the pool of potential solutions to be used by the

Nearshore Study, the Nearshore Database serves as a tool for documenting the scope of Sound-wide restoration needs and opportunities. The restoration community was provided several opportunities between 2006 and 2010 to add and update entries in the database. The Nearshore Study improved overall data quality and consistency by assigning spatial coordinates and translating the restoration descriptions into management measures using the *Management Measures Technical Report* (Clancy et al. 2009). A final call to the restoration community for submittals of new entries into the database was made in May 2010, resulting in a total of 543 entries (site records) in the database.

4.2 LEVEL 2: EVALUATION AND INITIAL SCREENING

Level 2 of the plan formulation strategy included initial screening of the 543 site records contained in the Nearshore Database. Sites that occurred in a location identified by one of the four strategies (including deltas, barrier embayments, coastal inlets, and beaches) were retained for further consideration. The team determined whether the remaining site records proposed the "right action" in the "right place;" in other words, if it centered on at least one of the seven restorative management measures that target the spatially-explicit strategic needs of the site. For example, if a proposed restoration action included management measures that restore ecosystem processes that support deltas (right action), and if it was located in a delta where restoration was likely to succeed (right place), then it would be eligible for further consideration.

To complete initial screening of the 543 site records, Study team planners, biologists, project managers and members of the Nearshore Science Team met to systematically review the sites considering the following elements:

- the landforms present at a given site,
- the management measures proposed,
- the level and type of degradation present at a given site
- the position of the site in the landscape.

Sites that included one or more measures considered to have a strong effect on a strategy (i.e., those most able to restore the associated process or processes) were retained for further consideration. When these sites included one or more measures considered to have a weak effect on the strategy (for example, a measure that would accelerate benefit accrual without addressing underlying processes), the sites were retained for further consideration but the weakness was noted. Sites that contained no restorative management measures were excluded from further evaluation. This initial screening step narrowed the list of sites from 543 to 198 to be carried forward for additional evaluation.

Study team members then met with representatives of the local restoration community to understand local constraints, confirm project details, and verify proponent interest. Sites were removed from the list of 198 for an array of reasons including significant concerns about landowner willingness, lack of public support, or the likelihood that the restoration may be completed by others. In some cases, two site records dealt with adjacent lands and were combined into one. Duplicate entries for the same or similar action with different project names were identified and merged in consultation with the project proponent(s). The result was a list of 46 site records suitable for development of conceptual designs, cost estimates, and additional evaluation.

4.2.1 Site Conceptual Designs

An interdisciplinary Conceptual Design Team (CDT) comprised of Study team members and expert consultants conducted field visits to each of the 46 candidate restoration sites. The CDT assessed site conditions, gathered data to characterize the site, obtained photographs, and evaluated "on-the-ground" opportunities and constraints. The CDT evaluated each site using a set of screening criteria to determine whether the proposed action is likely to achieve the Nearshore Study’s restoration objectives. Screening criteria were meant to identify any “fatal flaws” of the sites and included determining the following: (1) whether the site was sufficiently described and spatially defined to allow the Study team to develop conceptual designs and develop quantity estimates, (2) whether the site was consistent with one or more of the Nearshore Study’s restoration objectives and strategies, and (3) whether local proponents had precluded the Study team from including the site when developing conceptual designs. The results of this work are documented in characterization reports that describe the potential restoration opportunities in terms of ecological effectiveness and engineering feasibility (Strategic Restoration Conceptual Engineering — Final Design Report (aka “Conceptual Design Report”, ESA et al. 2011b). As a result of this evaluation and screening, six sites were removed from further consideration. Additionally, the four Big Quilcene River sites were combined into one site, and the two Telegraph Slough sites were combined, leaving 36 sites to proceed to conceptual design.

As described in section 4.1, a suite of 21 different management measures were identified for implementation across Puget Sound. Management measures identified for this study are fully outlined in the Management Measures for Protecting and Restoring Puget Sound Nearshore (Management Measures Technical Report, Clancy et al. 2009). Structural measures (e.g., armor removal, dike removal, channel rehabilitation, etc.) and non-structural measures (invasive species control, physical exclusion, public education, etc.) were identified and evaluated. A summary of the 21 management measures and their relationships to nearshore ecosystem processes are shown in Table 4-1.

Based on the results of the management measures evaluation and screening step, two site designs, one “full” and one “partial,” were developed for each of the remaining 36 sites. A “full” design includes management measure(s) to fully remove site-specific stressors, maximize the area of influence, and maximize improvements in ecosystem benefits. Land ownership was not considered as a potential constraint in developing the full restoration alternative; however, the continued existence of major durable infrastructure (e.g., transmission lines, highways, utilities, railroads) was generally assumed. The full design can be understood as a way to maximize site potential for process-based restoration by removal of stressors to the fullest extent possible, often expanding upon the original proposal for the site.

A second "partial" design was developed that addressed known constraints and concerns (from landowners, user groups, and the community) while still achieving process-based restoration. The partial design could differ from the full design in the number or type of management measures implemented, the area over which a management measure was applied, and/or the size or type of tidal openings. The partial restoration design was often similar to the description initially submitted to the Nearshore Database by the project proponent.

This step resulted in 72 designs at 36 sites, shown in Figure 4-3. Narrative descriptions of the sites, designs, assumptions, and future needs, along with the conceptual design plans, are documented in the Conceptual Design Report (ESA et al. 2011b).

It should be noted that this step of the plan formulation process was intended to identify conceptual alternatives for each site using the measures carried forward from preliminary screening while still evaluating a large number of potential alternatives across the Puget Sound. While only two site designs were developed at this stage, sites that were carried forward in the recommended plan underwent additional site-specific plan formulation and design. Chapter 6 describes the additional site-specific plan formulation steps that were used to further develop and refine site designs, including identification of site-specific planning objectives, constraints, and measures for each of the sites included in the recommended plan. This process allowed the study team to identify alternatives at a broad, regional scale and further refine alternatives at the site-specific scale as the plan formulation and evaluation process continued.

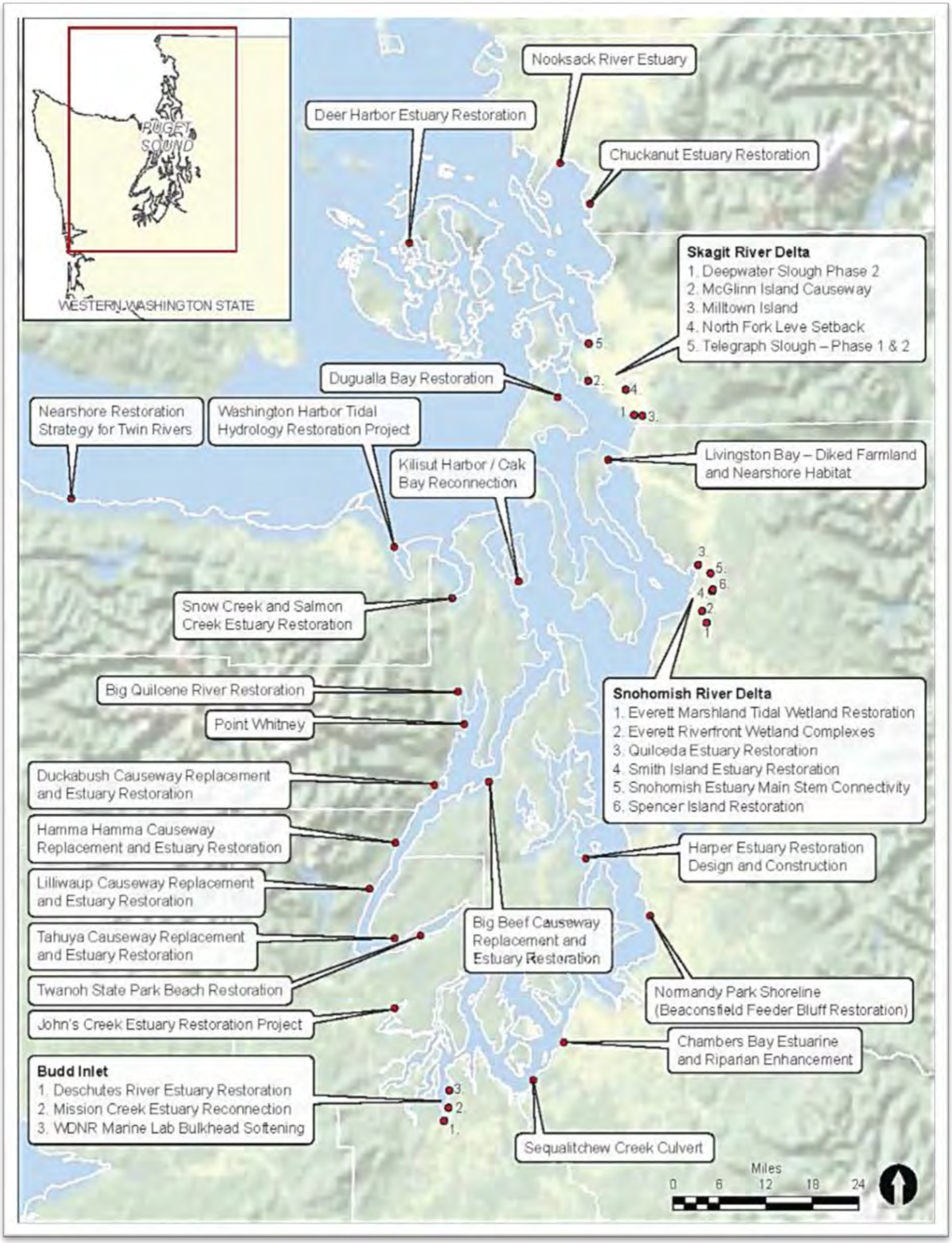


Figure 4-3. Location of 36 Sites

4.3 LEVEL 3: PERFORMANCE SCREENING

Level 3 of the plan formulation strategy included performance screening of the sites in the master plan. To effectively evaluate the 36 sites carried forward, the Nearshore Study team completed additional analysis including development of parametric cost estimates and evaluation of ecosystem outputs. The following sections outline the assumptions and outcomes of this work.

4.3.1 Evaluation of Site Benefits

An interdisciplinary team including Corps staff, members of the NST, and consultants developed an ecosystem output (EO) model to quantify the benefits that each site would provide. The framework of this model is consistent with the Nearshore Study's approach of restoring the ecosystem processes and structures to provide ecosystem functions to support habitats, biodiversity, and productivity. The model output is a product of quantity and quality. The quantity component of the model equation is defined as the area of restored process (in acres), and the quality component is comprised of multiple components that capture process, structure, and function. These three quality components are derived from calculations based on spatially explicit data in the Nearshore Geodatabase[1]:

- The process component is represented by one index: process degradation.
- The structure component is represented by five landscape indices: scarcity of landforms, heterogeneity of landforms, long-shore connectivity, cross-shore connectivity, and sinuosity.
- The function component is represented by one index modified from Simenstad et al. (2011): a site's ability to provide ecological outputs of regulating and supporting ecosystem functions. Only habitat-supporting and ecologically-related outputs were used (see Appendix G).

The model equation combines these components as follows:

$$\mathbf{EO} = \overbrace{\mathbf{A}}^{\text{Quantity}} * \overbrace{\mathbf{[(P^2 + S + F)/maximum\ possible\ score]}}^{\text{Quality}}$$

Where:

EO − ecosystem output (project benefits)

A − area of restored process, in acres (Quantity score)

P − process degradation index score, scale 0 − 10 (process component of Quality score)

S − 2 (Sc + H + Lc + Cc + Sn), scale 0 − 10 (structure component of Quality score)

Sc- scarcity, scale 0-1

H- heterogeneity, scale 0-1

[1] The Nearshore Geodatabase was initially compiled as part of the Change Analysis (Simenstad et al. 2011)

Lc- long-shore connectivity, scale 0-1
Cc- cross-shore connectivity, scale 0-1
Sn- sinuosity, scale 0-1

F – Ecosystem Functions Goods & Services Tier 2 score, scale 0 − 10 (function component of Quality score)
Maximum possible score for quality: 120

A documentation report titled "Puget Sound Nearshore Ecosystem Output Model Documentation Report" describes the theory, framework, and detailed methodology of this model and the associated indices listed above (see Appendix G). The Nearshore Study's Strategic Science Peer Review Panel (SSPRP, described in further detail in section 8.4) reviewed the documentation report. The Corps has reviewed and approved this model for use in this study.

4.3.2 Evaluation of Site Costs

Costs were estimated for the 36 sites and input into the Institute for Water Resources Plan for generation of alternatives and for CE/ICA. Costs used in the formulation and evaluation of alternatives are the economic costs of each site design, including pre-construction, engineering, and design (PED) costs; construction and construction management costs; and real estate costs.

Costs for PED, construction, and construction management were developed by Corps cost engineers in Micro-Computer Aided Cost Estimating System (MCACES)[2] using the quantities provided with the conceptual designs, standard features and rates, and input from the PDT. When necessary, quantities were developed by the cost engineer if not provided in the conceptual design reports. Items such as the fuel rates, rock pricing, haul distances, and markups were discussed within the team and held consistent throughout all site designs. Certain features, such as some bridges and levees, were assumed to have similar designs but were sized according to the needs of each alternative site design. Costs developed for the CE/ICA analysis utilized costs at the October 2011 price level and were annualized using a 4% discount rate (FY12 rate) and assumed similar construction durations across sites. Monitoring and adaptive management costs were included as a cost contingency and were confirmed to not to vary considerably among sites, with the study team concluding that these costs would not impact the outcomes of the CE/ICA analysis. Monitoring costs ranged from 0.9-0.95% and adaptive management costs ranged from 2.58-2.85% for each of the sites.

Operations, Maintenance, Repair, Rehabilitation, and Replacement (OMRR&R) costs were not included in this phase of evaluation because little was known about the cost of OMRR&R at the conceptual design level. Expected changes to OMRR&R were evaluated at a conceptual level, but it was subsequently determined that inclusion of OMRR&R costs had a moderate level of uncertainty but would not affect the screening of alternatives at this phase. OMRR&R is

[2] MCASES is cost estimating software used by Corps cost engineers.

evaluated and presented in the project costs for the recommended plan in Chapter 6 of this report.

Certified Class 3 cost estimates were developed for the recommended plan based on feasibility-level designs. Final feasibility-level cost estimates are presented in section 6.7 and the Cost Engineering Annex of Appendix B.

4.3.3 Additional Screening

An additional round of qualitative evaluation and screening was completed based on site benefits, preliminary costs, technical feasibility, and overall readiness to proceed. Similar to the screening described in section 4.2.1, screening criteria were meant to identify any “fatal flaws” of the sites or site designs (“full” and “partial”) and included determining the following: (1) whether the site or site design was sufficiently described and spatially defined to allow the Study team to develop conceptual designs and develop quantity estimates, (2) whether the site or site design was consistent with one or more of the Nearshore Study’s restoration objectives and strategies, and (3) whether the site or site design generally met site-specific objectives and avoided site-specific constraints.

This evaluation step was the primary mechanism to qualitatively screen the “full” or “partial” designs for each site as well as identify any “fatal flaws” with sites regardless of whether the “full” or “partial” design was carried forward. After this additional qualitative screening was completed, 41 designs were screened out from further evaluation, leading to 31 designs remaining. In addition, 12 sites were screened out from further evaluation during this step, leading to 24 sites remaining. As a result of this evaluation and screening step, 31 different site designs (representing a level of restoration labeled “full” or “partial”) located at the 24 unique sites were carried forward for additional analysis, evaluation, and screening.

4.3.4 Summary of Site Benefits and Costs

Table 4-4 provides an overview of the benefits and costs for the 31 site designs located at 24 sites. The site designs are grouped by strategy, which is shown in the left-most column.

Table 4-4. Benefits and Costs for Sites, by Strategy (October 2011 price level)

		Costs ($1,000s)		Benefits	
Strategy	**Site Design Name**	**First Costs[1]**	**Total Average Annual Costs**	**Area**	**Average Annual Net Ecosystem Output**
Delta	Big Quilcene Partial	$35,073	$1,632	25.5	0.6
	Deepwater Slough Partial	$6,652	$310	269.6	90.2
	Duckabush Full	$71,085	$3,309	39.4	12.9
	Duckabush Partial	$58,403	$2,719	38.1	12.3
	Everett Marshland Full	$357,549	$16,644	829.1	349.3

Strategy	Site Design Name	Costs ($1,000s) First Costs[1]	Total Average Annual Costs	Benefits Area	Average Annual Net Ecosystem Output
	Everett Marshland Partial	$154,286	$7,182	427.4	167.8
	Milltown Island Partial	$4,246	$198	214.2	64.0
	Nooksack River Delta Partial	$331,473	$14,132	1,807	650.5
	North Fork Skagit Delta Full	$64,393	$2,998	256.1	53.7
	Spencer Island Partial	$16,916	$787	313.2	136.0
	Telegraph Slough Full	$188,613	$8,779	832.2	253.9
	Telegraph Slough Partial	$93,922	$4,372	146.9	16.3
Beach	Beaconsfield Feeder Bluff Full	$7,929	$369	6.9	2.2
Beach	Beaconsfield Feeder Bluff Partial	$3,027	$141	5.5	1.3
Beach	Twin Rivers Partial	$5,546	$258	4.3	0.2
Beach	WDNR Budd Inlet Beach Full	$9,569	$446	2	1.1
Barrier Embayment	Big Beef Creek Estuary Full	$32,629	$1,519	29.6	7.9
Barrier Embayment	Dugualla Bay Partial	$72,289	$3,365	572	162.6
Barrier Embayment	Livingston Bay Full	$12,863	$599	244.6	41.6
Barrier Embayment	Livingston Bay Partial	$12,062	$561	238.7	40.5
Barrier Embayment	Point Whitney Lagoon Full	$9,522	$443	6.1	2.0
Coastal Inlet	Chambers Bay Full	$288,020	$13,408	83.5	8.5
Coastal Inlet	Chambers Bay Partial	$96,699	$4,502	47	3.4
Coastal Inlet	Deer Harbor Estuary Full	$6,679	$311	16.1	4.8
Coastal Inlet	Harper Estuary Full	$12,240	$569	6.2	1.7
Coastal Inlet	Harper Estuary Partial	$16,025	$746	5.7	1.1
Coastal Inlet	Lilliwaup Partial	$30,619	$1,425	19.6	1.1
Coastal Inlet	Sequalitchew Full	$166,320	$7,743	4.5	0.9
Coastal Inlet	Snow/Salmon Creek Estuary Partial	$37,798	$1,760	52.2	6.8
Coastal Inlet	Tahuya River Estuary Full	$28,917	$1,346	36.1	7.6
Coastal Inlet	Washington Harbor Partial	$17,666	$822	14	0.6

Note: 1. First costs include real estate, design, construction, and construction management.

4.4 LEVEL 4: COST EFFECTIVE AND INCREMENTAL COST ANALYSIS

Level 4 of the plan formulation strategy included cost effective and incremental cost analysis for the 24 sites carried forward from the previous step. As discussed in section 4.1.2, four restoration strategies were developed to address the planning objectives, with one strategy to address Objective 1 (deltas), two to address Objective 2 (embayments - one strategy for barrier embayments and one for coastal inlets), and one to address Objective 3 (beaches). Alternative plans were initially formulated to address each strategy because of the broad variety of and differences between ecological benefits that accrue from restoration of the different landforms. Restoration of the different landforms can have not only cumulative benefits, but potentially synergistic benefits as well. For example, restoring a large river delta site would benefit rearing salmonids, while restoring a beach would restore spawning habitat for forage fish, a primary prey resource for salmonids and many other species. The complexity of interactions among biota dependent on the nearshore zone means restoration benefits are needed across each strategy.

Because outputs from sites of one strategy are not directly comparable to outputs from sites of the other three strategies, and to ensure that at least one alternative plan includes sites from each strategy, alternative plans were generated through a multi-step process:

- First, the sites were organized into four subgroups, one for each strategy (see section 4.5.1).
- Second, IWR Planning Suite (certified version 2.0.6.0) was used to generate an initial array of alternative plans comprised of all possible combinations of sites within each strategy. Based on this evaluation, one or more cost effective sites within each strategy were carried forward (described in section 4.5.2).
- Third, IWR Planning Suite was used to generate a focused array of alternative plans comprised of all possible combinations of the sites across all strategies carried forward from the previous step. Based on this evaluation, a focused array of 23 best buy plans (including the No-Action plan) was identified (described in section 4.5.3).
- Finally, a final array of four alternatives was carried forward. Alternatives 2 and 3 are comprised of multiple sites and address all three of the study's objectives and all four of the study's strategies (described in section 4.5.4). Alternative 4 addresses only 1 objective (deltas) and the No-Action Alternative addresses none of the strategies.

The following sections provide a more detailed explanation of this process and the alternative plans selected as a result.

4.4.1 By-Strategy Subgroups

After estimating costs and benefits, the sites were grouped by the strategy they most prominently addressed. This step ensured that sites addressing each of the four strategies (and by extension all planning objectives) would ultimately be included in the implementation strategy, because the cost effective plans from each strategy were carried forward into the initial array of alternatives. The sites were grouped by strategy as shown in Table 4-4 and summarized below.

River Delta Strategy (9 sites; 12 site designs)

- Big Quilcene Partial
- Deepwater Slough Partial
- Duckabush Full
- Duckabush Partial
- Everett Marshland Full
- Everett Marshland Partial
- Milltown Island Partial
- Nooksack River Delta Partial
- North Fork Skagit Delta Full
- Spencer Island Partial
- Telegraph Slough Full
- Telegraph Slough Partial

Beach Strategy (3 sites; 4 site designs)

- Beaconsfield Feeder Bluff Full
- Beaconsfield Feeder Bluff Partial
- Twin Rivers Partial
- WDNR Budd Inlet Beach Full

Barrier Embayment Strategy (4 sites; 5 site designs)

- Big Beef Creek Estuary Full
- Dugualla Bay Partial
- Livingston Bay Full
- Livingston Bay Partial
- Point Whitney Lagoon Full

Coastal Inlet Strategy (8 sites; 10 site designs)

- Chambers Bay Full
- Chambers Bay Partial
- Deer Harbor Estuary Full
- Harper Estuary Full
- Harper Estuary Partial
- Lilliwaup Partial
- Sequalitchew Full
- Snow/Salmon Creek Estuary Partial
- Tahuya River Estuary Full
- Washington Harbor Partial

4.4.2 Initial Array of Alternatives

IWR Planning Suite was used to generate an initial array of alternative plans comprised of all possible combinations of sites within each of the four strategies described above. This approach was taken due to the software limitations of IWR Planning Suite; because of the large number of combinations of alternative plans that could occur if all 31 site designs at 24 sites were analyzed together, the IWR Plan software application was run four times, once for each strategy.

Each run of IWR Planning Suite identified an initial array of cost effective and best buy alternatives comprised of one or more sites within each strategy. For these runs of IWR Planning Suite, all sites within each strategy were identified as combinable with the exception of the sites that had multiple scales (full and partial). This approach ensured that the initial array of alternatives only included a single scale (full or partial) at each site. No sites were dependent on any other sites.

Through comparison of incremental costs and benefits of the best buy plans for each strategy, the PDT identified the sites within each strategy that made sense for inclusion in the next step of alternative formulation and evaluation using the process outlined in ER 1105-2-100 for identification of a NER plan. For each of the four IWR Plan software runs (one for each strategy), the Study team evaluated costs per output for each plan to determine whether it was “worth it” in terms of costs and outputs to carry forward the next cost effective increment. Based on this analysis, one or more plans were identified to be carried forward to the next step of the alternatives formulation process, while some plans were not carried forward due to exceptionally high incremental costs per unit.

An example outcome of this step is provided in Figure 4-4 where alternative plans for the coastal inlet strategy are graphed according to their incremental costs and outputs. The Economics Appendix F contains the tables and associated information for the other three strategies.

For the coastal inlet strategy, the eighth plan was selected for inclusion in the next step of formulation and evaluation. This plan was selected in part due to the substantial incremental cost increase that occurs between coastal inlet plans 8 and 9 ($1,577,000 to $8,603,000). Coastal inlet plan 9 includes the Sequalitchew site, with an incremental cost of $7,743,000 for 0.9 AAHU’s. Coastal inlet plan 8 includes 7 coastal inlet sites that were carried forward.

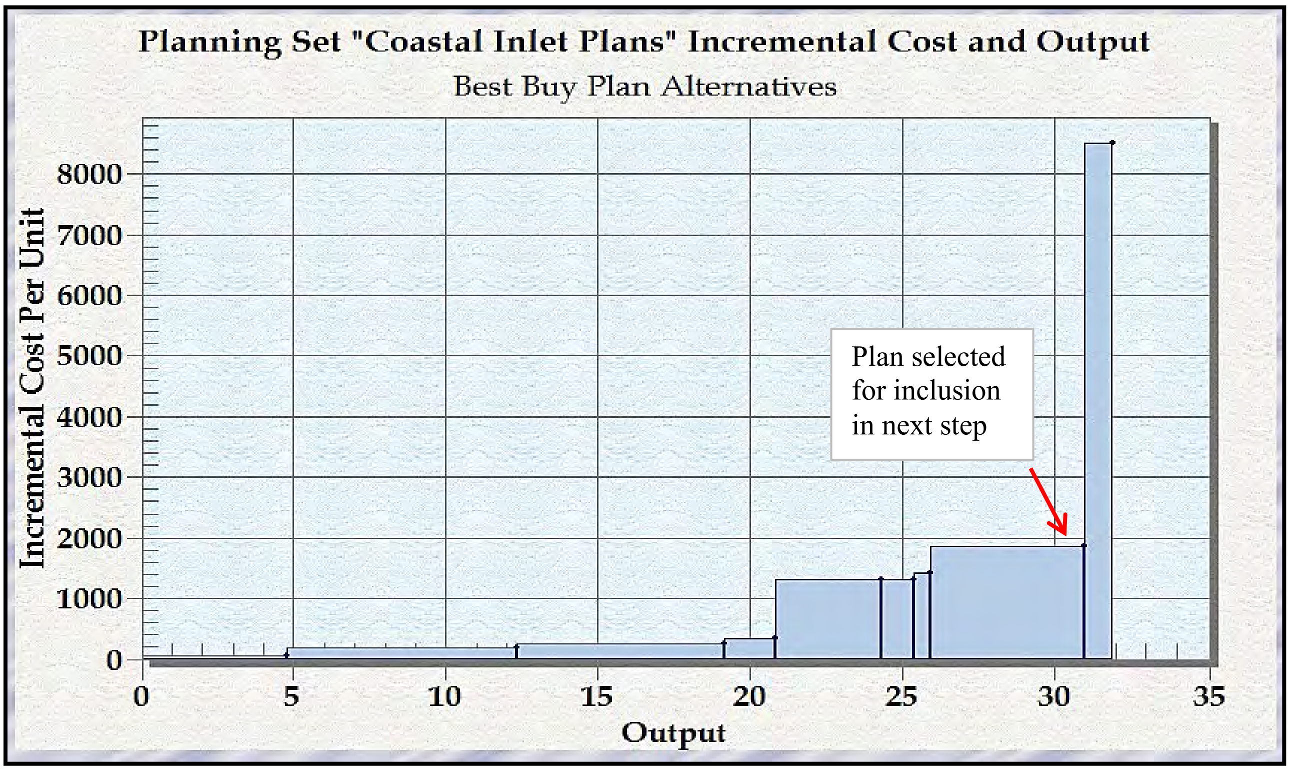


Figure 4-4. Incremental Cost and Output for Coastal Inlet Plans

A similar process was completed for the other three strategies, leading to the inclusion of four barrier embayment sites, eight river delta sites, and three beach sites (in addition to the four coastal inlet sites) for a total of 22 sites. Additional information about the evaluation of best buy plans for each strategy is presented in section 4 of the Economics Appendix. These sites were carried forward individually (versus part of a single, inseparable plan for each strategy) for the next step in the alternatives evaluation process.

4.4.3 Focused Array of Alternatives

IWR Planning Suite was used to generate a focused array of alternative plans comprised of all possible combinations of the 22 sites carried forward from the previous step. This analysis identified 23 best buy alternative plans that contain one or more sites and address one or more strategies. The 23 best buy plans are shown in Table 4-5 along with the associated average annual cost per output and incremental cost per output for each best buy plan. Each plan builds on the previous plan. Beginning with plan number 2, Milltown Island Partial is the only site included in this alternative. Plan number 3 includes Milltown Island Partial plus Deepwater Slough Partial, and plan number 4 includes those two plus Spencer Island Partial. This pattern continues until Chambers Bay Full is added to create the most expensive, highest output plan, plan number 23, which includes 22 sites. The last site added is the site with the highest incremental costs per output. Plans highlighted in green on Table 4-5 were carried forward to the final array of alternatives (described in section 4.4.4).

Table 4-5. Incremental Cost Analysis of Best Buy Plans (Oct 2011 price level)

Plan No.	Plan Name	Average Annual Output (HU)	Average Annual Cost ($1000)	Average Cost / Output ($1000/HU)	Incremental Output (HU)	Incremental Cost ($1,000)	Incr. Cost Per Output ($1,000)
1	No Action	0.0	$0	$0	0.0	$0	$0
2	Milltown Island Partial	64	$198	$3.1	64	$198	$3.1
3	plus Deepwater Slough	154.2	$508	$3.3	90.2	$310	$3.4
4	plus Spencer Island Partial	290.2	$1,295	$4.5	136	$787	$5.8
5	plus Livingston Bay	330.7	$1,856	$5.6	40.5	$561	$13.9
6	plus Dugualla Bay	493.3	$5,221	$10.6	162.6	$3,365	$20.7
7	plus Nooksack Delta Partial	1143.8	$19,353	$16.9	650.5	$14,132	$21.7
8	plus Telegraph Slough Full	1397.7	$28,132	$20.1	253.9	$8,779	$34.6
9	plus Everett Marshland Full	1747	$44,776	$25.6	349.3	$16,644	$47.6
10	plus N. Fork Skagit River Delta	1800.7	$47,774	$26.5	53.7	$2,998	$55.8
11	plus Deer Harbor Estuary	1805.5	$48,085	$26.6	4.8	$311	$64.8
12	plus Beaconsfield Bluff Partial	1806.8	$48,226	$26.7	1.3	$141	$108.5
13	plus Tahuya River Estuary	1814.4	$49,572	$27.3	7.6	$1,346	$177.1
14	plus Big Beef Creek Estuary	1822.3	$51,091	$28.0	7.9	$1,519	$192.3
15	plus Duckabush Delta Partial	1834.6	$53,810	$29.3	12.3	$2,719	$221.1
16	plus Point Whitney Lagoon Full	1836.6	$54,253	$29.5	2	$443	$221.5
17	plus Snow/Salmon Creek Partial	1843.4	$56,013	$30.4	6.8	$1,760	$258.8
18	plus Harper Estuary Full	1845.1	$56,582	$30.7	1.7	$569	$334.7
19	plus WDNR Budd Inlet Beach	1846.2	$57,028	$30.9	1.1	$446	$405.5
20	plus Twin Rivers Partial	1846.4	$57,286	$31.0	0.2	$258	$1,290.0
21	plus Lilliwaup Partial	1847.5	$58,711	$31.8	1.1	$1,425	$1,295.5
22	plus Washington Harbor Partial	1848.1	$59,533	$32.2	0.6	$822	$1,370.0
23	plus Chambers Bay Full	1856.6	$72,941	$39.3	8.5	$13,408	$1,577.4

Note: Plans highlighted in green were carried forward to the final array of alternatives (described in section 4.4.4).

Figure 4-5 shows the incremental cost analysis results graphically. As shown in Table 4-5 and Figure 4-5, the incremental average annual cost per output ranges from a low of $0 per output to $1,577 per output. The first 11 plans range in incremental average annual cost per output from $0 per output to $109 per output, while the next seven plans range in incremental average annual cost per output of $177 per output to $406 per output. A significant increase in cost per output occurs between plans 19 and 20 where the incremental cost per output increases from $406 per output to $1,290 per output. Figure 4-5 shows the incremental cost analysis graphically and indicates the two action alternatives that have been selected for final evaluation and consideration for the Tentatively Selected Plan (TSP), which are listed in Table 4-5 as plan number 12 and plan number 19.

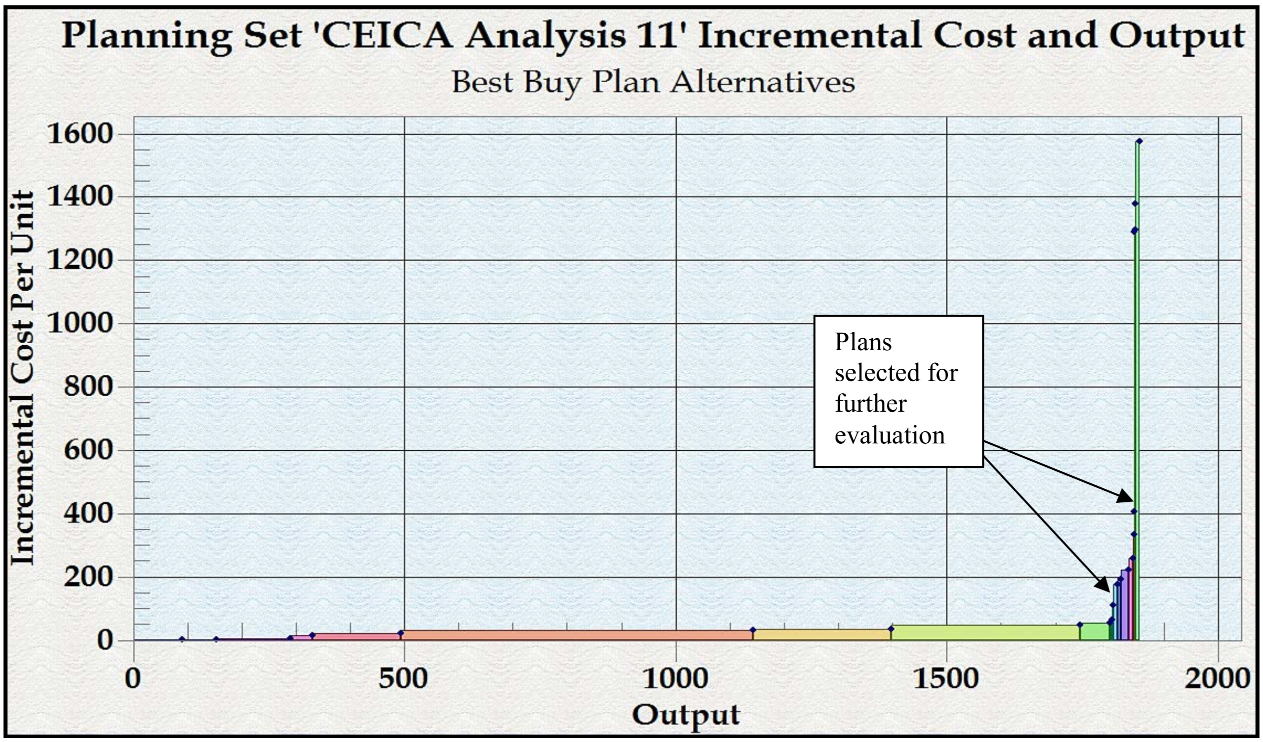


Figure 4-5. Incremental Cost Analysis

4.4.4 Final Array of Alternatives

After reviewing the analyses described above, the PDT identified a final array of three best buy alternatives and one non-best buy alternative to carry forward for final evaluation, comparison, and selection of the TSP. The plans selected for inclusion in the next step of the process are Plan 1, the No-Action Plan; Plan 12, which includes 11 sites; and Plan 19, which includes 18 sites. A fourth alternative not included in the CE/ICA analysis was carried forward based on the results of the implementation master plan development described in section 4.5.

Plans 2 through 10 were not carried forward because they do not address all four restoration strategies (river deltas, beaches, barrier embayments, and coastal inlets). Because the Nearshore

Study aims to recommend a comprehensive restoration plan that addresses ecosystem degradation across different habitat types and sub basins, these alternatives were not carried forward for further analysis or evaluation.

Plan 12 was carried forward in the final array because it is the first alternative that addresses all four restoration strategies, including beaches. Bluff-backed beaches are a key component of the sediment transport process in the nearshore zone, which is why the Beaconsfield site was carried forward.

Plans 13 through 18 were not carried forward in the final array of alternatives; the next plan carried forward for additional analysis was Plan 19. Plan 19 was selected due to the significant increase in incremental cost/output that occurs between Plan 19 and 20 (from $406/output to $1,290/output), as well as the study team's desire to evaluate a plan that, to the fullest extent possible, takes advantage of identified opportunities to implement cost-effective, high-quality restoration. Compared to Plan 12, Plan 19 contains three additional coastal inlet sites, two additional barrier embayment sites, one additional beach site, and one additional river delta site.

While Plans 20 through 23 have noteworthy environmental benefits, the incremental cost/output increases significantly for each of these plans. Although these plans would more completely address the broad restoration needs in the study area, it was determined that the proposed Federal investment of these plans is not justifiable and viable from a cost perspective.

Finally, one additional alternative was carried forward in the final array. As described in section 4.5, three sites are being recommended for construction authorization in a Chief's Report as part of the Puget Sound Nearshore implementation master plan. While this three-site alternative was not evaluated using the standard CE/ICA process summarized in previous sections of this report, it is comprised of a subset of sites included in Plan 19, which was found to be cost effective. This plan was carried forward in the final array of alternatives for additional evaluation, comparison, and trade-off analysis.

A summary of the final array of four alternatives is included below. Formal evaluation and comparison of these alternatives is presented in Sections 4.6 and 4.7.

No-Action Alternative

The No-Action Alternative is synonymous with the "Future Without-Project Condition." The assumption for this Alternative is that no project would be implemented by the Corps to achieve the planning objectives.

Alternative 2 (referenced as Plan 12 above)

Eleven sites were selected for Alternative 2. These sites address all four of the Nearshore Study strategies and are geographically representative of the entire study area (Figure 4-6). Sites included in Alternative 2 are the following:

- Beaconsfield Feeder Bluff
- Deepwater Slough
- Deer Harbor Estuary
- Dugualla Bay
- Everett Marshland
- Livingston Bay
- Milltown Island
- Nooksack River Delta
- North Fork Skagit River Delta
- Spencer Island
- Telegraph Slough

Alternative 3 (referenced as Plan 19 above)

Eighteen sites were selected for Alternative 3. Similar to Alternative 2, the sites included in Alternative 3 address all four of the Nearshore Study strategies and are geographically representative of the entire study area (Figure 4-6). Sites included in Alternative 3 are the following:

- Beaconsfield Feeder Bluff
- Big Beef Creek Estuary
- Deepwater Slough
- Deer Harbor Estuary
- Duckabush River Estuary
- Dugualla Bay
- Everett Marshland
- Harper Estuary
- Livingston Bay
- Milltown Island
- Nooksack River Delta
- North Fork Skagit River Delta
- Point Whitney Lagoon
- Snow Creek and Salmon Creek Estuary
- Spencer Island
- Tahuya River Estuary
- Telegraph Slough
- WDNR Budd Inlet Beach

Alternative 4

Three sites were selected for Alternative 4. These sites were selected based on the recommendations included in the implementation master plan described in section 4.5. Sites included in Alternative 4 include the following:

- Duckabush River Estuary
- Nooksack River Delta
- North Fork Skagit River Delta

Figure 4-6 shows the geographic locations of the sites included in the final array of alternatives.

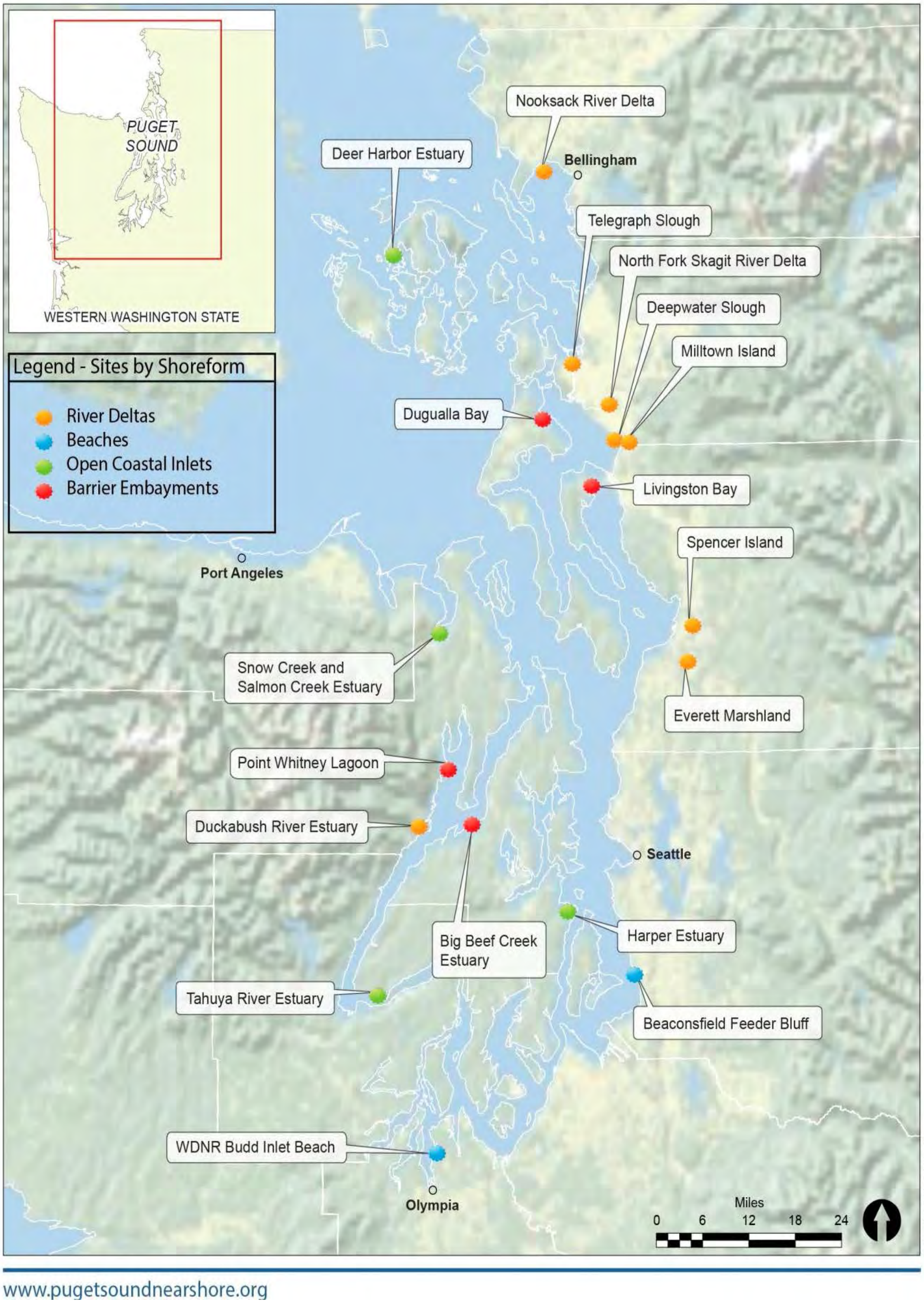


Figure 4-6. Geographic Locations of the Sites included in the Final Array of Alternatives

4.5 LEVEL 5: DEVELOP IMPLEMENTATION MASTER PLAN

Level 5 of the plan formulation strategy was the development of a master plan for implementing the 36 sites identified under the Level 3 evaluation. After the Level 4 evaluation was completed, a draft integrated Feasibility Report and Environmental Impact Statement (FR/EIS) was released for public review and comment in 2014. That draft report evaluated the final array of three alternatives formulated in Level 4, including the No-Action Alternative, Alternative 2 (11 sites) and Alternative 3 (18 sites). The draft FR/EIS identified Alternative 2 as the tentatively selected plan. Alternative 2 had a preliminary cost estimate of $1.1 billion.

Based on comments received on the draft FR/EIS during concurrent public, technical, and policy review, the study team coordinated efforts to revisit the overall ecosystem restoration strategy for Puget Sound. To reexamine study objectives and potential projects to be recommended for implementation, a workshop was convened in April 2015 with participation from the Corps Seattle District, Northwestern Division, and Headquarters offices, the non-Federal sponsor (Washington State Department of Fish and Wildlife), National Marine Fisheries Service, and the office of the Assistant Secretary of the Army for Civil Works. The objectives of that workshop were to do the following:

1. Reach agreement on criteria for prioritizing ecosystem restoration project sites for implementation under Corps of Engineers missions and authorities in the Puget Sound Nearshore study area;
2. Identify and select priority restoration project sites for Corps implementation;
3. Develop a strategy for project implementation involving the various Corps authorities and Programs; and,
4. Establish and agree on a path forward for completion of the Nearshore study and expeditious transition to project implementation consistent with national budgetary priorities and with the plan formulation and evaluation conducted to date.

As an outcome of the workshop, a tiered implementation approach was developed for those project sites deemed critical to comprehensively restore the ecological function of the Puget Sound Nearshore, including connectivity and size of large river delta estuaries, restore the number and quality of coastal embayments, and restore the size and quality of beaches and bluffs. Referred to as the "Master Plan" for Puget Sound Nearshore Ecosystem Restoration, The tiered strategy allows for a more diversified scope of projects to be implemented under various restoration authorities of the Corps and Puget Sound Nearshore partners. It was determined that the workshop would focus on the group of 36 sites formulated in Level 3 because that tier included formulation of a range of multiple conceptual site designs for all sites (72 total plan) that represent opportunities for comprehensive restoration of all four restoration strategies (beaches, coastal embayments, coastal inlets, and large river deltas). Site benefits and costs had been developed for all 36 sites.

Various approaches were considered for implementation of each of the group of 36 project sites. Those approaches included:

1. Continued formulation and evaluation of sites to ultimately seek authorization and implementation through the Corps General Investigations (GI) Program;
2. Implementation through existing Corps construction authorities under the Continuing Authorities Program (CAP). Existing CAP authorities include the Section 206 and 1135 authorities, both of which authorize the Corps to construct small-scale riparian and aquatic habitat restoration projects;
3. Implementation through the Corps Puget Sound and Adjacent Waters Program (PSAW), a standing authority that allows the Corps to implement small-scale aquatic habitat restoration program in the Puget Sound Region; and,
4. Projects to be completed by others using programs and authorities outside of Corps participation.

A number of qualitative criteria were evaluated to categorize the group of 36 sites into the appropriate implementation approaches described above, including:

- Estimated project costs: Smaller sites (i.e., estimated costs less than $20 million) were generally identified as implementable under CAP or PSAW, while sites with estimated costs greater than $20 million were identified as more appropriate to carry forward under the GI program or be implemented by others. For example, the estimated project cost for WDNR Budd Inlet Beach is approximately $10 million, leading the team to recommend site for implementation under CAP.

- Restoration potential: Sites were evaluated based on relative restoration benefits and costs (Ecosystem output, score, type of habitat restored, and location of restoration) and overall restoration potential.

- Lands and real estate considerations: Sites were evaluated based on availability of lands as well as amount of lands, easements, rights of way, or relocations required for the project. Evaluation of this criteria included an assessment of whether sites have land already in public ownership or whether sites have large relocation requirements.

- Overall readiness to proceed: Considerations of community endorsement, broader regional endorsement, and tribal support assisted the team in determining whether sites were suitable to move forward in the near-term or require additional coordination before site-specific analysis occurs. For example, a number of public comments related to proposed restoration at Everett Marshland led the team to recommend this site for further study under the GI program, allowing for additional coordination with local landowners and community stakeholders.

- Corps policy considerations: Some sites were identified as having outstanding policy concerns that will require additional coordination and analysis before being recommended for construction.

- Finally, 12 sites were identified where restoration work is complete, underway, or will soon be underway by others. These sites were categorized under the "projects to be completed by others" category in the master plan. For example, restoration at Deer Harbor is being carried forward by a local project proponent, leading the team to identify this as a site to be completed by others.

The implementation master plan identifies three sites recommended for construction authorization. Nine sites are recommended for further feasibility study, including additional NEPA analysis. The master plan also identifies 12 sites that will have additional study under CAP or PSAW and 12 sites that will be completed without Corps involvement. Table 4-7 identifies all 36 sites and the implementation categories that they have been placed under in the Master Plan.

The three sites recommended for initial authorization under this feasibility study include: (1) the Duckabush River Estuary; (2) the North Fork Skagit River; and, (3) the Nooksack River Delta. Each of those sites was previously evaluated under the Level 3 analysis. The North Fork Skagit and Nooksack River Delta sites were both included in Alternative 2 under the Level 4 analysis. However, to ensure consistency with NEPA requirements for full disclosure of all alternatives under consideration, these three sites are now grouped as Alternative 4 and described in more detail in the Level 6 evaluation that follows.

In summary, the primary driving rationale for selecting these three projects sites to move forward with as the priority projects under this feasibility study is as follows:

- The workshop participants made a conscious decision to focus current efforts on restoring river deltas. The projects under this category tend to be large-scale projects requiring restoration of natural hydraulic function, consistent with the Corps mission for ecosystem and expertise.

- The Nooksack River Delta currently has the least development and infrastructure of any of the large river deltas in Puget Sound and opportunity exists now to take advantage of that lack of development to restore a large portion of the estuary before further change occurs limiting that potential. Restoration of the Nooksack River Delta would provide 25 percent of the Puget Sound Action Agenda's 2020 estuarine habitat recovery goal in a single project.

- The Duckabush River Estuary is primarily in public ownership, allowing restoration to occur without acquisition of large-scale real estate interests and with the support of public agencies. The Duckabush site is located within Hood Canal and is a critical location for restoring the habitat and populations of Summer Chum Salmon. The benefits associated with restoring Hood Canal estuary habitat has been identified as a critical area for the restoration of the Puget Sound.

- The North Fork Skagit River is critically important to all five species of Pacific salmon as well as steelhead and sea-run cutthroat trout. Habitat productivity in the headwaters of this river is high due to the large extent of wilderness protection. However, the lower reaches of the river are highly degraded. This site near the delta provides an opportunity to restore large areas of natural habitat components critical for the life-history of salmonids and other species.

Chapter 6 of this report describes the three sites included in the recommended plan in more detail. Appendix K of this report includes more information about the nine sites identified for additional study. Table 4-6 identifies all 36 sites and the implementation categories that they have been placed under in the Master Plan.

Table 4-6. Implementation Master Plan

General Investigation: Chief's Report	General Investigation: Additional Study	Continuing Authorities Program: Section 206	Puget Sound and Adjacent Waters: Section 544	Projects to be Completed by Others
• Duckabush River Estuary • Nooksack River Delta • North Fork Skagit River Delta	• Big Beef Creek Estuary • Big Quilcene River • Chambers Bay • Dugualla Bay • Everett Marshland • Lilliwaup River Estuary • Snohomish River Estuary • Tahuya River Estuary • Telegraph Slough	• Chuckanut Estuary • Deepwater Slough • Everett Riverfront Wetland • Harper Estuary • Livingston Bay • McGlinn Island • Sequalitchew Creek • WDNR Budd Inlet Beach	• Quilceda Estuary • Spencer Island • Twanoh Beach • Twin Rivers	• Beaconsfield Feeder Bluff • Deer Harbor • Deschutes River Estuary • Hamma Estuary • Johns Creek Estuary Restoration • Kilisut Harbor/Oak Bay • Milltown Island • Mission Creek • Point Whitney Lagoon • Smith Island • Snow Creek and Salmon Creek Estuary • Washington Harbor

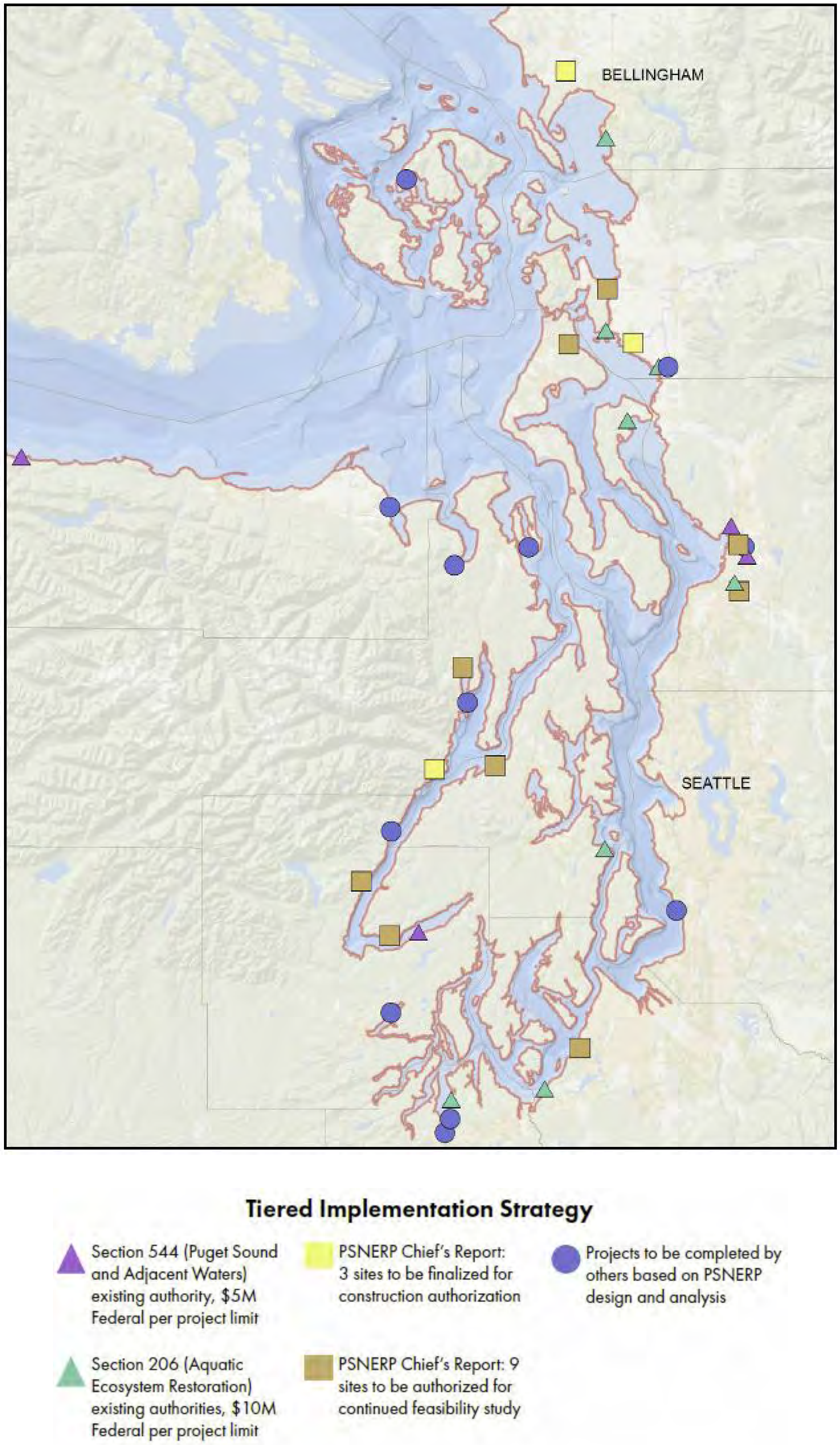


Figure 4-7. Master Plan: Tiered Implementation Strategy

4.6 LEVEL 6: SITE IMPLEMENTATION ANALYSIS – EVALUATION OF FINAL ARRAY OF ALTERNATIVES

Level 6 of the plan formulation strategy included site-specific implementation analysis and evaluation of the final array of alternatives. As initially presented in section 4.5.4, the Nearshore Study team selected a final array of four alternatives. In addition to the No-Action Alternative, Alternative 2 includes 11 sites while Alternative 3 includes 18 sites. Alternative 4 includes three sites. The alternatives are described below in more detail.

It should be noted that the tiered strategy for implementation of all 36 sites (described in section 4.5) allows for a more diversified scope of projects to be implemented under various restoration authorities and partners. Although the following sections evaluate and compare the final array of four alternatives for the purposes of this report, there are broad restoration benefits associated with the larger, 36-site master plan.

Table 4-7. Summary of Final Array of Alternatives

Site Name	Alternative 1 No-Action	Alternative 2 11 Sites	Alternative 3 18 Sites	Alternative 4 3 Sites	Strategy	EO Score (AAHU)	Acreage	Proposed Action
Deepwater Slough		X	X		River Delta	90.2	25.5	Lower existing dikes to grade. Excavate breaches to reconnect tidal channels. Remove a temporary bridge between the islands.
Everett Marshland		X	X		River Delta	349.3	829.1	Remove dikes along the Snohomish River; construct new dikes to maintain existing level of flood risk management. Fill agricultural ditches and reconstruct tidal channels. Reconnect surrounding streams to restored area. Upgrade railway bridges to allow for tidal exchange.
Milltown Island		X	X		River Delta	64	214.2	Breach west perimeter dikes in three locations. Create pilot channels associated with breach locations.
Nooksack River Delta		X	X	X	River Delta	166.32	1807	Breach and/or remove dikes along both sides of the Nooksack and Lummi Rivers; construct new levees to maintain existing level of flood risk management. Install log jams in Nooksack River. Partial restoration of river flow to Lummi River through installation of water control structure at confluence of Lummi and Nooksack Rivers; structure intended to facilitate transfer of freshwater and sediment to the Lummi River. Channel creation and rehabilitation on the Lummi River. Remove several filled causeways and replace with wide span bridges to allow for tidal exchange.
North Fork Skagit River Delta		X	X	X	River Delta	53.69	256.1	Lower and breach dikes; construct new dikes to maintain existing level of flood risk management. Excavate tidal channel network. Remove shore armor and other hardened surfaces and infrastructure.
Spencer Island		X	X		River Delta	136.0	313.2	Lower dikes adjacent to Steamboat and Union Sloughs. Expand existing breaches on the eastern and northern dikes and breach the western dike. Retain public access by constructing a replacement pedestrian bridge over new breach site.
Telegraph Slough		X	X		River Delta	253.9	932.2	Construct a bridge at State Route 20 and BNSF railroad over Telegraph Slough, raise these causeways west of Swinomish Slough to allow for tidal exchange. Excavate channel to connect distributary channels to Padilla Bay. Remove tidal dikes and Swinomish Channel Dike; construct new dike to maintain existing level of flood risk management. Remove old culverts and tidegates and install new culverts and tide gates.
Duckabush River Estuary			X	X	River Delta	12.3	38	Replace the Highway 101 causeway with a widespan bridge to allow full tidal flushing. Remove fill from Shorewood Road and adjacent areas. Reestablish tidally influenced distributary channels. Excavate channels within the marsh areas.

Site Name	Alternative 1 No-Action	Alternative 2 11 Sites	Alternative 3 18 Sites	Alternative 4 3 Sites	Strategy	EO Score (AAHU)	Acreage	Proposed Action
Dugualla Bay		X	X		Barrier Embayment	162.6	572	Remove roadway berm/dike and associated fill and replace with a widespan bridge to allow full tidal exchange. Excavate new tidal channel opening at Dike Road. Remove dikes and armoring and install culverts. Fill linear drainage ditches throughout site. Remove structures on acquired properties within area of proposed tidal flooding. Restore shoreline on east side of Dike Road.
Livingston Bay		X	X		Barrier Embayment	41.6	244.6	Lower dikes to existing grade; construct new dike to maintain existing level of flood risk management. Excavate new tidal inlet through breach; excavate tidal channels and starter channels. Remove fill to reestablish tidal inlet at its historic location. Remove small pump station and associated utilities. Nourish beach with excavated tidal inlet material.
Big Beef Creek Estuary			X		Barrier Embayment	8.5	91	Remove fill and armor associated with Seabeck Highway causeway. Replace current bridge with a widespan bridge across the embayment inlet and spit to allow full tidal exchange at Big Beef Creek Estuary. Restore tidal channel landward of the new bridge and around the spit.
Point Whitney Lagoon			X		Barrier Embayment	2.0	6.1	Remove all pond dikes and associated culverts, tide gates, and other infrastructure. Remove rock revetments, fill, and pavement on the spit. Placement of beach gravel on the lower elevations of the eastern portion of the spit. Remove all buildings and other structures in nearshore areas.
Beaconsfield Feeder Bluff		X	X		Beach	2.2	6.9	Remove approximately 800 feet of shoreline armoring. Minor regrading to recreate a gently sloping upper intertidal beach.
WDNR Budd Inlet Beach			X		Beach	1.1	2.0	Remove bulkheads and fill. Remove buildings, timber piles, and debris. Dredge to recreate tidal lagoon and excavate tidal channel to connect tidal lagoon with nearshore zone. Restore barrier beach and natural beach profile.
Deer Harbor Estuary		X	X		Coastal Inlet	4.8	16.1	Remove Channel Road bridge; remove associated embankment armor and fill. Construct a new bridge to allow full tidal flushing at the mouth of the inlet. Remove sediments at inlet. Remove nearshore debris (riprap and rock slope protection).
Harper Estuary			X		Coastal Inlet	1.7	6.2	Remove a portion of SE Olympiad Drive. Remove roadway embankment and armoring on the eastern side of the estuary. Remove fill and other debris from the estuary. Excavate a more sinuous stream channel and starter channels.

4.6.1 Alternative 1 – No-Action Alternative

This alternative is included for comparison purposes and represents future conditions without implementation of a large-scale Federal restoration project. Degradation trajectories would continue as influenced by development and existing restoration and protection authorities. Small-scale restoration requiring extensive local and state funding not supported by large-scale Federal investment would continue based largely on an opportunistic approach. Funding of restoration and protection would continue at funding levels and spatial scales already determined feasible by local entities.

4.6.2 Alternative 2 – Restore 11 Sites

4.6.2.1 *Geographic Locations*

Alternative 2 includes 11 sites. The majority of these 11 sites are focused around the Skagit and Snohomish River Deltas, with one site on the stretch of shoreline between Tacoma and Seattle (Beaconsfield) and one to the north in the San Juan Islands (Deer Harbor). These 11 sites represent the minimum restoration action required to make progress toward the four restoration strategies defined by the Nearshore Study. Sites are distributed in four of the seven Puget Sound sub-basins defined by the Nearshore Study (Figure 1-1), with eight of the 11 sites located in one sub-basin (Whidbey). The western portion of Puget Sound (including Hood Canal and the Strait of Juan de Fuca) as well as the South Puget Sound are not represented in this alternative.

4.6.2.2 *Restoration Sites Included*

Alternative 2 includes 11 of the 18 sites described in section 4.5.4. Sites included in this alternative range in size from six to 1,807 acres and include the following:

The seven large river delta sites selected for this alternative, ranging in size from 214 to 1,807 acres, include the following:

- Deepwater Slough
- Everett Marshland
- Milltown Island
- Nooksack River Delta
- North Fork Skagit River Delta
- Spencer Island
- Telegraph Slough

Only one site has been selected to address the open coastal inlet strategy and the associated focus on restoring tidal hydrology and freshwater input processes. This site is 16 acres:

- Deer Harbor Estuary

The barrier embayment strategy would be addressed at two sites, where the restoration of tidal hydrology is required, as well as reestablishment of a stable barrier beach to provide necessary low-energy conditions. The sites range from 239 to 572 acres and include the following:

- Dugualla Bay
- Livingston Bay

Only one cost-effective site has been identified to address beach strategy target processes of restoring sediment supply and transport. While the team evaluated several potential sites, most did not appear to meet the identified restoration requirement to restore sediment delivery processes, typically by the removal of shoreline armoring. This site is relatively small at six acres of area of restored process, but it remains ecologically significant:

- Beaconsfield Feeder Bluff

4.6.2.3 *Construction Costs*

The 11 sites that comprise Alternative 2 have a total first cost of approximately $1,063,899,000 (October 2011 price level). The average annual cost for Alternative 2 over the 50-year period of analysis is approximately $48,226,000.

4.6.2.4 *Ecosystem Benefits*

Benefits of this alternative would derive from removing nearly 75,162 linear feet of shoreline stressors, thereby restoring processes that would create 5,348 acres of tidally influenced wetlands in river deltas and shallow embayments; as well as sustain two beaches. Benefits to salmonids and forage fish would primarily focus on populations in the Snohomish and Skagit basins. Eight of the 11 sites are used for spawning and/or rearing and restoration will allow access at an additional three sites. Six of the 11 sites have documented or potential forage fish spawning within close proximity. Additionally, predators throughout the Puget Sound would benefit as these prey species disperse during the ocean portion of their lifecycle.

ESA-listed species in Puget Sound that have suffered from a loss or degradation of habitat would benefit from the removal of shoreline stressors at these 11 sites, either directly by using the restored habitat (as is the case for listed salmonids) or indirectly via reliance of their prey on the habitat (as is the case for killer whales and murrelets). Benefits to ESA-listed species would be similar to those discussed for Alternative 3, but to a lesser extent due to fewer stressors removed and associated habitat restored, and the limited geographic range of the proposed sites. Hood Canal salmon, eulachon, and green sturgeon would see little benefit since there are no sites in Hood Canal and only one in northern Puget Sound (where eulachon and Green sturgeon occur). ESA-listed species that would benefit from this alternative include Chinook salmon, bull trout, steelhead, and juvenile rockfish, and the predators that rely on them or other nearshore zone dependent species (killer whales and marbled murrelet).

Restored sediment transport and delivery to beaches and embayments will support ecologically valuable kelp and eelgrass beds (six of the 11 sites have eelgrass and/or kelp beds within close proximity). These beaches, shallow embayments, and kelp and eelgrass beds will provide refuge habitat for juvenile salmonids during shoreline migration, spawning substrate for forage fish (five of the 11 sites have documented or potential forage fish spawning within close proximity), and three-dimensional habitat for a variety of fish and invertebrates including juvenile rockfish, clams, and crabs. The restored wetlands in large river deltas and coastal embayments, and their associated tidal channels, would be colonized by native plants and invertebrates, resulting in critical rearing and foraging habitat for juvenile salmonids.

The additions and improvements of nearshore habitat would increase Puget Sound's shoreline complexity, diversity, and connectivity providing a variety of habitat types and ecological niches for many nearshore species that play key roles in the Puget Sound food web, as well as provide ecosystem functions like nutrient cycling and water purification. These benefits would ascend trophic levels yielding prey for many bird species such as great blue herons, dunlins, and bald eagles that use nearshore wetlands and beaches to forage, as well as marine mammals.

4.6.3 Alternative 3 – Restore 18 Sites

4.6.3.1 *Geographic Locations*

The 18 sites included in this alternative are geographically diverse. These sites range from the Nooksack River estuary in northern Puget Sound to the WDNR Budd Inlet beach in the South Sound, as well as three sites in Hood Canal, one in Discovery Bay on the Strait of Juan de Fuca, and several sites in between. Sites are distributed in six of the seven Puget Sound sub-basins defined by the Nearshore Study. The exception is the North Central Puget Sound sub-basin, which is small with limited restoration opportunities compared to other sub-basins (Figure 1-1).

4.6.3.2 *Restoration Sites Included*

All 18 sites described in section 4.5 are included in this alternative. This alternative includes eight sites addressing delta strategy target processes such as tidal and freshwater flow. The sites range in size from two to 1,807 acres. (*Indicates sites not included in previous 11-site alternative.)

The eight large river delta sites selected for this alternative, ranging in size from 38 to 1,807 acres, include the following:

- Deepwater Slough
- Duckabush River Estuary*
- Everett Marshland
- Milltown Island
- Nooksack River Delta
- North Fork Skagit River Delta
- Spencer Island
- Telegraph Slough

Four sites have been selected to address the open coastal inlet strategy and the focus on restoring tidal hydrology and freshwater input processes. These sites range from six to 52 acres:

- Deer Harbor Estuary
- Harper Estuary*
- Snow Creek and Salmon Creek Estuary*
- Tahuya River Estuary*

The barrier embayment strategy would be addressed at four sites, where the restoration of tidal hydrology is required, as well as reestablishment of a stable barrier beach to provide necessary low-energy conditions. The sites range from six to 572 acres and include the following:

- Big Beef Creek Estuary*
- Dugualla Bay
- Livingston Bay
- Point Whitney Lagoon*

Only two cost-effective sites have been identified to address beach strategy target processes of restoring sediment supply and transport. While the team evaluated several potential sites, most did not appear to meet the identified restoration requirement to restore sediment delivery processes, typically by the removal of shoreline armoring. These two sites are relatively small, with two and six acres of area of restored process, but remain ecologically significant:

- Beaconsfield Feeder Bluff
- WDNR Budd Inlet Beach*

4.6.3.3 *Construction Costs*

The 18 sites that comprise Alternative 3 have a total first cost of approximately $1,252,977,000 (October 2011 price level). The average annual cost over the 50-year period of analysis for Alternative 3 is approximately $57,028,000.

4.6.3.4 *Ecosystem Benefits*

Benefits from this alternative would derive from removing approximately 113,094 linear feet of shoreline stressors (most of which are tidal barriers, nearshore fill, and shoreline armoring), thereby restoring processes that would create or restore 5,517 acres of tidally influenced wetlands in river deltas and shallow embayments, as well as sustain a bluff-backed beach and a barrier beach system. These benefits would be distributed among all but one of the sub-basins in Puget Sound (North Central).

Restored sediment transport and delivery to beaches and embayments will support the ecologically valuable kelp and eelgrass beds (12 of the 18 sites have eelgrass and/or kelp beds within close proximity). Refuge habitat for juvenile salmonids will be provided (13 of the 18 sites have documented or potential forage fish spawning nearby), along with critical rearing and foraging habitat for juvenile salmonids (14 of the 18 sites are used by anadromous fish for spawning and/or rearing; restoration will allow for access at the remaining four sites).

The majority of the sites in Alternative 3 would benefit Chinook salmon, steelhead, and bull trout, and three sites would benefit Hood Canal summer chum salmon by providing rearing habitat for juveniles and restoring shoreline processes that sustain beaches and kelp and eelgrass beds for forage fish spawning (a preferred prey item). Benefits to Chinook and chum will indirectly benefit Southern Resident killer whales since they preferentially feed on these species during much of the year. Eulachon would benefit from sites restored in the northern portions of Puget Sound, including the 1,807 acres of restored river delta in the Nooksack Estuary. Species that have not necessarily seen declines in number due to habitat loss in Puget Sound would still benefit from added foraging areas (green sturgeon and Steller sea lions) and rearing habitat (kelp and eelgrass beds for juvenile rockfish).

4.6.4 Alternative 4 – Restore 3 Sites

4.6.4.1 *Geographic Locations*

The three sites included in this alternative are geographically diverse, representing process-based restoration opportunities across the Puget Sound nearshore zone. These sites range from the Nooksack River Delta in northern Puget Sound to the Duckabush River Estuary in Hood Canal. Sites are distributed in three of the seven Puget Sound sub-basins defined by the Nearshore Study (Figure 1-1).

4.6.4.2 *Restoration Sites Included*

This alternative includes three sites addressing delta strategy target processes such as tidal and freshwater flow. The three large river delta sites selected for this alternative, ranging in size from 38 to 1,807 acres, include the following:

- Duckabush River Estuary
- Nooksack River Delta
- North Fork Skagit River Delta

4.6.4.3 *Construction Costs*

The three sites that comprise Alternative 4 have a total first cost of approximately $454,269,000 (October 2011 price level). The average annual cost over the 50-year period of analysis for Alternative 4 is approximately $19,849,000.

4.6.4.4 *Ecosystem Benefits*

Benefits from this alternative would derive from removing approximately 28,860 linear feet of shoreline stressors (most of which are tidal barriers, nearshore fill, and shoreline armoring), thereby restoring processes that would create or restore 2,101 acres of tidally influenced wetlands in river deltas.

Restored sediment transport and delivery to river deltas will support the most biologically diverse habitats in the affected estuaries. Two of the three sites have eelgrass and/or kelp beds immediately downstream. Refuge habitat for juvenile salmonids will be provided along with critical rearing and foraging habitat (all three sites are used by anadromous fish for rearing). Two of the three sites have documented or potential forage fish spawning nearby, and all three sites support waterfowl concentrations.

This alternative removes over five miles of shoreline armoring that inhibits the natural physical processes that support habitat development for the ESA-listed species. This alternative includes the Duckabush River Estuary site in Hood Canal, which would benefit Hood Canal summer chum. Benefits to Chinook and chum will benefit Southern Resident killer whales since they preferentially feed on these species during much of the year. Eulachon would benefit from sites restored in the northern portions of Puget Sound, including the 1,807 acres of restored river delta in the Nooksack Estuary. Species that have not necessarily seen declines in number due to habitat loss in Puget Sound would still benefit from added foraging areas (green sturgeon and Steller sea lions) and rearing habitat (kelp and eelgrass beds for juvenile rockfish).

4.7 LEVEL 6: SITE IMPLEMENTATION ANALYSIS – COMPARISION OF FINAL ARRAY OF ALTERNATIVE PLANS

Level 6 of the plan formulation strategy included a comparison of the final array of alternatives. In this section, the final array of four alternative plans are compared to each other, with emphasis on the outputs and effects that will have the most influence in the decision-making process. Beneficial and adverse effects of each plan are compared including monetary and non-monetary benefits and costs. From this comparison, the tradeoffs between the plans are transparent. This comparison of alternatives is partially a reiteration of the evaluation presented in the previous sections with the exception that the three action alternatives are compared to each other, and not just against the without-project condition (aka the No-Action Alternative). The comparison of the alternatives is presented in terms of planning criteria and evaluation accounts, as well as the effects on significant resources described in detail in Chapter 5.

4.7.1 National Ecosystem Restoration Evaluation

Performance of the alternative plans with respect to the planning objectives appears in Table 4-7 along with additional key evaluation criteria (e.g., cost, acres restored, etc.) to inform the National Ecosystem Restoration (NER) evaluation.

Table 4-7. Planning Criteria Comparison

PLANNING CRITERIA	Alternative 1 No Action	Alternative 2 11 Sites	Alternative 3 18 Sites	Alternative 4 3 Sites
Strategy 1/ Objective 1 - Deltas	0 Sites 0 Acres Net EO[1] = 0[2]	7 Sites 4,521 acres Net EO = 1,598	8 sites 4,559 acres Net EO = 1,609	3 sites 2,101 acres Net EO = 717
Strategy 2/ Objective 2 - Beaches	0 Sites 0 Acres Net EO = 0	1 Site 6 acres Net EO = 1.3	2 Sites 8 acres Net EO = 2.5	0 Sites 0 acres Net EO = 0
Strategy 3/ Objective 3 - Embayments (Barrier Embayments)	0 Sites 0 Acres Net EO = 0	2 Sites 811 acres Net EO = 203.1	4 Sites 847 acres Net EO = 212.9	0 Sites 0 acres Net EO = 0
Strategy 4/ Objective 3 - Embayments (Coastal Inlets)	0 Sites 0 Acres Net EO = 0	1 Site 16 acres Net EO = 4.8	4 Sites 110 acres Net EO = 20.8	0 Sites 0 acres Net EO = 0
Acres of Restored Habitat	0 acres	5,354 acres	5,524 acres	2,101 acres
Net EO (Average Annual Benefits in Habitat Units)	0 EO	1,807 EO	1,846 EO	717 EO
Cost (Average annual at October 2011 price level)	$0	$48,226,000	$57,028,000	$19,849,000
Total Estimated Costs (October 2011 price level)	$0	$1,063,899,000	$1,252,977,000	$454,269,000

Notes: [1] Net EO, Environmental Outputs, is represented by Average Annual Benefits measured in Average Annual Habitat Units (AAHU or HU). [2]For comparative purposes, a 0 Net EO indicates that no action at any sites would have no net increase to ecosystem outputs.

In addition to the National Ecosystem Restoration evaluation presented above, the Principles and Guidelines establish additional accounts to facilitate the evaluation, display, and comparison of the effects of alternative plans. For the Environmental Quality (EQ) account, refer to Table 4-7 above and Table 5-10 for a display of ecological, cultural, and aesthetics attributes. For the Regional Economic Development (RED) account, there is no significant difference expected between the with- and without-project conditions for any alternative. For the Other Social Effects (OSE) account, Alternatives 2, 3, and 4 would all positively affect fish species of concern for many Native American tribes located in Washington State.

4.7.2 Trade-Off Analysis

Trade-off analysis is the procedure the Corps uses to identify the potential gains and losses associated with producing a larger or lesser amount of given outputs. The results of trade-off analysis are used in the formulation, evaluation, comparison, and selection of the recommended plan. The following tables and paragraphs summarize the key trade-offs between Alternatives 2, 3, and 4.

Acreage and Geographic Spread

Alternative #	*Acres Restored*	*Linear Feet of Stressors Removed*	*Geographic Spread: Sub-Basins*
Alternative 2	5,354	77,796 LF	3 of 7 sub-basins
Alternative 3	5,524	115,718 LF	6 of 7 sub-basins
Alternative 4	2,101	28,860 LF	3 of 7 sub-basins

Note: The 36-site master plan restores over 8,000 acres and includes all of the 7 sub-basins.

Complexity of Habitat Types

Alternative #	*# of River Delta Sites*	*# of Coastal Inlet Sites*	*# of Barrier Embayment Sites*	*# of Beach Sites*
Alternative 2	7	1	2	1
Alternative 3	8	4	4	2
Alternative 4	3	0	0	0

Note: The 36-site master plan includes 16 river delta sites, 10 coastal inlet sites, 6 barrier embayment sites, and 4 beach sites.

ESA-Listed Species

All sites in Alternatives 2, 3, and 4 include critical habitat for ESA-listed species. Alternative 3 would benefit more ESA-listed species and would have a greater breadth of benefits compared to the other two alternatives. Alternatives 3 and 4 would provide benefits to Hood Canal salmon including the ESA-listed summer chum, whereas Alternative 2, with no sites in Hood Canal, would not. Similarly, Alternative 3 is more likely to benefit green sturgeon and eulachon, which are only known to forage in the Strait of Juan de Fuca and northern Puget Sound (three sites are located in this area versus only one for Alternatives 2 and 4). Southern Resident killer whales would receive the greatest benefit from Alternatives 2 and 3 due to the inclusion of the Nooksack, Skagit, and Snohomish River Deltas. These sites would improve a substantial amount of habitat for salmon, a major component of the diet of the Southern Resident killer whales.

Principles and Guidelines Evaluation Criteria

Completeness – All sites included in Alternatives 2, 3, and 4 account for all necessary investments or other actions needed to ensure the realization of the planned restoration outputs at the scale of each site.

Effectiveness - All sites included in Alternatives 2, 3, and 4 effectively restore the processes that create and sustain Puget Sound nearshore ecosystems at the scale of each site. Alternative 3 is more effective overall than Alternatives 2 or 4 in that it addresses the observed problems at more locations around the sound.

Efficiency – Alternative 2 and Alternative 3 were identified through analysis as cost-effective and best-buy plans using the IWR Plan software. Both are considered to be efficient alternative plans. Alternative 4 was not identified as a best buy plan using the traditional CE/ICA approach;

however, the three sites included in Alternative 4 are components of Alternatives 2 (North Fork Skagit River Delta and Nooksack River Delta) or Alternative 3 (includes Duckabush River Estuary, North Fork Skagit River Delta, and Nooksack River Delta), which were both identified as best buy plans.

Acceptability – Acceptability is the extent to which the alternative plans are acceptable in terms of applicable laws, regulations, and public policies. Alternatives 2, 3, and 4 are all acceptable based on this definition.

4.8 TENTATIVELY SELECTED PLAN

After the Level 4 evaluation was completed, a draft integrated Feasibility Report and Environmental Impact Statement (FR/EIS) was released for public review and comment in 2014. That draft report evaluated the final array of three alternatives formulated in Level 4, including the No-Action Alternative, Alternative 2 (11 sites) and Alternative 3 (18 sites). The draft FR/EIS identified Alternative 2 as the tentatively selected plan. Alternative 2 had a preliminary cost estimate of $1.1 billion.

4.9 NATIONAL ECOSYSTEM RESTORATION PLAN

The Corps objective in ecosystem restoration planning is to contribute to national ecosystem restoration (NER). Contributions to national ecosystem restoration (NER outputs) are increases in the net quality and/or quantity of desired ecosystem resources. As described in section 4.5, a tiered implementation approach was developed for all 36 sites identified across Puget Sound deemed critical to restore the connectivity and size of large river delta estuaries, restore the number and quality of coastal embayments, and restore the size and quality of beaches and bluffs. The tiered strategy allows for a more diversified scope of projects to be implemented under various restoration authorities and partners. The implementation master plan identifies various approaches for implementation of the 36 projects: GI projects to be recommended for construction, GI projects recommended for additional study, projects to be completed under existing Corps construction authorities (CAP) or Puget Sound and Adjacent Waters Program (PSAW), and projects to be completed by others.

The NER Plan is the 36-site master plan. This plan reasonably maximizes ecosystem restoration benefits and restores over 8,000 acres across all seven Puget Sound sub-basins. The NER Plan includes 16 river delta sites, 10 coastal inlet sites, 6 barrier embayment sites, and 4 beach sites. Implementation of the plan will achieve over 60% of the estuary habitat restoration goals targeted for completion by 2020 in the Puget Sound Action Agenda. The NER Plan also supports five salmon recovery plans and meets all four planning objectives identified for this study.

The implementation strategy allows for the three sites to move forward now because they provide key restoration across three separate areas of the Puget Sound. The additional nine sites recommended for further study ensures a watershed level solution for the most complex, large scale restoration projects identified as critical for restoring the Puget Sound. Finally, the other 24 sites identified as part of the 36-site master implementation plan are being carried out under other Corps authorities or through non-federal actions and are complementary to achieving the overall study objectives. These can be completed concurrently with the implementation of sites recommended through the General Investigation study process. The NER plan is consistent with restoration objectives for Puget Sound, which is designated as an estuary of National Significance. The NER plan contributes to recovery of endangered species, supports treaty reserved fishing, hunting and gathering areas and contributes significantly to the recovery goals identified in the Puget Sound Action Agenda that was created by the Puget Sound Partnership.

Although this plan was not formally identified using the traditional CE/ICA approach, components of the plan were identified through analysis as cost-effective using the IWR Plan software. The NER Plan is complete, effective, and acceptable. The NER Plan accounts for all necessary investments or other actions needed to ensure the realization of the planned restoration outputs at the scale of each site. It will effectively restore the processes that create and sustain Puget Sound nearshore ecosystems at the scale of each site and is acceptable in terms of applicable laws, regulations, and public policies.

4.10 RECOMMENDED PLAN

The strategic master plan described above and in section 4.5 was developed after the TSP was initially identified. As such, the study team revisited the original plan formulation and evaluation results, ultimately revising the TSP to be consistent with the strategic implementation master plan. Of the 36 sites identified for implementation across Puget Sound, three are being recommended for construction authorization under this existing Corps feasibility study and are presented as the recommended plan, and the agency preferred alternative. The three-site recommended plan is smaller than the 11-site TSP that was originally identified; however, the recommended plan is one aspect of the broader strategy to implement all 36 sites across Puget Sound.

Based on the strategic implementation master plan, Alternative 4 is the recommended plan and agency preferred alternative and includes the following sites:

- Duckabush River Estuary
- Nooksack River Delta
- North Fork Skagit River Delta

Restoration at the Duckabush River Estuary would address habitat constraints in Hood Canal, which is a partially isolated geographic section of Puget Sound. Restoration at the Nooksack River Delta would provide 25 percent of Puget Sound Action Agenda’s 2020 estuarine habitat recovery goal in a single project. Inclusion of North Fork Skagit River Delta would restore floodplain and tidal connectivity in the estuary of the Skagit River, the largest and most productive river in Puget Sound.

Restoration of these three sites would support major portions of multiple recovery plans including, but not limited to the Puget Sound Chinook Salmon Recovery Plan of 2005, the Washington Comprehensive Wildlife Conservation Strategy of 2005, the Northern Pacific Coast Regional Shorebird Management Plan of 2000, and the Pacific Coast Joint Venture of 1996. Restoration would support the Summer Chum Salmon Conservation Initiative. Restoration of these sites would also benefit State of Washington Priority Habitats and Species categories of wintering waterfowl, bald eagle, and native amphibians.

5 COMPARISON OF ENVIRONMENTAL EFFECTS OF THE ALTERNATIVES*

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

Under NEPA, preparation of an EIS is triggered if a Federal action has potential to "significantly affect the quality of the human environment." Significance is based on the context and intensity of each potential effect. Context refers to the affected environment in which a project is proposed. Intensity refers to the severity of the effect, which is examined in terms of the type, quality, and sensitivity of the resource involved; location and extent of the effect; duration of the effect (short- or long-term); and other considerations. Beneficial effects are identified and described. The intensity of adverse effects refers to the degree or magnitude of a potential adverse effect, which is described as negligible, moderate, or substantial. Context and intensity are considered together when determining whether an impact is significant under NEPA.

This chapter provides information on issues relevant to selecting an agency preferred alternative and an environmentally preferred alternative as is required by NEPA. The analysis investigates the potential for proposed activities to affect (either adversely or beneficially) the various issues of concern and provides a comparative assessment of each alternative's expected effect on the environment. The assessment of environmental effects is based on a comparison of conditions with and without implementation of the proposed plan and related alternatives differentiated between the three action alternatives and the No-Action Alternative. Effects can be short-term or long-term, and beneficial or adverse. For the alternatives analysis in this chapter, the spatial scale of analysis focuses on the locations of the 18 proposed sites to provide a comparison between the No-Action Alternative and the three action alternatives. The time scale for analysis is a 50-year period beginning in 2015 extending to 2065. For all of the short-term construction effects identified in this chapter, these effects would be repeated in the event that adaptive management measures are undertaken after the appropriate monitoring period. Finally, certain topics were screened out of detailed analysis during the NEPA scoping process as described in section 3.5, and are therefore not covered in this section.

Alternative 3 is the environmentally preferred alternative due to having the greatest benefits for ecosystem function; however, Alternative 4 is selected as the agency preferred alternative as part of the implementation master plan as indicated in section 4.10.

5.1 PHYSICAL ENVIRONMENT: NEARSHORE PROCESSES AND STRUCTURES

This section provides an analysis of how each alternative would affect a variety of significant physical resources associated with nearshore processes and structures. Effects of the No-Action Alternative would avoid impacts from construction, but would forego the opportunity for important ecosystem restoration benefits. The action alternatives may have short-term construction impacts lasting an estimated six months to two years, yet would have long-term benefits to the physical attributes of the nearshore zone supporting ecosystem functions. For the two sites in Alternatives 2 and 3 (Telegraph Slough and Everett Marshland) that are near navigation channels, site features would be engineered so as to cause no significant impacts to operations and maintenance costs for navigation.

5.1.1 Nearshore Ecosystem Processes

As described in section 3.1, nearshore ecosystem processes influence marine and estuarine shorelines over diverse spatial and temporal scales and are responsible for the different complexes of landforms supporting a wide variety of flora and fauna described in section 3.2.

5.1.1.1 *Alternative 1 – No-Action Alternative*

Under the No-Action Alternative, ecosystem processes at the proposed sites would likely remain degraded and impaired. Given the level of impairment to nearshore processes at these locations, the associated habitats and biological resources would continue to decline or fail to recover and rebuild their populations, which would be a substantial negative effect to Puget Sound.

5.1.1.2 *Alternative 2 – 11 Sites*

Alternative 2 includes at least one site from each of the formulated strategies (see section 4.1.1.2). This alternative would restore 5,348 acres of tidal wetlands and would remove 75,162 feet of stressors from the nearshore zone. Restoration measures at these 11 sites include removal of at least 10 tidal barriers for more natural inundation and estuarine mixing, remove shoreline armoring in at least two sites for better sediment erosion and transport, excavate tidal channels in at least four sites to initiate natural channel development, and add plantings to riparian zones to initiate vegetation succession and shading to keep water temperatures cool. These stressor removal measures would restore the natural processes that support the habitat and organisms. Processes that would be restored include natural formation of tidal channels in estuaries, unrestricted flow of freshwater rivers and streams into estuaries, unrestricted movement and migration of fish and wildlife, movement of sand and gravel along a shoreline, natural erosion and accretion of a beach, and natural exposure of a bluff to wind and wave action.

5.1.1.3 *Alternative 3 – 18 Sites*

Alternative 3 includes 18 sites that together address all four of the formulated strategies for process-based restoration. This alternative would restore 5,517 acres of tidal wetlands and would remove stressors from 113,094 feet of the nearshore zone. Restoration measures at these 18 sites would include removal of at least 15 tidal barriers, remove shoreline armoring in at least 4 sites, excavate or improve tidal channels in at least 7 sites, and would involve a much greater area of additional riparian plantings than would occur in Alternatives 2 and 4. These measures would restore a larger area of the ecosystem processes than Alternatives 2 and 4, and this alternative adds a second beach restoration site, which is a rare restoration opportunity around the Puget Sound nearshore zone due to the length of shoreline in private ownership.

5.1.1.4 *Alternative 4 – 3 Sites*

Alternative 4 includes three sites; these are Duckabush River Estuary with 38 acres of saltwater and brackish wetlands restored, Nooksack River Delta with 1,807 acres of brackish and freshwater tidal wetlands restored, and North Fork Skagit River Delta with 256 acres of saltwater and brackish wetlands restored. This alternative would remove 1,270 feet of tidal barrier from the Duckabush Delta, and the Nooksack Delta site will have 11,910 feet of armor and tidal barriers removed. The North Fork Skagit site will remove 15,680 feet of shoreline armoring and will set levees well back from the river allowing a greater meander zone and tidal inundation. These amount to 2,101 acres of tidal wetlands restored and 28,860 linear feet of stressors removed from the nearshore zone allowing nearshore processes to return to the sites to support habitat and biological resources by influencing the physical structures of these sites. No beach restoration sites are included in this alternative.

5.1.2 Geologic and Physiographic Setting

The significant resources analyzed here are based on Shipman's (2008) classification system of geomorphological features that characterize the natural shoreline of Puget Sound. These landforms reflect the primary role of geomorphic processes in shaping the landscape. Approximately 10% of all Puget Sound shoreline is classified as "artificial" (Simenstad et al. 2011). Human-made structures and armoring inhibit the natural processes and are targeted for removal under the three action alternatives. The action alternatives represent substantial benefits.

5.1.2.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would continue the negative trajectory of the geologic and physiographic setting. The existing conditions would remain with artificial landforms that fail to support important habitats for Puget Sound species. One of the problems this study identified is the substantially decreased length and complexity of the Puget Sound shoreline. The combined shoreline length at all 18 proposed sites is 199,086 feet, or 38 miles as it has been shortened since historical conditions. Under the No-Action Alternative, this shoreline length would remain the same without improvement. Environmental protections and regulatory requirements may limit repair and/or replacement of artificial landforms, which may deteriorate over decades of exposure to natural elements (e.g. wind, waves). Natural landforms may re-emerge, but it would take decades for transition and there is high likelihood that human-made debris would be left behind to influence the natural landforms.

5.1.2.2 *Alternative 2 – 11 Sites*

Alternative 2 would remove artificial shoreline features and return sites to a more natural physiography that can support natural processes, by removing 75,162 feet of stressors from the nearshore zone. This work would increase shoreline length by 131,578 feet over the existing length of the 11 sites. The resulting length would be 166% of the existing length. The landforms of this alternative that would change from artificial back to their historical form include one bluff-backed beach, six deltas in tidal freshwater zones, one delta in an estuarine mixing zone, one open coastal inlet, one barrier estuary, and one barrier lagoon with estuarine mixing. The beneficial effects would extend beyond merely the length of stressor removal, but would not be as substantial as the extent of Alternative 3.

5.1.2.3 *Alternative 3 – 18 Sites*

Alternative 3 would remove 113,094 feet of stressors from the nearshore zone. This work would increase shoreline length by 125,474 feet over the existing length of the 18 sites. The resulting length would be 147% of the existing length. The landforms of this alternative that would change from artificial back to their historical form include one bluff-backed beach and a barrier beach, six deltas in tidal freshwater zones, two deltas in estuarine mixing zones, four open coastal inlets, three barrier estuaries, and one barrier lagoon with estuarine mixing.

5.1.2.4 *Alternative 4 – 3 Sites*

Alternative 4 would remove 28,860 feet of stressors among the three sites. This work would increase shoreline length by 23,568 feet over the existing length of the 3 sites. The resulting length would be 132% of the existing length. The landforms of this alternative that would change from artificial back to their historical form include one delta in freshwater tidal zone (Nooksack), and two deltas in estuarine mixing zones (Duckabush and North Fork). The geographic range is primarily in northern Puget Sound and includes the Duckabush intertidal site in Hood Canal. Removal of stressors at these three sites would more than double the shoreline length at each site as well as collectively. This would restore sediment import and export processes at these sites.

5.1.3 Oceanography

Tides, currents, and waves are the characteristics of the vast volume of water contained within Puget Sound. The dynamic interactions between the water and land are forces of nature beyond the control of humans on a large scale; however, removing the artificial landforms from the nearshore zone can restore natural processes at a local scale. Removal of stressors at nearshore zone sites in most cases will have the following effects:

- Expand the tidal prism (tidal flow in and out of an area).
- Likely reduce the magnitude of tidal currents when barrier are removed.
- Result in diurnal changes in salinity and temperature in the estuary.
- Restore natural sedimentation processes.

5.1.3.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would leave in place all dikes, berms, and other stressors commonly associated with river deltas and waterfront development. This would continue to impede freshwater input and estuarine mixing with negative effects on species that use the mixing zones for foraging, refuge, and reproduction, especially salmonids that use estuaries as critical transition zones between freshwater and saltwater life stages. At many of the proposed sites, freshwater input is channelized and confined to specific outlet locations, which creates localized areas of freshwater input and prevents natural mixing. Moderate habitat degradation would continue a downward trend through the period of analysis without restoration actions. The No-Action Alternative would have no effect on tides, currents, or wave action and would not meet the need to restore tidal wetlands and beach sedimentation.

5.1.3.2 *Alternative 2 – 11 Sites*

At eight of the 11 sites, degraded conditions would be rectified for freshwater input and distributary channel migration. This alternative would have no significant adverse effect on tides, currents, or interaction with the Pacific Ocean; in fact, it would restore 5,354 acres of tidal wetlands and beach area. This alternative would restore natural interaction between tidal and wave action with a bluff-backed beach (Beaconsfield Beach) and would allow natural sediment transport. This alternative includes one open coastal inlet (Deer Harbor Estuary) where the tidal barrier would be removed allowing tides, currents, and waves to interact with this landform. One barrier estuary (Dugualla Bay) and a barrier lagoon (Livingston Bay) would have their tidal barriers removed. These four sites amount to 833 acres of restored natural processes involving tides, currents, and waves. Other sites in this alternative are more related to freshwater reaches of the deltas, which would see benefits from increased tidal influence in their freshwater wetlands.

5.1.3.3 *Alternative 3 – 18 Sites*

At 15 of the 18 sites, degraded conditions would be rectified for freshwater input and distributary channel migration, which includes the largest river delta restoration opportunity in Puget Sound (Nooksack), along with several other large-scale sites. This alternative would have no significant adverse effect on tides, currents, or interaction with the Pacific Ocean; in fact, it would restore 5,523 acres of tidal wetlands and beach area. This alternative would restore natural interaction between tidal and wave action with a bluff-backed beach (Beaconsfield Beach) and a barrier beach (WDNR Budd Inlet Beach) and would allow natural sediment transport. There are four open coastal inlets where tidal barriers would be removed allowing tides, currents, and waves to interact with the landform at these locations. Three barrier estuaries and a barrier lagoon (Livingston Bay) would have their tidal barriers removed. These 10 sites amount to 965 acres of restored natural processes involving tides, currents, and waves. Other sites in this alternative are more related to freshwater reaches of the deltas, which would experience benefits from increased tidal influence in their freshwater wetlands.

5.1.3.4 *Alternative 4 – 3 Sites*

At all three of the sites in this alternative, degraded conditions would be rectified for freshwater input and the channel migration zone. Distributary channel migration would be improved at

Duckabush River Estuary and at the North Fork Skagit River Delta site. This alternative retains the largest proposed river delta restoration site (Nooksack); however, no beach restoration sites are included. One of these three sites amounts to 38 acres of restored natural processes involving tides, currents, and waves (Duckabush Estuary). The other two sites in this alternative are more related to freshwater reaches of the deltas, which would experience benefits from increased tidal influence in their freshwater wetlands.

5.1.4 Sedimentation and Erosion

Sediments move in longshore and cross-shore directions under the influence of wave and tidal forces. Artificial landforms in the nearshore zone hinder these natural processes that deliver substrates from areas of erosion to areas of deposition. Removal of stressors from the nearshore zone restores the natural processes that shape and influence the wetland and aquatic habitats critical for supporting VECs and ecosystem functions. Because substrate type determines species assemblages, nearly every type of flora and fauna of the nearshore zone would benefit from restoration of the natural sedimentation and erosion processes. Furthermore, restoration of these sediment transport processes would build resiliency into the ecosystem.

5.1.4.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would continue the degraded conditions of sedimentation and erosion processes, which would remain impaired at the proposed sites. Shoreline armoring would continue to prevent erosion of bluffs and transport of sediment to natural depositional features of beaches, bars, and spits. Other nearshore stressors would continue to disrupt longshore and cross-shore movement and sorting of substrates that support VECs such as forage fish.

5.1.4.2 *Alternative 2 – 11 Sites*

Alternative 2 would remove stressors from 75,162 feet of shoreline. Alternative 2 would restore sediment transport at 11 shoreline drift cells or deltas. Erosion of bluffs and restoration of tidal hydrology would allow for sediment transport and delivery that would provide appropriate substrate for wetlands, beaches, and submerged aquatic vegetation. Tidal and distributary channels would form at the mouth of these estuaries from the restored interactions between tidal hydrology and freshwater input. This alternative would meet the project purpose of nearshore process restoration but to a lesser degree than Alternative 3.

5.1.4.3 *Alternative 3 – 18 Sites*

Alternative 3 would remove stressors from 113,094 feet of shoreline. This would restore sediment transport, delivery, and erosion in each of these 18 shoreline drift cells or deltas. Benefits would be similar to those described for Alternative 2, but more so due to a greater amount of stressors removed. This would assist with rebuilding broad areas of wetlands by restoring appropriate substrate for their development and represents substantial positive effects.

5.1.4.4 *Alternative 4 – 3 Sites*

Alternative 4 would remove stressors from 28,860 feet of shoreline. This would restore sediment transport at these three delta sites. Restoration of tidal hydrology would allow for sediment transport and delivery that would provide appropriate substrate for wetlands, tidal distributary channels, and potentially for submerged aquatic vegetation at the Duckabush site. Tidal and distributary channels would form at the mouth of these estuaries from the restored interactions between tidal hydrology and freshwater input. This alternative would meet the project purpose of nearshore process restoration but to a lesser degree than Alternatives 2 and 3.

5.1.5 Hazardous, Toxic, and Radiological Waste (HTRW)

An HTRW site is defined as a site where a known or suspected uncontrolled release of a hazardous substance occurred, as defined in CERCLA (see section 3.1.5). Literature suggests that historically developed areas such as Puget Sound contain higher background concentrations of some hazardous substances that may affect biota, but these elevated background concentrations do not constitute HTRW as per ER 1165-2-132.

5.1.5.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would result in no change to the current status or future trends of HTRW contamination in Puget Sound.

5.1.5.2 *Alternative 2 – 11 Sites*

Based on available information, no HTRW sites exist in any of the 11 sites of Alternative 2. The WDOE has several databases that describe facilities of interest. The most general search is on their Facility/Site web page, which lists numerous facilities and sites of environmental interest (all 11 sites are represented in this search). A second database is their Confirmed and Suspected Contaminants Site List, which lists sites that are undergoing cleanup or awaiting further investigation (Everett Marshland, Dugualla Bay, and the Nooksack site have facilities on this list that are adjacent to, but not within, the proposed footprint). Lastly is the Hazardous Site List, which lists sites that have been assessed (Everett Marshland and Dugualla Bay have facilities on this list that are adjacent to, but not within, the proposed footprint).

Four of the 11 sites had historical industrial or commercial usage. Due to these uses, additional document research would be completed during PED to determine whether an uncontrolled release of hazardous substances occurred. Per ER 1165-2-132 *Hazardous, Toxic, and Radioactive Waste (HTRW) Guidance for Civil Works Projects*, HTRW would be avoided entirely or the non-Federal sponsor would complete cleanup activities as a non-cost-shared action.

5.1.5.3 *Alternative 3 – 18 Sites*

Based on available information including current footprint, no HTRW sites exist in 16 of the 18 sites of Alternative 3. Among the three databases that WDOE maintains regarding facilities of interest, the following two sites are included. At the Point Whitney Lagoon site, a septic tank has been removed and the site is under voluntary cleanup. Based on the information contained in the Environmental Site Assessment Level I report, one uncontrolled release from a leaking underground storage tank was documented at the Budd Inlet Beach site. This tank has been removed and the site is under voluntary cleanup.

Ten of the 18 sites had historical industrial or commercial usage. Due to these uses, additional document research would be completed during PED to determine whether an uncontrolled release of hazardous substances occurred. Per ER 1165-2-132 *Hazardous, Toxic, and Radioactive Waste (HTRW) Guidance for Civil Works Projects*, HTRW will be avoided entirely or the non-Federal sponsor will complete cleanup activities as a non-cost-shared action.

5.1.5.4 *Alternative 4 – 3 Sites*

A Phase 1 Environmental Site Assessment was completed for all sites under initial consideration. The Corps reviewed and updated these assessments for each of the three sites under current consideration (See Appendix B – Engineering). These most recent assessments were conducted in accordance with the scope and limitations of ASTM E1527-13: *Standard Practice for Environmental Site Assessments,* and ER 1165-2-132: *HTRW Guidance for Civil Works Projects*. The updated Phase 1 assessments for the North Fork Skagit and Duckabush Estuary revealed no confirmed or suspected HTRW in the project footprints. At North Fork Skagit, the surrounding area has one site of concern; however, given the nature of the site and its contaminants, as well as its distance and hydraulic disconnection from the proposed project site, this site will not pose a significant or critical risk to Alternative 4. The Duckabush River Estuary portion of Alternative 4 has no known or suspected HTRW in the surrounding areas.

The Nooksack River portion of Alternative 4 has no known or suspected HTRW within its proposed footprint. The Phase 1 Environmental Site Assessment revealed several recognized environmental conditions in connection with areas adjacent to the project footprint, although all but one of these sites have no potential to impact the proposed project. The one exception is the Wilder Hazardous Waste Landfill site, located approximately a half mile east of the project footprint. Currently, there is no reason to believe that contaminants from this site are flowing into Claypit Pond (a small, artificial lake next to the landfill site) due to low permeability of the surrounding soils. However, inundation of Claypit Pond from the Corps project has a limited probability of changing the groundwater gradient, or more generally the overall hydrology, such that contaminants originating from the hazardous waste landfill could more easily flow into the pond. Therefore, the Corps project as well as potential users of the restored areas, have the potential to be impacted by contamination. Currently, the extent of this risk is unknown, and additional investigations will be conducted during PED. This risk and risk management strategy is summarized in section 6.1.2. If the risk is found to be unacceptable, the non-Federal sponsor must decide how to manage that risk before construction occurs. Please refer to Appendix B for the complete assessment.

5.1.6 Water Quality

The primary contributor to diminished water quality at the proposed sites is polluted storm water runoff and excess nutrients from agriculture from the adjacent watersheds. The focus of the proposed work is stressor removal, which would not eliminate pollution sources to storm water; however, the proposed actions would increase the area of wetlands, which serve as natural filtration of pollutants in the environment. Construction activities for restoration projects often have short-term increases to turbidity that are minimized through specific construction practices.

5.1.6.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would have no effect on the status of the water quality parameters of the nearshore zone at the proposed sites. This alternative would fail to provide the important water filtration afforded by increased wetlands, which is critical to maintaining uncontaminated shellfish beds.

5.1.6.2 *Alternative 2 – 11 Sites*

Alternative 2 would restore 5,348 acres of tidal freshwater or estuarine mixing wetlands. Restoration would involve revegetation of riparian areas, which would increase shading and reduce water temperatures. Cooler water allows for higher concentration of dissolved oxygen, which benefits aquatic species. The increased area of wetlands would support a variety of functions that improve water quality, including sequestration of nitrogen and phosphates as well as pesticides and other chemicals that can harm the aquatic ecosystem. Temporary construction impacts may cause pulses of turbidity, but the duration of effect would only be a matter of hours; the overall benefits of Alternative 2 for water quality far outweigh minor construction effects. Improved water quality is critical to restoration of Puget Sound.

5.1.6.3 *Alternative 3 – 18 Sites*

Alternative 3 would restore 5,517 acres of tidal freshwater or estuarine mixing wetlands. At 15 of the 18 sites, restoration would involve revegetation of riparian areas, providing cooler water temperatures. The increased area of wetlands would support a variety of functions that improve water quality, including sequestration of nitrogen and phosphates as well as pesticides and other chemicals that can harm the aquatic ecosystem. Construction effects would be similar to those for Alternative 2, but would occur at more locations due to the larger number of sites. Likewise, the benefits of Alternative 3 would be similar to Alternative 2 but would cover a greater extent.

5.1.6.4 *Alternative 4 – 3 Sites*

Alternative 4 would restore 2,101 acres of tidal freshwater (Nooksack site) or estuarine mixing wetlands (Duckabush and North Fork sites). Restoration would involve revegetation of riparian areas at Nooksack and North Fork sites, which would increase shading and reduce water temperatures. Cooler water allows for higher concentration of dissolved oxygen, which benefits aquatic species. The increased area of wetlands at all three sites would support a variety of functions that improve water quality, including sequestration of nitrogen and phosphates as well as pesticides and other chemicals that can harm the aquatic ecosystem. Temporary construction impacts may cause pulses of turbidity, but the duration of effect would only be a matter of hours; the overall benefits of Alternative 4 for water quality far outweigh minor construction effects. The Corps would consult with WDOE during PED phase regarding minimizing construction impacts to water quality. Restoring wetlands would have a substantial benefit for water quality at these three sites, although the acreage of restoration is less than 40% of Alternatives 2 and 3.

5.1.7 Greenhouse Gas Emissions (GHGs)

Estimating the total quantity of GHGs that would be produced or absorbed by each of the proposed sites would require extensive analysis and numerous assumptions about each site's final design and construction. An estimation of GHGs should not only consider causes of GHG production, but also causes of GHG absorption, which offset and reduce the overall impact of GHGs. Artificial and natural reservoirs, or "sinks," absorb GHGs from the atmosphere. Large-scale natural carbon sinks include oceans, wetlands, grasslands, and forests. Vegetated land of any size, however, removes carbon from the atmosphere when the plants absorb CO_2 for photosynthesis. Most of the proposed actions involve active revegetation through landscaping and hydro-seeding or passive revegetation through removal of human-made structures (such as roads), which allows natural plant recruitment. All of these changes would increase absorption of CO_2, but the rate at which it is absorbed will depend on many factors, such as the type of plants, vegetation density, and climate. Therefore, it would be quite challenging to estimate GHG absorption for each site. Bearing the "rule of reason" in mind for structuring the GHG evaluation for an EIS, although an extensive quantified analysis cannot be done, a qualitative comparison can be drawn from simplified analysis of the primary causes of GHG production and absorption. The major sources of GHG emissions would be construction activities and construction materials, while the primary cause of carbon absorption would be increased vegetation. This section discusses these factors and how they can be used to estimate relative GHG emissions among the three alternatives and among the actions included in each alternative.

5.1.7.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would have no effect on GHGs. Alternative 1 does not involve construction activities and materials, and it would not change the amount of vegetation in the project area, so it would neither produce nor absorb GHG emissions.

5.1.7.2 *Alternative 2 – 11 Sites*

Simplified analysis of the construction activities and materials associated with the proposed actions for Alternative 2 indicates that this alternative would produce GHG emissions. At the same time, it would result in GHG absorption by increasing the vegetated land area. This analysis does not reveal whether the net effect would be an increase or decrease in global GHG quantities, although it does provide insight into the design and construction factors that affect GHG production and, more importantly, those factors that represent opportunities to mitigate the production of GHG, as introduced at the end of this section and detailed in section 5.7.3.

During construction activities, energy would be required to, for example, excavate soil, pave roadways, and haul materials to and from the site. The energy required for these activities would come from a hydrocarbon fuel (typically diesel) used by dump trucks, graders, pavers, and other construction equipment. The primary GHG produced during diesel combustion is CO_2. Therefore, the quantity of GHG emissions related to construction activities for the alternative can be estimated based on the quantity of diesel to be used during the construction at each site, as shown in Table 5-1 for Alternative 2 and Table 5-3 for Alternative 3.

Table 5-1. Estimated GHG Emissions Related to Construction Activities for Alternative 2

Site	Estimated Diesel Usage (gal)[1]	Estimated CO_2 Emissions (ton)[2]
Beaconsfield Feeder Bluff	5,200	58
Deepwater Slough	32,900	365
Deer Harbor Estuary	16,100	179
Dugualla Bay	336,100	3,731
Everett Marshland	2,249,200	24,966
Livingston Bay	61,200	679
Milltown Island	2,800	31
Nooksack River Delta	2,307,900	25,618
North Fork Skagit River Delta	539,800	5,992
Spencer Island	127,800	1,419
Telegraph Slough	992,300	11,015
Alternative 2 Total	6,671,300	74,053

[1] Quantity estimates were developed during preliminary cost analysis for the proposed sites.
[2] CO_2 emissions from diesel = 22.2 pounds/gallon (EPA 2005)

In addition to construction activities, construction materials represent a substantial source of GHG emissions for these actions. All materials have associated embodied emissions, or the emissions created throughout their lifecycles. For each product, the total embodied emissions depend on how the base materials are extracted, processed, transported, and constructed to create the final product, as well as how the product is disposed at the end of its usable life. Quantifying the total embodied emissions for all of the materials used on the proposed actions would require extensive analysis; however, it is reasonable to assume that the quantity of concrete and asphalt pavement used on these sites will provide a basis for comparison of the total embodied emissions for the proposed actions. These quantities can be estimated based on the area (in square feet [SF]) of new roadway and new bridges to be constructed, as shown in Table 5-2 and Table 5-4.

Table 5-2. Estimated Major Construction Areas for Alternative 2

Site	Estimated New Roadway Area (SF)[1]	Estimated New Bridge Deck Area (SF)[2]
Beaconsfield Feeder Bluff	0	0
Deepwater Slough	0	0
Deer Harbor Estuary	6,100	3,500
Dugualla Bay	206,400	27,000
Everett Marshland	391,700	48,100
Livingston Bay	0	0
Milltown Island	0	0
Nooksack River Delta	902,300	118,800
North Fork Skagit River Delta	0	0
Spencer Island	0	0
Telegraph Slough	486,500	40,800
Alternative 2 Total	1,993,000	238,200

[1]New roadways may be constructed with asphalt pavement or concrete.
[2]Bridge deck area is used to convey relative quantities of concrete used to construct bridges; it does not account for all bridge elements, such as foundations and approach slabs.

Moreover, analysis of the actions that produce relatively high levels of CO_2 can provide insight into which construction activities would have the greatest impact on GHG emissions. The total GHG emissions for these actions would depend heavily on the quantity of materials that must be hauled and the distance they must travel. The estimates in Table 5-3 were based on approximate material quantities and assumed locations for material sources and disposal sites, but these factors may provide substantial opportunities for reducing GHG emissions as the actions approach final design and construction.

5.1.7.3 *Alternative 3 – 18 Sites*

Similar to Alternative 2, simplified analysis of Alternative 3 indicates that this alternative would result in both GHG production and GHG absorption. Table 5-3 shows the total estimated diesel usage and the associated CO_2 emissions.

Table 5-3 Estimated GHG Emissions Related to Construction Activities for Alternative 3

Site	Estimated Diesel Usage (gal)[1]	Estimated CO_2 Emissions (ton)[2]
Beaconsfield Feeder Bluff	5,200	58
Big Beef Creek Estuary	144,900	1,608
Deepwater Slough	32,900	365
Deer Harbor Estuary	16,100	179
Duckabush River Estuary	159,400	1,769
Dugualla Bay	336,100	3,731
Everett Marshland	2,249,200	24,966

Harper Estuary	57,200	635
Livingston Bay	61,200	679
Milltown Island	2,800	31
Nooksack River Delta	2,307,900	25,618
North Fork Skagit River Delta	539,800	5,992
Point Whitney Lagoon	54,200	602
Snow Creek and Salmon Creek Estuary	189,800	2,107
Spencer Island	127,800	1,419
Tahuya River Estuary	111,100	1,233
Telegraph Slough	992,300	11,015
WDNR Budd Inlet Beach	24,200	269
Alternative 3 Total	7,412,100	82,276

[1] Quantity estimates were developed during preliminary cost analysis for the proposed sites.
[2] CO_2 emissions from diesel = 22.2 pounds/gallon (EPA 2005)

These estimates do provide a reasonable basis of comparison among the actions even though they do not account for all construction activities. The estimates in Table 5-3 were based on approximate material quantities and assumed locations for material sources and dump sites, but these factors may provide substantial opportunities for reducing GHG emissions as the actions approach final design and construction. Because the proposed sites for Alternative 2 are a subset of those included in Alternative 3, the construction activities and materials associated with Alternative 2 would produce less GHG emissions than Alternative 3. This is confirmed by the estimated CO_2 emissions related to construction activities listed in Table 5-1 and estimated roadway and bridge deck areas listed in Table 5-2. It can be qualitatively concluded that Alternative 3 would increase GHG absorption because it would increase the area of vegetated land; as a result, a decrease in GHGs would be anticipated and an indirect beneficial effect to climate change from the absorbed GHGs.

Table 5-4. Estimated Major Construction Areas for Alternative 3

Site	Estimated New Roadway Area (SF)[1]	Estimated New Bridge Deck Area (SF)[2]
Beaconsfield Feeder Bluff	0	0
Big Beef Creek Estuary	26,800	30,000
Deepwater Slough	0	0
Deer Harbor Estuary	6,100	3,500
Duckabush River Estuary	63,600	35,200
Dugualla Bay	206,400	27,000
Everett Marshland	391,700	48,100
Harper Estuary	0	0
Livingston Bay	0	0
Milltown Island	0	0
Nooksack River Delta	902,300	118,800
North Fork Skagit River Delta	0	0

Point Whitney Lagoon	0	0
Snow Creek and Salmon Creek Estuary	90,000	28,500
Spencer Island	0	0
Tahuya River Estuary	27,800	21,000
Telegraph Slough	486,500	40,800
WDNR Budd Inlet Beach	0	0
Alternative 3 Total	2,201,200	352,900

[1]New roadways may be constructed with asphalt pavement or concrete.
[2]Bridge deck area is used to convey relative quantities of concrete used to construct bridges; it does not account for all bridge elements, such as foundations and approach slabs.

5.1.7.4 *Alternative 4 – 3 Sites*

Similar to Alternatives 2 and 3, simplified analysis of Alternative 4 indicates that this alternative would result in both GHG production and GHG absorption. Table 5-5 shows the total estimated diesel usage and the associated CO_2 emissions.

Table 5-5. Estimated GHG Emissions Related to Construction Activities for Alternative 4

Site	Estimated Diesel Usage (gal)[1]	Estimated CO_2 Emissions (ton)[2]
Duckabush River Estuary	159,400	1,769
Nooksack River Delta	2,307,900	25,618
North Fork Skagit River Delta	539,800	5,992
Alternative 4 Total	3,007,100	33,379

[1] Quantity estimates were developed during preliminary cost analysis for the proposed sites.
[2] CO_2 emissions from diesel = 22.2 pounds/gallon (EPA 2005)

Alternative 4 would employ substantially less material for new roadways and bridge decks for overall lower GHG production than Alternatives 2 and 3. Table 5-6 shows the total estimated major construction areas for Alternative 4.

Table 5-6. Estimated Major Construction Areas for Alternative 4

Site	Estimated New Roadway Area (SF)[1]	Estimated New Bridge Deck Area (SF)[2]
Duckabush River Estuary	63,600	35,200
Nooksack River Delta	902,300	118,800
North Fork Skagit River Delta	0	0
Alternative 3 Total	965,900	154,000

[1]New roadways may be constructed with asphalt pavement or concrete.
[2]Bridge deck area is used to convey relative quantities of concrete used to construct bridges; it does not account for all bridge elements, such as foundations and approach slabs.

It is clear that Alternative 4 would have substantially less GHG production and absorption by having fewer sites than Alternatives 2 and 3. Construction represents a short-term release of GHGs while restoration of vegetated land areas would be expected to result in a long-term carbon sink although that level of analysis is not provided here. This analysis does not reveal whether the net effect would increase or decrease global GHG quantities but it provides some insight into GHG mitigation opportunities for the proposed actions.

Effects of GHG Emissions and Mitigation Measures

The potential effects of GHG emissions are by nature global and cumulative because they mix throughout the Earth's atmosphere from a variety of sources. The primary sources come from a few different sectors; various industries, energy sources such as coal and natural gas, personal consumption of fossil fuels, and natural causes are responsible for their release. The CO_2 emissions associated with the three alternatives have a minuscule difference when compared to the gigatonnes emitted globally every year; however, when GHG emissions from construction of restoration sites are combined with the GHG emissions from all sources and sinks, there would be a contribution to the global GHG emissions that are affecting climate change. Based on the enormity of GHG contributions from other sources, it is reasonable to assume that none of the alternatives for this project is large enough to have a significant effect on the climate because it would represent an extremely small fraction of the total GHG emissions produced globally.

Although the action alternatives would not cause substantial cumulative impacts associated with global climate change and there are no formally adopted NEPA thresholds of significance for GHG emissions, there are a number of mitigation measures that could be taken to reduce GHG emissions associated with Alternatives 2, 3, and 4. These measures would largely encompass best management practices (BMPs) related to conservation of construction materials and fuel used for construction activities and transportation of materials, as well as sequestration of CO_2 in restored wetlands and eelgrass beds. Details are provided in section 5.7.3.

5.1.8 Underwater Noise

The characteristics of sound pressure waves and animal sensitivity are described in section 3.1.8 of this document. Intrusive noise levels can have behavioral and physiological effects on animals. Behavioral consequences are actions such as abandoning hunting, diving or increasing swimming speed to flee the area, interrupted communication between individuals or pods, attempts to shield the young, and even panic and stranding (Richardson et al. 1995). Physiological consequences range from minor to lethal and can include temporary and permanent hearing loss, weight loss if prey cannot be captured, stress-induced health decline, and the lethal effect of hemorrhaging of the brain or other organs. Consequences from masked sounds can include other effects such as inability to avoid predators, being separated from the pod, or missed opportunities for group hunting. Chronic noise pollution can affect not only individuals, but also whole populations.

For a determination on whether construction related noise would affect marine mammals, fish, and birds, one must consider the frequency, location, intensity, and duration of the sound source as well as the audiogram of the recipient species. If an audiogram is available for a species, then using that audiogram helps to analyze the effects of noise on important biological resources;

otherwise, the hearing frequency range may be the best available information. Effects analysis requires calculating the sound exposure level (SEL) that the animal receives (described in section 3.1.8). Table 5-7 displays data collected on hearing capabilities of potentially affected species in the Nearshore Study area.

Table 5-7. Hearing capabilities of aquatic species and sound threshold for continuous and pulsed noise that can cause behavioral disruption and injury

Species	Audible Frequencies	Level B harassment (continuous)	Level B harassment (pulsed)	Level A injury
Fish (general)[2]	50Hz – 2kHz	150 dB_{RMS}	187 dB_{RMS}	206 dB_{RMS}
Herring[2]	70Hz – 200Hz	150 dB_{RMS}	187 dB_{RMS}	206 dB_{RMS}
Salmonids[2,7]	10Hz – 600Hz	150 dB_{RMS}	187 dB_{RMS}	206 dB_{RMS}
Rockfish[8]	50Hz – 2kHz	150 dB_{RMS}	187 dB_{RMS}	206 dB_{RMS}
Pinnipeds[5]	500Hz – 50kHz	120 dB_{RMS}	160 dB_{RMS}	190 dB_{RMS}
California sea lions	1kHz – 28kHz	120 dB_{RMS}	160 dB_{RMS}	190 dB_{RMS}
Harbor seals	1kHz – 50kHz	120 dB_{RMS}	160 dB_{RMS}	190 dB_{RMS}
Steller sea lions	500Hz – 32kHz	120 dB_{RMS}	160 dB_{RMS}	190 dB_{RMS}
Mysticete whales[4]	10Hz – 8kHz	120 dB_{RMS}	160 dB_{RMS}	180 dB_{RMS}
Minke whale[4]	10Hz – 500Hz	120 dB_{RMS}	160 dB_{RMS}	180 dB_{RMS}
Odontocete whales[4]	100Hz – 500kHz	120 dB_{RMS}	160 dB_{RMS}	180 dB_{RMS}
Killer Whale (orca)[3]	500Hz – 105kHz	120 dB_{RMS}	160 dB_{RMS}	180 dB_{RMS}
Diving birds[9] (developed for marbled murrelet)	Not available, presumed at 1kHz – 5kHz	150 dB_{RMS} (guideline)	183 dB_{RMS} (onset of injury)	202 dB_{RMS}

[1] square root of the mean of the squares of the values recorded over a given time interval [2]Blaxter and Hoss 1981; [3] Hall and Johnson 1971, Bain et al. 1993, Szymanski et al. 1999; [4] Gordon and Moscrop 1996; [5] Schusterman et al. 1972; [6] Bailey et al. 2010; [7] Knudsen et al. 1992; [8] Skalski et al. 1992; [9] SAIC 2011

For a determination on whether construction related noise would affect marine mammals, fish, and birds, one must consider the frequency, location, intensity, and duration of the sound source as well as the audiogram of the recipient species. If an audiogram is available for a species, then using that audiogram helps to analyze the effects of noise on important biological resources; otherwise, the hearing frequency range may be the best available information. Effects analysis requires calculating the sound exposure level (SEL) that the animal receives (described in section 3.1.8). Table 5-7 displays data collected on hearing capabilities of potentially affected species in the Nearshore Study area.

5.1.8.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would not have any effect on the underwater noise conditions in Puget Sound since it would avoid additional construction noise in the marine environment.

5.1.8.2 *Alternative 2 – 11 Sites*

This ecosystem restoration project would not constitute any long-term change to underwater noise in Puget Sound; however, construction of the proposed sites would have short-term underwater noise outputs that must be analyzed for effects on significant biological resources. At the current stage of site design, duration of noise-inducing activities cannot be estimated accurately at this time. During the next design phase, the potential effects would be thoroughly analyzed and all appropriate mitigation measures would be incorporated into construction methods. The activities that have been identified as part of the necessary construction work for this ecosystem restoration project are briefly described below:

- Pile driving may involve an impact pile hammer to drive steel piles into the substrate for solid support of the structures. For analysis in this document, the loudest sound level was used to assess effects; however, as an alternative to driving piles, construction could use vibration or hydraulic insertion methods. Another alternative to pile driving is drilled or augured holes for cast-in-place piles or piers. These methods would provide a significant sound reduction from traditional pile driving methods and would be used wherever feasible without sacrificing necessary structural integrity.
- A cofferdam or other water-isolation device most likely would involve use of a vibratory hammer for driving sheet-piles into sediment to encapsulate an area in the water to contain turbidity or to exclude aquatic animals. The frequency range is similar to round pole pile driving, but the decibel level is slightly quieter.
- Dredging may involve either a clamshell dredge or a pipeline dredge. Clamshell dredges produce various sound levels as they work and the decibel level depends largely on the substrate type with hard rock being louder than sand and mud. Pipeline dredges produce a constant sound profile at relatively low frequencies.
- Bridge construction often involves various construction methods including use of tugboats, drilling, rock placement, and pile driving. Some of these activities may be concurrent, but the nature of sound is such that sound pressure levels are not additive; for example, two boats idling at 85dB each would produce an audible sound at 88dB rather than 170dB. The SEL, however, would be calculated to estimate whether the duration of noise below the peak pulse threshold is creating enough energy to constitute harm or harassment to animals.

Implementing Alternative 2 would have no long-term effects on the ambient underwater noise conditions in Puget Sound. Construction would cause significant short-term noise disturbances at each of the 11 sites that have some noise-generating activity as described above. Sound levels would temporarily increase during construction with different characteristics and durations depending on the activity. Table 5-8 provides the noise-making construction activities and their likely dB level, along with how many sites in each alternative would have each type of activity. Potential noise-generating events associated with construction of each site were identified, and sound levels are estimated based on various data sources. Additionally, the sound pressure levels for the construction activities have been compared to the data available on aquatic species' hearing and the regulated sound threshold under the ESA and Marine Mammal Protection Act (MMPA) as presented in Table 5-7. Restoration work would involve noise levels that would cause behavioral responses or cause injury to aquatic animals if the noise were not mitigated.

However, construction methods would make every effort to use sound attenuation devices to reduce the noise below the regulatory thresholds.

Each method of construction that produces underwater noise can be mitigated through physical means such as bubble curtains and sound dampening mats, or through conservation measures such as having a certified monitor watching for wildlife. While noise may be significant at the construction sites, as the sound wave travels away from the noise-producing activity, the sound should attenuate below levels that cause harm to aquatic species.

5.1.8.3 *Alternative 3 – 18 Sites*

Implementing Alternative 3 would have no long-term effects on the ambient underwater noise conditions in Puget Sound. Ten sites in Alternative 3 have activities that would produce significant short-term underwater noise as described above. The temporary effects of noise that would occur during the construction necessary for Alternative 3 may include behavioral responses of animals that would flee the area, or could reach the level of physical harm. However, construction methods and timing would make every effort to use sound attenuation devices to reduce the noise below the regulatory thresholds. Alternative 3 has twice as many sites as Alternative 2 with noise-generating activities.

Table 5-8. Noise-making construction features and associated decibel levels for each alternative compared to the reaction or regulatory threshold under the ESA or MMPA

Construction Feature	Dominant Frequency and peak dB_{RMS}[1]	Alternative 2	Alternative 3	Alternative 4	Exceeds regulatory threshold for 1 or more species
Bridge construction (in-water work)[4] Rock placement Tugboats/barges Drilling	 No data available, but likely similar to clamshell dredging 100-500Hz, 170 dB_{RMS} 100-500Hz, 160 dB_{RMS}	5 sites	9 sites	2 sites	Yes; mitigation available
Pile driving[3]	30Hz - 8kHz, 192 dB_{RMS}	5 sites	10 sites	0 sites	Yes; mitigation available
Installation of cofferdam – likely vibratory sheet-pile driving[5]	25Hz - 4kHz, 182 dB_{RMS}	5 sites	10 sites	0 sites	Yes; mitigation available
Dredging[2]	Pipeline (continuous noise): 70Hz - 1000Hz, 110 dB_{RMS} Clamshell (continuous noise): 5Hz - 10kHz, 124 dB_{RMS}	1 site	2 sites	0 sites	No

[1] square root of the mean of the squares of the values recorded over a given time interval [2]Dickerson et al. 2001; Clarke et al. 2002; [3] Betke et al. 2004; [4] Richardson et al. 1995; [5] Illingworth & Rodkin, Inc. 2007

5.1.8.4 *Alternative 4 – 3 Sites*

Two of the three sites in Alternative 4, Nooksack and Duckabush, will have in-water work for bridge construction; however, neither of these sites will have pile driving other than a minimal amount of test holes. Both of these sites will have piles removed, but this noise is not as loud as driving piles. Bridge supports will be drilled and cast-in-place concrete piers to avoid causing noise impacts to aquatic species. The North Fork site has no activities that would cause noise impacts to aquatic fish and wildlife. Overall, this alternative poses negligible effects.

5.2 BIOLOGICAL ENVIRONMENT: NEARSHORE FUNCTIONS

This section provides an analysis of how each alternative would affect important nearshore biological resources. Effects of the different alternatives on the biological environment could be negative or positive. Three timeframes were considered when analyzing the effects of the action alternatives: construction, transition, and long-term trajectory. Construction effects are largely negative, but would be temporary, lasting six months to two years. Transition of the sites is expected to last a few months to a decade, depending on the conditions and targets of a particular restoration site. Long-term benefits are expected to last 50 years or more.

5.2.1 Vegetation

5.2.1.1 *Alternative 1 – No-Action Alternative*

This alternative would not meet the project purpose and need to restore ecosystem functions and structures that support vegetation. Kelp and eelgrass beds would continue to receive insufficient sediment delivery and transport that provides essential nutrients and riparian vegetation would continue to be sparse and/or dominated by non-native species due to presence of stressors that interrupt sediment dynamics and tidal hydrology.

Marine Submerged Vegetation

Under the No-Action Alternative, marine submerged vegetation at the sites would continue to be limited by diminished sediment delivery (leading to lack of suitable substrate), and lack of solar incidence caused by overwater structures and increased turbidity due to impervious surface and lack of native vegetation. In addition, a lost opportunity of eelgrass and kelp bed colonization would continue in intertidal and sub tidal areas at the proposed sites that have been filled.

Wetlands

The wetlands at the proposed sites would continue to be suppressed by tidal barriers and fill. Any freshwater wetlands that are present, either naturally or due to tidal barriers, would continue to be vulnerable to the spread of reed canary grass (an aggressive non-native species). Although more shoreline development in the Puget Sound region is inevitable, any additional loss of these wetlands would largely depend on the regulatory environment and enforcement of laws that protect such wetlands, like Sections 401 and 404 of the Clean Water Act. Wetland restoration efforts at the sites could occur, but would likely be a "piecemeal" approach rather than the large-scale process-based approach proposed here.

Riparian Vegetation
Riparian vegetation at the sites would continue to be displaced by the presence of shoreline stressors including shoreline armoring, railroads, dikes, and berms. Riparian areas likely would remain undisturbed, but continue to be dominated by invasive species of lesser ecological value.

5.2.1.2 *Alternative 2 – 11 Sites*

This alternative would remove 75,162 feet of shoreline stressors and restore 5,348 acres of tidal wetlands, which would promote the ecosystem structures and functions provided by wetlands, kelp and eelgrass beds, and riparian vegetation.

Marine Submerged Vegetation
Eelgrass occurs in patchy distributions at or near six of the 11 sites, and kelp beds occur in a patchy distribution at one site in this alternative. Temporary construction impacts to eelgrass and kelp would include turbidity caused by excavation and pulses of sediment released from newly tidally inundated areas, leading to potential for decreased light for the duration of construction and perhaps for a year as the storm season moves sediment away followed by recovery during the growing season. Long-term benefits would occur as sediment and nutrient transport increase when stressors are removed along approximately 113,094 feet of shoreline including armoring and tidal barriers, allowing for more suitable substrate and increases in light and nutrients nourishing growth and expansion of the beds within or along the fringes of the sites. Benefits may take two to four years to appear, but would endure for decades.

Wetlands
Under this alternative, the removal of tidal barriers and fill would restore 5,517 acres of tidal wetlands (both tidal freshwater and estuarine mixing). Additional areas of freshwater wetlands (not tidally influenced) are located at nine of the 11 sites; at most of these, the design proposes to remove tidal barriers to restore the estuarine mixing zone. This would convert these freshwater marshes into brackish marsh, a rarer ecotype. Due to the past disturbances created by diking and the proximity to agricultural lands, reed canary grass has likely pervaded these non-tidal freshwater wetlands. The other areas that would be tidally inundated are mostly agricultural lands that are no longer in use. As water of higher salinity inundates the restoration sites, the freshwater marsh vegetation would die off, leading to temporary decreases in vegetative cover until salt tolerant species colonize the area. Based on information from other estuarine restoration projects in the Puget Sound area, such as the Nisqually River estuary, it is likely that high marsh vegetation would establish within the first five years and lower marsh vegetation would take decades before establishment. Restoring these tidally influenced marshes would create a distribution of wetland zones that more closely matches pre-disturbance conditions, providing rearing and foraging areas for a variety of estuarine-dependent species.

Riparian Vegetation

Most riparian vegetation that would be impacted by construction activities, either by direct or indirect removal (removal of stressors with vegetation growing on them) consists of non-native species. Native vegetation would be protected to the extent possible. Invasive species would be replaced with native plants. As these riparian species become established, they would form an overhanging canopy that provides thermal refuge and a source of organic input for aquatic systems, as well as habitat for birds and small mammals. It is anticipated that there would be a net increase in riparian vegetation associated with this alternative.

5.2.1.3 *Alternative 3 – 18 Sites*

This alternative meets the project purpose and need by restoring 5,517 acres of tidal wetlands and removing 113,094 feet of shoreline stressors. In general, the substantial long-term benefits are greater than those described for Alternatives 2 and 4; however, there are greater short-term construction impacts associated with Alternative 3, although negligible in total impact.

Marine Submerged Vegetation

Eelgrass beds occur at or near 12 of the 18 sites in patchy and continuous distributions, and kelp occurs at or near four of the 18 sites in patchy distributions. Construction impacts would be similar to those described for Alternative 2, but to a greater extent due to the greater number of beds and the larger scale of construction. Benefits would be of similar types to those described for Alternative 2, with greater total benefit achieved since longer stressor length would be removed, providing proportionately more sediment delivery and nutrient transport.

Wetlands

Construction impacts on wetlands would be similar to those described for Alternative 2, but to a greater extent due to more freshwater wetlands being inundated with saltwater. Benefits would be similar to those described for Alternative 2, but would occur across a greater area since there would be more of the tidal wetlands restored than under Alternative 2.

Riparian Vegetation

Ten of the 18 sites include removal of invasive species and/or revegetation of riparian areas with natives. Construction impacts to riparian vegetation would be similar to those described for Alternative 2, but to a greater extent because of the larger number of sites. Benefits to riparian vegetation would be similar to those described in Alternative 2 with a larger area of riparian plantings and greater number and extent of stressors removed at Alternative 3 sites.

5.2.1.4 *Alternative 4 – 3 Sites*

This alternative would remove 28,860 feet of shoreline stressors and restore 2,101 acres of tidal wetlands, which would promote the ecosystem structures and functions provided by wetlands, kelp and eelgrass beds, and riparian vegetation. In general, there are fewer construction impacts associated with Alternative 4, but not as extensive long-term benefits due to having fewer sites.

Marine Submerged Vegetation
Eelgrass and kelp beds occur at Duckabush site and downstream from the Nooksack site in patchy and some continuous distributions. Construction impacts would be similar to those described for Alternative 2, but to a lesser extent due to the smaller number of beds and the smaller scale of construction. Benefits would be of similar types to those described for Alternative 2, with less total benefit achieved since shorter stressor length would be removed.

Wetlands
Construction impacts on wetlands would be similar to those described for Alternative 2, but to a lesser extent due to less area of freshwater wetlands being inundated with saltwater. Benefits would be similar to those described for Alternative 2, but would occur across a smaller area since there would be less area of tidal wetlands restored for Alternative 4.

Riparian Vegetation
Two of the three sites include removal of invasive species and/or revegetation of riparian areas with native shrubs and trees. The negligible construction impacts to riparian vegetation would be similar to those described for Alternative 2, but to an even lesser extent due to having fewer sites. Benefits to riparian vegetation would be similar to those described in Alternative 2, but across a smaller area of riparian plantings and less extent of stressors removed for Alternative 4.

5.2.2 Shellfish and other Macroinvertebrates

5.2.2.1 *Alternative 1 – No-Action Alternative*

Under Alternative 1, invertebrate communities on the human-made structures at the proposed sites would continue to be dominated by opportunistic, tolerant species, such as tube worms, barnacles, mussels, snails, and ascidians. Native clams, oysters, and other bivalves would be limited by lack of habitat due to the diking and filling of embayments, sub-optimal substrate due to interruption of sediment flow by shoreline armoring, and siltation caused by urban and agricultural run-off.

5.2.2.2 *Alternative 2 – 11 Sites*

Construction impacts on invertebrate communities would come from increases in turbidity and physical disturbance during beach regrading at one of the sites, dredging at one of the sites, and the removal of stressors in intertidal areas at all 11 sites. Removal of bridge pilings, abutments, and shoreline armoring, and the installation of water-isolation devices would be necessary at nearly all of the sites. These actions would have the short-term impact of disrupting or destroying benthic and epibenthic invertebrates. Once the stressors are gone, invertebrate colonization would follow a pattern of succession, with near complete recovery in one to three years (Hueckel and Buckley 1987, Martin 2012 pers. comm.) The 5,523 acres of restored habitat (which includes aforementioned tidal wetlands as well as beaches that would be restored) would transition to communities that include amphipods, isopods, and oligochaete and sabellid worms, as well as insect larvae in more freshwater areas. Invertebrate density and diversity would likely increase as the restored sites transition to native estuarine marsh vegetation. A variety of invertebrates in the higher salinity areas of embayments and beaches, including native clams, oysters, snails, and cancer crabs would benefit from increased sediment delivery (leading to more suitable substrate) and additional habitat provided by the removal of shoreline armor and tidal barriers. Upper inter-tidal and back-beach invertebrates, such as beach hoppers, would benefit from removal of shoreline armoring and planting of riparian vegetation. Restored areas adjacent to eelgrass beds may serve to increase the size and quality of these beds, thus increasing habitat for nudibranchs, shrimp, crabs, jellyfish, and anemones.

5.2.2.3 *Alternative 3 – 18 Sites*

Construction impacts on invertebrate communities of Alternative 3 would be similar to those described for Alternative 2, but to a greater extent due to the larger number and scale of sites and therefore more bottom disturbance. Likewise, benefits would be similar to those under Alternative 2, but more so with Alternative 3 because it restores more acreage of intertidal habitat for invertebrates to colonize.

5.2.2.4 *Alternative 4 – 3 Sites*

Construction impacts on invertebrate communities at the three sites of Alternative 4 would be similar to those described for Alternative 2, but to a lesser extent due to fewer sites and therefore less substrate disturbance. Likewise, benefits would be similar to those under Alternative 2, but less so with Alternative 4 because it restores less total acreage of intertidal habitat for invertebrates to colonize. The Nooksack River Delta site will be designed to minimize water quality impacts from directing water from the Nooksack River into the Lummi River because highly valuable shellfish beds are in the estuary downstream from the Lummi River. Similarly, short-term and long-term effects of sediment to shellfish habitat at the Duckabush estuary will be minimized through design.

5.2.3 Fish

5.2.3.1 *Alternative 1 – No-Action Alternative*

The severe lack of functioning beaches is inhibiting support for beach spawning forage fish. The present fish populations would continue to use beach habitat that is degraded due to shoreline armoring effects on sediment dynamics, which in turn affect beach profiles and marine vegetation that provide valuable nursery and foraging habitat, as well as estuaries that provide rearing, foraging, and refuge habitat where dikes and causeways severely limit tidal hydrology.

Demersal/Benthic Fish

Many demersal/benthic fish species would not be affected by the persistence of stressors along the shoreline at the project sites. Much of the rocky habitat occupied by reef dwelling fish, such as rockfish and lingcod, has not undergone significant change and is not present at any of the sites. The exceptions are fishes that use estuaries and softer substrate, such as flounder and certain sculpin species, and rockfish species that use kelp and eelgrass beds as nurseries for juveniles. These species would continue to be displaced by shoreline stressors such as tidal barriers, fill, and shoreline armoring.

Forage Fish
Forage fish would continue to be negatively affected by suboptimal habitat at the project sites, particularly since their spawning habitats on beaches and submerged vegetation are altered by shoreline stressors that hamper processes such as sediment delivery and nutrient transport. Although other restoration actions that benefit forage fish are likely to occur, these would not likely be the large-scale process-based efforts as proposed in this feasibility study.

Anadromous Fish
Under the No-Action Alternative, anadromous fish would continue to be limited by a lack of suitable habitat caused by the loss or modification of the shoreline. Bulkheads and over-water structures would continue to decrease shallow water habitat for migration, and diking and filling of estuarine habitat would limit rearing and spawning. Although many programs in Puget Sound and its associated river basins benefit salmonids, these would not be the large-scale program that restores ecological processes as proposed in this feasibility study and there would be no opportunity for synergistic benefits provided by multiple restoration programs in the region. The No-Action Alternative would maintain the status quo of stagnant or declining acreage of salmon habitat and would fail to assist with the recovery of these populations.

5.2.3.2 *Alternative 2 – 11 Sites*

Under Alternative 2, fish communities would see some short-term negative but primarily long-term positive effects. Negative effects would come from construction activities causing 1) increases in turbidity from excavation of fill and dikes and dredging, and 2) noise and vibration associated with pile and/or sheet-pile driving, dredging, and large equipment operation for excavation and demolition. See section 5.1.8 for a more detailed analysis of how noise might affect fish species. Elevated levels of turbidity could cause physiological damage to gills, and elevated noise could cause a behavioral response to flee or delay migration. Working within designated periods when fish are less likely to be present and during low tides would minimize effects of noise and turbidity on fish. The positive effects of Alternative 2 would vary among fish categories and among sites; details are discussed below.

Demersal/Benthic Fish
Most reef-dwelling fish, such as rockfish and greenlings, would not be affected by the proposed actions since none of the actions occur where there is substantial reef habitat. Predatory fish like lingcod that are typical of reef habitats that feed heavily on forage fish (Beaudreau 2009) would benefit from increases in habitat for those forage fish species (discussed in the following section). Juvenile rockfish species that use kelp and eelgrass beds as nurseries would benefit

from improvement to these habitat types. Several of the sites are located in river deltas, embayments, and beaches where there is finer substrate. Fish that occupy this habitat, such as flounder and certain species of sculpin, would benefit from the removal of tidal barriers and armoring, thus expanding brackish areas (5,517 acres) for foraging.

Forage Fish

Forage fish species that use beaches and submerged aquatic vegetation for spawning, such as sand lance and herring, would benefit from restored sites where 115,718 feet of armoring, tidal barriers, and other nearshore structures that inhibit sediment delivery and nutrient transport would be removed. Forage fish that use river deltas, such as longfin smelt and eulachon, would benefit from restored sites where tidal barriers would be removed, leading to an increase in spawning and foraging habitat. These benefits to forage fish would also benefit species in higher trophic levels since the forage fish are a preferred prey item for a variety of nearshore species.

Anadromous Fish

Anadromous fish, particularly salmonids, would benefit from restored sites where armoring, tidal barriers, and fill in river deltas, embayments, and beaches would be removed. Removal of shoreline armoring would result in 1) more shallow water habitat used for juvenile migration (particularly Chinook and chum), 2) a potential increase in eelgrass beds that are used by juvenile salmonids (mostly Chinook and chum) as nurseries for holding and rearing, and 3) more suitable spawning beaches and kelp and eelgrass beds for forage fish that are preferred prey of salmon. Removal of tidal barriers would result in 5,517 acres of restored tidal wetlands for juvenile rearing and foraging. Other anadromous species, such as sturgeon and anadromous forage fish, would also benefit from this estuarine habitat.

5.2.3.3 *Alternative 3 – 18 Sites*

Negative effects from construction would be more disruptive to fish communities than under Alternative 2 due the greater number and scale of the sites under this alternative, which requires removal of more roads and levees, construction of more levees, more raising of roads, and more bridge building. A greater number of sites in Alternative 3 would require dredging, excavation of fill, and pile and/or sheet-pile driving, causing greater increases in turbidity, noise, and vibration than Alternative 2.

Beneficial effects to fish communities would be similar to those discussed for Alternative 2, although to a greater extent. This is due to 1) more tidal wetlands restored for rearing and foraging, 2) more spawning and foraging habitat for forage fish species (a preferred prey item of salmon) because of more shoreline stressor length removed, and 3) more benefit to kelp and eelgrass beds that provide juvenile rearing habitat.

5.2.3.4 *Alternative 4 – 3 Sites*

Negative effects from construction would be substantially less disruptive to fish communities than under Alternatives 2 and 3 due the smaller number and scale of the sites under this alternative, which requires removal of fewer roads and levees, construction of fewer levees, less raising of roads, and less bridge building. Fewer sites in Alternative 4 would require dredging, excavation of fill, and are not likely to include any pile and/or sheet-pile driving, causing fewer short-term increases in turbidity, noise, and vibration than Alternatives 2 and 3.

Beneficial effects to fish communities would be similar to those discussed for Alternative 2, although to a lesser extent. This is due to 1) less tidal wetlands restored for rearing and foraging, 2) less spawning and foraging habitat for forage fish species (a preferred prey item of salmon) because of less shoreline stressor length removed, and 3) less benefit to kelp and eelgrass beds that provide juvenile rearing habitat. Alternative 4 does not include any beach restoration sites, primarily due to a lack of willing landowners; therefore, there is no opportunity for benefits to the beach-spawning forage fish in this alternative.

5.2.4 Birds

5.2.4.1 *Alternative 1 – No-Action Alternative*

Birds at the project sites would continue to be limited by lack of suitable estuarine tidal flats and eelgrass beds that provide foraging habitat. Loss of habitat for bird prey, including forage fish, juvenile salmonids, a variety of invertebrates, and marine vegetation would affect species such as great blue herons, dunlins, sandpipers, and brandts. Opportunistic species like gulls, Canada geese, and crows would continue to flourish at the sites due to their adaptation to the human environment. Migratory species that use the agricultural fields in the winter are likely to continue to be populous, assuming there is no future urbanization in those areas.

5.2.4.2 *Alternative 2 – 11 Sites*

Construction activity including pile driving, demolishing roads and bridges, and hauling off large amounts of material would cause temporary disturbances to bird communities due to noise (both airborne and underwater) and the presence of heavy equipment. See section 5.1.8 for more details on how underwater noise may affect diving birds. These disturbances would likely cause a behavioral response to flee the area. Best management practices, such as working outside of the nesting season, would minimize these impacts. At several sites, agricultural areas would be flooded due to removal of tidal barriers. These areas are often used heavily by migratory species; allowing tidal flow to enter would likely lead to a transition from communities dominated by snow geese and trumpeter swans (which are not habitat limited in the Puget Sound region) to a wider variety of species like goldeneye, sandpipers, wigeons, scaups, and brandts that are associated with saltwater habitats. Freshwater marshes that would be flooded with brackish water would transition from species like mallards and pintails to the saltwater species mentioned previously. A variety of birds that depend on forage fish and juvenile and adult salmon would greatly benefit from restored sites where these fishes' habitats (including marshes, eelgrass beds, and spawning beaches) are increased.

5.2.4.3 *Alternative 3 – 18 Sites*

Construction effects on bird communities would be similar to those described for Alternative 2, but to a greater extent due to the larger number and scale of the sites. Transitions to bird communities that are more indicative of saltwater in agricultural areas and freshwater areas are expected under this alternative as well; however, the benefits to shorebirds and waterfowl would be greater than Alternative 2 since there would be more acreage of tidal wetland creation or improvement for their use and to support their prey.

5.2.4.4 *Alternative 4 – 3 Sites*

Construction effects on bird communities would be similar to those described for Alternative 2, but to a lesser extent due to fewer sites. Transitions to bird communities that are more indicative of saltwater in agricultural areas and freshwater areas are expected at the North Fork site. Overall benefits to shorebirds and waterfowl would be the same types of habitats as Alternatives 2 and 3 but would have a lesser extent as there would be less acreage of tidal wetland creation or improvement for their use and to support their prey.

5.2.5 Marine Mammals

5.2.5.1 *Alternative 1 – No-Action Alternative*

Marine mammals dependent on prey that use the nearshore zone would continue to be limited by the lack of suitable habitat for those prey. This would particularly affect the Southern Resident killer whales, which feed preferentially on Chinook and chum salmon. Fill, dikes, and shoreline armoring at the project sites limit the area and quality of haul-out locations for harbor seals.

5.2.5.2 *Alternative 2 – 11 Sites*

The primary impacts to marine mammals would result from noise disturbances caused by pile and/or sheet-pile driving, which could cause behavioral response such as fleeing, interfere with ability to locate prey, or result in physiological damage. See section 5.1.8 for a more detailed analysis of how noise may affect marine mammals. All of the sites requiring pile driving are located in shallow embayments and river deltas, and this activity would predominantly occur during low tides to minimize underwater noise. Harbor seals are the marine mammal most likely to be affected by noise due to their ubiquitous distribution in Puget Sound and their tendency to swim into river deltas and embayments, where most of the sites are located. With the exception of Deer Harbor, Southern Resident killer whales are not likely to occur in the project areas during pile driving since it would occur during designated work periods when the killer whales are concentrated around the San Juan Islands and southern Vancouver (Hauser 2007, Kriete 2007). Transient killer whales are only intermittent visitors of Puget Sound so the likelihood is low that this pile driving would harm them. Other cetaceans, including baleen whales and porpoises require deeper water than what occurs at the project sites, so they have a low likelihood of encountering pile driving, especially if it occurs during low tides. Elevated turbidity could cause temporary displacement of marine mammals as well, likely those that occur in shallower water, such as harbor seals.

Long-term benefits to marine mammals would be closely tied to the benefits provided to their prey, including increased habitat for forage fish and salmonids (discussed in previous sections). Southern Resident killer whales would likely gain the most benefits from restoring processes that increase habitat for Chinook and chum salmon. Other marine mammals like porpoises, sea lions, and seals would benefit as well, but to a lesser extent since their diet consists of a wider variety of fish, some of which are not nearshore dependent. For example, harbor seals feed preferentially on herring from December through March, but generally select hake for the remainder of the year (Olesiuk 1993), which is not a nearshore-dependent species. Other benefits include better beach habitat for harbor seal haul-out due to the removal of shoreline armoring, and increased foraging habitat due to the removal of tidal barriers.

5.2.5.3 *Alternative 3 – 18 Sites*

Negative effects to marine mammals would be similar to those discussed for Alternative 2, but to a greater extent because of the larger number and scale of sites that require pile driving, and the closer proximity to summertime Southern Resident killer whale distribution. Benefits to marine mammals that feed on nearshore-dependent species would be more than Alternative 2, as Alternative 3 restores substantially more tidal wetlands that support their prey and removes a great deal more shoreline stressors. This would mean more foraging area for pinnipeds, particularly harbor seals, under Alternative 3, which includes a second beach restoration site with its potential as a harbor seal haul-out site.

5.2.5.4 *Alternative 4 – 3 Sites*

Negative effects would be similar to Alternative 2, but to a much smaller extent due to the smaller number and scale of sites with construction in marine habitat. Only Duckabush would have noise or turbidity in an estuary adjacent to marine mammal habitat. Benefits to marine mammals that feed on nearshore-dependent species would be less than Alternatives 2 and 3, as those restore substantially more tidal wetlands that support marine mammal prey items. This would mean less benefit to foraging area for pinnipeds, particularly harbor seals, under Alternative 4, which does not include any beach restoration sites.

5.2.6 Invasive Species

5.2.6.1 *Alternative 1 – No-Action Alternative*

Under the No-Action Alternative, invasive species would continue to exploit human-made structures at the project sites and out-compete native species.

5.2.6.2 *Alternative 2 – 11 Sites*

The proposed sites have not been surveyed for invasive species. If invasive species are present, removal of human-made structures paired with revegetation efforts would lead to repopulation with native species that are more likely to colonize the estuarine and beach habitat.

5.2.6.3 *Alternative 3 – 18 Sites*

Effects of this alternative would be similar to those described for Alternative 2, but to a greater extent due to removal of substantially longer linear footage of human-made structures.

5.2.6.4 *Alternative 4 – 3 Sites*

Effects of this alternative would be similar to those described for Alternatives 2 and 3, but to a lesser extent due to removal of substantially less linear footage of human-made structures.

5.2.7 Rare, Threatened, and Endangered Species

Many of the species discussed in section 3.2.7 occur at the 18 sites analyzed in this document. Table 5-9 summarizes the federally threatened and endangered species associated with all 18 of the proposed project sites (USFWS 2012).

5.2.7.1 *Alternative 1 – No-Action Alternative*

ESA-listed species at the sites would continue to be limited by shoreline stressors that impede natural, habitat-forming processes. These inhibited processes have implications that ascend trophic levels. Chinook, Hood Canal chum, steelhead, and bull trout would continue to be limited by sub-optimal rearing and foraging habitat at the site locations, as well as lack of suitable habitat for prey species like forage fish. Southern Resident killer whales, which are dependent on these salmonids, would, by trophic association, also be limited by this lack of habitat. ESA-listed rockfish would not likely be affected, since they are typically associated with rocky substrate in deeper water and are more vulnerable to fishing pressure than shoreline stressors. However, the persistence of stressors that inhibit processes necessary for healthy kelp and eelgrass beds, which serve as nurseries, may continue to limit juvenile rockfish.

5.2.7.2 *Alternative 2 – 11 Sites*

Construction impacts on rare, threatened, and endangered species would be similar to those discussed for fish, mammals, and birds in previous sections. Primary impacts would be elevated turbidity from excavation, and noise and vibration associated with pile driving. Both of these impacts could cause a behavioral response of fleeing or delayed migration, and/or physiological damage. These impacts would be minimized by adhering to the conservation measures recommended by USFWS and NMFS, including working during designated periods when ESA-listed species are least likely to be present and during low tides.

Positive effects on ESA-listed species would be similar to those discussed for fish, birds, and mammals in previous sections. The removal of stressors along over 70 miles of shoreline at these 11 sites would increase habitat-forming processes for many ESA-listed species, leading to responses at many trophic levels. Removing tidal barriers, fill, and armoring would increase foraging and rearing habitat for juvenile salmonids (5,517 acres of tidal wetlands), as well as increase sediment delivery and nutrient transport to encourage spawning of forage fish (an important prey item for salmon) on beaches and kelp and eelgrass beds. Eulachon are present at two of the 11 sites and would see habitat benefits from restoration. Improvements in kelp and eelgrass beds would provide better nurseries for juvenile ESA-listed salmonids and rockfish. Removal of shoreline armoring would increase sediment delivery for forage fish spawning and create shallow water habitat for the migration of juvenile Chinook salmon. These improvements in habitat for forage fish and salmon would lead to an increase in prey base for marbled murrelet, humpback whales, and Southern Resident killer whales. This alternative has no sites in Hood Canal; therefore, ESA-listed summer chum here would not see benefits.

Table 5-9. Federally Listed Threatened and Endangered Species and Critical Habitat Occurring in or around the Project Sites

Project Site	Bocaccio	Canary Rockfish	Yelloweye Rockfish	Eulachon	Hood Canal Summer Chum		Puget Sound Chinook Salmon		Coastal/ Puget Sound Bull Trout		Puget Sound Steelhead	Green Sturgeon	Southern Resident Killer Whale		Humpback Whale	Marbled Murrelet	Golden Paint Brush
					Sp	CH	Sp	CH	Sp	CH			Sp	CH			
Beaconsfield Feeder Bluff	x	x	x				x	x	x	x	x		x		x	x	
Deepwater Slough							x	x	x	x	x						
Deer Harbor Estuary	x	x	x	x			x	x			x	x	x	x	x	x	
Dugualla Bay	x	x	x				x	x	x	x	x		x			x	
Everett Marshland							x	x	x	x	x						
Livingston Bay	x	x	x				x	x	x	x	x		x			x	
Milltown Island							x	x	x	x	x						
Nooksack River Delta				x			x	x	x	x	x	x	x	x	x	x	
North Fork Skagit River Delta							x	x	x	x	x		x[1]	x[1]			
Spencer Island							x	x	x	x	x						
Telegraph Slough	x	x	x				x	x	x	x	x						
Big Beef Creek Estuary	x	x	x		x	x	x	x	x		x		x		x	x	
Duckabush River Estuary				x	x	x	x	x	x	x	x		x		x	x	
Harper Estuary	x	x	x				x	x	x	x	x		x		x	x	
Point Whitney Lagoon	x	x	x	x	x	x	x	x	x	x	x		x		x	x	
Snow Creek and Salmon Creek Estuary	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Tahuya River Estuary	x	x	x		x	x	x	x	x	x	x		x		x	x	
WDNR Budd Inlet Beach	x	x	x				x	x	x		x		x			x	

Sp-species, CH-critical habitat. If CH is not listed underneath a given species then it is not present at any of the project sites.

Note 1: Only prey items of Southern Resident Killer Whale are present.

Other species that are rare but not ESA-listed include Coho salmon, northern abalone, sea otters, California buttercup, and sharpfruited peppergrass. While Coho salmon would certainly benefit from the increased rearing habitat, the other species are not likely to be affected since they tend to occupy rocky shorelines.

5.2.7.3 *Alternative 3 – 18 Sites*

Construction effects to ESA-listed species would be similar to those for Alternative 2, but to a greater extent due to the larger number and scale of the sites and their locations. Alternative 3 has more sites in Hood Canal and in northern Puget Sound, where there tends to be higher numbers of ESA-listed species because of the proximity to the Strait of Juan de Fuca and Strait of Georgia with their greater biodiversity. Since Hood Canal summer chum, eulachon, and green sturgeon are present at more sites in this alternative, they see more impacts from construction activities; conversely, they would gain more long-term benefits. Benefits to other species would be similar to those discussed for Alternative 2 but to a greater degree due to substantially more acreage of restored tidal wetlands and much longer length of shoreline stressors removed. Project sites in Hood Canal and southern Puget Sound where wetlands would be restored could improve water quality for Olympia oysters (a depleted species that were once common in Puget Sound), as results of this project combine synergistically with results of other recovery efforts.

5.2.7.4 *Alternative 4 – 3 Sites*

Construction impacts to ESA-listed species located in or near the three sites of this alternative would be similar to those discussed for Alternatives 2 and 3, such as elevated turbidity from excavation, and noise and vibration associated with pile driving; although, the only pile driving for this alternative is for testing and pile removal and would therefore be quieter. Impacts could cause a behavioral response of fleeing or delayed migration, and/or physiological damage. These impacts would be minimized by adhering to the conservation measures recommended by USFWS and NMFS, including working during designated periods when ESA-listed species are least likely to be present and during low tides. Table 5-10 provides a summary of the effects determinations at each of the three sites in Alternative 4. Details and rationale for these determinations were provided to NMFS and USFWS in Specific Project Information Forms as part of the Section 7 consultation process. In each case where a "Likely to Adversely Affect" determination has been made, this is due to short-term construction impacts, which will be outweighed by the long-term benefits of the project. The ESA consultation documents appear in Appendix J.

Positive effects on ESA-listed species would be similar to those of Alternatives 2 and 3, but to a lesser extent due to having only three sites in Alternative 4. This alternative removes over 5 miles of shoreline armoring that inhibits the natural processes that support habitat development for the ESA-listed species at these sites. Unlike Alternative 2, this alternative includes the Duckabush River Estuary site in Hood Canal, which would benefit Hood Canal summer chum.

Table 5-10. Summary of effects determinations for ESA-listed species and their critical habitat associated with the proposed restoration sites of Alternative 4.

	Duckabush Estuary	Nooksack River Delta	North Fork Skagit River Delta
Bocaccio	NE	NE	NE
Canary Rockfish	NE	NE	NE
Yelloweye Rockfish	NE	NE	NE
Eulachon	NE	NE	NE
Hood Canal Summer Chum	LAA	LAA	LAA
critical habitat	NLAA	NLAA	NLAA
Puget Sound Chinook Salmon	LAA	LAA	LAA
critical habitat	NLAA	NLAA	NLAA
Coastal/Puget Sound Bull Trout	LAA	LAA	LAA
critical habitat	NLAA	NLAA	NLAA
Puget Sound Steelhead	LAA	LAA	LAA
Green Sturgeon	NE	NE	NE
Southern Resident Killer Whale	NLAA	NLAA	NLAA
critical habitat	NLAA	NLAA	NLAA
Humpback Whale	NE	NE	NE
Marbled Murrelet	NLAA	NE	NE
Spotted Owl	NE	NE	NE
Golden Paintbrush	NE	NE	NE

NE = No Effect; NLAA = Not Likely to Adversely Affect; LAA = Likely to Adversely Affect

5.3 CULTURAL RESOURCES

Effects to cultural resources and historic properties are discussed in the context of the regulations implementing Section 106 of the National Historic Preservation Act (NHPA)(36 CFR 800). Section 106 requires Federal agencies to take into account the effects of their actions on historic properties. Historic properties are cultural resources that are eligible for listing or listed on the National Register. As described in section 3.3, cultural resources at a minimum must be 50 years old or older to be considered eligible for the National Register, although more recent properties with exceptional significance may be considered. Each of the 18 proposed sites was analyzed for its potential to affect cultural resources. The analysis is broken down broadly by the categories of places or properties for which specific information exists in the available records or has been provided through consultation: prehistoric and historic archaeological resources, and historic buildings and structures.

5.3.1 Archaeological Resources

The geographical areas identified in this study for nearshore restoration overlaps with those areas that were used by native populations for village locations, resource gathering areas, and other uses; therefore, there is a high probability of encountering cultural resources in any nearshore restoration sites, not just those identified in these three action alternatives.

5.3.1.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would have no immediate effect on prehistoric archaeological resources. Artificial and natural processes may continue to erode and deteriorate known archaeological resources, while exposing previously undiscovered sites and isolated artifacts. No change would occur in the management condition of archaeological resources; Federal actions or undertakings would continue to be reviewed in accordance with Section 106 of the NHPA. Even without implementing nearshore restoration described in the subsequent action alternatives, there will continue to be significant risks of loss of cultural resources resulting from development, natural processes, and recreation.

5.3.1.2 *Alternative 2 – 11 Sites*

This alternative has a significant potential to impact prehistoric archaeological resources, although not as great as Alternative 3 because there are fewer restoration sites. For the 11 restoration sites included in the TSP, cultural resource surveys have been conducted within portions of ten sites. The exception is the Beaconsfield Feeder Bluff site. Six of the restoration sites contain previously recorded archaeological sites. Of the 28 previously recorded archaeological sites within the TSP, only one is eligible for listing on the NRHP; the remaining 27 archaeological sites are unevaluated. Deer Harbor contains one lithic scatter site. Dugualla Bay contains six shell midden sites. Livingston Bay contains one shell midden site. The Nooksack River Delta restoration site contains 13 unevaluated archaeological sites ranging from shell middens, and lithic scatters and a historic debris scatter (Table 5-11). The North Fork Skagit River Delta contains five previously recorded archaeological sites, and one archaeological district is located either within or directly adjacent to the restoration site. These sites include a pre-contact habitation site that is a contributing element to Fishtown Archaeological District located adjacent to the restoration site with the remainder identified as shell middens (See Table 5-11). The Everett Marshland site contains one lithic scatter. The Spencer Island site contains a shell midden along the eastern border of the project area.

The locations of most of the proposed sites present a moderate to high potential for archaeological resources to exist, as Native American Tribes often constructed village locations at the confluences of streams and rivers. A comprehensive inventory and National Register evaluation of all prehistoric archaeological resources and traditional cultural properties at each site would need to be completed in PED; inventory work for each site should be conducted no more than five years in advance of construction. The Corps would consult with the SHPO and other interested parties regarding identification and evaluation strategies, and develop and implement mitigation measures prior to construction where adverse effects could not be avoided. During preparation of the Draft FR/EIS, the Corps initiated NHPA Section 106 consultation on Alternative 2 (the TSP). Since then, the recommended plan changed to Alternative 4 (see below). With the exception of the Nooksack River Delta and the North Fork Skagit River Delta (Alternative 2 sites in common with the recommended plan), any of the restoration sites that may be carried forward from Alternative 2 under other authorities would undergo their own Section 106 consultation should they become authorized (see Alternative 4 below for the PA process).

5.3.1.3 *Alternative 3 – 18 Sites*

This alternative has a significant potential to impact prehistoric archaeological resources. This alternative contains seven additional restoration sites (Big Beef Creek Estuary, Duckabush River Estuary, Harper Estuary, Point Whitney Lagoon, Snow Creek and Salmon Creek Estuary, Tahuya River Estuary and WNDR Budd Inlet Beach) compared to Alternative 2. Of these seven additional sites, all but one (Point Whitney Lagoon) have had previous cultural resource surveys conducted within portions of the restoration sites. One archaeological site (remnants of a historic fence and fruit tree) has been recorded in the Duckabush River Estuary but has not been formally evaluated (See Table 5-11). A comprehensive inventory and National Register evaluation of all prehistoric archaeological resources and traditional cultural properties at each site would need to be completed; inventory work for each site should be conducted no more than five years in advance of construction. The Corps initiated consultation on the 18 sites, but has not fully consulted on any of the sites in this alternative other than the three in the preferred alternative. The Corps would consult with the SHPO and other interested parties regarding future identification and evaluation strategies, and develop and implement mitigation measures as identified in the PA prior to construction where adverse effects could not be avoided.

5.3.1.4 *Alternative 4 – 3 Sites*

As with the other two action alternatives, this alternative has significant potential to impact prehistoric and historic archaeological resources. All three sites have had previous cultural resource surveys conducted within portions of the restorations sites. In addition, all three locations contain previously recorded archaeological sites and have a high potential for containing additional unrecorded archaeological sites. The majority of the previously recorded archaeological sites have not been formally evaluated for the National Register. Table 5-11 lists the known archaeological sites that are located in each of the three proposed restoration sites of the Recommended Plan.

The Corps has prepared a Programmatic Agreement (PA) outlining the Section 106 process that will be followed (Appendix D). The PA includes which Section 106 tasks need to occur prior to construction (e.g. fieldwork), how Section 106 consultation will occur, how determinations of eligibility will be made, how findings of no adverse effect will be determined, how findings of adverse effects will be made, and how the PA will be implemented, and a dispute resolution procedure. In addition, the PA provides for a variety of treatment measures that can be used for mitigation of an adverse effect (See Appendix E of the PA). The treatment measures are standard types of mitigation actions used for adverse effects and the costs of these treatment measures have been taken into account during cost estimation for this project.

Table 5-11. Known archaeological sites located in the Nooksack River Delta, North Fork Skagit River Delta, and Duckabush Estuary proposed restoration sites.

Site Number*	Description	NRHP Eligibility	Location	Potential Effect to Resource Based on Current Design**
Nooksack River Delta Archaeological Sites				
45SH27	Pre-contact shell midden; Pre-Contact burial	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH170	Pre-contact shell midden; Historic trash scatter	Unevaluated	In project area	Unknown at this time
45WH526	Pre contact shell midden- possible village	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH723	Pre-contact shell midden; pre contact burial	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH734	Pre-contact lithic scatter	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH742	Pre-contact isolate	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH847	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH848	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH862	Pre-contact shell midden; Historic trash scatter	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH863	Pre-contact lithic scatter	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH896	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH907	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH908	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design
North Fork Skagit River Delta Archaeological Sites				
Fishtown Archaeological District 11	*Sqwikwikwab,* ethnohistoric village and historic town site	Eligible	Adjacent to project area	Appears that it will be affected based on current project design
45SK34	Pre-contact habitation site	Eligible: Part of archaeological district (DT11)	Extends into project area	Appears that it will be affected based on current project design
45SK35	Pre-contact shell midden site	Unevaluated	In project area	Appears that it will be affected based on current project design
45SK78	Pre-contact shell midden site	Unevaluated	Just outside of project area	Appears that there will be no effect based on current project design
45SK80	Cave with pile of shell	Unevaluated	Adjacent to project area	Appears that there will be no effect based on current project design
45SK87	Pre-contact shell midden site	Unevaluated	In project area	Appears that it will be affected based on current project design
Duckabush Estuary Archaeological Sites				
45JE362	Duckabush Orchard	Unevaluated	In project area	Potentially affected

*Location of sites is based on information from the DAHP database and site form data. Note existing site boundaries have not been field verified for this project.

**Project designs could change in PED. The effect or lack of effect to the resources is based on the current information to date and is subject to change if project designs change.

Signatories to the PA include the Corps, the Washington SHPO, the ACHP, WDFW, and the Lummi Nation. The Lummi Nation is a signatory due to the Nooksack restoration project extending onto the reservation and because the Lummi Nation has a recognized Tribal Historic Preservation Officer (THPO) who has assumed the responsibilities of the State Historic Preservation Officer (SHPO) on tribal lands. The Washington Department of Transportation (WSDOT) is an invited signatory due to their interest in the Duckabush Bridge located in the Duckabush restoration site. For any other sites that receive authorization and funding, these will undergo a separate consultation process for compliance with NHPA.

5.3.2 Historic Buildings and Structures

5.3.2.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would have no immediate effect on historic buildings and structures. The built environment at sites, however, would not remain static but would continue to evolve. Adverse impacts unrelated to the Federal action that are expected to occur to some buildings and structures include non-compatible modifications, deterioration due to neglect, abandonment, and possible damage from flooding or other natural disasters. Other buildings and structures will likely be maintained and/or restored in manners consistent with the Secretary of Interior's guidelines and standards for the treatment of historic properties. The number of potential historic properties will increase as buildings and structures reach the 50-year hallmark for National Register consideration. There would be no change in the current management condition affecting historic buildings and structures; Federal actions or undertakings would continue to be reviewed in accordance with Section 106 of the NHPA.

5.3.2.2 *Alternative 2 – 11 Sites*

This alternative has potential for significant impact on historic buildings and structures. Nine of the restoration sites contain previously recorded historic structures as well as historic structures not currently recorded but known to exist. Livingston Bay contains four previously inventoried historic structures: these include the John P. and Annie Larson Farm (eligible to the NRHP), the John Hanson House (requires further evaluation), and two non-eligible structures. Dugualla Bay contains the Dugualla Lake dike and pumping system, which was reportedly constructed in the 1910s to 1920s. Deepwater Slough contains the Deepwater Slough levee system. The levee system has been recommended ineligible for inclusion on the NRHP; however, the levee system has not been formally evaluated. The Nooksack River Delta site contains 13 previously inventoried historic properties located either within the restoration site area or directly adjacent to it. Of the 13 properties, five have been determined not eligible, six are unevaluated and finally, the Marietta/Custer Grange Hall located just outside of the Nooksack River Delta area is eligible to the NRHP. The North Fork Skagit River Delta site contains an unevaluated historic granary, the unevaluated Skagit levee, and an historic farming complex that contains a barn listed on the Washington Heritage Barn Register. Two sites included in this alternative (Spencer Island and Telegraph Slough) contain levees. The Spencer Island levees have been inventoried but will need to be formally evaluated. The Telegraph Slough levees will need to be inventoried and evaluated. The Everett Marshland site contains a historic barn, a historic bridge proposed for removal, and the Marshland Dike and Ditch System (recommended ineligible but not formally evaluated). Finally, the Milltown Island site contains a dike that has been recommended ineligible to NRHP but has not been formally evaluated. As with the archaeological sites mentioned in section 5.3.1.3, the restoration sites in this alternative, with the exception of the Nooksack River Delta and the North Fork Skagit River Delta, would undergo their own Section 106 consultation, which would include a comprehensive inventory and National Register evaluation of all built-environment resources at each site. Potential adverse impacts to National Register-eligible historic buildings and structures would be mitigated as appropriate through the Section 106 process. For the Nooksack River Delta, the North Fork Skagit River Delta, and the Duckabush River Estuary restoration sites, the Corps has prepared a PA outlining the Section 106 process that will be followed (see 5.3.1.4 for the PA process).

5.3.2.3 *Alternative 3 – 18 Sites*

Alternative 3 has greater potential impact on historic buildings and structures due to having more proposed sites. Alternative 3 contains the same historic properties as Alternative 2 but includes more historic resources at four additional sites. Four of the restoration sites in this alternative contain either previously recorded historic structures or historic structures not currently recorded but are known to exist. The Duckabush site contains the Highway 101 causeway, including two bridges. Of the two bridges on the causeway, one (the Duckabush Bridge) is listed in the NRHP. The second bridge has been inventoried and recommended ineligible but has not been formally evaluated. The Snow Creek and Salmon Creek Estuary contains a possible mill site, sections of Highway 101, and an abandoned segment of the Port Angeles & Western railway. The Tahuya River Estuary site contains a collapsed structure, a road bridge, and wood pilings. These structures have been inventoried but not formally evaluated. In addition, based on the previous land use there is a high likelihood that a sawmill may be located within the restoration area. Finally, the WDNR Budd Inlet Beach site contains the previously inventoried marine station dock that has been recommended not eligible to the NRHP. This restoration site also contains a marine laboratory and concrete bulkhead that need to be inventoried.

A comprehensive inventory and National Register evaluation of all built-environment resources at each site would need to be completed; inventory work for each site should be conducted no more than five years in advance of construction. The Corps would consult with the SHPO and other interested parties regarding future identification and evaluation strategies, and develop and implement mitigation measures prior to construction where adverse effects could not be avoided. While NHPA Section 106 compliance was initiated for this alternative during preparation of the Draft FR/EIS, the process was changed when the plan was reformulated. Any of the restoration sites that may be carried forward from this alternative under different authorities would undergo their own Section 106 consultation at a future date should they become authorized. The exceptions from this alternative are the Nooksack River Delta and the North Fork Skagit River

Delta, with the addition of the Duckabush Estuary restoration site for which the Corps has prepared a PA outlining the Section 106 process that will be followed (See section 5.3.1.4 for a description of the PA).

5.3.2.4 *Alternative 4 – 3 Sites*

This alternative has significant potential to impact resources eligible for listing to the NRHP. All three sites included in this alternative have had previous cultural resource surveys conducted within portions of the restorations sites. All three locations contain additional unrecorded structures that have not yet been surveyed and evaluated. The Corps has prepared a PA outlining the Section 106 process that will be followed (See section 5.3.1.4). Table 5-12 lists the known historic structures that are located in each of the three proposed restoration sites of the Recommended Plan.

Table 5-12. Known historic structures located in the Nooksack River Delta, North Fork Skagit River Delta, and Duckabush Estuary proposed restoration sites.

Description*	Date Constructed	NRHP Eligibility	Location	Potential Effect to Resource Based on Current Design**
Nooksack River Delta Structures				
Janet's House-1816 Bayon Road, Bellingham	1930-1950	Unevaluated-WISSAARD states undetermined-SHPO	In project area	Appears that it will be affected based on current project design
Wylanoux House (Howell House)	1912	Unevaluated	On border of project area	Appears that there will be no effect based on current project design
Kwina Slough Levee	1927	Unevaluated	In project area	Appears that it will be affected based on current project design
Nooksack River Levee	1900, 1935, 1955	Unevaluated	In project area	Appears that it will be affected based on current project design
Lummi River Levee	1900	Unevaluated	In project area	Appears that it will be affected based on current project design
Jones House-1880 Marine Drive, Bellingham		Not eligible	In side project area	No effect as house has been determined not eligible
1850 Shady Lane-Historic single family residence	1950	Unevaluated	On border of project area	Appears that there will be no effect based on current project design
Scarborough-1857 Marine Drive, Marietta	1920	Not Eligible	In project area	No effect as house has been determined not eligible
White-1853 Marine Drive, Marietta	1915	Not Eligible	In project area	No effect as house has been determined not eligible
Marietta/Custer Grange Hall	1920	Eligible	Just outside project area	Appears that there will be no effect based on current project design
1835 Marine Drive-Historic single family residence	1925	Not Eligible	In project area	No effect as house has been determined not eligible
1801 Marine Drive Historic single family residence	1949	Not Eligible	In project area	No effect as house has been determined not eligible
WH207-Boundary marker	?	Marine Drive Point Roberts	In project area	Appears that there will be no effect based on current project design
North Fork Skagit River Delta Structures				
North Fork Skagit River Levee	1935	Not Evaluated	In project area	Appears that it will be affected based on current project design

45SK337	Summers Farm Barn 1885	Washington Historic Barn Register	In project area	Appears that it will be affected based on current project design
Duckabush Estuary Structures				
Duckabush River Bridge	1934	Listed on NRHP	In project area	Adverse effect with proposed removal
Northern Distributary Channel Bridge	1934	Unevaluated	In project area	Adverse effect with proposed removal

*Location of sites is based on information from the DAHP database and site form data. Note existing site boundaries have not been field verified for this project.

** Project designs could change in PED. The effect or lack of effect to the resources is based on the current information to date and is subject to change if project designs change.

5.4 SOCIO-ECONOMIC RESOURCES AND HUMAN ENVIRONMENT

This section discusses effects to the significant socioeconomic resources in the Nearshore Study area. The two periods considered when analyzing effects are the likely period of construction lasting approximately six months to two years depending on the scope of each site, and the 50-year period of analysis for ecosystem benefits. The spatial scale of analysis is different for each resource type as some effects would be Sound-wide and others would only occur at the site level.

5.4.1 Shoreline Ownership and Land Use

As described in detail in section 3.4.1, land uses around the nearshore zone include residential areas, public and private recreational properties, industrial sites, agricultural areas, aquaculture, and publicly and privately held boat launching sites among other uses. This section analyzes potential effects to properties at the proposed sites.

5.4.1.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would have no effect to shoreline ownership or land use. With no ecosystem restoration at the proposed sites, property owners may elect to install or strengthen shoreline armoring as a response to sea level change. Such modifications would further reduce natural ecosystem processes that are already degraded.

5.4.1.2 *Alternative 2 – 11 Sites*

No sites would move forward without necessary land ownership or easements in place. Three of the 11 sites are wholly or mostly in public ownership. Five of the 11 sites are wholly or mostly in private ownership. The remaining three involve a mix of public and private ownership. Many lands associated with the Nooksack River Delta are in tribal jurisdiction and would require close coordination with the Lummi Nation. Assuming landowner concerns are addressed through agreements or avoidance, project lands would become public lands or include easements to allow proposed activities to occur. Compared to Alternative 3, this alternative does not take full advantage of opportunities that could occur on public lands for high priority restoration and protection. Land use changes expected from this alternative would result from converting agricultural lands to wetlands as well. This loss is often a necessity of ecosystem restoration, due to the fertile soils provided by riverine wetlands and the historic diking for farmland. In addition, acquisition of farmland is often easier than acquisition of more densely developed areas with residences and businesses. The amount of agricultural land that would be converted is a small fraction of the total acreage for each county where the project(s) occur and the loss of crop production would likely be absorbed by other nearby farms. Any economic losses associated with this conversion of lands would be minor and insignificant at a county scale. Individual farmers would be compensated for their loss through the purchase agreement with the local sponsor.

5.4.1.3 *Alternative 3 – 18 Sites*

As with Alternative 2, no sites could move forward without necessary land acquisition or easements in place. A significant portion of all acreage involved for this alternative occurs on publicly held lands, although some private property occurs within the site design footprints. Six of the 18 sites in this alternative are wholly or mostly in public ownership. Six other sites are wholly or mostly in private ownership and the remaining six are a mix of public and private ownership. In general, the sites that are primarily in private ownership are smaller in size and complexity. Most of the larger and more complex sites encompass an even mix of public and privately owned lands. Some properties may already have easements, or may involve property acquisition, expected to occur through purchases from willing landowners.

Many of the northern sites in areas like Skagit and Snohomish counties include lands being used for agricultural purposes, which has historically been an incompatible land use with restoration activities. Loss of farmland has been a controversial subject, with local ordinances to achieve “no net loss of farmlands.” For eight of the 18 sites, agricultural land use would change to wetlands due to this restoration project. This loss is often a necessity of ecosystem restoration, due to the fertile soils provided by riverine wetlands and the historic diking for farmland. The spirit of “no net loss of farmlands” is to prevent suburban and urban development. In addition, acquisition of farmland for ecosystem restoration is often easier than acquisition of more densely developed areas with residences and businesses. The amount of agricultural land that would be converted is greater than Alternative 2, but still a small fraction of the total acreage for a given county where the project(s) occur and the loss of crop production would likely be absorbed by other nearby farms. Any economic losses associated with this conversion of lands would be minor and insignificant at a county scale. Individual farmers would be compensated for their loss during the purchasing agreement with the local sponsor.

5.4.1.4 *Alternative 4 – 3 Sites*

As with Alternatives 2 and 3, no sites would move forward without necessary land ownership or easements in place. Duckabush includes privately held, commercial, Jefferson County, and state and Federal lands (U.S. Forest Service), with public as the dominant ownership at 87% of the total site acreage. Nooksack property types include private, commercial, Whatcom County, NFS, Bureau of Indian Affairs (BIA) lands, and Lummi Nation lands. Private ownership is approximately 50% of acreage for the Nooksack site, whereas 30% is public ownership (NFS and Whatcom County) and 20% is Tribal lands held in trust or owned by Lummi Nation. Finally, property for North Fork Skagit River includes private, commercial, Skagit County, and NFS lands, with private as the dominant ownership at 97% of the total site acreage.

Each of the three sites underwent analysis for its land use and potential conversion. Conversion of farmland to wetland is less than for Alternatives 2 and 3. The North Fork Skagit River Delta site, located in Skagit County, includes five acres used for agricultural purposes. This is less than 0.005 percent of farmland in Whatcom County. Loss of farmland has been a controversial subject, with local ordinances to achieve “no net loss of farmlands.” The spirit of “no net loss of farmlands” is to prevent development. This loss is often a necessity of ecosystem restoration, due to the fertile soils provided by riverine wetlands and the historic diking for farmland. According to the Natural Resources Conservation Service (NRCS), the North Fork site is 1.8% prime farmland. The remainder of the site is comprised mainly of prime farmland if it was drained (94.9%), prime farmland if it was irrigated (0.1%), or not prime farmland (3.2%). The Duckabush River Estuary site will convert only 0.2 acres Prime and Unique Farmland and 0.2 acres of Statewide Important or Local Important Farmland, which account for less than 0.001% of farmland in Jefferson County. The Nooksack River Delta site is 43% prime farmland. The remaining 1,031.7 acres (57%) are either not prime farmland or would be prime farmland with additional modification, such as the land being drained, irrigated, or drained and either protected from flooding or not frequently flooded during the growing season. This is less than 0.01 percent of farmland in Whatcom County. These areas would be converted to wetlands or other habitat type after construction of the restoration project given the small fraction of the total farm acreage conversion for a given county where the projects occur, impacts would be minor and insignificant. Individual farmers would be compensated for their loss during the purchasing agreement with the local sponsor and the loss of crop production would likely be absorbed by other nearby farms.

5.4.2 Public Access and Recreation

Public access is important to the residents of the State of Washington and was included as an overarching policy of the 1971 Shoreline Management Act. Local communities often reflect this interest during public comment periods and design charrettes for proposed projects. Restoration and protection efforts in the nearshore zone are opportunities to improve public access and recreation in areas that may have had limited or informal access before. A challenge with public access and recreation opportunities for the Nearshore Study is to make sure it meets the needs of the user groups for an area and still allows for process-based ecosystem restoration at a site. To achieve both goals, in some instances, access sites or recreational features must be relocated.

5.4.2.1 *Alternative 1 – No-Action Alternative*

The No-Action Alternative would have no addition or subtraction of public access points to the shoreline. Many of Puget Sound's recreation opportunities rely on natural resources such as whale watching, bird watching, fishing, and shellfishing, as described in section 3.4.2. Aspects of each of these resources are in decline throughout the region, and to take no action toward restoring nearshore ecosystem processes would mean that these downward trends could continue. Loss of the natural resources that are the target of recreational activities would lead to decline in numbers of individuals participating in those activities. Not only would this have an immeasurable impact on families whose traditions surround these activities, but this would also have the indirect effect of decreasing revenue to the local and regional economies that rely on sales of goods and services related to recreational activities.

5.4.2.2 *Alternative 2 – 11 Sites*

Alternative 2 would not significantly affect long-term public access. During construction activities, some access and recreation sites may be temporarily closed. Dike-top trails associated with two of the 11 sites would replace existing conditions for walking and bird watching; there would be no expenditure toward addition of public recreation features in this alternative. Restoration of 5,348 acres of tidal wetlands would support fish and wildlife species and associated recreational opportunities such as increased bird watching opportunities; the increased salmon habitat could be presumed to assist with recovery of diminished populations thereby adding potential for increased sportfishing. Finally, there is a chance for potential displacement or substitution of recreation opportunities associated with this alternative. Waterfowl hunting opportunities may be displaced by new or different recreation opportunities (e.g., bird watching) at some of the sites included in this alternative, and two marinas would be removed. These are Blake's Marina (a small recreational marina) on the North Fork of the Skagit River and Twin Bridges Marina as part of the Telegraph Slough restoration site. There are eight other marinas within a 10-mile radius of these two marinas, which indicates ample locations for boat storage and launching.

5.4.2.3 *Alternative 3 – 18 Sites*

Alternative 3 would improve public access to the shoreline. During construction activities, some access and recreation sites may be temporarily closed. Many of the sites include work that would make visiting the shoreline easier, and a more enjoyable experience for those who value natural shorelines. The proposed activities at the Point Whitney Lagoon site would increase beach area available for public and tribal access by removing infrastructure and fill, and relocating the parking area off the spit. Pedestrian beach access would be maintained but would require walking from an upland parking area. The Snow Creek and Salmon Creek Estuary site would include a pedestrian trail feature that would replace an abandoned railroad grade that some use for walking and birding activities. This new segment of trail would serve as a portion of the proposed 130-mile long, multi-purpose, Olympic Discovery Trail that will eventually extend from Port Townsend to the Pacific Ocean. Two other sites include dike-top trails in which restoration work would replace existing conditions and would support activities such as walking and bird watching. The Harper Estuary site would involve relocation of a boat launch. The overall restoration of 5,517 acres of tidal wetlands would have the same types of associated recreational opportunity increases as Alternative 2, but to a greater extent. Finally, there is a chance for potential displacement or substitution of recreation opportunities associated with this alternative. Waterfowl hunting opportunities may be displaced by new or different recreation opportunities (e.g., bird watching) at some of the sites included in this alternative, and two marinas would be removed. These are Blake's Marina on the North Fork of the Skagit River and Twin Bridges Marina as part of the Telegraph Slough restoration site.

5.4.2.4 *Alternative 4 – 3 Sites*

Alternative 4 would not improve public access to the shoreline. During construction activities, some access and recreation sites may be temporarily closed. There would be no expenditure toward addition of public recreation opportunity in this alternative. Restoration of tidal wetlands at Duckabush would support fish and wildlife species and associated recreation such as increased bird watching opportunities; the increased salmon habitat could be presumed to assist with recovery of diminished populations thereby adding potential for increased sportfishing. Finally, there is potential for displacement or substitution of recreation opportunities associated with this alternative: Blake's Marina, which consists of a 120-foot day-use dock, a 500-foot overnight-use dock and a boat ramp, all located within the North Fork Skagit River site would be removed. The lower Skagit River has other nearby launch sites that would absorb the low volume of vessel traffic.

5.4.3 Commercial Fisheries and Aquaculture

The Puget Sound offers an unparalleled opportunity for commercial harvest of marine species, which supports a lucrative industry that caters to customers around the world. Improving, or at a minimum, maintaining harvest levels is imperative for sustaining this sector of the economy and has a direct influence on the quality of life for residents who earn their living in this sector.

5.4.3.1 *Alternative 1 – No-Action Alternative*

Commercial fisheries for finfish have been declining in recent years while commercial shellfish harvests have been relatively stable. The No-Action Alternative may have a negligible effect that continues the decline of commercially harvested species, especially salmon. Additionally, this alternative would maintain degraded conditions that have reduced shellfish growing habitat. Sediment transport processes would remain inhibited. Moreover, this alternative would fail to provide the important water filtration afforded by increased wetlands, which is critical to keeping uncontaminated shellfish beds. This alternative could have indirect economic consequences to commercial fisheries and aquaculture due to failure to improve conditions for these species.

5.4.3.2 *Alternative 2 – 11 Sites*

Alternative 2 would provide significant benefits to salmon rearing habitat, which assists with population recovery. Removal of armoring, tidal barriers, and artificial fill in river deltas, embayments, and beaches would provide more shallow water habitat for juvenile salmon migration, increase eelgrass beds that are critical nursery areas, and provide more spawning beaches for forage fish, an important prey item for salmon. Benefits to multiple aspects of salmon ecology would assist with recovery of this important commercially harvested resource.

The shellfish aquaculture industry has been expanding operations into available suitable habitat around Puget Sound. Restoring important ecosystem processes of the nearshore zone could help to restore important landforms such as beaches and mudflats, and could help enhance and expand areas available for shellfish growing. Dugualla Bay supported native oyster populations before it was diked; restoration at the site may allow recolonization by native oysters. Removal of shoreline armoring and tidal barriers would benefit clams, oysters, and crabs by increasing sediment delivery and appropriate grain size distribution. Two of the 11 sites in this alternative have geoduck, Dungeness crab, hard clam, and oyster populations in close enough proximity that they might experience direct benefits.

5.4.3.3 *Alternative 3 – 18 Sites*

Benefits of Alternative 3 would be similar to those in Alternative 2, but to a greater extent due to having a substantially longer length of stressors removed, creating more acreage for invertebrates to colonize. This opportunity includes the potential shellfish production benefits at the Tahuya River Estuary and Point Whitney Lagoon sites. Proposed activities at the Tahuya River Estuary site are anticipated to improve shellfish production in the lower estuary by increasing transport of coarse material downstream. The Point Whitney Lagoon site supports a native oyster population within the lagoon as well as tribal commercial, ceremonial, and subsistence and public recreational harvest on tidelands. While there is concern regarding reduced infrastructure as well as a change to hydraulics and salinity to support shellfish aquaculture at this site (i.e., compatibility of restoration efforts with ongoing shellfish production activities), negative impacts can be largely avoided with proper planning, and a long-term increase in shellfish may be realized. Five of the 18 sites in this alternative have geoduck, Dungeness crab, hard clam, and oyster populations in close enough proximity that they might experience direct benefits.

5.4.3.4 *Alternative 4 – 3 Sites*

Benefits of Alternative 4 would be similar to those described for Alternatives 2 and 3 but to a lesser extent due to having substantially less acreage of wetland restoration and shorter length of shoreline armoring removal. Removal of armoring, tidal barriers, and artificial fill at the North Fork Skagit River Delta would provide significant benefits to salmon rearing habitat, which assists with population recovery. The next design phase for the Nooksack River Delta site will require careful attention to plans for diversion of flow from the Nooksack River to the Lummi

River to ensure no negative effects occur to the shellfish operations in the estuary. Impacts from restoration of sediment transport process to shellfish habitat at the Duckabush estuary will be taken into careful consideration during the next phase of design for short-term and long-term effects. Negative effects to shellfish will be avoided to the maximum extent practicable.

5.4.4 Transportation

The areas of analysis for impacts to transportation are each restoration site. This scale is selected because none of the 18 proposed sites individually or collectively would affect broad-scale transportation issues in the Nearshore Study area, but individual sites could affect localized traffic around their community. Many of the proposed sites would affect transportation infrastructure, mainly because this is one of the major stressors that has caused degradation to the nearshore environment. In general, transportation components of the proposed sites involve lengthening roadway bridges to restore ecosystem processes to function as they did in historical nearshore conditions. Table 5-13 provides a summary of the transportation infrastructure that would be modified for each of the 18 proposed sites in the final array of alternatives.

Table 5-13. Transportation Infrastructure Affected

Site	Transportation Infrastructure
Beaconsfield Feeder Bluff	• None
Big Beef Creek Estuary	• Lengthen Seabeck Highway NW bridge and realign roadway
Deepwater Slough	• None
Deer Harbor Estuary	• Lengthen Channel Road Bridge and realign roadway
Duckabush River Estuary	• Construct new Highway 101 bridge, and raise and realign highway • Construct new raised interchange at intersection of Duckabush Road, plus a private drive to north of Duckabush Road and Highway 101 • Construct new bridge at Shorewood Road
Dugualla Bay	• Lengthen Highway 20 bridge and realign highway • Lengthen Dike Road bridge and realign roadway
Everett Marshland	• Construct two new bridges on Lowell-Snohomish Road and realign roadway • Lengthen BNSF Railway bridge
Harper Estuary	• Construct new bridge at SE Olympiad Drive
Livingston Bay	• None
Milltown Island	• None
Nooksack River Delta	• Construct new bridge on Ferndale Road and realign roadway • Construct new bridge on Slater Road and realign roadway at Lummi River • Construct new bridge on Slater Road over Tennant Creek • Raise portions of Slater Road and Marine Drive • Construct new bridge on Hillaire Road and realign roadway • Construct new bridge on Imhoff Road and realign roadway • Construct new bridge on Haxton Way and realign roadway
North Fork Skagit River Delta	• None

Point Whitney Lagoon	• None
Snow Creek and Salmon Creek Estuary	• Lengthen Highway 101 bridge and realign highway • Remove abandoned railway bridge and embankment
Spencer Island	• None
Tahuya River Estuary	• Lengthen NE North Shore Road bridge and realign roadway • Relocate helipad
Telegraph Slough	• Lengthen Highway 20 bridge and realign highway • Lengthen BNSF Railway
WDNR Budd Inlet Beach	• None

Bridge construction costs are classified as Lands, Easements, Rights-of-way, Relocations, and Disposal areas (LERRDs).

5.4.4.1 *Alternative 1 – No-Action Alternative*

Under the No-Action Alternative, transportation infrastructure within the nearshore environment would not be replaced or modified. The roads, highways, bridges, and lengths of railway in the area of analysis would deteriorate as they age, requiring continued maintenance and repair. Some of this infrastructure within the zones of tidal influence may need to be modified in response to sea-level changes associated with climate change.

5.4.4.2 *Alternative 2 – 11 Sites*

Alternative 2 would involve the replacement and/or modification of transportation infrastructure including roadways and bridges to restore nearshore ecosystem processes. This proposal involves modification of transportation infrastructure at five of the 11 sites. These modifications involve seven road bridge sites including three new bridges and associated road realignments as well as reconstruction of two railway bridges. Detour routes and/or temporary structures would be developed to ensure that vehicle and rail traffic can still pass through sites during construction. Since designs are at the conceptual level, it is not yet possible to estimate duration of construction or the detour route. During the construction period, drivers may experience inconvenience due to traffic detours, but when completed, transportation infrastructure would be back in place and traffic would flow as normal.

5.4.4.3 *Alternative 3 – 18 Sites*

Alternative 3 would involve the replacement and/or modification of transportation infrastructure including roadways, bridges, and rail lines and associated bridges, to restore nearshore ecosystem processes. Alternative 3 involves modifying transportation infrastructure at 10 proposed sites, including constructing 19 bridges (10 new and nine reconstructions) and associated road realignments, and two railway bridge sites. In addition, one abandoned railway site (a bridge with embankment) would be removed.

5.4.4.4 *Alternative 4 – 3 Sites*

Alternative 4 would involve the replacement and/or modification of transportation infrastructure including roadways and bridges to restore nearshore ecosystem processes. This proposal involves modification of transportation infrastructure at two of the three sites. These modifications involve two new bridges for the Duckabush site, one of which replaces a culvert at Shorewood Road. Most of the new construction on Highway 101 can take place with the old roadway in place and in use; however, there would be a period when constructed approaches or culvert replacements would result in temporary interruptions to traffic. Additionally, a temporary roadway at Duckabush Road would likely be constructed to provide ingress-egress from the river valley. Annual average daily traffic counts for Highway 101 at Duckabush Road is 2,200 as of 2014 (WSDOT 2014). The Nooksack River Delta site includes construction of six new bridges, realignment of roads, and raising portions of Slater Road and Marine Drive as well as raising Ferndale Road onto a setback levee. Roads within the Nooksack site are all rural, local roads. Some of the road construction in the Nooksack Delta would result in detours or temporary interruptions to traffic. No transportation impacts are anticipated with the North Fork Skagit River Delta site. Detour routes and/or temporary structures would be developed to ensure that vehicle traffic can still pass through sites during construction. During the construction period, drivers may experience inconvenience due to traffic detours, but when completed, transportation infrastructure would be back in place and traffic would flow as normal.

5.4.5 Public Safety

NEPA requires that public safety be considered in the alternatives analysis of Federal proposals. The Corps anticipates no reduction in public safety from the proposed project as all applicable laws, regulations, and codes will be complied with during design and construction phases.

5.4.5.1 *Alternative 1 – No-Action Alternative*

Under the No-Action Alternative, public safety infrastructure within the nearshore environment would not be modified or improved and will require ongoing maintenance and repair. Levees are typically under the responsibility of local diking districts or counties that provide maintenance. The Corps would not alter any levees for ecosystem restoration under the No-Action Alternative; any changes to these levees for public safety are and would continue to be the responsibility of the levee owners. Transportation infrastructure and utilities in the study area such as bridges, roads, railroads, conduits and pipelines would require continued maintenance, repair, or replacement to insure public safety.

5.4.5.2 *Alternative 2 – 11 Sites*

For any management measures or site features that may be relevant to public safety, the Corps would apply all current engineering and design regulations to achieve no reduction in any aspects of public safety.

Alternative 2 would involve the replacement and/or modification of various components of infrastructure that have public safety criteria including armoring, utilities, roads, bridges for vehicles or trains, and levees. As described in section 4.6, for each of the restoration sites in which the Corps is proposing to breach a levee and construct a new levee, the new levee will maintain the same level of residual flood risk as the levee it is replacing. Alternative 2 includes five sites in which a new or setback levee would be constructed to protect public or private property from inundation that could result from the restoration work. This alternative includes two sites, Beaconsfield Feeder Bluff and Dugualla Bay, where existing shoreline armoring is proposed for removal. Neither project would have any effect on public safety as the sites would be designed to prevent any new or additional risk.

This proposal involves modification of road alignments at four of the 11 sites: Deer Harbor Estuary, Dugualla Bay, Everett Marshlands, and Nooksack River Delta. Each modification would conform to current road design safety standards applicable to the type and size of roadway being modified. There would be no reduction to public safety at any of these sites; in fact, conforming to updated standards would likely improve safety.

Alternative 2 includes twelve road bridges and reconstruction of two railway bridges. One of these bridges is a section of Highway 20 at Telegraph Slough. Each modification would conform to current bridge design safety standards applicable to the type and size of bridge being modified. There would be no reduction to public safety at any of these sites; in fact, conforming to updated standards would likely improve safety and will allow for predicted sea level change.

Alternative 2 contains two sites that would affect utility corridors. These are along State Route 20 at the Telegraph Slough site and at the Everett Marshland with work within the Lowell-Snohomish River Road prism. The Corps anticipates no impacts to public safety and the resulting project may actually improve conditions relevant to public safety as all modifications would conform to current design safety standards.

One benefit of wetland restoration is increased usage by waterfowl; however, bird and other wildlife that are attracted to wetlands can pose a risk to air traffic. The Dugualla Bay site is approximately one mile east of Ault Field, part of Naval Air Station Whidbey Island. The proposed restoration at this site would change the site from a freshwater lake to an estuary connected to Skagit Bay. According to the Navy's Bird/Animal Aircraft Strike Hazard (BASH) program, there are a variety of measures that help minimize risk to aircraft from bird and animal strikes. The Corps would work closely with the Navy and the BASH program manager to ensure that any change in bird usage of the tidal area is in compliance with the BASH program.

5.4.5.3 *Alternative 3 – 18 Sites*

Alternative 3 would involve the replacement and/or modification of a greater number than Alternative 2 of components of infrastructure that have public safety criteria including roadways, bridges, and levees to restore nearshore ecosystem processes.

Alternative 3 contains the same five sites as Alternative 2 with new levees, and no additional sites in which levees would be constructed. The same is true for the need for utility relocations; Alternative 3 has no additional sites that affect major utility corridors beyond those already discussed for Alternative 2.

There are two additional sites in Alternative 3 that involve armoring that would be removed. At the Snow Creek and Salmon Creek estuary, the armoring removal would not threaten any infrastructure. Removal of armor at Big Beef Creek Estuary is associated with the bridge proposed for replacement. The new bridge would have all appropriate protection measures required for new construction.

Alternative 3 involves modifying one additional road alignment other than the three included in Alternative 2. This involves permanent removal of approximately 425 feet of SE Olympiad Drive and associated fill that is bisecting the freshwater marsh and saltwater estuarine area at Harper Estuary. Closure of this section of road would require a traffic analysis assessing impacts to local residences and emergency services to maintain the same level of public safety.

This alternative includes constructing 19 bridges (10 new and nine reconstructions) and three railway bridges. Two of these bridges are sections of Highway 101, at the Duckabush River estuary and at the Snow Creek and Salmon Creek estuary. Transportation infrastructure would meet all current safety criteria and designs will allow for predicted sea level change. Alternative 3 does not include any additional sites where wetland restoration is proposed near an airfield.

5.4.5.4 *Alternative 4 – 3 Sites*

Alternative 4 would involve the replacement and/or modification of various components of infrastructure that have public safety criteria including armoring, utilities, roads, bridges for vehicles or trains, and levees. For each of the restoration sites in which the Corps is proposing to breach a levee and construct a new levee, the new levee will maintain the same level of residual flood risk as the levee it is replacing. Alternative 4 includes two sites (Nooksack and North Fork) in which levee breaching or removal for ecosystem benefits necessitates construction of new levees. New levees would protect public or private property from inundation that could result from the restoration work. Neither project would have any effect on public safety as the sites would be designed to prevent any new or additional risk.

This proposal involves modification of road alignments at two sites: Duckabush River Estuary and Nooksack River Delta. Each modification would conform to current road design safety standards applicable to the type and size of roadway being modified. There would be no reduction to public safety at any of these sites; in fact, conforming to updated standards would likely improve safety.

Alternative 4 includes seven road bridge replacements: two at Duckabush and six at Nooksack. Each modification would conform to current bridge design safety standards applicable to the type and size of bridge being modified. There would be no reduction to public safety at any of these sites; in fact, conforming to updated standards would likely improve safety and will allow for predicted sea level change.

Alternative 4 would not affect any major utility corridors. Further site analysis would occur during PED to ensure no loss of services to the public. The Corps anticipates no impacts to public safety and the resulting project may actually improve conditions relevant to public safety as all modifications would conform to current design safety standards. This alternative does not include any sites where wetland restoration is proposed near an airfield.

5.5 SUMMARY OF ENVIRONMENTAL CONSEQUENCES

This section summarizes the expected effects on significant environmental resources described in preceding sections. Table 5-14 provides a summary of these effects in comparative format. In addition to the comparison of environmental effects of the alternatives, NEPA requires consideration of certain other aspects of any Federal project requiring an EIS (40 CFR 1502.16). These include the following:

- Adverse environmental effects that cannot be avoided should the proposal be implemented
- The relationship between short-term uses of the human environment and the maintenance and enhancement of long-term biological productivity
- Any irreversible or irretrievable commitments of resources
- Any areas of controversy and unresolved issues

The *adverse environmental effects that cannot be avoided* are all of the remaining effects after avoidance and minimization measures have been employed. Remaining potential effects are in two categories: cultural resources and aquatic animals affected by underwater noise. Implementing the restoration action would result in unavoidable adverse effects to cultural resources as detailed in section 5.3. For any restoration site that becomes authorized, the Corps would consult with the SHPO, ACHP, THPO, and tribes on appropriate mitigation measures on a case-by-case basis according to the PA to achieve full compliance with the NHPA. Finally, underwater noise during construction may cause unavoidable harm to a few aquatic animals at the individual level, but not at the population level (See section 5.7 for mitigation measures).

The *short-term uses of the human environment* would ultimately benefit the maintenance and enhancement of long-term productivity of the ecological resources of the Puget Sound region.

Some of the short-term uses of resources would include a temporary closure of some public access points for the duration of construction, and some land would be cleared for access and staging. There would be no long-term negative effects to productivity; in fact, the purpose is to restore the natural processes that support productivity and the resilience of the ecosystem to support biological resources that humans value. A net increase in vegetation would result in an increase in primary biological productivity and could increase capacity for carbon sequestration.

The *irreversible or irretrievable commitments of resources* would involve energy and materials for removal of stressors and rebuilding of critical infrastructure that must be replaced. The irretrievable commitment of resources would largely be due to the construction materials required for modification of critical infrastructure including any highway realignments, bridge replacements, and road relocations. As shown in the GHG emissions analysis, Alternative 2 would burn approximately 6.7 million gallons of diesel fuel resulting in 74,000 tons of CO_2 emissions. Alternative 3 would involve more diesel and related emissions at approximately 7.4 million gallons of diesel fuel burned resulting in 82,000 tons of CO_2 emissions. Alternative 4 would burn less diesel at approximately 3 million gallons and would have 33,000 tons of CO_2 emissions. The historical structures and archaeological sites at the restoration sites are cultural resources that are non-renewable and would be either removed (structures), buried, or destroyed (archaeological sites) to successfully restore ecosystem processes. The impact to structures and artifacts is an irreversible commitment of these resources. For any unavoidable adverse effects (removal or destruction) to National Register-eligible historic properties, the Corps will consult on a case- by-case basis to identify necessary mitigation measures from the list included in the PA with the SHPO, ACHP, THPO, tribes, and other interested parties.

There are no *areas of controversy or unresolved issues* among the Federal, state, or local agencies consulted during this project. Some controversy arose through individual property owners who voiced concerns regarding potential effects to their properties that may result from the proposed restoration. During feasibility phase, hydraulic engineers performed an analysis to determine probability of risk to potentially affected properties. Site design during PED would take landowner concerns into account—reflected by design modifications—and sites would only go forward after landowner concerns have been addressed. Any unresolved cultural resources issues will be resolved through the procedures described in the PA.

The Corps is continuously considering project impacts to Native American Tribes and the benefits and risks associated with the proposed restoration actions. In addition to the potential effects to cultural resources discussed in section 5.3, there may be temporary impacts to shellfish beds and fishing during construction of the preferred alternative. Restoration is generally encouraged by tribes and the Corps has support from many tribes specifically for the Nearshore Study. The Corps plans to continue consultation and coordination with affected tribes throughout the process to ensure the project avoids any interruptions to tribal fisheries, impacts to shellfish are minimized, and all other tribal resources are considered during design phase.

Table 5-14 Summary of Environmental Consequences

		ALTERNATIVE 1 No Action	ALTERNATIVE 2 11 Sites	ALTERNATIVE 3 18 Sites	ALTERNATIVE 4 3 Sites
PHYSICAL ENVIRONMENT: NEARSHORE PROCESSES & STRUCTURE					
Nearshore Processes	Short-Term Construction Effects	N/A	Immediate removal of stressors, some immediate restoration of processes.	Immediate removal of stressors, some immediate restoration of processes.	Immediate removal of stressors, some immediate restoration of processes
	Long-Term Project Effects	Continued decline of ecosystem function due to impaired processes.	Restores target processes with improved ecosystem functions on 5,348 acres of wetlands. Restores 5.5 acres of sediment delivery on a beach.	Restores target processes with improved ecosystem functions on 5,517 acres of wetlands. Restores 7.5 acres of sediment delivery on beaches.	Restores target processes with improved ecosystem functions on 2,101 acres of wetlands. No beach sites are included.
Geologic and Physiographic Setting	Short-Term Construction Effects	N/A	Immediate removal of 75,162 feet of shoreline stressors.	Immediate removal of 113,094 feet of shoreline stressors.	Immediate removal of 28,860 feet of shoreline stressors
	Long-Term Project Effects	Continued influence of artificial landforms. Continued decrease in length and complexity of the shoreline	Increases shoreline length by 131,578 feet over existing 11 sites. The resulting length would be 166% of the existing length.	Increases shoreline length by an additional 125,474 feet over existing 18 sites. The resulting length would be 147% of the existing length.	Increases shoreline length by 23,568 feet over existing 3 sites. The resulting length would be 132% of the existing length.
Oceanography	Short-Term Construction Effects	N/A	Medium amount of localized and temporary impacts to currents due to temporary work structures. Immediate benefits of freshwater inputs and distributary channels at 10 of 11 sites.	Greatest amount of localized and temporary impacts to currents due to temporary work structures. Immediate benefits of freshwater inputs and distributary channels at 16 of 18 sites.	Least amount of localized and temporary impacts to currents due to temporary work structures. Immediate benefits of freshwater inputs and distributary channels at all 3 sites.
	Long-Term Project Effects	No oceanography effects. Dikes in river deltas will continue to channelize fresh water input and inhibit freshwater mixing.	Restoration of 5,348 acres of tidally influenced wetlands. Freshwater influence restored at 5 of 11 sites.	Restoration of 5,517 acres of tidally influenced wetlands. Freshwater influence restored at 10 of 18 sites.	Restoration of 2,101 acres of tidally influenced wetlands. Freshwater influence restored at all 3 sites
Water Quality	Short-Term Construction Effects	N/A	Same effects as Alternative 3, but less risk due to smaller number and size of projects.	Risk of fuel spill and encountering undocumented sources of contaminants. Tidal inundation of farmland with short-term releases fecal col., turbidity, Dissolved Oxygen, nutrients.	Same effects as Alternative 3, but less risk due to smaller number and size of projects.

Water Quality	Long-Term Project Effects	Water quality will continue to vary based on local, natural, and anthropogenic stressors.	Potential improvement in water quality due to 5,348 acres of wetlands added. Benefits similar to Alternative 3, but smaller magnitude due to smaller number and size of sites.	Potential improvement in water quality due to 5,517 acres of wetlands added. Added riparian shading would lower water temperatures.	Potential improvement in water quality due to 2,101 acres of wetlands added. Similar benefits to Alternatives 2 and 3, but to a lesser extent.
Sedimentation & Erosion	Short-Term Construction Effects	N/A	Release of sediment from excavation and stressor removal.	Release of sediment from excavation and stressor removal, to a greater extent than Alternative 2 and 4.	Release of sediment from excavation and stressor removal, to a much lesser extent than Alternatives 2 and 3.
	Long-Term Project Effects	Remain impaired due to stressors such as shoreline armoring.	Restored sediment delivery and transport due to removal of 77,796 linear feet of stressors.	Restored sediment delivery and transport due to removal of 115,718 linear feet of stressors.	Restored sediment delivery and transport due to removal of 28,860 linear feet of stressors.
HTRW	Short-Term Construction Effects	N/A	None; HTRW sites will either be avoided, or cleaned up by non-Federal sponsor.	Same as Alternative 2.	Same as Alternative 2.
	Long-Term Project Effects	N/A	None; HTRW sites will either be avoided, or cleaned up by non-Federal sponsor.	Same as Alternative 2.	Same as Alternative 2.
Greenhouse Gas Emissions	Short-Term Construction Effects	N/A	Estimated 74,053 tons of GHG emissions from construction activities.	Estimated 82,276 tons of GHG emissions from construction activities.	Estimated 33,379 tons of GHG emissions from construction activities.
	Long-Term Project Effects	N/A	GHG absorption expected (less than Alternative 3) as vegetation establishes; difficult to estimate.	GHG absorption expected as vegetation establishes; may offset construction effects.	GHG absorption expected (less than Alternative 3) as vegetation establishes; difficult to estimate.
Underwater Noise	Short-Term Construction Effects	N/A	5 projects have noise-producing activities that may cause behavior disruption or harm to aquatic species.	10 projects have noise-producing activities that may cause behavior disruption or harm to aquatic species.	2 projects have noise-producing activities that may cause behavior disruption or harm to aquatic species.
	Long-Term Project Effects	N/A	Low likelihood for harm to birds or marine mammals, or loss of few fish in close proximity to pile driving.	Greater likelihood for harm to birds or marine mammals, or loss of few fish in close proximity to pile driving.	Very low likelihood for harm to birds or marine mammals, or loss of fish in close proximity to minor pile driving for removal.

		ALTERNATIVE 1 No Action	ALTERNATIVE 2 11 Sites	ALTERNATIVE 3 18 Sites	ALTERNATIVE 4 3 Sites
BIOLOGICAL ENVIRONMENT: NEARSHORE FUNCTIONS					
Vegetation	Short-Term Construction Effects	N/A	Similar impacts to those described for Alternative 3, but to a lesser extent due to fewer and smaller projects.	Temporary turbidity disturbance to kelp, eelgrass, and nearby wetlands. Riparian vegetation would be removed from structures being removed.	Similar impacts to those described for Alternative 3, but to a much lesser extent due to fewer and smaller projects.
	Long-Term Project Effects	Marine and riparian vegetation would stay limited by poor sediment delivery and shading by overwater structures. Tidal wetlands would remain constrained by fill and dikes.	Less freshwater marsh loss than Alternative 3, but less tidal wetlands restored and less riparian planting. Less benefit to kelp and eelgrass due to less length of stressors removed than Alternative 3.	Minor conversion of freshwater to saltwater marsh plants from restoring tidal inundation. 5,517 acres of tidal wetlands restored. Riparian planting at several projects. Sediment delivery benefits to eelgrass and kelp.	Less freshwater marsh conversion than Alternative 3, but less tidal wetlands restored and less riparian planting. No direct benefits to eelgrass and kelp.
Shellfish & Other Macro-invertebrates	Short-Term Construction Effects	N/A	Similar to those described for Alternative 3, but to a lesser extent due to less bottom disturbance and less dredging.	Temporary increases in turbidity, due to dredging and excavation may cause disturbance to benthic and epibenthic communities.	Similar to those described for Alternative 3, but to a lesser extent due to less bottom disturbance and no dredging.
	Long-Term Project Effects	Lack of habitat in diked and filled intertidal areas, poor substrate supply, and siltation and pollution from run-off would continue to limit shellfish and other invertebrates.	Similar to those described for Alternative 3, but to a smaller extent due to less area of estuarine habitat restored and shorter length of shoreline stressors removed.	Transition to brackish guild where tidal inundation is restored. Benefits to eelgrass support invertebrate diversity. Armor removal and riparian plants benefit upper intertidal and backshore invertebrates.	Similar to those described for Alternative 3, but to a much smaller extent due to less area of estuarine habitat restored and a much shorter length of shoreline stressors removed.
Fish	Short-Term Construction Effects	N/A	Similar to those described for Alternative 3, but to a smaller extent due to less excavation, less pile driving, and less dredging.	Turbidity from excavation and dredging, and noise and vibration from pile driving could cause animals to flee, delay migration, or cause physical harm.	Similar to those described for Alternative 3, but to a much smaller extent due to less excavation, no pile driving other than testing, and no dredging.
	Long-Term Project Effects	Fish would remain limited by lack of estuarine habitat for them and their prey due to filled and diked	5,348 acres of estuarine habitat restored for anadromous fish rearing and foraging. Removal of shoreline stressors creates shallow water habitat for	Similar to those described for Alternative 2, but to greater extent due to more estuarine habitat restored and longer length of stressors removed.	Similar to those described for Alternative 2, but to a smaller extent due to less estuarine habitat restored and shorter length of stressors removed.

		wetlands, and lack of shallow water habitat and spawning substrate along armored shorelines.	migration corridors, spawning beaches, and benefits kelp and eelgrass.		
Birds	Short-Term Construction Effects	N/A	Disturbance from noise from pile driving and operation of heavy equipment.	Similar Alternative 2, but to a greater extent due to more pile driving and heavy equipment.	Similar Alternative 2, but to a much smaller extent due to less pile driving and heavy equipment.
	Long-Term Project Effects	Birds would remain limited by lack of estuarine foraging habitat. No effect to migratory species that use farm fields.	Additional foraging opportunities due to the 5,348 acres of restored estuarine habitat. Transition from freshwater species to brackish guild.	Similar to those described for Alternative 2, but to a greater extent due to more estuarine habitat being restored.	Similar to those described for Alternative 2, but to a much smaller extent due to less estuarine habitat being restored.
Mammals	Short-Term Construction Effects	N/A	Pile driving noise may disturb marine mammals in locating prey, flee response, or temporary hearing loss.	Similar to those described for Alternative 2, but to a greater extent due to more pile driving.	Very little disturbance to marine mammals anticipated due to almost no pile driving.
	Long-Term Project Effects	Marine mammals dependent on nearshore species would continue to suffer from lack of habitat for their prey.	Added prey base, including forage fish and salmonids, due to the increase in quantity and quality of habitat for these prey species.	Similar to those described for Alternative 2, but to a greater extent due to more new estuarine habitat created for their prey.	Similar to those described for Alternative 2, but to a much smaller extent due to less new estuarine habitat created for their prey.
Invasive Species	Short-Term Construction Effects	N/A	Less vegetative ground cover for a short duration; overall benefit to stop the spread of invasive species.	Invasive removal similar to Alternative 2, although to a greater degree due to more sites.	Invasive removal similar to Alternative 2, although to a lesser degree due to fewer sites.
	Long-Term Project Effects	Invasive species would continue to exploit human-made structures and outcompete native species.	Would result in planting and natural repopulation with native species; would stop the spread from these sources.	Same as those described for Alternative 2, but to a greater extent due to the removal of more invasive vegetation.	Same as those described for Alternative 2, but to a lesser extent due to the removal of invasive vegetation at fewer sites.
Rare, Threatened, and Endangered Species	Short-Term Construction Effects	N/A	Same effects as described for fish, birds, and mammals - primarily from turbidity and noise from excavation and pile driving.	Same as those described for Alternative 2, but to a greater extent due to more excavation and pile driving.	Same as those described for Alternative 2, but to a lesser extent due to less excavation and almost no pile driving.

	Long-Term Project Effects	Filled, diked, and armored shoreline would continue to limit salmonid rearing and forage fish (preferred prey) habitat. Lack of suitable prey habitat would continue to limit food sources for ESA species.	Listed salmonids would benefit from restored estuaries. Shallow water habitat created by removing shoreline armoring would enhance migration corridors. Higher trophic level species benefit from restored habitat of their prey base.	Same as those described for Alternative 2, but to a greater extent due more estuarine habitat being restored and sites where there are more ESA-listed species that would benefit from stressor removal.	Same as those described for Alternative 2, but to a much smaller extent due less estuarine habitat being restored and fewer total sites for ESA-listed species that would benefit from stressor removal.
		ALTERNATIVE 1 No Action	**ALTERNATIVE 2 11 Sites**	**ALTERNATIVE 3 18 Sites**	**ALTERNATIVE 4 3 Sites**
CULTURAL RESOURCES					
Archaeo-logical Resources	Short-Term Construction Effects	N/A	Potential to affect or encounter known or unknown archaeological resources.	Same as Alternative 2, although to a greater degree due to larger number and size of sites.	Potential to affect both known and unknown archaeological site located in each restoration site. Mitigation would follow the PA (Appendix D).
	Long-Term Project Effects	Future development could impact both known and unknown archaeological resources.	Work would affect 32 known archaeological sites at several restoration sites. Risk of adverse effect to National Register-eligible sites due to projects. Mitigation measures chosen and implemented per the PA will mitigate the adverse effect. Mitigation measures have the potential to contribute information to regional understanding of pre-history and history of the Pacific Northwest.	Same as Alternative 2, although to a greater degree due to larger number and size of restoration sites.	Potential to affect both known and unknown archaeological site located in each restoration site. Mitigation would follow the PA (Appendix D).
Historic Buildings & Structures	Short-Term Construction Effects	N/A	Access to any NRHP structures on site would be limited during construction.	Same as Alternative 2.	Same as Alternative 2. Mitigation would follow the PA (Appendix D).
	Long-Term Project Effects	Future developments would likely result in both adverse and positive impacts to	Loss of historic properties including levees, residential and agricultural structures (i.e. historic barns, granary, and residences) sections of railroad	Same as Alternative 2, with potential impacts to additional historic properties including, the National Register listed	Work may affect historic buildings/structures and levees located in each restoration area including the Duckabush Bridge.

		historic buildings and structures.	line, bridges, dike systems, marine laboratory, and many agricultural and residential buildings. Potential benefits would result from mitigation and or documentation measures outlined in the PA.	Duckabush Bridge, and marine laboratory.	Mitigation would follow the PA (Appendix D).
		ALTERNATIVE 1 No Action	**ALTERNATIVE 2 11 Sites**	**ALTERNATIVE 3 18 Sites**	**ALTERNATIVE 4 3 Sites**
SOCIO-ECONOMIC RESOURCES					
Shoreline Ownership & Land Use	Short-Term Construction Effects	N/A	Property purchase or construction easements from and owners will need to occur prior to construction.	Property purchase or construction easements from land owners will need to occur prior to construction.	Property purchase or construction easements from land owners will need to occur prior to construction.
	Long-Term Project Effects	No change to shoreline ownership and land-use except by regulatory mechanisms.	Permanent increase in publicly owned lands and/or changes of land use to conservation easement.	Permanent increase in publicly owned lands and/or changes of land use to conservation easement across greater area than Alternative 2.	Permanent increase in publicly owned lands and/or changes of land use to conservation easement.
Public Access & Recreation	Short-Term Construction Effects	N/A	Present access and recreation opportunities may be temporarily limited or closed during construction.	Present access and recreation opportunities may be temporarily limited or closed during construction.	Present access and recreation opportunities may be temporarily limited or closed during construction.
	Long-Term Project Effects	May continue downward trend in loss of natural resources, access, and recreation opportunities.	Improvements to beach access limited to replacement of two dike-top trails. One boat ramp will be removed.	Improved pedestrian access at four sites. One boat ramp removed and one relocated. Adds length to the Olympic Discovery Trail.	One boat ramp at North Fork Skagit River will be removed.
Commercial Fisheries & Aquaculture	Short-Term Construction Effects	N/A	Not likely to affect commercial fisheries or aquaculture during construction.	Not likely to affect commercial fisheries or aquaculture during construction.	Not likely to affect commercial fisheries or aquaculture during construction.
	Long-Term Project Effects	Continued decline of commercial finfish and shellfish populations due to habitat degradation and loss.	Significant benefits to commercial fish and shellfish species by increasing habitat and improving water quality, but less than Alternative 3.	Significant benefits to commercial fish and shellfish species by increasing habitat and improving water quality.	Benefits to commercial fish and shellfish species by increasing habitat and improving water quality, but much less than Alternatives 2 and 3.

Transportation	Short-Term Construction Effects	N/A	Road closures, vehicle traffic re-routing.	Road closures, vehicle traffic rerouting, and 1 railroad bypass.	Fewer road closures, less vehicle traffic re-routing than other Alternatives.
	Long-Term Project Effects	No direct impacts to transportation. Vulnerable infrastructure may experience occasional or prolonged loss of use due to sea level change (e.g., overtopping, flooding).	No change to transportation. Structures would be less vulnerable to sea level change (may be larger or higher roads/bridges).	No change to transportation. Structures would be less vulnerable to sea level change (may be larger or higher roads/bridges). Bridge removal at Harper would add 1 mile to drive around.	No change to transportation. Structures would be less vulnerable to sea level change (may be larger or higher roads/bridges).
Public Safety	Short-Term Construction Effects	N/A	Temporary road detours would adhere to all current safety standards.	Temporary road detours would adhere to all current safety standards.	Temporary road detours would adhere to all current safety standards.
	Long-Term Project Effects	No change to public safety.	Replacement of armoring, utilities, roads, bridges, and levees incidental to the restoration efforts. No loss to public safety.	Replacement of armoring, utilities, roads, bridges, and levees incidental to the restoration efforts. No loss to public safety.	Replacement of armoring, utilities, roads, bridges, and levees incidental to the restoration efforts. No loss to public safety.

5.6 CUMULATIVE EFFECTS OF THE AGENCY PREFERRED ALTERNATIVE

Cumulative effects can result from the incremental effects of the proposed action when added to the effects of other past, present, and future actions, regardless of which government agency or private entity undertakes such actions. When effects that are individually minor combine over space or time, the cumulative effects can be significant. This section discusses the analysis of Alternative 4, which was selected as the Agency Preferred Alternative.

5.6.1 Cumulative Effects Analysis Methodology

The cumulative effects analysis incorporates information from a variety of sources. Each proposed restoration site design was examined to evaluate the expected environmental effects. Then records from local entities were reviewed to determine the combined effects expected from restoring sites in each sub-basin. The time scale for analysis of cumulative effects includes projects 10 years past, active projects, and projects planned for the next 10 years. The spatial scale of analysis for each site is its sub-basin. Effects from past, present, and reasonably foreseeable future projects within these sub-basins were quantified by examining records available through the following sources: Washington State Department of Transportation database (WSDOT 2012); Puget Sound Regional Council's Transportation 2040 Plan (PSRC 2010); Lead Entity Habitat Work Schedule Public Portal map with descriptions of completed, active, and proposed restoration projects (WDFW et al. 2012); and the Corps' database of Clean Water Act Section 404 permits issued for restoration projects within tidally influenced areas (USACE 2012b). In addition, the Corps contacted WDFW watershed stewards for their input into the cumulative effects analysis. After analyzing each of these sources, a cumulative effects analysis was compiled for each proposed site in combination with expected effects from other actions in the same sub-basin.

5.6.2 Summary of Past, Present, and Future Actions and Cumulative Effects by Sub-basin

Each of the sub-basins where one or more of the three proposed restoration sites are located was analyzed for cumulative effects based on the temporal and spatial scales described above and analysis results for each sub-basin are summarized in the following sections.

5.6.2.1 *Whidbey Sub-basin*

Negative effects to ecological processes in the Whidbey Sub-basin are a result of past and present diking for agriculture in the Skagit, Stillaguamish, and Snohomish Rivers, and on Whidbey Island, and extensive fill in the Snohomish Estuary due to urbanization in the City of Everett. One of the proposed sites is located in the Whidbey Sub-basin; this is the North Fork Skagit River Delta site.

The Whidbey Sub-basin has many opportunities for restoration since most of the surrounding land use is not residential or commercial development. Most of these restoration efforts are focused around the three major river deltas (Skagit, Stillaguamish, and Snohomish), led by entities such as Snohomish County, Skagit Fisheries Enhancement Group, and TNC. In the past 10 years, there have been 20 completed projects restoring and protecting a variety of shoreline habitats in the Whidbey Sub-basin, including several large-scale restoration efforts like Union Slough and Diking District 6 in the Snohomish River delta, and phase 1 of Deepwater and Fisher Sloughs in the Skagit River delta. There are 18 active restoration actions, including Qwuloolt in the Snohomish River, and 13 similar proposed actions such as McElroy Slough in the Skagit River and Biringer Farms in the Snohomish River Delta. The Lummi Tribe is constructing mitigation bank areas downstream from the proposed project site. This data is current as of 2014.

Skagit County has been considering improving and raising levees and constructing new levees along the lower Skagit River. In the past 10 to 20 years the Corps of Engineers Regulatory Branch has issued roughly 50 Nationwide Permit 13: Bank Stabilization letters of permission and over twice as many Individual Permits (likely associated with development), which are scattered throughout the sub-basin, but many are concentrated in the City of Everett on the Snohomish River, along the Skagit River, and Padilla Bay. In Skagit and Snohomish Counties, WSDOT has 87 completed projects and 34 active projects, many of which are in and around the City of Everett. These projects include widened lanes on SR 20, armoring the Skagit River along SR 20 and SR 530, storm water treatment, creating wetlands, adding large woody debris, and improving fish passage in the Snohomish River delta.

The cumulative effects of multiple restoration actions in these river deltas and the surrounding areas, including those in the preferred alternative, would provide wetland habitat and coastal embayments and help offset the negative impacts of past and ongoing development in the basin. Cumulative effects to ecological and other resources expected within this sub-basin are summarized in Table 5-15.

Table 5-15. Cumulative Effects Expected in the Whidbey Sub-basin

What cumulative effects could occur within the Whidbey Sub-basin from Nearshore Study-identified work combined with other past, present, and future actions?	
Ecological Resources	Although other projects in the sub-basin may occur concurrently with the construction at the site in this sub-basin included in the preferred alternative, work would occur during allowable work periods and low tides to minimize effects of turbidity and noise. The incremental cumulative effects of construction of this site would be temporary. Long-term cumulative effects of multiple restoration actions in this sub-basin would support large populations of salmon, and resident and migratory birds, as well as commercially important shellfish. Since the three rivers in this sub-basin support large runs of salmon, particularly the Skagit, restoration efforts could aid in the recovery of Southern Resident killer whales by supporting their prey.
Socioeconomics	Restoration of tidally influenced marshes may decrease abundance of freshwater waterfowl for hunting and limit access for recreation. Increases in recreational

	fishing could result from the improvements in habitat. There is a growing concern in Snohomish and Skagit Counties over loss of farmland in the highly fertile floodplains and deltas of Skagit, Snohomish, and Stillaguamish Rivers mostly due to development, but also because of restoration. Large-scale restoration efforts in these river deltas, including those in the preferred alternative, may have cumulative effects to croplands. Job opportunities would arise from construction of these restoration sites as well as others in the basin, which may extend to individuals outside of the Whidbey sub-basin.
Transportation	This site would permanently affect one short rural road. Other construction in this sub-basin would likely be concurrent with restoration work and concentrated around the City of Everett, with no potential for cumulative effects associated with the North Fork Skagit River Delta site.
Cultural Resources	The Whidbey sub-basin is extremely rich in archaeological resources and historic built environment. This sub-basin contains some of the earliest and rarest archaeology sites in western Washington. Despite industrial growth and the extensive land modification in this sub-basin due to agriculture and tidal reclamation, the region was used extensively ethnographically, and has a high potential to yield substantive data about early historic interactions with tribal groups and agricultural development.

5.6.2.2 *San Juan Islands/Georgia Strait Sub-basin*

Many areas in the San Juan Islands/Georgia Strait Sub-basin are unchanged from historical conditions, largely due to the dominance of rocky shorelines in the San Juan Islands making alterations difficult. Shoreline alterations are a result of diking in the Nooksack River delta, armoring around the City of Bellingham, and the restriction of coastal embayments by nearshore roads in the San Juan Islands. One of the proposed sites is located in this sub-basin: the Nooksack River Delta near the Canadian border.

In the past 10 years, there have been 19 completed projects restoring habitat in the San Juan Islands/Georgia Strait Sub-basin, with 26 Nationwide 27: Aquatic Habitat Restoration permits issued. These projects include actions in the Nooksack Delta like Smuggler's Slough implemented by the Lummi Nation, salt marsh restoration near the City of Bellingham, and a few small-scale projects in the San Juan Islands implemented by the Friends of the San Juans restoring pocket beaches and embayments. There are nine active restoration and protection actions and five similar proposed actions. The Corps of Engineers Regulatory branch has issued approximately 30 to 40 Nationwide 13: Bank Stabilization permits and 50 to 100 Individual Permits in the last 10 to 20 years in the basin, many of which are concentrated in Anacortes, Bellingham, and harbors in the San Juan Islands. WSDOT completed 25 projects in the last 10 years that involved widening roads and replacing bridges and culverts, including the realignment of a road away from the Nooksack River; another 11 projects are active. No major road improvements with potential effects are planned in the area other than widening Mt. Baker Road and replacing culverts in northern Orcas Island. This data is current as of 2014.

The cumulative effects of large-scale restoration in the Nooksack River and smaller projects in the San Juan Islands would provide wetland habitat and coastal embayments and help offset past and ongoing development in the basin. Cumulative effects to ecological and other resources within this sub-basin are summarized in Table 5-16.

Table 5-16. Cumulative Effects Expected in the San Juan Islands/Strait of Georgia Sub-basin

What cumulative effects could occur within the San Juan Islands/Strait of Georgia Sub-basin from the Nearshore Study-identified work combined with other past, present, and future actions?	
Ecological Resources	Although other projects in the sub-basin may run concurrently with Nooksack, work would occur during allowable work periods and low tides to minimize cumulative effects of turbidity and noise. Large-scale restoration efforts in the Nooksack River delta combined with improvements to embayments and pocket beaches would provide rearing habitat for juvenile salmonids. Kelp and eelgrass beds should improve as sediment and nutrient inputs are restored, which would provide nursery habitat for many fish and invertebrates. Significant improvement in the Nooksack River estuary may aid in the recovery of Chinook salmon, and thus benefit Southern Resident killer whales.
Socioeconomics	Restoration of tidally influenced marshes in the Nooksack may decrease abundance of freshwater waterfowl for hunting and limit access. Increases in recreational fishing could result from the improvements in habitat. Commercial shellfish beds in the Nooksack River delta may be affected by dike removal, but overall would benefit from increased sediment and nutrient delivery and more wetlands that would improve water quality. Job opportunities would arise from construction of restoration sites, which may extend to individuals outside of the San Juan/Strait of Georgia sub-basin.
Transportation	The Nooksack River delta site would require the construction of six new bridges and raising roads. Other construction in this sub-basin may be concurrent with the proposed restoration work, but not likely in the same area. Cumulative effects are possible; however, they would be limited to the duration of construction.
Cultural Resources	Due to the large volume of archaeological sites that would be affected by the proposed restoration work, (known archaeological sites within the Nooksack River Delta) there is potential for significant loss of prehistoric and historic information about this sub-basin. Many of these sites, which have been identified as part of regional studies in the sub-basin, have not been subject to thorough documentation and present an unknown amount of research potential. As restoration activities that include the removal of agricultural or flood control structures may subject resources to degradation through tidal influences, there is potential for a high density of sites from one cultural group to be lost. However, comprehensive data recovery and analysis from these sites may add to a regional understanding of prehistory throughout the sub-basin. Cultural resource losses in the sub-basin are primarily attributable to new commercial and residential construction projects and demolition due to neglect; these activities will continue in the near future. Restoration activities have potential for adverse effects to National Register-eligible archaeological sites and historic buildings and structures located within the Nooksack River Delta. Resolution of adverse effects to National Register-eligible archaeological sites or historic buildings/structures would follow the procedures outlined in the PA.

5.6.2.3 *Hood Canal Sub-basin*

Negative effects to ecological processes in the Hood Canal Sub-basin are a result of nearshore roads such as Highway 101 restricting tidal flow at many of the tributary rivers and small creeks, diking in larger river deltas like Skokomish and Big Quilcene, and extensive armoring in the southern portions. One proposed restoration site is located in this sub-basin: Duckabush River Estuary near the northern end of Hood Canal. Cumulative effects to ecological and other resources within this sub-basin are summarized in Table 5-17.

Table 5-17. Cumulative Effects Expected in the Hood Canal Sub-basin

What cumulative effects could occur in the Hood Canal Sub-basin from Nearshore Study-identified work if combined with other past, present, and future actions?	
Ecological Resources	Although other projects in the sub-basin may be concurrent with construction at the Duckabush River Estuary, work would occur during allowable work periods and low tides to minimize cumulative effects of turbidity and noise. Restoration of wetlands in the larger river deltas and smaller embayments would benefit salmon and birds. Removing tidal barriers would increase sediment and nutrient delivery to eelgrass beds in Hood Canal and provide suitable substrate for forage fish.
Socioeconomics	Restoration efforts that benefit salmon would benefit recreational fishing. Improvements to water quality from increased wetlands would benefit the shellfish industry in Hood Canal. Job opportunities would arise from construction of the Duckabush restoration site as well as others in the basin, which may extend to individuals outside of the Hood Canal Sub-basin.
Transportation	The new bridge construction for replacement of the two bridges at the Duckabush Estuary would cause only short-term closures to Highway 101. Traffic would see minor effects during construction. No other WSDOT projects are planned in the area, so there would be little to no cumulative effects.
Cultural Resources	While limited archaeological surveys have been completed around the proposed site, shorelines of the Hood Canal sub-basin contain a variety of prehistoric shell middens, lithic scatters, and burial sites, as well as historic logging and homesteading sites. While development has been limited around Hood Canal, transportation projects, such as Highway 101, have impacted traditional tribal lands and archaeological sites. If sites are found within this area, their disturbance would contribute to an ongoing loss of prehistoric and historic data about the region. Losses of historic properties in the sub-basin are primarily attributable to new rural residential construction, demolition due to neglect, and highway modernization projects; these activities will continue in the near future. Over the 50-year analysis period for the project, bridges would likely be modernized or replaced with or without the project. Restoration activities at Duckabush would have an adverse effect to the National Register-listed Duckabush Bridge. In addition, there is potential for adverse effects to cultural resources that are currently unknown in the Duckabush River Estuary site. Resolution of adverse effects to National Register-eligible archaeological sites or historic buildings/structures including the National Register-listed Duckabush Bridge would follow the procedures outlined in the PA.

In the past 10 years, there have been 44 completed projects restoring and protecting a variety of habitats in Hood Canal with 31 Nationwide 27: Aquatic Habitat Restoration permits issued.

There are 16 active restoration projects and 22 proposed. These projects include dike removal in larger deltas like the Big Quilcene and Skokomish Rivers, and culvert replacement in several small streams that empty into Hood Canal. The Hood Canal Salmon Recovery Group is responsible for implementing many of these projects. In addition, the USACE has proposed a large-scale project to restore the Skokomish River. The project focuses on restoring year-round fish passage, increasing habitat complexity and quantity, wetland restoration, and reconnecting off-channel aquatic habitats.

The Corps of Engineers Regulatory branch has issued approximately 50 Nationwide 13: Bank Stabilization permits and an equal amount of Individual Permits in the last 10 to 20 years in the Hood Canal basin, many of which are along the shoreline of Hood Canal. No major road improvements with potential effects are planned in the area. WSDOT has completed 24 projects in Kitsap and Jefferson Counties, such as repairing the Hood Canal Bridge, removing creosote dolphins, upgrading culverts to fish friendly structures, and adding truck lanes. No such projects are proposed to occur near the proposed restoration site in the near future. This data is current as of 2014.

5.6.3 Summary of Direct and Indirect Effects with Synergistic and Countervailing Interactions

Interactive effects may be additive, countervailing, or synergistic (the net cumulative effect is greater than the sum of the individual effects).

Ecological Resources – Negative effects during construction would only endure for brief periods and would vary depending on the resource. Benefits of restoration activities would be countervailing to the construction effects, and the cumulative benefits of restoration along with other restoration actions described in the analysis above would be additive around Puget Sound.

Socioeconomics – Negative cumulative effects include loss of a small dock/marina with the associated decrease in revenue, potential decrease in area or relocation of area where waterfowl hunting is accessible on foot, and potential decrease in area available for shellfish growing pending further analysis at the Nooksack River Delta site. Across all Nearshore Study-identified restoration sites, in conjunction with other restoration actions around Puget Sound, total shellfish growing areas are expected to have a net increase. Other cumulative benefits include improved resiliency and adaptation to SLC across various nearshore habitat types as well as the replaced infrastructure – a pro-active investment that may preclude more expensive emergency reactions. In addition, the restoration sites are expected to provide additional habitat capacity for juvenile salmon rearing, which may increase fish populations and therefore sport and tribal fishing opportunities.

Transportation – Some traffic disruptions and temporary detours could increase commute times for residents at the affected localities during construction. The overall improved traffic flow at each site involving roadwork is expected to be a countervailing effect to the temporary traffic disruptions. Other cumulative benefits of multiple sites would include reduced susceptibility to road closures due to flooding, and early adaptation to anticipated sea level change.

Cultural Resources – The proposed restoration sites have varying degrees of probability for encountering buried, undocumented artifacts. If such cultural resources are encountered at multiple sites, this would constitute a cumulative effect of disturbance to multiple resources around Puget Sound. Restoration of tidal influences has the indirect effect of continuing the erosion of certain archaeological sites, especially those periodically exposed and subject to wave and wind erosion such as shell middens. Artifacts from sites may erode from their original contexts, lose scientific value, or be exposed for incidental collecting by beach visitors. Mitigation measures for these impacts would be assessed on a site-specific basis and may include archaeological data recovery and site avoidance. However, the loss of valuable cultural resources associated with archaeological sites cannot be entirely mitigated.

Potential for cumulative effects to the historic-age built environment around Puget Sound ranges from low to high depending on sub-basin. The three proposed sites have structures related to historic-age industrial and waterfront-related resources, historic agricultural landscapes including dikes and farmstead buildings and structures, and Highway 101 with historic bridges. The Puget Sound region has been experiencing significant losses attributable to urban sprawl, modernizing and industrial development projects, demolition due to neglect, new commercial and residential construction, and railroad and highway modernization projects.

5.6.4 Cumulative Effects Comparison of Alternatives

The No-Action Alternative has no cumulative effects associated with restoring nearshore landforms; however, it can be inferred that the continued lack of functioning nearshore processes is having the cumulative effect of overall degraded ecosystem functions in Puget Sound. The trajectory for this effect is a continued decline of ecological resources, which influences socioeconomics and recreation quality throughout the region. Alternative 3 would add more acreage of wetlands and remove more linear feet of stressors than Alternatives 2 and 4. Therefore, Alternative 3, combined within other previous and ongoing restoration efforts in the Puget Sound, has potential for greater positive cumulative effects to ecological resources. Positive cumulative effects on socioeconomics of Alternative 3 are greater than Alternatives 2 and 4 due to the improvements in habitat for many commercially valuable species; however, Alternative 3 has potential for greater negative cumulative effects to agricultural lands. Negative cumulative effects to transportation are greater in Alternative 3 due to the temporary closure of more roads; however, the overall benefits of road and bridge updates and improvements are assumed to outweigh the minor effect of temporary road closures. Alternative 3 has far more restoration sites than Alternatives 2 and 4 with certain removal of historic-age structures and likelihood of encountering cultural resources during site restoration activities. All appropriate mitigation would be conducted; however, some loss is anticipated. Alternative 3 is the environmentally preferred alternative due to having the greatest benefits for ecosystem function; however, Alternative 4 is selected as the agency preferred alternative as part of the implementation master plan described in section 4.3.

5.7 MITIGATION MEASURES*

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

NEPA regulations at 40 CFR 1500.2(f) state that Federal agencies shall, to the fullest extent possible, use all practicable means consistent with the requirements of the Act and other essential considerations of national policy to restore and enhance the quality of the human environment, and avoid or minimize any possible adverse effects of their actions on the quality of the human environment. Furthermore, at 40 CFR 1508.20, NEPA defines mitigation to include avoiding impacts by not taking an action, minimizing the magnitude, rectifying the impact through restoring the resource, reducing the impact over the life of the action, or compensating for the impact. Agencies are required to identify and include in the action all relevant and reasonable mitigation measures that could reduce negative effects of the action.

Site restoration would involve construction in proximity to ecological resources. Each site would have short-term construction-related effects with varying spatial and temporal scales and degrees of intensity. Construction designs would include practices that avoid and minimize effects to significant resources.

5.7.1 Standard Practices to Mitigate Negative Effects of Construction

Specific measurable and enforceable mitigation measures will be developed for each site based on its specific impacts. Construction designs and timing would include standard measures:

- In-water work would occur during designated periods consistent with recommended periods established by WDFW and approved by NMFS and USFWS.
- The Corps would schedule work outside of bird nesting season except where unavoidable.
- Each construction site would have an approved Environmental Protection Plan.
- Traffic alterations would be designed to minimize impediments, with the shortest and least disruptive detours possible, and in coordination with the relevant transportation agency(s).
- Bridge reconstruction would provide adequate clearances for navigation of recreational boats on navigable rivers to the extent practicable.

5.7.2 Best Management Practices to Protect Water Quality

Restoration sites in the nearshore zone would involve, by necessity, some in-water work and significant areas of ground clearing. Protecting water quality from storm water runoff would require implementation of best management practices (BMPs) to avoid excessive runoff and elevated turbidity in the receiving water body. As completed sites evolve, they would contribute sediments to the nearshore zone by design; however, it is important to avoid excessive pulses of sediment during the construction phase that are more than what the surrounding biota can easily tolerate. Every site would have a Storm water Pollution Prevention Plan, Temporary Erosion and Sedimentation Control Plan, and Diversion and Care of Water Plan approved by a Corps staff biologist. Construction contractors would be required to obtain a Construction Storm water Permit under Section 402 of the Clean Water Act. Standard construction storm water BMPs can be incorporated into site designs, operational procedures, and physical measures on site. The following are some examples of frequently used BMPs:

- Minimize area of ground disturbance and vegetation clearing.
- Use the site's natural contours to minimize run-off and erosion.
- Do not expose the entire site at one time; avoid bare soils during rainy months.
- Stabilize erodible surfaces with mulch, compost, seeding, or sod.
- Use features such as silt fences, gravel filter berms, silt dikes, check dams, and gravel bags for interception and dissipation of turbid runoff water.

5.7.3 Mitigation Measures for Effects of Greenhouse Gas Emissions

There are no legal requirements to mitigate for GHG emissions; however, BMPs are available for fuel and material conservation during construction. Such BMPs include the following:

- Maximizing use of construction materials that are reused or that have a high percentage of recycled material content, such as recycled asphalt pavement, concrete, and steel.
- Obtaining construction materials and equipment from local producers or vendors to minimize energy use for shipping.
- Encouraging construction personnel to carpool or use a crew shuttle van.
- Turning off equipment when not in use to reduce idling.
- Maintaining equipment in good working order to maximize fuel efficiency.
- Routing truck traffic through areas where the number of stops and delays would be minimized, and using off-peak travel times to maximize fuel efficiency.
- Scheduling construction activities during daytime hours or during summer months when daylight hours are the longest to minimize the need for artificial light.
- Implementing emission-control technologies for construction equipment.
- Using ultra low sulfur (for air quality) and biodiesel fuels in construction equipment.
- Using warm mix asphalt or cool pavement rather than hot mix asphalt.
- Using renewable energy produced onsite or offsite. For example, using solar-powered generators to supply electricity for field offices and construction lighting.

5.7.4 Mitigation Measures for Underwater Noise Effects

As described in section 5.1.8, certain project sites would have noise-producing activities that have potential for adverse effects to aquatic species. Construction methods would incorporate as many mitigation measures as feasible to reduce noise effects to below harmful thresholds. Pile drivers can use shielding and dampening methods and materials at the point of impact; bubble curtains use controlled, specially sized air bubbles to dampen the sound pressure waves to minimize effects on aquatic life. Additionally, sound-absorptive mats called sound aprons made of rubber, lead-filled fabric, or plastic layers can be hung around the noise source to help shield the aquatic environment from excessive noise. Construction timing can avoid exposure of animals to sound by observing designated periods to schedule the noise-inducing activities for times when the animals are not likely present, and by limiting work to low tides to take advantage of the way shallow water attenuates low frequencies and to reduce the area of effect. Marine mammal and bird monitoring plans can be implemented to alert construction teams when the animals are nearby and work should stop until the animals leave.

5.7.5 Best Management Practices and Mitigation Measures for Cultural Resources

The Corps will consult with the SHPO, ACHP, and federally recognized Native American Tribes on appropriate mitigation measures following the procedures laid out in the PA. Specific plans for BMPs for cultural resources are listed below:

- Update Historic Context for Levee Systems
- Identification of Area of Potential Effect (APE)
- Identification and Evaluation of Historic Properties:
    - Updated Literature Review/Background Research
    - Archaeological Survey and Testing
    - Historic Age Buildings and Structures Inventory
    - Traditional Cultural Property Inventory

If any cultural resources identified within the APE are eligible for the National Register, the Corps will make effects assessments. Should the proposal have an adverse effect on an eligible cultural resource that cannot be avoided, the Corps would work toward a resolution of adverse effects with the SHPO/ACHP, tribes, and other consulting parties following the procedures laid out in the PA. Examples of mitigation measures include but are not limited to the following:

- Recordation packages using digital photography and 35 mm black-and-white film photography
- Treatment Plans
- Public Interpretation
    - Museum/Traveling exhibits
    - Public talks
    - Educational material prepared for local schools
    - Interactive websites
- Oral History Documentation
- Historic Property Inventory
- Geo-Referenced Historical Maps and Aerial Photographs

6 RECOMMENDED PLAN

Based on the results of over 10 years of analysis by the Nearshore Study, the Corps is proposing a suite of ecosystem restoration sites throughout the Puget Sound that address degradation of the nearshore zone. The comprehensive restoration strategy for Puget Sound identified a total of 36 sites for restoration. Of those 36 sites, three are recommended for construction authorization under this Corps feasibility study and are presented as the recommended plan in this chapter. In addition to these three sites, nine sites are recommended for additional study under the Corps general investigations program. These sites are discussed further in Appendix K.

The implementation strategy allows for the three sites to move forward now because they provide key restoration across three separate areas of the Puget Sound. The additional nine sites recommended for further study ensure a watershed level solution for the most complex, large-scale restoration projects identified as critical for restoring the Puget Sound. Finally, the other 24 sites identified as part of the 36 site master implementation plan are being carried out under other Corps authorities or through non-federal actions and are complementary to achieving the overall study objectives. These can be completed concurrently with the implementation of sites recommended through the General Investigation study process.

The recommended plan includes three sites that, taken together, restore 2,101 acres of tidally influenced wetlands and would remove 28,860 linear feet of stressors from the nearshore zone, restoring the natural processes that support VECs and promoting the ecosystem structures and functions provided by wetlands, kelp and eelgrass beds, and riparian vegetation. Sites included in the recommended plan have costs ranging from $91 million to $262 million per site, with an estimated total project first cost of approximately $451.6 million (March 2016 price level). There are no costs or features (local betterments) that have been identified for implementation.

Please reference section 6.1 and Appendix B (Engineering) for detailed information regarding the three sites in the recommended plan. A map of the three sites included in the recommended plan is presented in Figure 6-1.

Figure 6-1. Geographic Locations of the Sites included in the Recommended Plan

6.1 SITES INCLUDED IN THE RECOMMENDED PLAN

The following sections provide additional information about each of the three sites of the recommended plan. Specific design details about each site can be found in Appendix B (Engineering Appendix).

6.1.1 Duckabush River Estuary

6.1.1.1 *Site Description, Geographic Location & Context*

The Duckabush River is one of several major river systems that drain the east slope of the Olympic Mountains to Hood Canal. The broad river delta fans out into Hood Canal on the south side of the Black Point Peninsula at approximately Mile 310 of Highway 101 (Figure 6-2). The estuary contains salt marshes, eelgrass beds, and extensive mud and gravel flats that support productive shellfish beds. The Duckabush Estuary is also home to harbor seals, bald eagles, and regionally significant winter waterfowl.

The Duckabush River is contained within a single channel through the site before emptying into the marsh and submerged marsh outboard of the site. The historical northern arm of the river has been blocked, is aggraded, and is now a partially filled dead-end tidal channel in the middle portion of the site. The Duckabush River Estuary was bisected by an early roadway and bridge that spanned the two distributary channels. A portion of the roadway, dikes, and abutments remain in place today. The majority of this infrastructure was removed and replaced in 1934 with two separate bridges as part of the construction of Highway 101. This highway cuts across the intertidal river delta and estuary wetland complex, spanning the main channel and a former distributary channel via two bridges. The Highway 101 bridges impact the Duckabush estuary, disrupting tidal circulation and impeding fish access to productive salt marsh and slough habitats (WDFW and PNPTT 2000). These hydrologic constrictions along with fill within the estuary have led to decline in mudflats and salt marshes. In addition, training berms are in place at the southern distributary arm of the Duckabush River, just upstream of the Highway 101 crossing, to control lateral movement of the channel and prevent river flows into the historical distributary channels. These berms severely restrict lateral connectivity with tidal channels and salt marsh habitat (Correa 2003).

The Duckabush Estuary is home to trumpeter swans, bald eagles, and regionally significant winter waterfowl. Harbor seals haul out in this location throughout the year and pupping occurs in the winter. The extensive mud and gravel flats are productive shellfish beds. Salt marshes and eelgrass beds characterize the upper and lower intertidal and subtidal areas, respectively. Herring use this eelgrass for spawning. The Duckabush River hosts four ESA-listed species of salmon: Hood Canal summer chum, Puget Sound steelhead, Coastal/Puget Sound bull trout, and Puget Sound Chinook salmon. The wild Chinook run is nearly extirpated from this river.

The proposed restoration would restore tidal and riverine hydrology to 38 acres of the Duckabush River Delta. This action would allow for natural habitat forming processes including sediment and detritus exchange, tidal channel formation, freshwater input, and tidal flushing within the delta.

6.1.1.2 *Site-Specific Goals & Objectives*

The goal of this project includes restoration of tidal exchange and re-establishment of distributary channels to improve connectivity in the Duckabush River Estuary. The following are the site-specific objectives for the Duckabush River Estuary, and all are applicable for the 50-year period of analysis:

- Reconnect and restore lost tidally influenced areas including estuarine and freshwater tidal wetlands in the Duckabush River Estuary.
- Re-establish distributary channels in the Duckabush River Estuary to promote greater diversity of delta wetland habitats.
- Restore mudflats and salt marsh in the Duckabush River Estuary.

6.1.1.3 *Site-Specific Constraints*

The following are notable issues that could constrain the plan formulation:

- The project cannot adversely affect the use of Highway 101 as the primary north-south access corridor for the Olympic Peninsula in Washington State.
- The Duckabush Bridge is listed on the National Register. Effects to this bridge will be evaluated and actions to avoid or mitigate potential impacts will be identified.
- The Skokomish Indian Tribe is a federally recognized tribal nation that has treaty-reserved fishing, hunting, and gathering rights in the project area; negative effects to tribal interests will be avoided to the maximum extent practical.

6.1.1.4 *Initial Plan Formulation*

Previously existing plans for this restoration site were considered during the Study Team's initial plan formulation process. Elements found in the Hood Canal Coordinating Council's 2004 publication titled, Salmon Habitat Recovery Strategy for the Hood Canal & Eastern Strait of Juan de Fuca" as well as their "2005 Hood Canal & Eastern Strait of Juan de Fuca Summer Chum Recovery Plan" are included in the Nearshore Study design alternative. While the prior plans' goals and objectives were focused on the recovery of a single species of salmon, the plans dovetailed very well into the Nearshore Study's goals and objectives to provide a holistic restoration of substantial areas of aquatic nearshore habitats. The Corps used aspects of these plans as a starting point for initial plan formulation activities.

As described in section 4.1, a suite of 21 different management measures were identified for implementation across Puget Sound. Management measures identified for this study are fully outlined in the Management Measures for Protecting and Restoring Puget Sound Nearshore (Management Measures Technical Report, Clancy et al. 2009). Structural measures (e.g., armor removal, dike removal, channel rehabilitation, etc.) and non-structural measures (invasive species control, physical exclusion, public education, etc.) were identified and evaluated. A summary of the 21 management measures and their relationships to nearshore ecosystem processes are shown in Table 4-1. As described in section 4.1, the 21 management measures were classified into three groups: restorative measures, prerequisite measures, and protective measures. Of the 21 management measures originally identified, nine management measures were carried forward in the formulation of alternative plans. Seven of the nine measures are classified as restorative measures, which exert long-lasting effects on ecosystem processes and will often provide the best opportunity of achieving complete restoration of processes, directly meeting the planning objectives of this study. In addition to these nine restorative measures carried forward.

Based on the screening described in section 4.1, the study team evaluated which of the nine remaining management measures could be implemented at the Duckabush River Estuary site. The team qualitatively determined whether the identified measures met the site-specific planning objectives and generally avoided site-specific planning constraints. The following five management measures were carried forward for evaluation at this site:

- Remove, modify, or realign the Highway 101 causeway to restore the tidal prism of the delta as well as reconnect freshwater and tidal flows to remnant distributary, tidally influenced channels, and tributary wetlands
- Remove fill (training berms) from the Duckabush River upstream of Highway 101 and adjacent areas to reconnect the river to its intertidal floodplain and wetlands, restore floodplain and estuary wetland processes, and increase channel density
- Reestablish tidally influenced distributary channels, replace a culvert at Shorewood Road with a bridge, and excavate channels within the marsh areas to restore tidal channel formation, exchange of aquatic organisms, and sediment accretion and erosion for greater habitat diversity, which increases biodiversity
- Large wood placement for channel stability, which will increase habitat complexity
- Riparian revegetation for shading, nutrient inputs, and complexity of bank habitat (non-structural measure)

The primary measure for this site is hydraulic modification associated with the Highway 101 causeway and two bridges spanning the estuary, as these structures are the key impediment to restoration at the site. Early plan formulation activities were driven by two key planning constraints outlined above: maintain the Highway 101 transportation corridor and evaluate effects to the Duckabush Bridge (NRHP listed). These key constraints guided the plan formulation process for this site and led the team to identify four bridge removal or realignment options:

1. **Complete removal and realignment of the Highway 101 causeway and bridges.** This plan includes full removal of the Highway 101 causeway and bridges across the estuary. An elevated roadway on a 2,100-foot-long bridge would be constructed in a new alignment further upstream from the existing highway, allowing the greatest extent of tidal exchange in the estuary as well as allowing natural meandering of the channel for dynamic habitat creation.

2. **Limited removal and realignment of the Highway 101 causeway and bridges.** This plan would retain the present roadway on the south end of the Duckabush Bridge and dead-end the roadway at the Duckabush Bridge. A new road and causeway would be constructed to the east to maintain the Highway 101 transportation corridor. This plan was not recommended because it would fail to achieve a substantial portion of the ecosystem objectives at this site by keeping the main channel locked in place without possibility for natural meandering important for dynamic habitat creation. In addition, this plan would leave in place one of the primary stressors identified as a problem at this site (Duckabush Bridge).

3. **Retain Duckabush Bridge and Elevate Causeway.** This plan would retain the existing Duckabush Bridge superstructure and elevate it onto a causeway in its existing alignment. This plan is not recommended because it would fail to achieve a majority of the ecosystem objectives at this site by preventing process-based restoration and would not improve ecosystem functions due to failure to remove the primary stressors identified as a problem at this site.

4. **Retain Duckabush Bridge and Relocate Causeway.** This plan would remove the roadway on both ends of the Duckabush Bridge but keep the bridge in place. A pedestrian access boardwalk would be constructed to allow visitor access to the historic bridge. A new roadway would be constructed to the east to maintain the Highway 101 transportation corridor. This plan is not recommended because it would not achieve a substantial portion of the ecosystem objectives at this site by keeping the main channel locked in place without possibility for natural meandering and leaves in place one of the primary stressors identified as a problem at this site. The boardwalk would shade an area that should otherwise support tidal wetlands, and the required parking area would forego the need for a vegetated wetland buffer area to protect the investment in restoration at the site. Finally, additional revetment/scour protection measure for the bridge footings would likely be required, and there is a high possibility that the boardwalk would have to be moved, repaired, or reconstructed to account for dynamic river processes.

Plan #1 (Complete removal and realignment of the Highway 101 causeway and bridges) was carried forward because it meets the study objectives, avoids constraints, and restores critical habitat for nationally significant resources. Removal and realignment of the causeway will allow tidal exchange to the entire estuary, allow the channel to dynamically evolve over time, and restore freshwater input as well as sediment transport.

6.1.1.5 *Summary of Proposed Action*

The restoration proposal would include the removal of the Highway 101 causeway and bridges across the estuary, allowing significant restoration of tidal exchange in the Duckabush River Estuary. An elevated roadway on a 2,100-foot-long bridge would be constructed in a new alignment further upstream from the existing highway, allowing for tidal exchange to occur and distributary channels to develop while maintaining the key transportation route on Highway 101. Berms along the river would be removed to restore channel migration and channels would be excavated at or near their historical configurations, which would reestablish tidal and freshwater connections throughout the estuary. The bridge span of 2,100 feet, discussed in Engineering Appendix Section 1-6.1.1, is the result of feasibility level engineering of the conceptual design to accommodate modern design standards for the highway and result in no new areas of fill in the estuary. Figure 6-2 depicts the key design elements at the Duckabush River Estuary.

6.1.1.6 *Hydrology & Hydraulics*

Flood Limits: The Duckabush River Estuary is confined within steep valley walls. High tides fill the estuary from one side to the other at Highway 101. The primary source of flooding in the vicinity of the site comes from coastal storm surge associated with low pressure and large storms on the Pacific side of the Olympic Peninsula. The 1% Annual Exceedance Probability (AEP) coastal base flood elevation indicates a static rise of about 6.5 feet above the highest high tide level. The replacement of the causeway at Duckabush with an elevated bridge will not affect coastal flood elevations. The bridge removal will potentially reduce backwater and flooding associated with high flows on the Duckabush River.

Modeling: Flood elevations for the Duckabush site were taken from the Federal Emergency Management Act (FEMA, 1982) Flood Insurance Study for Jefferson County. In addition, both USACE (2003) and USBR (2004) both conducted channel migration zone studies on the Duckabush River at and above the estuary and this information was used to confirm the expected width of the active channel after bridge and road embankment replacement. In PED, survey information along with a tidal hydraulics analysis will be used to model the flows in the estuary and confirm the expected area of benefits from the causeway removal. The Base Flood Elevation from coastal flooding will be verified to inform the design of the final bridge and roadway elevation. River modeling and sedimentation analysis is needed to ensure no adverse effects of the increased conveyance downstream on upper reaches of the Duckabush River as well as to predict the evolution of the restored distributary channels and their effect on the estuary.

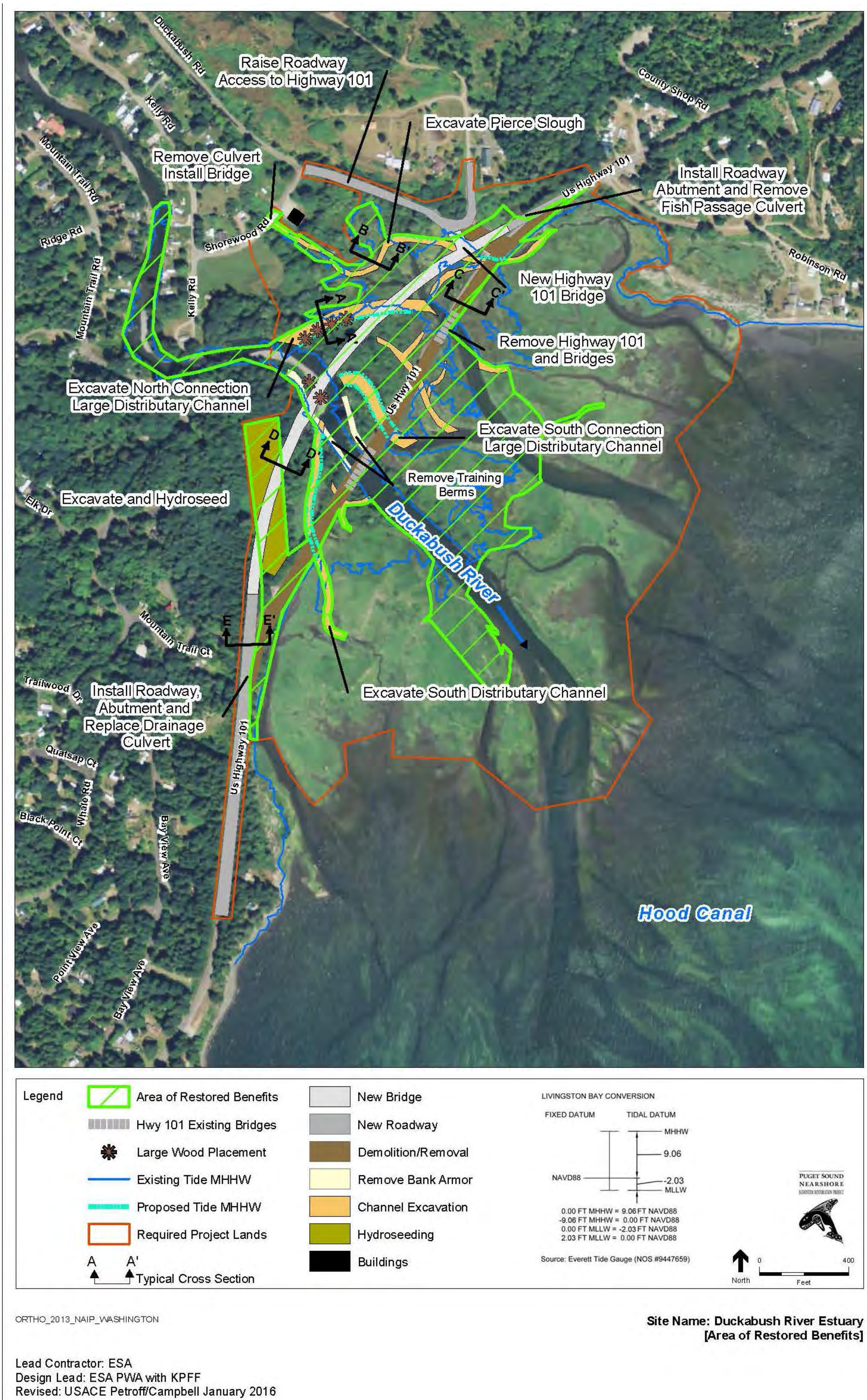


Figure 6-2. Duckabush River Estuary

6.1.1.7 *Operations & Maintenance*

Operations and maintenance costs for the Duckabush restoration are related to maintenance and repair of the new bridge, roadway, and roadway embankment. Additional OMRR&R activities may include actions such as removal of invasive plant species, debris and sediment removal to maintain tidal flow to the north distributary channel, and maintenance of culverts including removal of debris and sediment. The annual OMRR&R estimate is approximately $122,000 per year; OMRR&R activities are a non-Federal sponsor responsibility.

6.1.1.8 *Public Review*

There were no specific comments related to Duckabush during public review of the Draft FR/EIS. The Corps and non-Federal sponsor will continue to coordinate with landowners and stakeholders as the study progresses.

6.1.1.9 *Risk & Uncertainty*

The study team has used a risk-based strategy in their approach to formulating the project from the early stages of the study. Key risks or uncertainties associated with this site include the following, along with the strategy to reduce risk as the study continues.

Earthwork Quantities

> Risk and Cause: Earthwork quantities were determined based on available LiDAR data. In addition, no soil investigations have been done on site to characterize possible settlement of the project features.
> Risk Management: Additional survey data, LiDAR and soils information will be obtained during the PED phase. Additional hydraulic modeling and geotechnical analysis will be conducted to refine the size and scale of roadway embankments. PED costs include estimates for obtaining the required data and performing necessary engineering analyses. The Cost Schedule Risk Analysis (CSRA) for the project has identified risks associated with the variability in existing survey/ LiDAR data with varying resolution as well as uncertainty in future settlement of roadway embankments. Cost contingencies reflect the uncertainty in quantities of material required for construction.

Bridges & Roads: Foundation and Placement

> Risk & Cause: The bridge and foundation geometry are likely to change based on design to occur in PED. Some elements of the scope of the proposed bridge may be adjusted based on additional analysis and design (e.g., longer spans, larger piers, or raising the bridge).
> Risk Management: Additional survey data, LiDAR and soils information will be obtained during the PED phase. Additional hydraulic modeling and geotechnical analysis will be conducted to refine the size, scale, and alignment of the new bridge. PED costs include estimates for both obtaining the required data and performing necessary engineering

analyses. Cost contingencies reflect the uncertainty in quantities of material required for construction.

Duckabush Bridge Removal

Risk & Cause: The Duckabush Bridge is listed on the NRHP and is proposed for removal as part of the recommended plan.
Risk Management: Section 106 coordination and consultation for an agreement document (i.e., a PA) is complete. If it is determined that the project will have an adverse effect on any significant structures, the Corps will avoid, minimize, or mitigate following Section 106 procedures and stipulations in the PA. Effects to the Duckabush Bridge will be evaluated and actions to avoid or mitigate potential impacts will be confirmed during PED. The current cost estimate assumes $500,000 for mitigation associated with the Duckabush Bridge removal. The cost estimate also assumes complete removal of the bridge; it is assumed the existing structure will not be relocated intact to another location. Cost contingencies reflect the potential for mitigation costs higher than currently estimated.

6.1.1.10 *Ecosystem Restoration Benefits*

As Figure 6-2 depicts, this site restores several processes including sediment transport, freshwater input, tidal exchange, distributary channel migration, and marsh accretion. Restoration of this site provides benefits to ESA critical habitat for Chinook salmon, Hood Canal summer chum, steelhead, and bull trout as well as direct benefits to harbor seals, bald eagles, waterfowl, shellfish, and the highly valuable eelgrass habitat at the edge of the site. This project provides an opportunity to reconnect floodplain and intertidal wetlands, improving tidal exchange, sediment transport, and estuary development. Realignment of roads and bridges will restore tidal inundation and hydrology, and reconnection of distributary channels to promote greater diversity of delta wetland habitats. Additional benefits include the following:

- Reconnects and restores 38 acres of scarce tidal marsh and estuarine mixing zone by removing 1,270 linear feet of tidal barrier, roadway, and shoreline armoring, allowing unrestricted flow of freshwater into the estuary (meets site-specific planning objective #1)
- Restores distributary channels, allowing formation of a tidal channel network and more natural tidal exchange for improved estuarine habitat that supports many fish, bird, and invertebrate species (meets site-specific planning objective #2).
- Restores mudflats that benefit native shellfish harvested on the public tidelands and the shorebirds that feed on mudflat invertebrates, as well as salt marsh habitat that benefits waterfowl, shrimp, crab, and salmon (meets site-specific planning objective #3).
- Restores large river delta that provides valuable nursery habitat for juvenile salmon species, increasing survival and supporting Puget Sound population recovery.

6.1.1.11 *Significance*

- Addresses habitat constraints in Hood Canal, which is a partially isolated geographic section of Puget Sound
- Restores intertidal and shallow sub tidal areas that are habitat for recreationally and culturally important shellfish such as oysters, mussels, and clams
- Supports Summer Chum Salmon Conservation Initiative to recover this ESA-listed species
- Supports Puget Sound Chinook Salmon Recovery Plan to recover this ESA-listed species

6.1.1.12 *Site-Specific Environmental Impacts*

Removal of 1,270 feet of tidal barrier and restoration of 38-acre tidal wetlands will achieve long-term benefits in the previous section (*Ecosystem Restoration Benefits*), but will also have short-term construction impacts listed below that are necessary to achieve the benefits.

Physical Environment: Nearshore Processes and Structure

Processes, Physiographic Characteristics, Oceanography, and Sedimentation and Erosion: These resources would all be positively effected as described in the previous section (*Ecosystem Restoration Benefits*) primarily by providing unrestricted tidal flow to the estuary.

HTRW: A Phase 1 Environmental Site Assessment was conducted in conformance with the scope and limitations of ASTM E1527-13: *Standard Practice for Environmental Site Assessments,* and ER 1165-2-132: *HTRW Guidance for Civil Works Projects*. This assessment has shown no evidence of recognized environmental conditions in connection with the proposed project footprint, nor any conditions at neighboring sites that have the potential to affect work at the project site. Please refer to Appendix B (Engineering) for the complete Phase 1 assessment.

Water Quality: Water quality would experience pulses of turbidity during removal of the Highway 101 bridges and fill across the estuary for the new wide-span bridge piers and culverts; however all work would be done using best management practices during construction of the new bridge including isolation devices such as cofferdams or equivalent, silt curtains, and timing work during low tides to prevent turbidity from affecting the aquatic environment. Installation of water isolation devices may cause pulses of turbidity, but the duration of effect would only be a matter of hours and for an area not likely to exceed an estimate of 600 feet based on velocity of flow in the estuary. Long-term water quality would improve by allowing unrestricted tidal flushing of the estuary and greater freshwater flow into the adjacent nearshore environment.

Greenhouse Gases: Construction machinery was estimated to have GHG emissions of 1,769 tons of CO_2 based on types of machinery that would be used and estimated duration of construction.

Underwater Noise: Machinery would cause underwater noise in the estuary during bridge removal and reconstruction from drilling, and cast-in-place work for pier installation and potential for vibratory pile driving for pile removal if needed. These impacts would be limited to the duration of construction and minimized by working during low tides and low flows. If work occurs from a platform on top of estuary substrate, this would further minimize noise effects.

Biological Environment: Nearshore Functions

Vegetation: Effects to riparian vegetation would be minimized by using temporary access routes via the existing system of county and farm access roads. Staging areas would be determined during the PED phase. Areas free of trees and other native vegetation would be utilized to the extent practicable. Some areas would need to be cleared during construction, such as areas along the installation of the new HWY 101 Bridge, excavation of the North Channel connection to the mainstem of the Duckabush River, and an area of the new Duckabush Road. The number and sizes of trees felled will be determined during PED phase. Replanting of disturbed areas would occur following construction. Eelgrass and patches of brown kelp grow downstream from the project site. Turbidity generated from construction would not be substantial enough to harm this aquatic vegetation given its proximity to the project and the BMPs that would be used.

Shellfish: Shellfish populations are downstream from the project footprint; short-term and long-term effects of sediment to shellfish habitat at the Duckabush estuary will be minimized through design and the implementation of BMPs. For other macroinvertebrates within the project site, actions would have the short-term impact of disrupting or destroying benthic and epibenthic invertebrates. Once the stressors are gone, invertebrate colonization would follow a pattern of succession, with near complete recovery in one to three years (Hueckel and Buckley 1987, Martin 2012 pers. comm.).

Fishes: This estuary hosts herring spawning beaches and serves as a migration corridor for multiple species of salmonids. Negative effects would come from construction activities causing 1) increases in turbidity from excavation of fill, and 2) noise and vibration associated with large equipment operation for excavation and demolition. Elevated levels of turbidity could cause physiological damage to gills, and elevated noise could cause a behavioral response to flee or delay migration. Working within designated in-water work window periods of 16 July to 31 August when fish are less likely to be present and during low tides would minimize effects of noise and turbidity on fish.

Birds: This area has a great blue heron colony, osprey nesting, trumpeter swans, and waterfowl concentrations. Construction activity including demolishing roads and bridges and hauling off large amounts of material would cause temporary disturbances to bird communities due to noise and the presence of heavy equipment, likely causing a behavioral response to flee the area. No long-term impacts to bird population are anticipated, although a transition to communities more typical of brackish environments is likely. Felling of any potential nesting trees would occur prior to the nesting season.

Mammals: A couple of small seal haul-out locations have been reported at the Duckabush estuary near the main river outlet. Impacts to marine mammals would result from noise disturbances caused by bridge construction activities, which could cause behavioral response such as fleeing, or interfere with ability to locate prey. Underwater noise generating activities such as drilling and casting of piers would occur farther up in the estuary during low tides and low flows, and therefore are not expected to exceed thresholds that would cause physical harm. If work occurs from a platform on top of estuary substrate, this would further minimize noise effects. Impacts to other aquatic mammals like river otter, beavers, and muskrat would derive from noise and turbidity associated with construction. These impacts may result in the response to flee the area, but would not have any long-term impacts to populations in the project area.

Rare, Threatened, or Endangered Species: Impacts to ESA-listed species are similar to those described for fish, birds, and mammals. Through coordination with NMFS and USFWS, the ESA-listed species and critical habitat that the Corps consulted on include the following determinations: Likely to Adversely Affect bull trout, Puget Sound Chinook salmon, Hood Canal Summer chum salmon, and Puget Sound steelhead; Not Likely to Adversely Affect critical habitat for these three salmonids; and Not Likely to Adversely Affect Southern Resident killer whale or its critical habitat. No marbled murrelet or spotted owl nests occur within disturbance range of the site. (See appendix J for ESA consultation documents.)

Cultural Resources

The Duckabush site contains the Highway 101 causeway, including two bridges. Of the two bridges on the causeway, one (the Duckabush Bridge) is listed in the NRHP. The second bridge has been inventoried and recommended ineligible but has not been formally evaluated. One archaeological site is located in the Duckabush project area and has not been formally evaluated. Table 6-1 lists the known cultural resources located in the Duckabush site and the potential effect based on the current project design. Impacts to cultural resources are documented in section 5.3; see tables 5-11 and 5-12.

The Corps has prepared a Programmatic Agreement outlining the Section 106 process that will be followed in PED (Appendix D). The PA is the mechanism for Section 106 compliance as long as the PA stipulations are implemented in PED. The PA includes which Section 106 tasks need to occur prior to construction (e.g. fieldwork), how Section 106 consultation will occur, how determinations of eligibility will be made, how findings of no adverse effect will be determined, how findings of adverse effects will be made, and how the PA will be implemented, and a dispute resolution procedure. In addition, the PA provides for a variety of treatment measures that can be used for mitigation of an adverse effect (See Appendix E of the PA). The treatment measures are standard types of mitigation actions used for adverse effects and the costs of these treatment measures have been taken into account during cost estimation for this project.

Table 6-1 Duckabush Estuary Archaeological Sites

Duckabush Estuary Archaeological Sites				
Site Number*	**Description**	**NRHP Eligibility**	**Location**	**Potential Effect to Resource Based on Current Design****
45JE362	Duckabush Orchard	Unevaluated	In project area	Potentially affected
Duckabush Estuary Structures				
Description*	**Date Constructed**	**NRHP Eligibility**	**Location**	**Potential Effect to Resource Based on Current Design****
Duckabush River Bridge	1934	Listed on NRHP	In project area	Adverse effect with proposed removal
Northern Distributary Channel Bridge	1934	Unevaluated	In project area	Adverse effect with proposed removal

*Location of sites is based on information from the DAHP database and site form data. Note existing site boundaries have not been field verified for this project.

**Project designs could change in PED. The effect or lack of effect to the resources is based on the current information to date and is subject to change if project designs change.

Socio-Economic Resources and Human Environment

Land Use: The Duckabush River Estuary site will convert only 0.2 acres Prime and Unique Farmland and 0.2 acres Statewide Important or Local Important Farmland to tidal wetlands according to NRCS consultation. This accounts for less than 0.001% of farmland in Jefferson County. Given this small fraction, impacts to farmland would be minor and insignificant. The individual farmer(s) would be compensated for their loss during the purchasing agreement with the local sponsor and the loss of crop production would likely be absorbed by other nearby farms. Duckabush includes privately held, commercial, Jefferson County, and state and Federal lands (U.S. Forest Service), with public as the dominant ownership at 87% of the total site acreage. Property acquisition would occur by the local sponsor. Minor land use changes are the only anticipated long-term impact from this project.

Commercial Fisheries: Restoration of tidal wetlands at Duckabush would support fish and wildlife species by creating additional habitat for foraging and refuge. Impacts from restoration of sediment transport process to shellfish habitat at the Duckabush estuary will be taken into careful consideration during the next phase of design to avoid short-term and long-term effects.

Recreation: Temporary impacts to recreation are likely due to limited access to such areas during bridge and road replacement. Recreation such as increased bird watching opportunities may increase as more estuary dependent species use the area; however, benefits to recreation are incidental to the project as there will be no expenditure toward increased access or recreation features.

Transportation: Transportation impacts will be short term during the construction of the new Highway 101 Bridge, altering the interchange at Duckabush Road and the new bridge at Shorewood Road. The Corps would design and sequence the work to minimize traffic interruptions and delays. Bridge modification would conform to current bridge design safety standards applicable to the type and size of bridge being modified.

Public Safety: There would be no reduction to public safety at any of these sites; in fact, conforming to updated standards would likely improve safety and will allow for predicted sea level change.

6.1.1.13 *Site Summary Statistics*

- Acres Restored: 38 acres of scarce tidal marsh and estuarine mixing zone
- Removes 1,270 linear feet of tidal barrier, roadway, and shoreline armoring
- Total Project Cost: $90.5 M (refer to Table 6-2 for cost summary)

Table 6-2. Project Cost Summary – Duckabush River Estuary

Project Cost Component	Project First Cost ($1,000s; October 2015 price level)
Construction and Real Estate	
Construction Costs (including mitigation)	$17,473
Real Estate Costs (including relocations)	$48,115
Planning, Engineering and Design (PED)	$16,174
Construction Management (CM)	$6,401
Monitoring	$205
Adaptive Management	$2,151
Total Estimated First Cost	**$90,523**
Amortized Cost (3.125% discount rate[1])	$3,711
Annual OMRR&R[2]	$122
Total Average Annual Cost (AAC)	$3,833
Total Benefits (AAHU)	12.3
Total AAC / AAHU	**$312**

[1] Includes interest during construction (IDC). [2] Operations, maintenance, repair, replacement & rehabilitation (non-Federal sponsor responsibility)

6.1.2 Nooksack River Delta

6.1.2.1 *Site Description, Geographic Location & Context*

The Nooksack River is the northernmost of the 16 major river deltas in Puget Sound and originates from glaciers on and around Mt. Baker, a 10,700-foot-high peak in the Cascade Mountains. In the upper watershed, three main forks converge before the river enters the flatter, agricultural lowlands. The Nooksack River delta is centered on Lummi Nation lands north of Bellingham (Figure 6-4). It encompasses nearly all of the Nooksack and Lummi River estuaries below Ferndale, Washington. The Lummi River, located in the lowland estuary and discharging to Lummi Bay, was once the main discharge route for the Nooksack River. The Lummi River is now mostly disconnected from the Nooksack River and only receives occasional high flows from the Nooksack through a culvert. The Nooksack River currently discharges to Bellingham Bay near the community of Marietta. The project area covers parts of the Lummi Nation lowlands as well as agricultural land south of Ferndale. Almost the entire project area lies below the 100-year flood elevation.

The lower Nooksack River has been significantly altered. Large changes to the channel morphology of the Lower Nooksack River occurred after western settlement of the region in the second half of the 19th century. The flow path of the Nooksack River has been modified since the mid-19th century beginning with active removal of large wood, draining, diking, and levee construction. Prior to 1860, the Nooksack River emptied into both Lummi and Bellingham Bays with flows shifting between the two outlets over time, depending on logjams. In the late 1800s, the Nooksack River was diverted to drain into Bellingham Bay.

Prior to the diversion and development, the lower Nooksack River consisted of numerous channels and sloughs, and had a major outlet into Lummi Bay. After the diversion of the Nooksack River into Bellingham Bay, the Lummi River became a high water overflow channel from the Nooksack River at RM 4.5. During low flow conditions, the Lummi River acts as a slough, dominated by tidal influence. During periods of Nooksack River high flows, the Lummi River carries a small amount of fresh water to Lummi Bay.

Historically, the lower Nooksack and Lummi Rivers were associated with numerous estuarine and tidally-influenced riverine wetlands, but well over half of this habitat was drained and diked for conversion to agricultural use. The Nooksack River has a heavily impacted floodplain and very poor riparian conditions throughout the mainstem and most tributaries. Dikes and levees, lining 33% of the total shoreline, have converted nearly all of the mainstem Nooksack River to a single channel, resulting in a major loss of slough, side channel, and off-channel habitat as well as significantly shortening and simplifying the previously long and complex shoreline. In fact, the historical delta shoreline was 47% longer than it is today (Simenstad et al. 2011). In addition to channel confinement, wetlands have been filled, compounding the loss. These floodplain impacts are believed to be one of the greatest salmonid habitat problems in the downstream project areas. The entire length of the mainstem Nooksack River also has a severely degraded riparian condition, with remarkably poor shade levels and most reaches with little to no canopy cover.

In general, the majority of fish and wildlife populations found within the Nooksack River basin are in a depressed state in relation to their historic condition. The Nooksack River system supports nine species of salmonids, represented by more than 20 distinct stocks that are separated by their run timing and spawning location. Three of these species are listed under the Endangered Species Act: Puget Sound Chinook, Puget Sound steelhead, and Coastal/Puget Sound bull trout. The Nooksack River is one of five geographic areas considered essential for recovery of the Puget Sound Chinook Evolutionarily Significant Unit. Other anadromous salmonid species found in the Nooksack River include riverine sockeye, Coho, even-year and odd-year pink, and chum salmon; summer and winter steelhead; and coastal cutthroat trout. Runs of all of these species have declined significantly from historic levels.

The Nooksack floodplain has suffered a substantial loss of its tidal freshwater and estuarine wetlands from 8,785 acres recorded in U.S. Coastal and Geodetic Survey maps in 1888 down to only 3,211 acres remaining today representing a 64% loss. This includes a 71% loss of vegetated tidal wetlands. More than half of the remaining acreage is disconnected from natural hydrology by dikes, roads, and tidegates. This area is important habitat for migratory shorebirds of the Pacific Flyway, waterfowl, trumpeter swans, Canada geese, and the Wrangell Island snow geese.

While this is a substantially degraded floodplain, it is a key candidate for broad areas of restoration because of having no major cities or development that preclude restoration work. The proposed restoration at the Nooksack River Delta would modify levees, roads, and other hydrological barriers to restore riverine and tidal flow and sediment transport and delivery processes to the Nooksack River Delta, restoring 1,807 acres (or 20% of the whole floodplain available for restoration) of scarce tidal freshwater wetlands. This represents a rare opportunity to restore such a substantial portion of a Puget Sound delta.

6.1.2.2 *Site-Specific Goals & Objectives*

The goal of this project includes restoration of estuarine emergent marsh, scrub-shrub wetlands, and forested floodplain along the Nooksack River delta to improve connectivity and reduce fragmentation along the channel. The following are the site-specific objectives for the Nooksack River Delta, and all are applicable for the 50-year period of analysis:

- Reconnect and restore freshwater input to lost floodplain habitats including channel meander zone, shoreline complexity, and shaded aquatic habitat in the Nooksack River Delta.
- Restore tidal inundation to reconnect lost tidally influenced area including estuarine and freshwater tidal wetlands and tidal channels in the Nooksack River Delta.
- Re-establish intertidal and shallow sub tidal topography of the Nooksack River Delta to restore tidal prism and salinity gradient to increase nearshore habitat capacity and productivity for fish, birds, and other estuarine species.
- Improve aquatic habitat connectivity between lower river systems and upstream habitat networks of the Nooksack River.
- Restore a more natural riparian corridor along the Nooksack River Delta.

6.1.2.3 *Site-Specific Constraints*

There are a number of site-specific constraints that a recommended plan would attempt to avoid during formulation. The following are a list of notable issues that constrain the plan formulation:

- The project cannot prevent the use of Ferndale Road, Marine Drive, Kwina Road, Haxton Way, Hillaire Road, and Slater Road. These roads provide the only access to portions of the Lummi Indian Reservation, and the only access to the Lummi Island ferry terminal located on the Lummi Peninsula. Slater Road and Marine Drive are part of the main transportation corridor to two of the industries in the Cherry Point Heavy Impact Industrial Zone. When both roads are closed, access to the Reservation, the Lummi Island ferry, and the Cherry Point industries is through, or to the north of, the City of Ferndale, approximately 2 miles north of Slater Road. This detour can more than double travel times to and from Bellingham and result in severe congestion in the City of Ferndale. These road closures have substantial impacts on the economic, public health, and safety of the affected areas (FEMA 2015).
- The Nooksack Tribe and Lummi Tribe are federally recognized tribal nations that have treaty-reserved fishing, hunting, and gathering rights in the project area. Negative effects to tribal interests will be avoided. Increasing flood risk to significant areas of tribal lands should be avoided to the extent practicable.
- The project will avoid a single known HTRW site located approximately one half mile east of the Slater Road/Nooksack River bridge.
- The project will avoid two mitigation banks downstream of the project area and will not directly benefit the mitigation banks.

6.1.2.4 *Initial Plan Formulation*

Previously existing plans for this restoration site were considered during the Study Team's initial plan formulation process. Elements found in the 2005 salmon recovery chapter are included in the Nearshore Study design alternative (WRIA 1 Salmonid Recovery Plan), the 1999 Whatcom County Flood Hazard Management Plan (CFHMP), and the Lummi Multi Hazard Mitigation Plan (2004, 2007, 2010). The Corps used aspects of these plans as a starting point for initial plan formulation activities.

As described in section 4.1, a suite of 21 different management measures were identified for implementation across Puget Sound. Management measures identified for this study are fully outlined in the Management Measures for Protecting and Restoring Puget Sound Nearshore (Management Measures Technical Report, Clancy et al. 2009). Structural measures (e.g., armor removal, dike removal, channel rehabilitation, etc.) and non-structural measures (invasive species control, physical exclusion, public education, etc.) were identified and evaluated. A summary of the 21 management measures and their relationships to nearshore ecosystem processes are shown in Table 4-1. As described in section 4.1, the 21 management measures were classified into three groups: restorative measures, prerequisite measures, and protective measures. Of the 21 management measures originally identified, nine management measures were carried forward in the formulation of alternative plans. These measures exert long-lasting effects on ecosystem processes and will often provide the best opportunity of achieving complete restoration of processes, directly meeting the planning objectives of this study.

Based on the screening described in section 4.1, the study team evaluated which of the nine remaining management measures could be implemented at the Nooksack River Delta site. The team qualitatively determined whether the identified measures met the site-specific planning objectives and generally avoided site-specific planning constraints. Based on this evaluation, one additional non-structural measure, residential relocations, was identified as a possible feature for the Nooksack River Delta. The following nine management measures were carried forward for evaluation at this site:

- Armor removal for streambank restoration and reconnecting floodplain habitat
- Dike removal or modification for floodplain freshwater marsh restoration
- Setback levees to maintain existing levels of flood risk management
- Riparian revegetation for shading, nutrient inputs, and complexity of bank habitat (non-structural measure)
- Large wood placement for increased habitat complexity
- Partial restoration of river flow to Lummi River through installation of water control structure at confluence of Lummi and Nooksack Rivers; structure intended to facilitate transfer of freshwater and sediment to the Lummi River
- Regrading of the Lummi River to allow for more frequent engagement by fluvial flows from the upper watershed
- Residential relocations (non-structural measure)

These measures were combined to form a number of viable alternatives that attempted to meet objectives and avoid constraints. The size and scale of measures were identified to take advantage of existing topography and using the existing flood risk features in the area where applicable. Based on the initial plan formulation, evaluation, and screening activities summarized above, one alternative was identified that meets the study objectives, avoids constraints, and restores critical habitat for nationally significant resources.

6.1.2.5 *Summary of Proposed Action*

The restoration proposal includes actions on both the Nooksack River and Lummi River. Portions of the Nooksack River's right and left bank dikes will be removed, allowing the river to be reconnected to historical tidal areas and floodplain habitats. A new setback levee will be constructed along the right bank of the Nooksack River to maintain existing levels of flood risk management in the area while still allowing reconnection of high value floodplain habitats. As described above, the setback levees are required to maintain social and tribal acceptability at the site. The setback levee will generally follow the existing Ferndale Road alignment, as the existing embankments are already raised and the road provides primary access to portions of the Lummi Indian Reservation.

No setback levees are proposed for the left bank of the Nooksack River because the restored area is uninhabited north of Marine Drive and ties into high ground. In addition to the levee removals and setback levee construction on the Nooksack River, large woody debris structures will be installed to promote hydraulic stability and improve habitat complexity. On the downstream end of the project footprint, a flood-prone portion of the community of Marietta will be relocated to restore a small portion of the floodplain, avoid flooding impacts from the left bank levee removal, and avoid additional project costs associated with providing flood risk management features to this relatively small area.

A new water control structure (i.e., diversion feature) will be installed at the confluence of the Lummi and Nooksack Rivers. This structure is intended to facilitate transfer of freshwater and sediment to the Lummi River, while preventing avulsion of the mainstem to the west. The Lummi River channel will be regraded to reconnect it to Nooksack River flows, allowing the Lummi River channel elevation to better match the Nooksack River channel at the confluence, increasing conveyance capacity, and encouraging normal geomorphic processes in the river.

On the Lummi River, approximately 12,000 linear feet of berm would be removed to regain all of the shoreline complexity and dynamic shoreline processes on the north bank in the vicinity of North Red River Road, west of Haxton Way. A new setback levee will be constructed along the north bank of the Lummi River to allow reconnection of high value floodplain habitats while maintaining existing levels of flood risk management in the area. As described above, the setback levees are required to maintain social and tribal acceptability at the site.

Finally, the restoration proposal includes several road removals and/or relocations. Portions of existing roadways will be removed or raised to allow for floodplain restoration in the areas where levees are removed. Construction of new bridges or installation of culverts on both the Nooksack and Lummi Rivers will allow tidal exchange across the restored Nooksack River Delta. Please refer to the Engineering Appendix for a full description of road/bridge modifications included in the proposed alternative.

The restoration at the Nooksack River Delta is intended to complement, but not depend on, the implementation of the proposed Lummi Nation Wetland and Habitat Bank (Lummi Nation 2008). The two mitigation bank features would be constructed by the Lummi Nation and would not be implemented as part of a federally funded restoration project; mitigation bank features are not included in the proposed Federal project footprint and the area of hydraulic effect of the Federal project does not overlap the mitigation bank areas.

Figure 6-4 depicts the key design elements at the Nooksack River Delta.

6.1.2.6 *Separable Elements Analysis*

To help inform initial plan formulation and analysis, a qualitative evaluation of three different geographical elements of the Nooksack River Delta site was completed. The three areas evaluated included (1) Lummi River Area, (2) Diversion Control Area, and (3) Nooksack River Area (Figure 6-3). A summary of the results of this qualitative evaluation are included below:

Summary of Costs and Benefits:

	Area 1 – Lummi River	**Area 2 – Diversion Control**	**Area 3 – Nooksack River**
% of Total Project Cost	44%	6%	51%
% of Benefits	18%	6%	76%

The Nooksack River Area of this site provides the majority of ecosystem restoration benefits as calculated in the Ecosystem Outputs model and accounts for a majority of associated costs. Inclusion of the Lummi River Area provides about one-fifth of the ecosystem restoration benefits at this site for a lesser percentage of total project cost compared to the Nooksack Area. Installation of the proposed water diversion structure represents a small portion of the Ecosystem Outputs score and a corresponding small fraction of project costs; however, this project component is a critical need for ESA-listed salmonids in this watershed.

Restoration of both channels of the river, as well as providing the fish passage and flow regulation through the proposed diversion structure, is critical to achieve comprehensive ecosystem benefits at this site. Levee removal provides habitat capacity for juvenile salmon rearing, and each additional area of floodplain restoration supports more unique fish as they distribute among the rearing and refuge habitat that becomes available; therefore, it is important to restore both river channels, and to add as much shoreline length and salmon habitat capacity as possible. Installation of a water diversion structure would provide year-round flow and solve a fish passage issue in the five miles of the Lummi River to allow adult salmon access to spawning areas in the greater Nooksack watershed. ESA-listed salmon populations are currently suffering from pre-spawn mortality, which would be remedied by providing fish passage with the diversion structure. Lack of flow and fish passage also limits juvenile salmon migration outward to parts of the estuary that are underutilized and can provide greater productivity and survival.

The Nooksack/Lummi delta overall has lost over 70 percent of its historical estuarine mixing wetlands. In addition to providing ESA species habitat, the Lummi River area represents an important area of approximately 325 acres of wetlands restoration that would significantly add to the sparse wetlands available along this channel. Restoration would provide cooler water temperatures in this channel. Finally, restoration of both distributary channels provides foraging habitat for Great Blue Herons as well as beaver, mink, and muskrat habitat. The aquatic-oriented mammals are likely to set up residence on only one side of each river channel, so restoration along both banks of both river channels will benefit additional individuals and family groups expanding the regional populations.

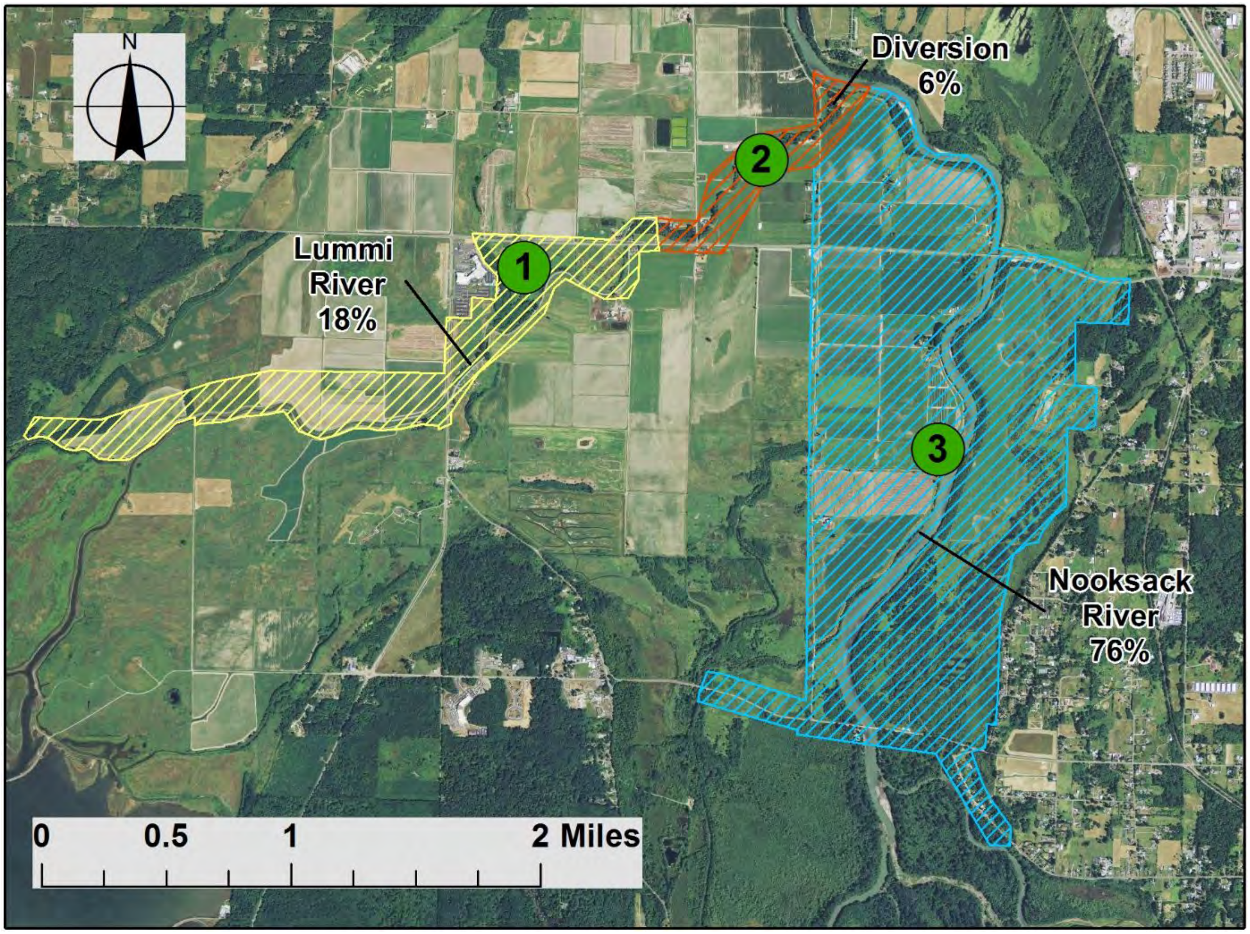


Figure 6-3. Geographical Elements of Nooksack River Delta Site

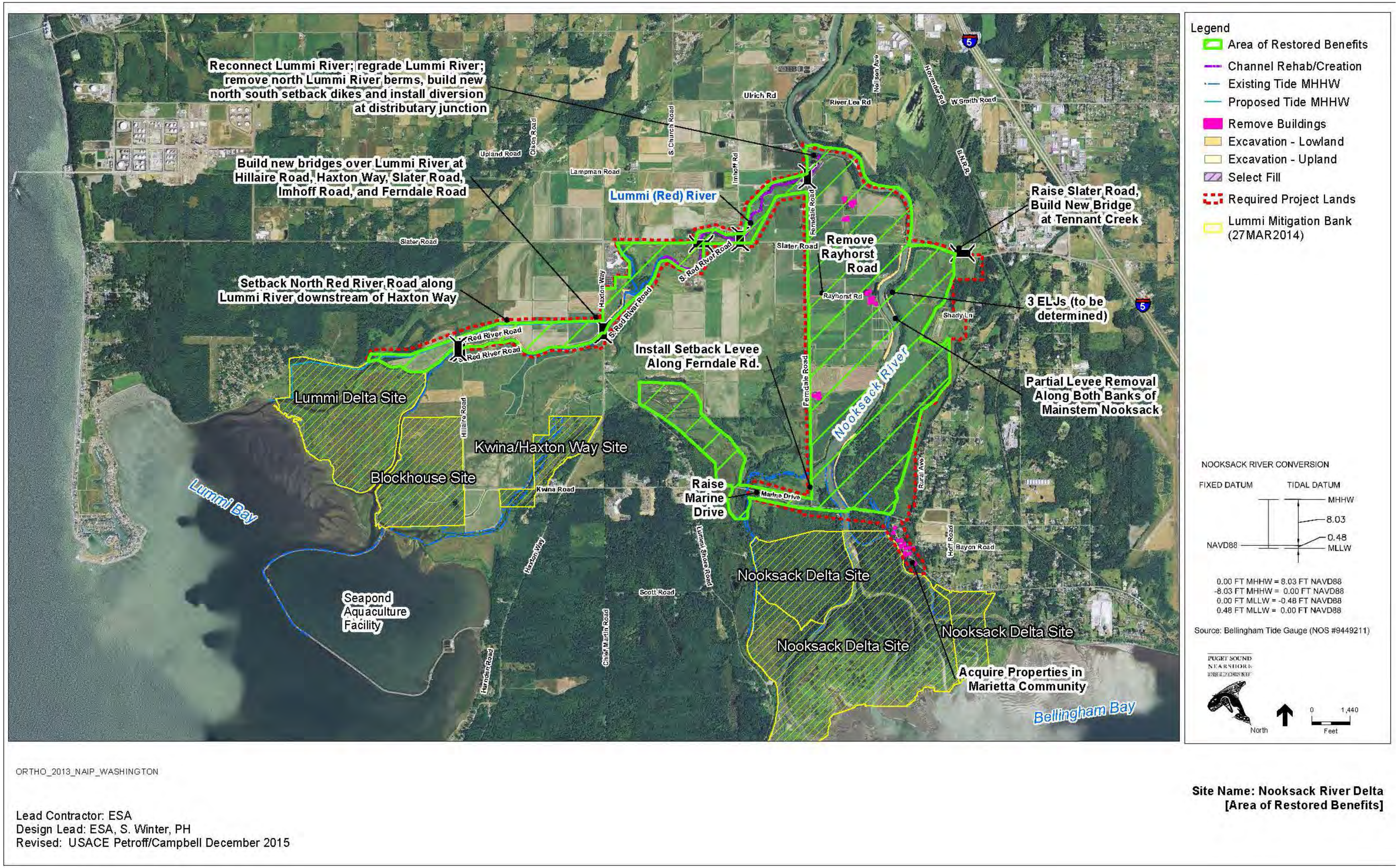


Figure 6-4. Nooksack River Delta

6.1.2.7 *Hydrology & Hydraulics*

Flood Limits: The hydraulics and hydrology for all restoration sites in the Puget Sound Nearshore Ecosystem Restoration Project were evaluated using an area of potential hydraulic effects specific to the construction requirements for each particular site. The upstream and lateral limits were set according to the 1% AEP (100-year) base flood elevation as determined by the FEMA Flood Insurance Study for unincorporated Whatcom County, community 53073C (revised 2007). The seaward limit was taken as the downstream extent of most estuarine sediments visible on aerial photographs. The base flood elevation as determined by FEMA ranges from over 12 feet (NAVD88) near Bellingham Bay to approximately 25 feet at the junction of the Lummi and Nooksack Rivers, a distance of about 4.6 miles.

Modeling: Current water surface profiles from 1991 as reported in the FEMA Flood Insurance Study will need to be revised to reflect the proposed changes in the floodplain. To forecast the new water surface profiles, a 2-D hydraulic model will have to be implemented in PED that reflects the proposed geometry of the delta and the planned design and operations of the engineered diversion structure. An existing 1-D unsteady hydraulic model (FEQ) has been developed by Whatcom County and the Lummi Nation. This model could be used to assist the programming of a 2-D HECRAS model of the Nooksack River Delta. The 2D RAS model would investigate water surface elevations under future without-project and future with-project conditions. The modeling is required to establish the final levee setback elevations and alignments, design bridge piers and abutments as well as to confirm the extent of benefits for the restored area. A geomorphic analysis and sediment transport model will be completed in PED to consider channel response to setback levees over the project life both within and adjacent to project boundaries as part of the levee design and the benefits optimization. In certain locations, such as at the diversion structure, a 3-D model may be required to support the design of the structure at an appropriate cost-effective scale.

Existing Levee System: After damaging floods in the 1920s and 1930s, both sides of the Nooksack River were lined with levees from Ferndale to just upstream of the Marine Drive Bridge. These levees primarily protect agricultural lands. The levees are non-Federal, and owned by Whatcom County and the City of Ferndale. Portions of Marine Drive serve a role in flood risk management, in that access across the Nooksack River is preserved during moderate flooding. The project plan is to remove the Dean Foods levee and to remove portions of the Rayhorst levee downstream of Slater Road.

The Nooksack Delta has three leveed areas listed in the National Levee Database (shown in Figure 6-5):

- The Ferndale/Nooksack levee system consisting of Rainbow Slough, Rayhorst, Sigardson, Ferndale Water Treatment Plant, and Ferndale levees along with high ground, Haxton Way, and North Red River Road provide flood risk management to the largest area.

- The Red River Levee provides flood risk management to the Lummi Delta and is entirely on Lummi Tribal Lands.
- The Dean Foods levee area is located on the left bank of the Nooksack River. The Dean Foods levee is no longer maintained and has been abandoned as a levee. The land behind and including the Dean Foods levee up to high ground has been purchased as a conservation easement by WDFW.

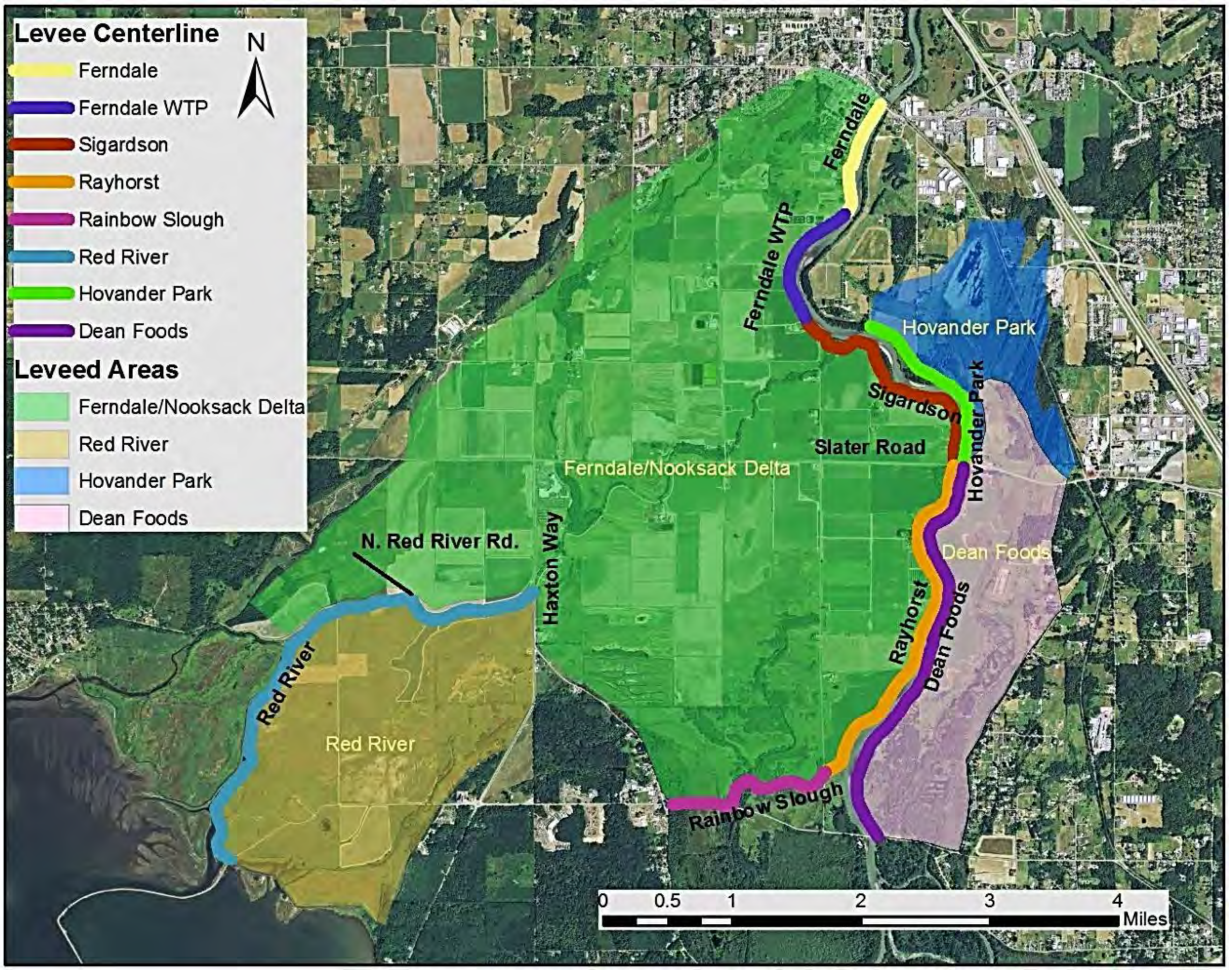


Figure 6-5. Leveed Areas in the Nooksack Delta (Source: National Levee Database)

Table 6-3 the existing levees in the Nooksack River Delta. The level of residual risk is given, where available, as the AEP for the overtopping flow. The Levee Screening Action Classification (LSAC) for all right bank levees in the Nooksack Delta is "4" or "low risk warranting priority actions to reduce risk."

Table 6-3. Levee details for Nooksack Delta (Sources: Corps Levee Screening, Whatcom County)

Levee System	Levee	LSAC Rating	PL 84-99 (Y/N)	Level of Residual Risk (AEP)	% Area Inundated > 2 ft.
Ferndale/Nooksack Delta					
	Rainbow Slough	4	Y	10%	82%
	Rayhorst	4	Y	2%**	83%
	Sigardson	4	Y	10%	94%
	Ferndale WTP	4	Y	20%	99%
	Ferndale	4	Y	20%	98%
	Red River Road	NA	N	20%††	NA
Red River					
	Red River	4	Y	20%	100%
Hovander/Dean Foods					
	Hovander Park	NA	Y	10%	100%
	Dean Foods	NA	N	NA	NA

** Levee screening has 10%, 2% is per Whatcom County including recent upgrades.
†† Assumption is the same as Red River Levee, which was built at the same time.
NA = Not Applicable.

6.1.2.8 *Justification of Setback Levees*

The NER Plan for restoration of the Nooksack River Delta includes removing existing levees along both the Nooksack and Lummi Rivers to restore freshwater and tidal hydraulic connectivity to floodplain habitats that have been cut off due to levees being located directly adjacent to the riverbank. To balance restoration opportunity while managing flood risk on adjacent floodplain lands, the NER Plan also includes construction of new setback levees along the floodplain restoration project area.

As described above, the floodplain in the project area is currently constrained by non-federal levees. Most existing levees are enrolled in the PL 84-99 program, have LSAC ratings of 4 (low risk), and generally provide levels of residual risk ranging from 10% to 20% Annual Exceedance Probability (AEP). The restoration project recommends reconnecting and widening the floodplain by moving the existing levees further from the Nooksack River, i.e., setting back the levees to allow natural processes to occur across a restored, wider floodplain.

The NER Plan at the Nooksack River Delta, which includes setback levees, reasonably maximizes ecological restoration, avoids a large-scale takings of Native American reservation land, and is consistent with the Corps efforts to promote integrated water resources management across the Nation. By considering economic benefits, ecosystem quality, and health and public safety, proposed actions at the Nooksack River Delta are compatible with the risk to natural resources (natural and beneficial functions of floodplains) and human resources (life and property). This integrated approach to water resource planning considers ecosystem restoration and flood risk management as two key objectives needed in the watershed.

Design of Setback Levees

The setback levees are not intended to provide direct ecosystem restoration benefits; rather, the recommended setback levees are designed to provide the current level of flood risk management to adjacent lands – primarily Lummi Nation Reservation lands – not included in the restoration footprint. The setback levees are designed to tie into higher elevation features and will follow the road alignments, as the embankments are already raised and the roads provide primary access to portions of the Lummi Reservation. The setback levees are included as features of the NER Plan.

To inform design and cost estimates for the NER Plan at Nooksack, the study team completed a qualitative evaluation of different levels of residual risk for the setback levees. The team evaluated setback levees that provide a lower level of residual risk than the existing levees, setback levees that provide an equivalent level of residual risk as the existing levees, and setback levees that provide a higher level of residual risk compared to the existing levees.

Setback levees that provide equivalent levels of residual risk to the existing levees are the minimum cost effective structure necessary to realize ecosystem restoration outputs at the site. Setback levees that provide a lower level of residual risk are not cost effective; designing the setback levees at a lower level of residual risk will provide similar ecosystem outputs at a higher cost. Setback levees that provide a higher level of residual risk would adversely impact significant tribal resources as described below and are not recommended as part of the NER Plan for this site.

Based on this qualitative evaluation, the NER Plan includes setback levees designed to maintain existing levels of residual risk. The proposed project does not intend to decrease the level of residual flood risk for the leveed area. For example, at the Nooksack River, the existing Rayhorst levee is enrolled in the PL 84-99 program and has a level of flood risk management established by the Corps in Levee Screening as 10% AEP. The proposed setback levee will be constructed to the same 10% AEP level of residual risk.

Quantities for setback levees take into account the uncertainty in existing topography, soils information, and hydraulics and reflect the fact that the setbacks will create slow flowing backwater areas away from the main flow of the river. Fill volumes and associated levee heights will be confirmed in the pre-construction, engineering, and design phase when soils information and land elevations are available, and levee foundation analysis and hydraulic modeling is completed.

Induced Flooding Analysis

The study team completed an induced flooding analysis to determine whether mitigation for induced flooding (i.e., inclusion of setback levees) is justified as part of this ecosystem restoration project. Per Corps guidance (ER 1105-2-100, para E-18.f), mitigation is appropriate when economically justified or there are overriding reasons of safety, economic or social concerns, or a determination of a real estate taking (flowage easement, etc.) has been made.

In the absence of detailed hydraulic modeling by the Corps, the water surface for inundated area has been set at an elevation of 17 feet North American Vertical Datum of 1988 (NAVD88) based on flooding from right bank of the Nooksack River below Slater Road for the 2% AEP (50-year) event of 57,000 cfs. According to Whatcom County, this is the current level of residual risk for the Rayhorst Levee (Figure 6-5). The 2% AEP leveed water surface in this reach, as modeled by Whatcom County is 22 feet NAVD88 at the north end of Rayhorst levee and 17 feet NAVD88 at the south end. The levee toe lies mostly near or below 17 feet NAVD88. Assuming that levee removal causes a substantial lowering of water surface, the 17 foot elevation was chosen as a reasonable low end expected level of inundation for the 2% AEP event. On Figure 6-6, the inundated area with setback levees in place is about 2 square miles. An additional 7.5 square miles are inundated if there are no setback levees.

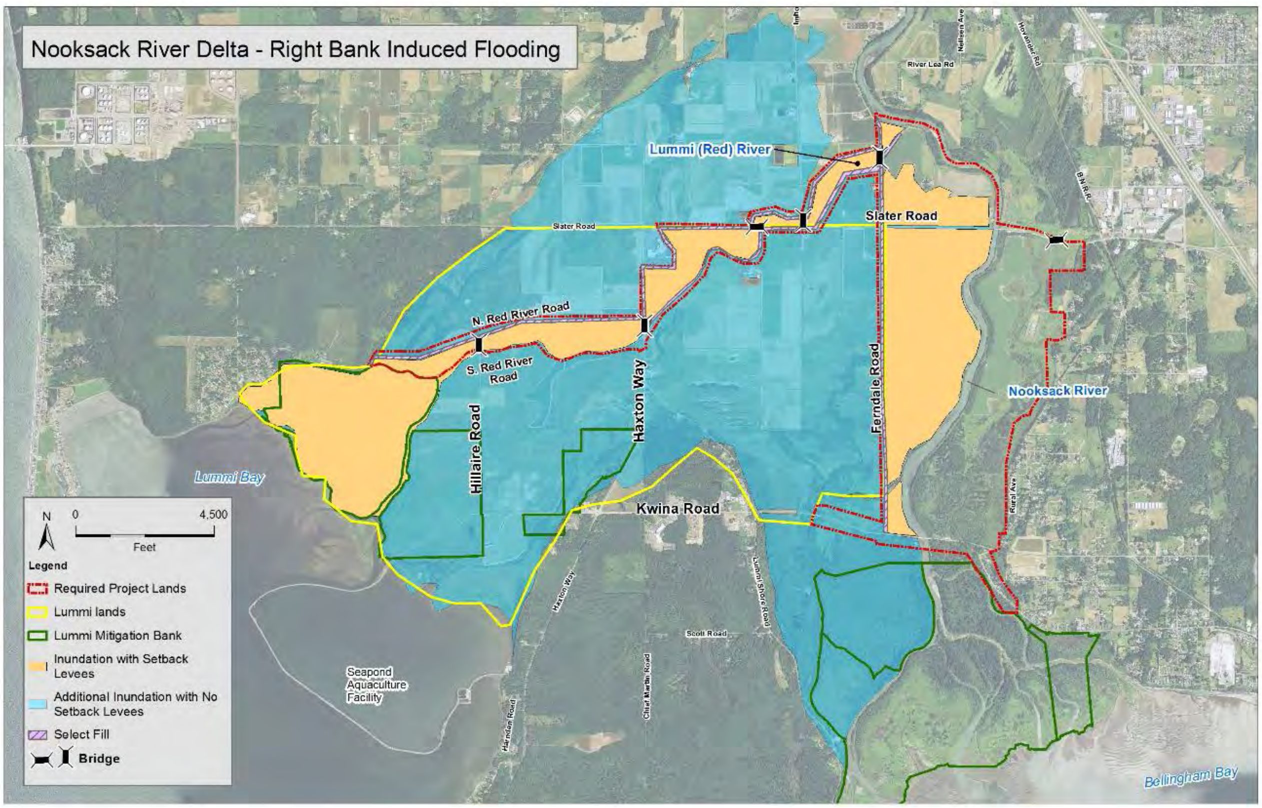


Figure 6-6. Inundation of project area with and without setback levees

If the existing levees are removed and no setback levees are constructed, approximately 3,900 acres of land – including 2,800 acres on Lummi Nation reservation lands (approximately 23% of the Lummi Reservation) – will be at increased risk of inundation (Figure 6-6) during frequent flood events. Under this scenario, substantial induced flooding to a Native American reservation would occur. Based on the analysis summarized in the previous paragraph, additional flooding (on the order of feet) for flood events more frequent than the 10% AEP (10-year) event (e.g. 2, 5, up to 10 year events) would occur under this scenario. Events less frequent than 10% AEP will overtop the levee, so there would be no change from current conditions for those events (e.g. 10 year up to 25, 50, 100+ year floods).

Justification of Setback Levees

Mitigation for induced flooding is also appropriate when there are overriding reasons of safety, economic, or social concerns. There are a number of significant, overriding reasons of safety, economic, and social concerns at the Nooksack River Delta site, primarily tied to the Lummi Tribal Reservation. Item 4 of the Economic and Environmental Principles for Water and Related Land Resources Implementation Studies (Public Law 89-80, as amended) states, "Federal water resources planning is to take into account international implications, including treaty obligations." The Lummi Nation reservation was established in the Treaty of Point Elliott in 1855. The reservation is located within the Lummi Nation's traditional territory; the reservation area and surrounding land has been occupied by the Lummi Nation since time immemorial. No authority currently exists for a State or Federal Agency to condemn or take land designated within this reservation. The Federal trust responsibility to Native American Tribes arises from the treaties signed between them. Under Article VI, Clause 2 of the U.S. Constitution, treaties with the Tribes are the supreme law of the land, superior to State laws, and equal to Federal laws. Therefore, pursuing large-scale restoration involving inducing flooding beyond the current footprint cannot occur without Congressional action to modify the reservation and condemn or take land within the reservation for an ecosystem restoration project.

In addition, due to the limited land-base of the Lummi Tribal Reservation, loss of the use of those lands would significantly impact the social and cultural cohesion of the Lummi Nation. The Lummi Nation has strict codes relating to adversely affecting cultural sites and archaeological resources. The Lummi Nation's Code of Laws declares, "the integrity of the Lummi traditions, cultural heritage, and values is threatened due to encroachment of the dominant United States and Canadian societies and governments…strict tribal control over activities within the boundaries of the Lummi Reservation and tradition use areas within the ceded territory is vital to the future existence of the Lummi Nation." The Code of Laws also indicates that federal or state laws and/or policies shall not adversely affect the need for the Lummi people and the Lummi Nation to sustain its customs, practices, and traditions of its culture. In addition to the submerged and submersible lands within the jurisdiction of the Lummi Nation, cultural sites that may be adversely impacted without setback levees include at least 124 archaeological sites (historic debris scatters, pre-contact lithic scatters, lithic isolates, culturally modified trees, shell middens/camps, historic homesteads, pre-contact villages, and pre-contact burials). There are four known burial locations within the Lummi Nation and at least one traditional cultural properties that may be affected if large areas of the Lummi Reservation are inundated. A loss of the use of Lummi Nation lands and associated impacts to significant cultural resources present overriding economic and social concerns.

Finally, as described in the site-specific planning constraints for the Nooksack River Delta, the project cannot prevent the use of Ferndale Road, Marine Drive, Kwina Road, Haxton Way, Hillaire Road, and Slater Road to the extent practicable. These roads provide the only access to portions of the Lummi Indian Reservation, and the only access to the Lummi Island ferry terminal located on the Lummi Peninsula. Slater Road and Marine Drive are part of the main transportation corridor to two of the industries in the Cherry Point Heavy Impact Industrial Zone. When both roads are closed, access to the Reservation, the Lummi Island ferry, and the Cherry Point industries is through, or to the north of, the City of Ferndale, approximately 2 miles north of Slater Road. This detour can more than double travel times to and from Bellingham and result in severe congestion in the City of Ferndale. These road closures have substantial impacts on the economic, public health, and safety of the affected areas (FEMA 2015), presenting an overriding safety concern without setback levees included at the site.

The setback levees are included in the NER Plan at the Nooksack River Delta site and are integral in providing protection of tribal lands from induced flooding caused by the ecosystem restoration action. In addition, the setback levees are also appropriate mitigation features based on overriding reasons of safety, economic, and social concerns. The Corps has coordinated with the non-Federal sponsor and Lummi Nation during the formulation of this restoration site to ensure the project achieves restoration while still providing comparable levels of flood risk management to tribal lands. The Nooksack River Delta project is designed to achieve large-scale ecosystem restoration benefits while still being compatible with tribal interests. This project is consistent with the Federal trust responsibility to Native American Tribes and the Corps will continue to seek input from the Lummi Nation as project designs are refined. The Lummi Nation provided a letter of continuing support for the Puget Sound Nearshore study, including specific support for the Nooksack River Delta site. The letter also highlighted the importance of the Federal trust responsibility to the Lummi Nation.

6.1.2.9 *Operations & Maintenance*

Operations and maintenance costs for the Nooksack restoration are related to maintenance and repair of levees, culverts, roadways, and embankments as well as maintenance and repair of the bridges and the diversion structure. Additional maintenance tasks are the maintenance of plantings and removal of invasive plant species at the site. The annual OMRR&R estimate is approximately $705,000 per year; OMRR&R activities are a non-Federal sponsor responsibility.

6.1.2.10 *Public Review*

Site-specific comments received during public review were related primarily to concerns from the agricultural community regarding conversion of farmland for ecosystem restoration. The Lummi Nation submitted a letter of support for restoration at this site. The Corps and non-Federal sponsor will continue to coordinate with landowners and stakeholders.

6.1.2.11 *Risk & Uncertainty*

The study team has used a risk-based strategy in their approach to formulating the project from the early stages of the study. Key risks or uncertainties associated with this site include the following, along with the strategy to reduce risk as the study continues:

Earthwork Quantities

Risk and Cause: Earthwork quantities for setback levees, abutments, and other measures were determined based on available LiDAR data. In addition, no soil investigations have been done on site to characterize possible settlement of the setback levee.
Risk Management: Additional survey data, LiDAR and soils information will be obtained during the PED phase. Additional hydraulic modeling and geotechnical analysis will be conducted to refine the size and scale of setback levees. PED costs include estimates for both obtaining the required data and performing necessary engineering analyses. The CSRA for the project has identified risks associated with the variability in existing survey/ LiDAR data with varying resolution as well as uncertainty in future settlement of the setback levee. Cost contingencies reflect the uncertainty in quantities of material required for construction.

Bridges & Roads: Foundation and Placement

Risk & Cause: Bridge and foundation geometry is likely to change based on additional design during PED. Some elements of the proposed bridges may be adjusted based on additional analysis and design (e.g., longer spans, larger piers, or raising the bridges).
Risk Management: Additional survey data, LiDAR, and soils information will be obtained during PED phase. Additional hydraulic modeling and geotechnical analysis will be conducted to refine the size, scale, and alignment of the new bridges. PED costs include estimates for obtaining the required data and performing necessary engineering analyses. Cost contingencies reflect the uncertainty in quantities of material required for construction.

HTRW

Risk & Cause: Results of a Phase 1 Environmental Site Assessment indicate one HTRW site is adjacent to, but not within, the project footprint. Because detailed hydraulic modeling has not been completed, there is uncertainty about the potential of a hydraulic connection to the adjacent HTRW site in the future with-project condition.
Risk Management: Hydraulic modeling and groundwater flow analysis will be required during PED to confirm whether there is a hydraulic connection to the HTRW site adjacent to the project footprint. If there is a hydraulic connection, the non-Federal sponsor can implement measures outside of the project footprint to reduce risk associated with hydraulic connection. Measures could include relocation of a small drainage outlet near the site or actions to cut off the area of interest from the reconnected floodplain, including construction of a small berm or regrading a small area. Measures to reduce hydraulic connection to the

area of interest will be a non-Federal responsibility and can be completed prior to construction. In addition, the Corps could modify a small portion of the project footprint to avoid a hydraulic connection with the site. Potential measures to reduce this risk will not significantly affect the cumulative ecosystem benefits at the project site.

6.1.2.12 *Ecosystem Restoration Benefits*

As Figure 6-4 depicts, this site restores many critical ecosystem processes including sediment transport, freshwater input, tidal exchange, channel migration, exchange of aquatic organisms, detritus distribution, marsh accretion, overbank deposition, and natural topography features that form when riverbanks are allowed to overflow naturally and deliver overbank deposition. Restoration of this site, the fourth largest of the 16 Puget Sound deltas, provides substantial benefits to ESA critical habitat for Chinook salmon, steelhead, and bull trout as well as direct benefits to bald eagles and other raptors, waterfowl, and native amphibians. Additional benefits include the following:

- Reconnects and restores 1,807 acres of scarce tidal freshwater marsh and lost floodplain habitats, including restoration of highly productive tidal freshwater wetland habitats that support biodiversity and provide connectivity between land and sea (meets site-specific planning objectives #1 and #2).
- Re-establishes tidal inundation to intertidal and shallow sub tidal areas by removing 11,910 linear feet of armoring from riverbank for the benefit of fish, birds, and other estuarine species (meets site-specific planning objective #3).
- Improves nearshore and adjacent uplands connectivity for exchange of water, sediments, nutrients, woody debris, and freshwater-dependent mammals such as mink, river otter, beavers, and muskrat that cross both habitat types (meets site-specific planning objective #4).
- Restores sediment input for marsh accretion downstream from the project site for improved resilience of the estuary to effects of sea level change.
- Improves large acreages of habitat for Washington State Priority Species and Habitats for peregrine falcon, bald eagle, waterfowl, and shorebirds; will have downstream benefits for herring by improving water quality through wetland restoration and indirect benefits for the orcas seen offshore in summertime.
- Nearly doubles the shoreline length and adds valuable aquatic habitat complexity from its degraded, shortened, and armored condition by removing over two miles of human-built stressors.

Restores large river delta that provides valuable nursery habitat for juvenile threatened salmon species, increasing survival and supporting Puget Sound population recovery.

6.1.2.13 *Significance*

- Provides 25 percent of Puget Sound Action Agenda's 2020 estuarine habitat recovery goal in a single project
- Supports major portions of multiple recovery plans including, but not limited to Puget Sound Chinook Salmon Recovery Plan of 2005, Washington Comprehensive Wildlife Conservation Strategy of 2005, Northern Pacific Coast Regional Shorebird Management Plan of 2000, and Pacific Coast Joint Venture of 1996
- Tribal support for Nooksack Delta restoration
- Central to Whatcom County's comprehensive approach to managing flooding and restoring estuary habitat in the lower Nooksack River
- Complementary to multiple wetland restoration projects nearby and upstream from the proposed restoration site

6.1.2.14 *Site Specific Project Impacts*

Removal of 11,910 feet of armoring and tidal barriers for restoration of 1,807 acres of tidal wetlands and floodplain habitat will achieve long-term benefits that are discussed in the previous section (Ecosystem Restoration Benefits) , but will also have short-term construction impacts listed below that are necessary to achieve the benefits.

Physical Environment: Nearshore Processes and Structure

<u>Processes, Physiographic Characteristics, Oceanography, and Sedimentation and Erosion:</u> These resources would all be positively effected as described in the previous section (Ecosystem Restoration Benefits) primarily by providing unrestricted tidal and freshwater flow, reestablishing sediment transport and delivery, and reconnecting potions the Lummi and Nooksack Rivers with their floodplains.

<u>HTRW:</u> A Phase 1 Environmental Site Assessment was started in 2010 and completed in 2015 by members of the USFWS and the USACE, Seattle District (See Engineering Appendix). Preliminary results of this analysis indicate that there is one HTRW site, the Wilder Hazardous Waste Landfill site, located approximately a half mile east of the project; the HTRW site footprint and is adjacent to, but outside of the project footprint. The Phase 1 analysis determined there is a small risk of contaminants in the landfill being mobilized by possible flooding or increased hydraulic connection as a result of the proposed project. This risk can be mitigated by the non-Federal sponsor prior to construction. This risk is discussed in "Risk and Uncertainty" above, and is fully detailed in Appendix B – Engineering Appendix, Chapter 2.

<u>Water Quality:</u> Water quality would experience pulses of turbidity during breaching of levees, and the removal of five narrow bridges and replacement with wide-span bridge piers and culverts; however, all work would use BMPs including isolation devices such as cofferdams or equivalent, silt curtains, and timing work during low flows to prevent turbidity from affecting the

aquatic environment. Installation of water isolation devices may cause pulses of turbidity, but the duration of effect would only be a matter of hours and for an area not likely to exceed an estimate of 1,000 feet based on velocity of flow in the rivers. Long-term water quality conditions would improve by allowing unrestricted freshwater and tidal exchange in the estuary and attenuation of sediments and pollutants into reconnected floodplain wetlands. Additional water quality sampling may be required during PED to analyze water quality issues in the Nooksack to ensure any problems are not introduced to the Lummi through the proposed diversion structure.

Green House Gases: Construction machinery was estimated to have GHG emissions of 25,618 tons of CO_2 based on types of machinery that would be used and estimated duration of construction.

Underwater Noise: Machinery would cause underwater noise in the freshwater environment during bridge construction from drilling and cast in place for pier installation and vibratory pile driving for pile removal. Impacts from would be limited to 10-18 months at any one location and minimized by working during low flows when sensitive species are least likely to be present.

Biological Environment: Nearshore Functions

Vegetation: Temporary access routes can occur via the existing system of county and farm access roads. Staging areas will be determined during the PED phase. Areas free of trees and other native vegetation will be utilized to the extent practicable. Some areas would need to be cleared during construction, such as areas along the installation of the new bridges, excavation of the levees, and building of setback levees. The number and sizes of trees and other vegetation felled will be determined during PED phase. Replanting of disturbed areas would occur following construction. Patchy and continuous eelgrass grows downstream from the Nooksack and Lummi Rivers. Turbidity from construction would not be substantial enough to harm this aquatic vegetation.

Shellfish: Impacts to shellfish populations would be minimal, as all of the work occurs well upstream of the marine waters. Changes in water quality from directing water from the Nooksack River into the Lummi River and the potential impacts to shellfish beds in the Lummi Estuary will be minimized by project design and coordination with the Lummi Tribe. The next design phase for the Nooksack River Delta site will require careful attention to plans for diversion of flow from the Nooksack River to the Lummi River to ensure no negative effects occur to the shellfish operations in the estuary. For other macro-invertebrates within the project site, actions would have the short-term impact of disrupting or destroying benthic and epibenthic invertebrates. Once the stressors are gone, invertebrate colonization would follow a pattern of succession, with near complete recovery in one to three years (Hueckel and Buckley 1987, Martin 2012 pers. comm.).

Fishes: Herring are present downstream from the project site and the estuary serves as a migration corridor and rearing habitat for multiple species of salmonids including a rare run of spring Chinook salmon that make up a tiny fraction of the ESA-listed population. Negative effects would come from construction activities causing 1) increases in turbidity from excavation of fill, and 2) noise and vibration associated with large equipment operation for excavation and demolition. Elevated levels of turbidity could cause physiological damage to gills, and elevated noise could cause a behavioral response to flee or delay migration. Working within designated in-water work window of 16 July to 15 August when fish are less likely to be present and during low tides would minimize effects of noise and turbidity on fish.

Birds: This area hosts a variety of birds including eagles and other birds of prey, songbirds, and waterfowl concentrations in the upstream areas, as well as wading birds and water fowl in the downstream areas. Construction activity including demolishing bridges and levees, hauling off large amounts of material, and installation of new bridges and setback levees would cause temporary disturbances to bird communities due to noise and the presence of heavy equipment, likely causing a behavioral response to flee the area. Impacts from would be limited to 10-18 months at any one location and would not have any long-term negative impacts to bird communities. Felling of any potential nesting trees would occur prior to the nesting season.

Mammals: No impacts to marine mammals are anticipated as the work occurs well upstream of marine waters. Impacts to other aquatic mammals like river otter, beavers, and muskrat would derive from noise and turbidity associated with construction. These impacts would likely result in the response to flee the area, but would not have any long-term impacts to populations in the project area.

Rare, Threatened, or Endangered Species: Impacts to ESA listed species are similar to those described for fish, birds, and mammals. Through coordination with NMFS and USFWS, the ESA-listed species and critical habitat that the Corps consulted on include the following determinations: Likely to Adversely Affect bull trout, Puget Sound Chinook salmon, and Puget Sound steelhead; Not Likely to Adversely Affect critical habitat for these three salmonids; and Not Likely to Adversely Affect Southern Resident killer whale or its critical habitat. No marbled murrelet or spotted owl nests occur within disturbance range of the site (see Appendix J).

Cultural Resources

Impacts to cultural resources are documented in section 5.3; see tables 5-11 and 5-12.

The Nooksack River Delta restoration area contains 13 unevaluated archaeological sites ranging from shell middens, and lithic scatters and a historic debris scatter. In addition, the 13 previously inventoried historic properties located either within the restoration site area or directly adjacent to it. Of the 13 properties, five have been determined not eligible, six are unevaluated, and finally, the Marietta/Custer Grange Hall located just outside of the Nooksack River Delta area is eligible to the NRHP. Table 6-4 lists the known cultural resources located either in or adjacent to the Nooksack River Delta site and the potential effect based on the current project design.

Table 6-4 Nooksack River Delta Archaeological Sites

Site Number*	Description	NRHP Eligibility	Location	Potential Effect to Resource Based on Current Design**
Nooksack River Delta Archaeological Sites				
45SH27	Pre-contact shell midden; Pre-Contact burial	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH170	Pre-contact shell midden; Historic trash scatter	Unevaluated	In project area	Unknown at this time
45WH526	Pre contact shell midden-possible village	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH723	Pre-contact shell midden; pre contact burial	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH734	Pre-contact lithic scatter	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH742	Pre-contact isolate	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH847	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH848	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH862	Pre-contact shell midden; Historic trash scatter	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH863	Pre-contact lithic scatter	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH896	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH907	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design
45WH908	Pre-contact shell midden	Unevaluated	In project area	Appears that there will be no effect based on current project design

Nooksack River Delta Structures				
Description*	**Date Constructed**	**NRHP Eligibility**	**Location**	**Potential Effect to Resource Based on Current Design****
Janet's House-1816 Bayon Road, Bellingham	1930-1950	Unevaluated-WISSAARD states undetermined-SHPO	In project area	Appears that it will be affected based on current project design
Wylanoux House (Howell House)	1912	Unevaluated	On border of project area	Appears that there will be no effect based on current project design
Kwina Slough Levee	1927	Unevaluated	In project area	Appears that it will be affected based on current project design
Nooksack River Levee	1900, 1935, 1955	Unevaluated	In project area	Appears that it will be affected based on current project design
Lummi River Levee	1900	Unevaluated	In project area	Appears that it will be affected based on current project design
Jones House-1880 Marine Drive, Bellingham		Not eligible	In side project area	No effect as house has been determined not eligible
1850 Shady Lane-Historic single family residence	1950	Unevaluated	On border of project area	Appears that there will be no effect based on current project design
Scarborough-1857 Marine Drive, Marietta	1920	Not Eligible	In project area	No effect as house has been determined not eligible

White-1853 Marine Drive, Marietta	1915	Not Eligible	In project area	No effect as house has been determined not eligible
Marietta/Custer Grange Hall	1920	Eligible	Just outside project area	Appears that there will be no effect based on current project design
1835 Marine Drive-Historic single family residence	1925	Not Eligible	In project area	No effect as house has been determined not eligible
1801 Marine Drive Historic single family residence	1949	Not Eligible	In project area	No effect as house has been determined not eligible

*Location of sites is based on information from the DAHP database and site form data. Note existing site boundaries have not been field verified for this project.
**Project designs could change in PED. The effect or lack of effect to the resources is based on the current information to date and is subject to change if project designs change.

The Corps has prepared a PA outlining the Section 106 process that will be followed in PED (Appendix D). The PA is the mechanism for Section 106 compliance as long as the PA stipulations are implemented in PED. The PA includes which Section 106 tasks need to occur prior to construction (e.g. fieldwork), how Section 106 consultation will occur, how determinations of eligibility will be made, how findings of no adverse effect will be determined, how findings of adverse effects will be made, and how the PA will be implemented, and a dispute resolution procedure. In addition, the PA provides for a variety of treatment measures that can be used for mitigation of an adverse effect (See Appendix E of the PA). The treatment measures are standard types of mitigation actions used for adverse effects and the costs of these treatment measures have been taken into account during cost estimation for this project.

Socio-Economic Resources and Human Environment

Land Use: As described in section 5.4.1, the change in land use in the Nooksack delta will convert approximately 1,600 acres of prime or important farmland according to NRCS consultation; however, this is less than 0.01 percent of farmland in Whatcom County. Given this small fraction, impacts to farmland would be minor and insignificant. The individual farmer(s) would be compensated for their loss during the purchasing agreement with the local sponsor and the loss of crop production would likely be absorbed by other nearby farms. Some properties may already have easements, or may involve property acquisition through purchases by the local sponsor; land use changes are the only anticipated long-term impact from this project. Many lands associated with the Nooksack River Delta are in tribal jurisdiction and would require close coordination with the Lummi Nation.

Commercial Fisheries: Restoration of tidal wetlands in the Lummi and Nooksack River estuaries would support fish and wildlife species by creating additional habitat for foraging and refuge. Impacts from diversion of Nooksack River flows to the Lummi River on shellfish beds in Lummi Bay will be evaluated and minimized during the PED phase.

Recreation: Temporary impacts to recreation are likely due to limited access to such areas during bridge replacements. Recreation such as increased bird watching opportunities may increase long-term as more wetland dependent species use the area; however, benefits to recreation are incidental to the project as there will be no expenditure toward increased access or recreation features.

Transportation: Transportation impacts will be short-term during the construction of the six new bridges and raising portions of Slater Road and Marine Drive. The Corps would design and sequence the work to minimize traffic interruptions and delays. Bridge modification would conform to current bridge design safety standards applicable to the type and size of bridge being modified. The Corps would design and sequence the work to minimize traffic interruptions and delays. Bridge modification would conform to current bridge design safety standards applicable to the type and size of bridge being modified.

Public Safety: There would be no reduction to public safety at any of these sites; in fact, conforming to updated standards would likely improve safety and will allow for predicted sea level change.

6.1.2.15 *Site Summary Statistics*

- Acres Restored: 1,807 acres of scarce tidal freshwater marsh
- Removes 11,910 linear feet of armoring from riverbank, which is shown to increase rearing capacity of juvenile Chinook by more than 500% (Beamer and Henderson 1998)
- Total Project Cost: $261.8 M (refer to Table 6-5 for cost summary)

Table 6-5. Project Cost Summary – Nooksack River Delta

Project Cost Component	Project First Cost ($1,000s; October 2015 price level)
Construction and Real Estate	
Construction Costs	$99,187
Real Estate Costs (including relocations)	$99,452
Planning, Engineering and Design (PED)	$44,099
Construction Management (CM)	$17,455
Monitoring	$506
Adaptive Management	$1,106
Total Estimated First Cost	**$261,805**
Amortized Cost (3.125% discount rate[1])	$11,427
Annual OMRR&R[2]	$705
Total Average Annual Cost (AAC)	$12,132
Total Benefits (AAHU)	650.5
Total AAC / AAHU	**$19**

[1] Includes interest during construction (IDC). [2] Operations, maintenance, repair, replacement & rehabilitation (non-Federal sponsor responsibility)

6.1.3 North Fork Skagit River Delta

6.1.3.1 *Site Description, Geographic Location & Context*

The North Fork Skagit River empties into Skagit Bay south of La Conner, Washington (Figure 6-7). The Skagit River is critically important to all five species of Pacific salmon as well as steelhead and sea-run cutthroat due to the habitat productivity of large wilderness areas in the upper watershed upstream from the diked and developed floodplain, as well as the total areal extent of the aquatic habitat in the delta, which is the target for restoration efforts. It hosts 30 percent of all anadromous fish in Puget Sound and the largest populations of pink and chum in the contiguous United States (North Cascades Institute 2002). The Skagit River and its tributaries also host the largest populations of ESA-listed bull trout, steelhead, and wild Chinook in the Puget Sound Basin (USFWS 2004, Smith no date). While the Skagit hosts a large percentage of Puget Sound's salmon, the populations are a fraction of their historical levels. Declining salmon runs has led to a decrease in nutrient input to the river and a decrease in food available for bald eagles, bears, and over 100 other species of the northwest that rely on abundance and high nutritional value of salmon, including ESA-listed southern resident killer whales. Additionally, the depressed levels of salmon populations have all but eliminated the once great commercial fishing industry of Western Washington, severely reduced sportfishing, and significantly impacted the Native American tribes whose cultures center on salmon returns.

Over the last century, the Skagit River has lost around 75 percent of its off-channel habitat due to the diking of the river and land use practices; most of this loss has been in the lower Skagit Basin in the floodplain and delta area (Beechie et al. 1994, Collins and Sheikh 2002). Many beaver ponds, side channels, and sloughs once used by salmon have been disconnected from the main river channel. In the last century, the Skagit Basin has lost approximately 80 percent of historic estuarine delta habitat, including a loss of 35 percent of estuarine mixing habitat, 98 percent of low salinity transitional habitat, and 89 percent of its freshwater tidal habitat (Simenstad et al. 2011). The lower Skagit basin has lost approximately 45 percent of the historic side slough habitat (424,200 m^2) that provided critical rearing and refuge functions in the floodplain (Beechie et al. 1994). The Skagit Delta has lost approximately 75 percent of its distributary channel habitat (Beechie et al. 2001). A reduction in the number of side channels and sloughs, changes and reductions in the quality of riparian vegetation, and a reduction in the number of high quality stream channel pools has significantly reduced the amount of available refugia for juvenile salmonids. This means the salmon are at much greater risk of predation and they lose weight trying to fight strong river currents rather than resting and growing for ocean phase survival. The greatest loss of salmonid habitat has occured in the lower river and estuary where only 20% of the historical tidal wetlands and associated channels remain (Simenstad et al. 2011). The estuarine loss has been identified as one of the most significant limiting factors in the recovery of Chinook and other salmon in the Skagit Basin (SWC 2005, Beamer et al. 2005, Smith no date). Chinook and other salmon using the estuary are all fighting for the same limited resources and the result is direct loss of fish due to predation, starvation, and lack of fitness for the ocean phase of their lives. Restoration actions in the Skagit River tidal delta have been linked to increased rearing capacity for Chinook salmon as well as system-wide positive responses (Greene and Beamer 2011). Researchers estimate that the delta and estuary are only at about 10 percent of the total goal of restored area (Greene and Beamer 2011).

The Skagit River Delta area is a critical waterfowl wintering area due to the mild climate and available habitats, including marshes, intertidal flats, and adjacent agricultural fields. It is an important stopping point for migratory birds along the Pacific Flyway such as trumpeter swans and Wrangel Island snow geese. At least 190 species of birds have been documented in the project area (WDFW 2006). These birds including raptors, waterfowl, shorebirds, game birds, and songbirds. Wading birds, such as great blue heron, use the Skagit Basin as either over-wintering grounds or as permanent residents, utilize the estuary areas year round. Shorebirds use flooded agricultural fields and estuaries mainly as a critical feeding station during their long migration and as over-wintering habitat. Dunlin and black bellied plover winter in the Skagit delta. Although a large number and variety of birds use the area, this broad delta could be substantially more productive in its restored condition with native plants and greater areas of distributary channels in the nearshore zone to support significantly greater populations of birds.

The proposed restoration at the North Fork Skagit River Delta is located between the former Dry Slough inlet and the western levee system's end near Rawlins Road. The proposed project reconnects and restores wetlands on both banks of the river, restores natural shoreline and provides 256 acres of scarce tidal freshwater marsh on both north and south sides of the river. These habitat types are important to all riverine species, such as salmon and other fish species, resident and migratory waterfowl, and aquatic-oriented mammals such as river otters, beavers, and mink because of the high productivity of aquatic insects, which are an important food source for fish and waterfowl, and dense low-growing vegetation that supports small mammals. Tidal zones act as a transitional mixing zone for in- and out-migrating fish, and provide rearing and nesting habitat for migrating shorebirds and resident waterfowl.

6.1.3.2 *Site-Specific Goals & Objectives*

The goal of this project includes restoration of estuarine emergent marsh, scrub-shrub, and forested floodplain along the North Fork Skagit River to improve connectivity and reduce fragmentation along the channel. The following are the site-specific objectives for the North Fork Skagit River Delta, and all are applicable for the 50-year period of analysis:

- Reconnect and restore lost floodplain habitats including channel meander zone, shoreline complexity, and shaded refuge habitat in the North Fork Skagit River Delta.
- Reconnect and restore lost tidally influenced areas including estuarine and freshwater tidal wetlands as well as tidal channels in the North Fork Skagit River Delta.

- Re-establish foraging habitat in the North Fork Skagit River Delta for Great Blue Herons, and improve resting and foraging tidal flat habitats for large flocks of waterfowl and migratory shorebirds of the Pacific Flyway.
- Improve aquatic habitat connectivity between lower river systems and upstream habitat networks of the Skagit River.
- Restore a more natural riparian corridor along the North Fork Skagit River Delta.

6.1.3.3 *Site-Specific Constraints*

There are several site-specific constraints that a recommended plan would attempt to avoid during formulation. The following are a list of notable issues that constrain the plan formulation:

- The project cannot prevent the use of Best Road Bridge, as this bridge is a primary access to Fir Island, connecting it with Interstate 5 and State Route 20.
- The project will avoid one known HTRW site located on the north portion of the river.
- The Swinomish Tribe and Upper Skagit Tribe are federally recognized tribal nations that have treaty-reserved fishing, hunting, and gathering rights in the project area. Negative effects to tribal interests will be avoided to the extent practical.

6.1.3.4 *Initial Plan Formulation*

Previously existing plans for this restoration site were considered during the Study Team's initial plan formulation process. Elements found in the 2005 Skagit Chinook Recovery Plan are included in the Nearshore Study design alternative. While the prior plan's goals and objectives were focused on the recovery of a single species of salmon, the plan dovetailed very well into the Nearshore study's goals and objectives to provide a holistic restoration of substantial areas of aquatic nearshore habitats. The Corps used the preliminary Chinook Recovery Plan alternative and project footprint as a starting point for initial plan formulation activities.

As described in section 4.1, 21 management measures were identified for implementation across Puget Sound. Management measures identified for this study are detailed in "Management Measures for Protecting and Restoring Puget Sound Nearshore" (Management Measures Technical Report, Clancy et al. 2009). Structural measures (e.g., armor removal, dike removal, channel rehabilitation, etc.) and non-structural measures (invasive species control, physical exclusion, public education, etc.) were identified and evaluated. A summary of the 21 management measures and their relationships to nearshore ecosystem processes are shown in Table 4-1. As described in section 4.1, the 21 management measures were classified into three groups: restorative measures, prerequisite measures, and protective measures. Of the 21 management measures originally identified, nine management measures were carried forward in the formulation of alternative plans. These measures exert long-lasting effects on ecosystem processes and will often provide the best opportunity of achieving complete restoration of processes, directly meeting the planning objectives of this study.

Based on the screening described in section 4.1, the study team evaluated which of the nine remaining management measures could be implemented at the North Fork Skagit site. The team qualitatively determined whether the identified measures met the site-specific planning objectives and generally avoided site-specific planning constraints. The following five management measures were carried forward for evaluation at this site:

- Armor removal for streambank restoration and reconnecting floodplain habitat
- Dike removal or modification for floodplain freshwater marsh restoration
- Channel rehabilitation or creation for side channel restoration and floodplain reconnection
- Riparian revegetation for shading, nutrient inputs, and complexity of bank habitat (non-structural measure)
- Setback levees for floodplain reconnection and side channel development

The five management measures carried forward after screening were combined to form a number of viable alternatives that attempted to meet objectives and avoid constraints. The size and scale of measures were identified to take advantage of existing topography, using the existing flood risk features in the basin where applicable and tying into the existing forested habitat in the project area. Measures proposed on the southern shoreline that impact the Best Road Bridge were screened out, as this bridge is a primary access to Fir Island, connecting it with Interstate 5 and State Route 20. In addition, the existing bridge alignment does not impede ecosystem processes, and removal or realignment would have minimal benefits and actually have short-term impacts to the riparian corridor. Alternatives were also designed to avoid impacts to a storm water detention area for the Best and Fir Roads. Finally, due to the nature of the area's flat floodplain morphology, the alternatives required inclusion of a flood risk measure to prevent extensive flooding beyond the project area, avoid inducing damage to structures, and avert flood impacts to the road network. Based on the initial plan formulation, evaluation, and screening activities summarized above, one alternative was identified that meets the study objectives, avoids constraints, and restores critical habitat for nationally significant resources.

6.1.3.5 *Summary of Proposed Action*

The restoration proposal includes actions on both the south and north banks of the North Fork Skagit River. The current alternative takes advantage of existing infrastructure and topography to minimize new work and therefore, project costs. An exception would be the eastern most portion of the alternative, which is separable from the primary project features and will require additional analysis.

Approximately 13,000 feet of levee along the south bank will be lowered to allow creation of a tidal channel network on the south side of the river. In addition to lowering levees, a new levee will be constructed along a road alignment (Rawlins Road) to promote riverine and tidal exchange in the project area, to isolate the restoration area from surrounding agriculture, and to maintain existing levels of flood risk management to surrounding land and infrastructure, including 208 structures on Fir Island. This setback levee alignment follows the embankment for Rawlins Road and ties into the coastal dike system.

On the north bank of the river, approximately 3,140 feet of shore armoring will be lowered. Site topography and an upland levee provide site boundaries and flood risk management without the need for a new levee on the river's north side; the northern boundary ties into high ground and the existing Diking District 9 levee. Planned breaches in the lowered levee and in the area of armor removal as well as excavated channels on both banks of the river will allow for water to access the newly restored floodplain. Replanting lowered levees will restore a natural riparian corridor along the river from 1,700 feet upstream of the Best Road Bridge to the end of the current south bank levee system on Fir Island.

The proposal includes levee lowering and excavation of new tidal channels on the eastern portion of the project footprint. In PED, additional hydraulic and hydrologic modeling for the vicinity of the Best Road Bridge will determine whether project designs will be refined for this area or whether the area will be removed from the project footprint. This area is separated from the rest of the project area by the bridge. Potential removal of this portion of the project from the proposal would not impact the remaining design and would result in comparable reductions to both area restored and total project cost. Figure 6-8 depicts the key design elements at North Fork Skagit River Delta.

6.1.3.6 *Separable Elements Analysis*

To help inform initial plan formulation and analysis, a qualitative evaluation of three different geographical elements of the North Fork Skagit site was completed. The three areas evaluated included: (1) South – West Area, (2) South – East Area, and (3) North Area (Figure 6-7).

A summary of the results of this qualitative evaluation are included below:

Summary of Costs and Benefits:

	South – West Area	**South – East Area**	**North Area**
% of Total Project Cost	74%	18%	8%
% of Benefits	67%	8%	25%

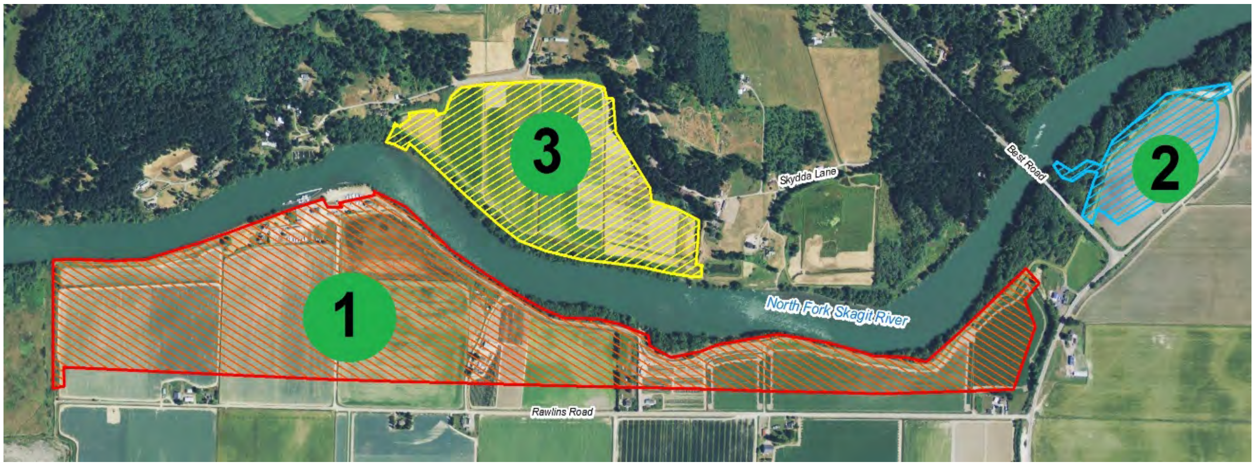
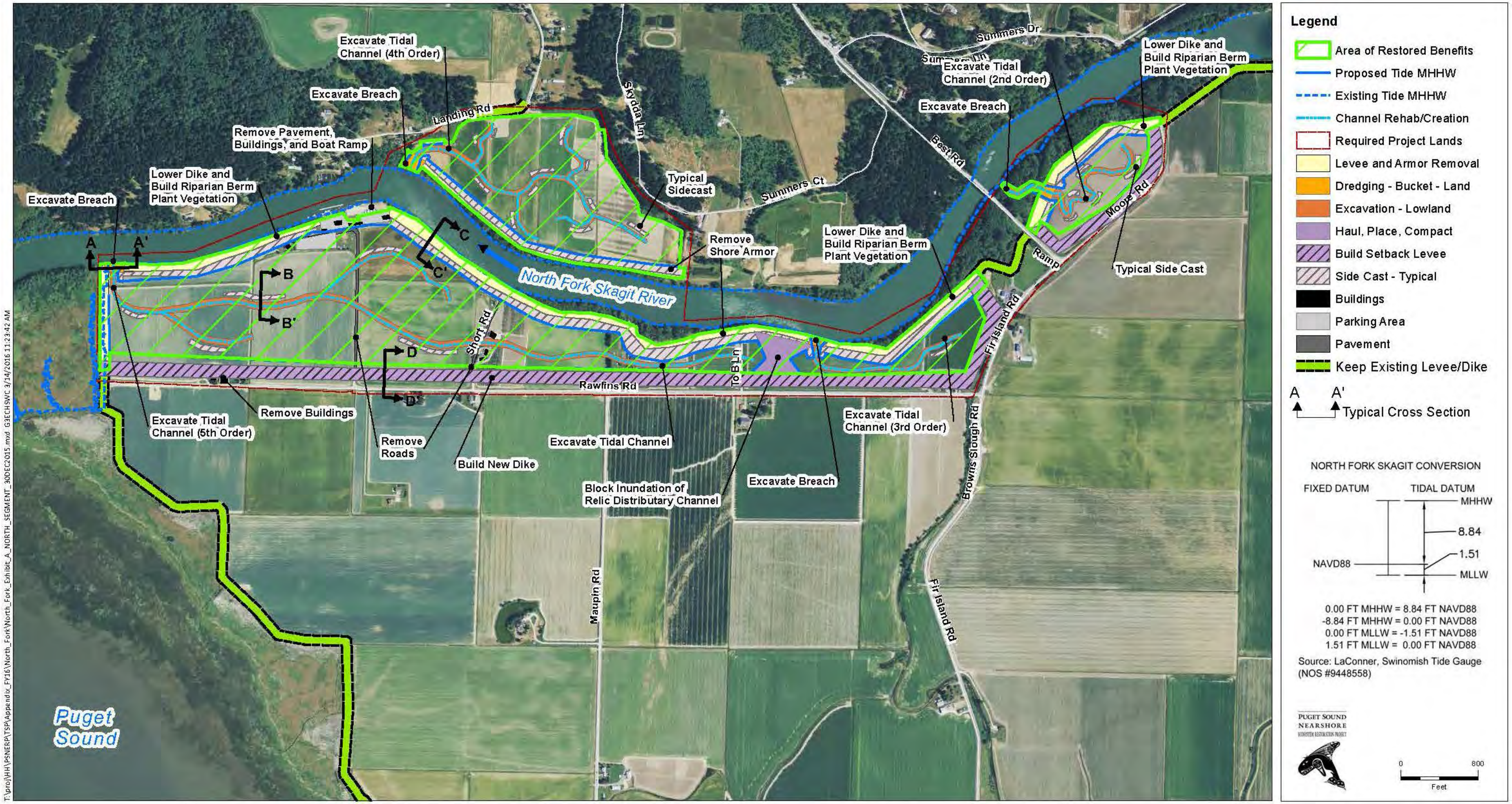


Figure 6-7. Geographical Elements of North Fork Skagit Site.

The South – West Area of this site provides the majority of ecosystem restoration benefits and associated costs. Inclusion of the North Area provides one-quarter of the ecosystem restoration benefits at this site for a marginal percentage of total project cost. Restoration of both banks of the river (south area plus north area; left and right riverbanks) is critical to achieve benefits at this site. Armor removal provides habitat capacity for juvenile Chinook rearing, and each additional foot of armor removal supports more unique fish as they distribute along the left and right riverbanks; therefore, it is important to restore both banks of the river, and to add as much shoreline length and Chinook salmon habitat capacity as possible. In addition, creation of tributary channels provides rearing habitat for juvenile Coho salmon and each additional foot of tributary supports additional fish as they distribute along the channels; therefore, it is important to create and accelerate the development of tributary channels along both banks of the river to add as much tributary length and Coho salmon habitat capacity as possible. Finally, creation of tributary channels provides foraging habitat for Great Blue Herons as well as beaver, mink, and muskrat habitat. The aquatic-oriented mammals are likely to set up residence on only one side of the North Fork of the Skagit River, so restoration along both banks of the river will benefit additional individuals and family groups expanding the regional populations.

As described above, additional hydraulic and hydrologic modeling for the vicinity of the Best Road Bridge (South – East Area) will determine whether project designs will be refined or whether the area will be removed from the project footprint. The modeling is to support the final design of levee elevations and alignment, channel and breach dimensions and protection of bridge abutments as well as to confirm the extent of benefits for the restored area. This area is separated from the rest of the project area by the bridge. Potential removal of this portion from the proposal would not affect the remaining design and would result in comparable reductions to both area restored and total project cost.



ORTHO_2013_NAIP_WASHINGTON

Site Name: North Fork Skagit River Delta [Area of Restored Benefits]

Lead Contractor: ESA
Design Lead: Anchor QEA, G. Sassen, ASLA
Revised: USACE Petroff/Campbell December 2015

Figure 6-8. North Fork Skagit River Delta

6.1.3.7 *Hydrology & Hydraulics*

Flood Limits: The study used available data to determine the extent of the potential floodplain limits. The hydraulics and hydrology for the restoration site were evaluated using an area of potential hydraulic effects specific to the restoration requirements for each particular site. The limits of the area for this site were established using 1% AEP base flood elevations derived from a combination of FEMA Flood Insurance Rate Maps and Flood Insurance Studies as well as Corps base flood elevation determinations. According to the FEMA flood insurance mapping for unincorporated areas of Skagit County, community 530151 (revised 1985), the entire site lies well within the 1% AEP (100-year) floodplain and away from floodplain boundaries.

Modeling: This part of the North Fork Skagit River is tidally influenced. Hydraulic modeling is required to support the final design levee elevations and alignments, channel and breach dimensions and protection of bridge abutments for the Best Road Bridge. Modeling will also confirm the extent of benefits for the restored areas as well as the expected evolution of the project through sedimentation. Additional modeling during PED will include consideration of tidal influences since the amount of increased tidal prism is required to ensure a design of the breach openings and tidal channel dimensions that minimizes maintenance costs. An existing river flow model has been developed for the Skagit River as part of the Skagit GI and can be used to make preliminary estimates of the with-project changes in riverine hydraulics in the project vicinity. A three-dimensional estuarine and coastal ocean model, including sedimentation effects, has been developed at the Pacific Northwest National Laboratory (PNNL) with support from the Skagit Watershed Council and the Skagit River System Corporative. This model has been successfully used to evaluate restoration projects in the Skagit watershed and is available to use during the project design phase. Hydraulic modeling including coastal and sedimentation analyses for the North Fork Skagit site is discussed in Appendix B Section 3-2 and summarized in Appendix B Section 3-21.

Existing Levee System: On the south side of the North Fork Skagit River, Skagit Diking District 22 is a connected levee system that, combined with a system of sea dikes, provides flood risk management to all of Fir Island (Figure 6-9). Fir Island is a flat low-lying part of the Skagit Delta that relies on agriculture and tourism, including fishing, wildlife viewing, as well as popular and economically significant tulip and daffodil festivals. The Diking District 22 levee system has a 2% AEP (50-year) level of residual risk based on levee screening conducted by the Corps. This levee system is part of the Corps PL84-99 Program and received a Levee Safety Action Classification (LSAC) of 4 – low risk in the 2014 Levee Screening Program fact sheet.

Skagit Diking Districts 1 and 9, combined with outcrops of high ground, protect areas on the north side of the North Fork Skagit River from flooding. Diking District 9 is adjacent to the project site and has a level of residual risk from overtopping of over 0.2% AEP (500-years). No alterations are proposed for the Diking District 9 levee.

To confirm the need for a setback levee on the southern boundary of this site (versus acquisition of property or easements), the study team examined the effects of induced flooding; the estimated value of real estate interests that may be susceptible to induced flooding, as well as the estimated costs for construction of levees.

Approximately 6,700 acres of land – most of Fir Island – will be at risk from riverine flooding if the existing levee is removed at the North Fork Skagit River Delta site. Preliminary real estate evaluation indicates the value of the area protected by the proposed levee is approximately $94 million. The estimated cost of the levee is $32 million. Acquisition of affected real estate would be significantly more costly than building the proposed levee. Because of this cost comparison and because the new levee would promote the establishment of riparian processes and isolates the restoration area from agricultural runoff, the study team determined that construction of the levee at this site is the preferred method to achieve the ecosystem restoration benefits at the North Fork Skagit River Delta.

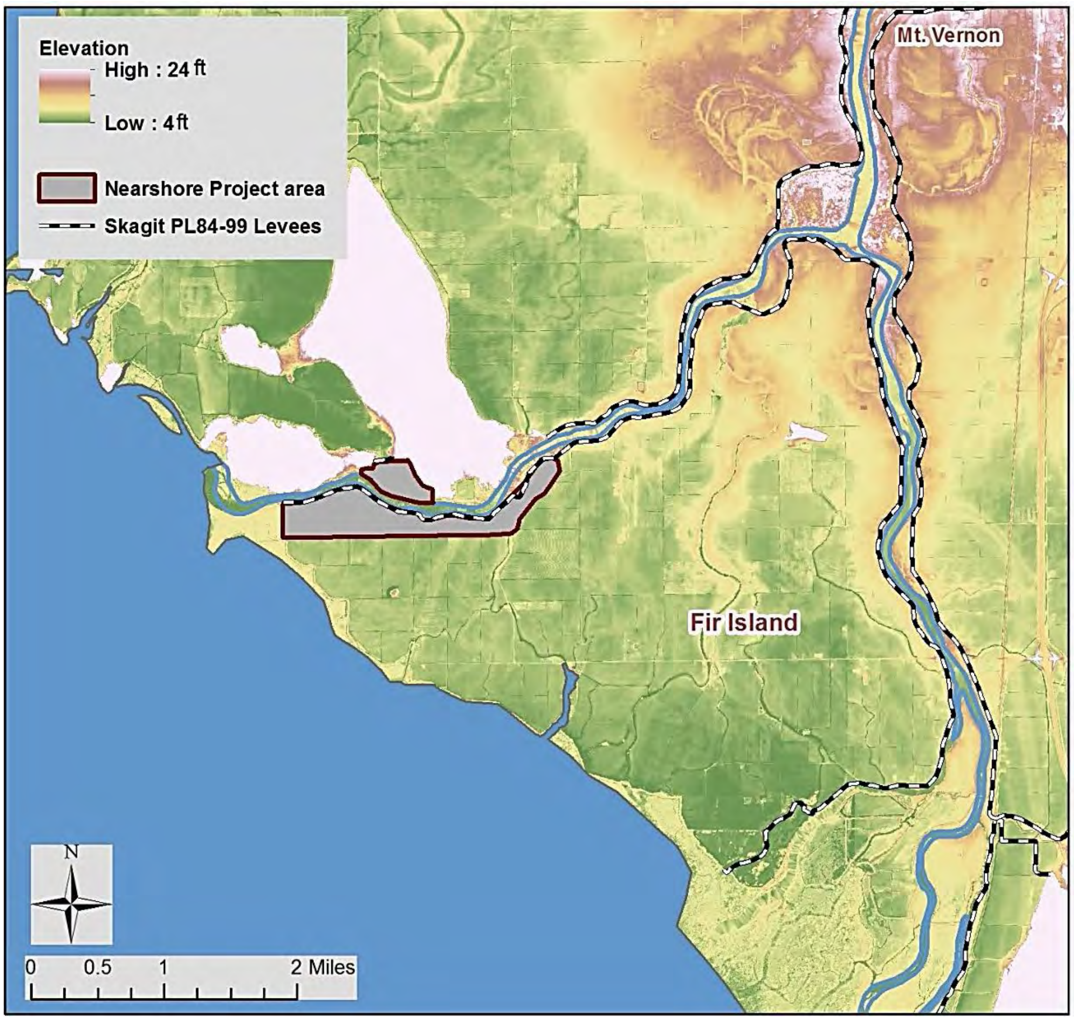


Figure 6-9. Levee systems in the project vicinity

Table 6-6. Induced flooding estimates from North Fork Skagit River Delta project

Source of Flooding	Current Level of Residual Risk	Estimated Level of Residual Risk without Levee	Estimated Area Protected by Levee (Acres)	Real Estate Value of Area Protected by Levee ($1,000s)	Cost of Levee ($1,000s)
Riverine	2% AEP (50-year)	20% -50% AEP (2-5 years)	6,700	$93,800	$31,738

6.1.3.8 *Operations & Maintenance*

Operations and maintenance costs for the North Fork Skagit site are related to maintenance and repair of levees as well as maintenance of plantings and removal of invasive plant species in the project area. The annual OMRR&R estimate is approximately $36,000 per year; OMRR&R activities are a non-Federal sponsor responsibility.

6.1.3.9 *Public Review*

Site-specific comments received during public review were related primarily to concerns from the agricultural community regarding conversion of farmland for ecosystem restoration. The Corps and non-Federal sponsor will continue to coordinate with landowners and stakeholders as the design progresses.

6.1.3.10 *Risk & Uncertainty*

The study team has used a risk-based strategy in their approach to formulating the project from the early stages of the study. Key risks or uncertainties associated with this site include the following, along with the strategy to reduce risk as the study continues:

Earthwork Quantities

> Risk and Cause: Earthwork quantities for setback levees, abutments, and other measures were determined based on available LiDAR data. In addition, no soil investigations have been done on site to characterize possible settlement of the setback levee.
> Risk Management: Additional survey data, LiDAR, and soils information will be obtained during the PED phase. Additional hydraulic modeling and geotechnical analysis will be conducted to refine the size and scale of setback levees and levee alignment near the Best Road Bridge. PED costs include estimates for both obtaining the required data and performing necessary engineering analyses. The CSRA for the project has identified risks associated with the variability in existing survey/ LiDAR data with varying resolution as well as uncertainty in future settlement of the setback levee. Cost contingencies reflect the uncertainty in quantities of material required for construction.

6.1.3.11 *Ecosystem Restoration Benefits*

As Figure 6-8 depicts, this site restores several processes including sediment transport, freshwater input, tidal exchange, channel migration, marsh accretion, overbank deposition, and natural levee formation that occurs when riverbanks are allowed to overflow naturally and deliver overbank deposition. Restoration of this site provides benefits to ESA critical habitat for Chinook salmon and bull trout as well as direct benefits to bald eagles, waterfowl, western toads, salmon, bull trout, and steelhead. Additional benefits include the following:

- Reconnects and restores 256 acres of scarce tidal freshwater marsh and lost floodplain habitats, including restoration of highly productive tidal freshwater wetland habitats that support biodiversity and provide connectivity between land and sea (meets site-specific planning objective #1).
- Re-establishes and improves shorebird foraging and resting tidal flat habitats for large flocks of Dunlin, Great Blue Herons and other marine birds and migratory shorebirds, which historically existed and could increase bird populations in health and numbers if restored (meets site-specific planning objective #2).
- Improves nearshore and adjacent uplands linkages for exchange of water, sediments, nutrients, woody debris, and freshwater-dependent mammals that cross both habitat types (meets site-specific planning objective #3).
- Restores a more natural riparian corridor by removing 16,140 linear feet of riprap from riverbank, providing juvenile salmon rearing habitat/benefits, tidal wetlands, and small tributaries (meets site-specific planning objective #4).
- Restores large river delta that provides valuable nursery habitat for juvenile threatened salmon species, increasing survival and supporting Puget Sound population recovery.

6.1.3.12 *Significance*

- Restores floodplain and tidal connectivity in the estuary of the Skagit River, the largest and most productive river in Puget Sound
- Included in the Puget Sound Chinook Salmon Federal Recovery Plan
- Provides habitat for Pacific Northwest indigenous species on the lower North Fork Skagit River, where limited restoration opportunities and estuary habitats exist
- Benefits State of Washington Priority Habitats and Species categories of wintering waterfowl, bald eagle, and western toad

6.1.3.13 *Site Specific Project Impacts*

Removal of 15,680 feet of levee and associated armoring for restoration of 256 acres of tidal freshwater wetlands/floodplain habitat will achieve long-term benefits that are discussed in the previous section (*Ecosystem Restoration Benefits*), but will also have short-term construction impacts listed below necessary to achieve the benefits.

Physical Environment: Nearshore Processes and Structure

Processes, Physiographic Characteristics, Oceanography, and Sedimentation and Erosion: These resources would all be positively effected as described in the previous section (*Ecosystem Restoration Benefits*) primarily by reconnecting a portion of the North Fork Skagit River with its floodplain.

HTRW: A Phase 1 Environmental Site Assessment was started in 2010 and completed in 2015 by members of the USFWS and the USACE, Seattle District (See Engineering Appendix). The records search did not identify any known or suspected hazardous substance releases in the project footprint. The Washington State Department of Ecology lists one state cleanup site in the vicinity of the project footprint, 0.4 miles north of the river on the east side of Best Road. It is not expected to affect or be affected by any Corps actions due to its distance from the proposed project and the lack of a hydraulic connection to the site. Anecdotal evidence along with historical observation indicated the possibility of a former Skagit County garbage dump to the west of Brown's Slough Road (now called Fir Island Rd). Skagit County records show no historical landfills on Fir Island. If additional information arises during the course of the project that suggests there are HTRW concerns within the project area, the suspected HTRW area will be avoided. Please refer to Appendix B (Engineering) for the complete Phase 1 assessment.

Water Quality: Water quality would experience pulses of turbidity during breaching of levees and excavation of channels along both banks of the river; however all work would be done using best management practices during construction including isolation devices such as cofferdams or equivalent, silt curtains, excavating channels prior to complete breaching of levees, and timing work during low flows to prevent turbidity from affecting the aquatic environment. The need for isolation devices at this site will be evaluated during PED. Installation of water isolation devices may cause pulses of turbidity, but the duration of effect would only be a matter of hours and for an area not likely to exceed an estimate of 1,000 feet based on velocity of flow in the rivers. Long-term water quality conditions would improve by allowing attenuation of sediments and pollutants from the river into reconnected floodplain wetlands.

Green House Gases: Construction machinery was estimated to have GHG emissions of 5,992 tons of CO^2 based on types of machinery that would be used and estimated duration of construction.

Underwater Noise: Machinery would may cause underwater noise in the freshwater environment during excavation and armor removal. However, in-water work would occur during low flows when sensitive species are least likely to be present.

Biological Environment: Nearshore Functions

Vegetation: Temporary access routes can occur via the existing system of county and farm access roads. Vegetation falling within the footprint of areas necessary for excavation, armor removal, building a setback levee, and staging will likely need to be removed. These areas will be determined during the PED phase. Little vegetation exists in the proposed levee setback area. Areas free of trees and other native vegetation will be utilized to the extent practicable. Replanting of disturbed areas would occur following construction. Turbidity from construction would not be substantial enough to harm this aquatic vegetation. No eelgrass or kelp occur at or downstream from the project site.

Shellfish: No shellfish populations occur at or downstream from the project footprint. For other macroinvertebrates within the project site, actions would have the short-term impact of disrupting or destroying benthic and epibenthic invertebrates. Once the stressors are gone, invertebrate colonization would follow a pattern of succession, with near complete recovery in one to three years (Hueckel and Buckley 1987, Martin 2012 pers. comm.).

Fishes: This site in the lower North Fork Skagit River serves as a migration corridor for all five species of Pacific salmon plus steelhead, cutthroat, bull trout, and Dolly Varden. Negative effects would come from construction activities causing 1) increases in turbidity from excavation of fill, and 2) vibration associated with large equipment operation for excavation. Elevated levels of turbidity could cause a behavioral response to flee or delay migration, but would not be substantial enough to cause physiological damage. Working within the designated work window of 15 June through 31 August when fish are less likely to be present and during low tides would minimize effects of turbidity on fish.

Birds: This area hosts bald eagles and over-wintering waterfowl concentrations. Construction activity including armoring removal, channel excavation, and hauling off large amounts of material would cause temporary disturbances to bird communities due to noise and the presence of heavy equipment, likely causing a behavioral response to flee the area. No long-term impacts to bird populations are anticipated.

Mammals: No impacts to marine mammals are anticipated as the site is well upstream of marine waters. Impacts to other aquatic mammals like river otter, beavers, and muskrat would derive from noise and turbidity associated with construction. Effects would likely cause a response to flee the area, but would not have long-term impacts to populations in the project area.

Rare, Threatened, or Endangered Species: Impacts to ESA listed species are similar to those described for fish, birds, and mammals. Through coordination with NMFS and USFWS, the ESA-listed species and critical habitat that the Corps consulted on include the following determinations: Likely to Adversely Affect bull trout, Puget Sound Chinook salmon, and Puget Sound steelhead; Not Likely to Adversely Affect critical habitat for these three salmonids; and Not Likely to Adversely Affect Southern Resident killer whale or its critical habitat. No marbled murrelet or spotted owl nests occur within disturbance range of the site (see Appendix J).

Cultural Resources

The North Fork Skagit River Delta contains five previously recorded archaeological sites, and one archaeological district located either within or directly adjacent to the restoration site. These sites include a pre-contact habitation site that is a contributing element to Fishtown

Archaeological District located adjacent to the restoration site with the remainder identified as shell middens. In terms of the built environment the North Fork Skagit River Delta site contains an unevaluated historic granary, the unevaluated Skagit levee, and an historic farming complex that contains a barn listed on the Washington Heritage Barn Register Table 6-7 listed the known cultural resources located in or adjacent to the North Fork Skagit River Delta site and the potential effect based on the current project design

The Corps has prepared a PA outlining the Section 106 process that will be followed in PED (Appendix D). The PA is the mechanism that allows for Section 106 compliance as long as the PA situations are implemented in PED. The PA includes which Section 106 tasks need to occur prior to construction (e.g. fieldwork), how Section 106 consultation will occur, how determinations of eligibility will be made, how findings of no adverse effect will be determined, how findings of adverse effects will be made, and how the PA will be implemented, and a dispute resolution procedure. In addition, the PA provides for a variety of treatment measures that can be used for mitigation of an adverse effect (See Appendix E of the PA). The treatment measures are standard types of mitigation actions used for adverse effects and the costs of these treatment measures have been taken into account during cost estimation for this project.

Table 6-7 North Fork Skagit River Delta Archaeological Sites

North Fork Skagit River Delta Archaeological Sites				
Site Number*	**Description**	**NRHP Eligibility**	**Location**	**Potential Effect to Resource Based on Current Design****
Fishtown Archaeologic	*Sqwikwikwab*, ethnohistoric village and	Eligible	Adjacent to project area	Appears that it will be affected based on current project design
45SK34	Pre-contact habitation site	Eligible: Part of the archaeological	Extends into project area	Appears that it will be affected based on current project design
45SK35	Pre-contact shell midden site	Unevaluated	In project area	Appears that it will be affected based on current project design
45SK78	Pre-contact shell midden site	Unevaluated	Just outside of project area	Appears that there will be no effect based on current project design
45SK80	Cave with pile of shell	Unevaluated	Adjacent to project area	Appears that there will be no effect based on current project design
45SK87	Pre-contact shell midden site	Unevaluated	In project area	Appears that it will be affected based on current project design
North Fork Skagit River Delta Structures				
Description*	**Date Constructed**	**NRHP Eligibility**	**Location**	**Potential Effect to Resource Based on Current Design****
North Fork Skagit River Levee	1935	Not Evaluated	In project area	Appears that it will be affected based on current project design
45SK337	Summers Farm Barn 1885	Washington Historic Barn Register	In project area	Appears that it will be affected based on current project design

*Location of sites is based on information from the DAHP database and site form data. Note existing site boundaries have not been field verified for this project.

**Project designs could change in PED. The effect or lack of effect to the resources is based on the current information to date and is subject to change if project designs change.

Socio-Economic Resources and Human Environment

Land Use: As described in section 5.4.1, the change in land use at the North Fork site will convert only 5 acres of prime or important farmland according to NRCS consultation. Which is only .005 percent of total farmland in Skagit County. Given this small fraction, impacts to farmland would be minor and insignificant. The individual farmer(s) would be compensated for their loss during the purchasing agreement with the local sponsor and the loss of crop production would likely be absorbed by other nearby farms. Some properties may already have easements, or may involve property acquisition by the local sponsor; minor land use changes are the only anticipated long-term impact from this project. Restoration of tidal wetlands has potential for displacement or substitution of recreation opportunities associated with this site: Blake's Marina, which consists of a 120-foot day-use dock, a 500-foot overnight-use dock and a boat ramp would be removed. The lower Skagit River has other nearby launch sites that would absorb the low volume of vessel traffic.

Commercial Fisheries: No commercial fisheries or aquaculture are anticipated to be negatively affected by this project. Restoration of tidal wetlands in the Skagit River estuaries would support fish and wildlife species by creating additional habitat for foraging and refuge.

Recreation: Temporary impacts to recreation may occur due to limited access during construction. Blake's Marina would be removed and relocated to another nearby launch site in the lower Skagit River. Recreation such as increased bird watching opportunities may increase long-term as more wetland species use the area; however, benefits to recreation are incidental to the project as there will be no expenditure toward increased access or recreation features.

Transportation: No effects to transportation are anticipated; only local roads occur at this site and the bridge that crosses the river at this location will not be affected.

Public Safety: New constructed levees will maintain the same level of flood protection as the levee it is replacing; new levees would protect public or private property from inundation that could result from the restoration work.

6.1.3.14 *Site Summary Statistics*

- Acres Restored: 256 acres of scarce tidal freshwater marsh
- New tidal channel excavation for fish habitat and acceleration of site benefits: 19,617 linear feet
- Removes 16,140 linear feet of riprap from riverbank anticipated to increase rearing capacity of juvenile Chinook by more than 500% (Beamer and Henderson 1998)
- Total Project Cost: $99.3 M (refer to Table 6-8 for cost summary)

Table 6-8. Project Cost Summary – North Fork Skagit River

Project Cost Component	Project First Cost ($1,000s; October 2015 price level)
Construction and Real Estate	
Construction Costs	$62,497
Real Estate Costs (including relocations)	$13,922
Planning, Engineering and Design (PED)	$14,286
Construction Management (CM)	$6,167
Monitoring	$379
Adaptive Management	$2,050
Total Estimated First Cost	**$99,299**
Amortized Cost (3.125% discount rate[1])	$4,070
OMRR&R[2]	$36
Total Average Annual Cost (AAC)	$4,106
Total Benefits (AAHU)	53.7
Total AAC / AAHU	**$76**

[1] Includes interest during construction (IDC). [2] Operations, maintenance, repair, replacement & rehabilitation (non-Federal sponsor responsibility)

6.2 Design and Construction Considerations

The study team has taken a risk-based approach to the level of design developed in the feasibility phase. The designs included in this FR/EIS (Appendix B) are detailed enough to support certifiable cost estimates and defensible Section 902 cost limit. The study team has identified the necessary studies and data collection to be performed during PED phase to manage specific risks and uncertainties. The studies are summarized in Appendix B, Sections 1-21, 2-21, and 3-21. They include the following:

- Property and utility investigations: Parcel ownership, property boundaries and utility survey - needed to confirm acquisition requirements and refine real estate and relocation costs,
- Data collection: Topography, bathymetry, tidal gauging and soils testing - needed to support civil and structural design as well as hydraulic and hydrologic analyses,
- Hydraulic and hydrologic analysis and modeling: Riverine, coastal and sedimentation studies - needed to optimize design features, refine construction cost estimates, confirm areas of environmental benefits, identify areas of induced flooding and predict/minimize actions for O&M.
- Geotechnical analyses: Foundation design, analysis of settlement and seepage of project features and identification of disposal and borrow sites- needed to finalize design features and refine cost estimates.
- Structural analyses: Design of bridge deck and supporting structure for gravity, wind and seismic effects – Needed to finalize bridge designs and refine cost estimates.

- Civil Engineering analyses: Pavement design including traffic study for roadways and approaches – Needed to finalize designs and refine costs estimates.
- Cultural resources investigations: Survey for archaeological and historic resources in areas proposed for excavation – needed for Section 106 compliance and to finalize project footprint.
- Phase II Environmental Site Assessment: (Nooksack Only), Assessment of historic fills for contaminants – needed to finalize project footprint.

In developing the cost estimate for the feasibility study, specific borrow sources and disposal areas were identified to determine haul distances. These locations will be confirmed during PED. For the Nooksack and North Fork sites, multiple borrow sources are located within 30 miles of the sites along the Interstate highway corridor. A haul distance of 30 miles was used. At Duckabush, which is in a more remote area, the haul distance for borrow was estimated at 60 miles either to the North at Port Angeles or to the South at Tumwater.

The study team will continue to develop the scope, schedule, and budget for PED activities as the study continues. Prior to commencement of the PED phase, team members will participate in a technical scoping workshop to confirm scope and cost of the studies summarized above, as well as potential scaling and sequencing of proposed studies.

6.3 Real Estate Considerations

The recommended plan includes three sites that have a total real estate footprint of 2,480 acres: Duckabush River Estuary (58 acres), Nooksack River Delta (2,080 acres), and North Fork Skagit River Delta (342 acres). Based on the current project footprints, approximately 220 landowners would be affected, with the total estimated land values estimated at $30,989,000.

Due to the conceptual level of detail of current project designs, land values were estimated based on fee value. As project designs are refined and additional data is gathered during PED, specific real estate interests will be identified and assigned to the project lands as applicable. At this time, standard real estate interests anticipated for the project lands include Fee, Perpetual Road Easement, Temporary Work Area Easement, Perpetual Channel Improvement Easement, and Perpetual Flowage Easement *(Occasional Flooding).* It is unknown whether any Non-Standard Estates will be required for this project; the need for any Non-Standard Estates will be identified during PED.

In addition, tribal lands and interests will be further defined during the PED phase. Informational conversations between the Corps, Non-Federal Sponsor, and the Lummi Indian Tribe are underway, as the Lummi Indian Tribe has landownership interests at the Nooksack River Delta site. The Lummi Tribe continues to be supportive of the proposed restoration project.

Utility/Facility Relocation items as well as Uniform Relocation Assistance (PL 91-646) requirements will be further defined during PED. An initial assessment of utilities that could be impacted include electrical, water/sewer, telecommunications, roads, and bridges. Preliminary

Uniform Relocation Assistance (PL 91-646) assumptions and scope resulting from the project activities have also been identified and apply primarily to the Nooksack River Delta and North Fork Skagit River Delta sites. See Appendix C (Real Estate Plan) for additional real estate detail and associated maps.

6.4 Monitoring and Adaptive Management

The Nearshore Study's Monitoring and Adaptive Management Plan (Monitoring Plan; Appendix E) is a framework for development of site-specific plans based on the restoration strategy that is primary for the site—river delta, barrier embayment, coastal inlet, or beach. The goals of the monitoring plan are to determine whether the management measures applied to the sites are producing the desired effects and to determine whether corrective action is needed to improve effectiveness. Processes are inherently difficult to measure and quantify directly, and on their own do not tell the full story of restoration success. Therefore, structural and functional responses typically are monitored as indicators of restored processes. Each landform type has predicted ecological outcomes that would indicate the performance of a restoration site. Performance is documented through an evaluation of monitoring results. Site-specific objectives were developed for each site in the Recommended Plan. Even the most strategically planned restoration actions can yield unexpected results. Monitoring documents and diagnoses these results especially in the early, formative stages of a project and provides information useful for taking corrective action. In this way, it reduces the risk of failure and enables effective, responsive management of restoration actions.

The site-specific monitoring plans (Annexes A, B, and C to Appendix E) contain metrics that must be monitored to evaluate whether they follow a predicted response. The performance target for each response is developed from the best scientific understanding of how the system will evolve following restoration site implementation. Metrics for each indicator are selected to provide enough information to track an indicator through its predicted response, as well as to explain why when performance reflected by an indicator is or is not developing as predicted. Each indicator in the Monitoring and Adaptive Management Plan is presented in Appendix E along with its predicted response and the metrics required to monitor it. The site-specific monitoring plans contain metrics and performance targets that are tied to evaluation of project objectives. These performance targets, if not met, will trigger an adaptive management action. The Corps will implement the Monitoring Plan to provide the necessary post-construction monitoring that will verify implementation and effectiveness of the management measures.

The complete site-specific monitoring plans are presented as Annexes A, B, and C of Appendix E after the overall framework. Examples of monitoring metrics include increased tidal prism, increased riverbank complexity, wetland development, increased soil salinity, and increased ground coverage of native vegetation. Some of the parameters require only a few years of monitoring to determine whether the management measures have been successful, while other processes can take many years to decades to develop and therefore require monitoring up to and perhaps beyond the cost-shared period of 10 years. Each monitoring metric has recommended adaptive management measures in cases where the performance target is not met. Costs for monitoring and adaptive management based on current designs for each site of the Recommended Plan are as follows:

- Duckabush Estuary – $205,000 Monitoring; $2,151,000 Adaptive Management
- Nooksack River Delta – $506,000 Monitoring; $1,106,000 Adaptive Management
- North Fork Skagit River Delta – $379,000 Monitoring; $2,050,000 Adaptive Management

While the Ecosystem Outputs Model (Appendix G) quantified site-specific characteristics for how they met overall project planning objectives, the Monitoring Plan does not revisit these broad parameters from a Sound-wide analysis. Instead, the three Annexes of the Monitoring Plan take the site-specific restoration objectives for each project site and outline which parameters can be measured to determine levels of project success. No further validation or investigation for the Ecosystem Output Model is planned regarding meeting objectives.

6.5 Environmental Operating Principles and Campaign Plan

The Corps has reaffirmed its long-standing commitment to environmental conservation by formalizing a set of Environmental Operating Principles (EOPs) applicable to decision-making in all programs. The EOPs outline the Corps' role and responsibility to sustainably use and restore our natural resources in a world that is complex and changing. The recommended plan meets the intent of the EOPs.

The Corps' Campaign Plan includes specific goals and objectives to deliver integrated, sustainable, water resources solutions. This project primarily supports the Corps' Campaign Plan Goals 2 and 4. These goals include transformation of the Civil Works process to deliver enduring and essential water resource solutions using effective transformation strategies as well as build resilient people, teams, systems, and processes to sustain a diverse culture of collaboration, innovation, and participation to shape and deliver strategic solutions. The project meets the intent of these Campaign Plan goals.

6.6 Consideration of Climate Change

In the Pacific Northwest, climatic changes are expected to trend towards warmer, wetter winters and hotter, drier summers. Models developed by the University of Washington Climate Impacts Group (CIG) predict the following scenarios for Pacific Northwest temperatures in the 21st century (as compared to the 20th):

- The rate of change of temperature will be greater,
- The total amount of temperature change will be greater,
- All seasons will be warmer, especially in the months of June through August,

- The average annual temperature will likely exceed the range of average annual temperatures during the 20th century, and
- Changes in nearshore sea surface temperatures, though smaller than on land, are likely to substantially exceed inter-annual variability.

Existing seasonal patterns of rainfall may shift, with a decrease in summer and an increase in winter. Average annual precipitation will likely stay within the range of 20th century annual average precipitation (Climate Impacts Group 2008). Most of this precipitation is expected to fall as rain and not snow, causing lower flows in the summer (due to lack of snow melt) and higher flows in the winters (due to increased rain) in the many rivers and streams that empty into Puget Sound. There is a strong consensus among climate change investigations that future storm events in the region will be more intense and more frequent compared to the recent past (USACE 2015).

In addition to changes in precipitation and air temperatures, predicted estimates for sea level change in Puget Sound range from low estimates of 0.4 feet to high estimates of 6.3 feet between 2015 and 2115 depending on location. This range incorporates slightly higher sea level rises expected in the south Puget Sound around Olympia and Tacoma and slightly lower expected rises in the north Puget Sound around Friday Harbor and Bellingham Bay. More detailed information and analysis on climate change and how it may affect the Puget Sound basin is incorporated in section 3.6 (Future without-Project Conditions).

Proposed restoration at the three sites included in the Recommended Plan concentrates on removing the environmental stressors leading increased natural resiliency of the restored areas to climate change effects. The Engineering Appendix (Appendix B) for these sites address risk of sea level change using low, intermediate, and high scenarios developed for Corps coastal investigations (USACE 2013). Removal of nearshore stressors such as dikes, armoring, and causeways will result in the creation and/or restoration of 2,101 acres of tidally influenced wetlands. With shoreline stressors removed, these wetlands should be able to adjust to changing geomorphic processes associated with changing sea levels; shifting landward, if there is room, as water rises and sediment accretes. These wetlands can function as a buffer from storm surge during short events and provide storage capacity during flooding events. In contrast to the open Washington coast, Puget Sound is primarily fetch limited. To generate wind waves and setup, winds have to be aligned just right and this rarely happens for long periods of time. The tendency is to have short duration coastal events coupled with longer duration riverine flooding. During these short events, some reduction of peak coastal surge can occur since the events may not be long enough for development of a steady state. In the rarer cases of sustained winds, the existence of wetlands may actually increase surge heights, since the surge flows over the rougher underlying land surface.

Wetland habitats will become even more essential to nearshore-dependent species that will be subject to the stress of increased temperature, varying velocities in rivers, and ocean acidification. In addition, the augmented infrastructure, such as replacements of causeways with wide-span bridges at many of the sites, will better withstand the storm surges and flooding events that are expected to occur in the coming century. Further design iterations will ensure that these structures can withstand the predicted climatic changes and rising seas in the region.

The design approach for sites in the Nearshore Study with respect to SLC during feasibility phase is as follows:

- As detailed in section 3.5.6.2, sites assume a single 100-year intermediate rate of rise scenario (~2 ft) throughout the Nearshore Study. This is also about equal to the 50-year high rate of rise. The project performance is assessed for the other two scenarios.
- Restoration features such as channel excavations are allowed to evolve naturally. No adaptation for SLC is included since the design intent is to remove the stressor and allow the system to evolve naturally regardless of SLC. This is in accordance with the rationale presented in Appendix B, Attachment B, *Applied Geomorphology Guidelines and Hierarchy of Openings*.
- Levees at Nooksack and North Fork Skagit River Deltas are designed for the existing level of residual risk only. Since the levees are subsections of larger river and coastal diking systems, adaptive management for SLC in these systems will need to be considered on a system-wide basis. In the future, depending on the timing of SLC, individual diking districts may decide to either raise entire levee/dike systems or modify flood risk management areas to accommodate coastal change.
- As an example, the Lummi River setback levees, as currently estimated, range in crest elevation from 15 to 20 feet NAVD88. This implies that the most seaward extents of the levees will begin to be overtopped by the base coastal flood by 2078 (about 50 years after construction) for the high rate of rise assumption and by 2155 (about 130 years after construction) for the intermediate level of rise.
- Levee design features such as wide crest widths and shallow side slopes allow for levee raising by others in the future as part of a flood risk management project without impacting restoration benefits. Flood risk reduction is not a component of the PSNERP so no adaptive management SLC costs have been included for levees; however, levees will be designed for overtopping if this is indicated in PED when the final levee crest elevations are refined. Appendix B, the Engineering Appendix, discusses the effects of low and high 100-year SLC scenarios as well as the 100-year intermediate (design) scenario.
- Bridges and roadways at Duckabush and Nooksack are designed so that the low chord of the bridge exceeds the Base Flood Elevation plus the 100-year intermediate level of rise (about equal to the 50-year high level of rise) by three feet to allow for debris passage. Appendix B, the Engineering Appendix, discusses the effects of low and high 100-year SLC scenarios as well as the 100-year intermediate (design) scenario. The effects are primarily related to additional OMRR&R costs for the bridges.
- The cost estimate includes added OMRR&R costs from the high sea level rate of rise assumption in the Cost Schedule Risk Assessments.

6.7 Economic/Cost Summary

Based on March 2016 price levels, the estimated project cost is $451,627,000 (with contingency), which includes monitoring costs of $1,090,000 and adaptive management costs of $5,307,000. In accordance with the cost share provisions in Section 103(c) of the WRDA of 1986, as amended {33 U.S.C. 2213(c)}, the Federal share of the project first cost is estimated to be $293,558,000 and the non-Federal share is estimated to be $158,069,000, which includes a 65% Federal and 35% non-Federal cost-share for restoration features. The non-Federal costs include the value of lands, easements, rights of-way, relocations, and disposal areas (LERRD) estimated to be $161,489,000. The LERRD estimate exceeds the 35% non-Federal cost share for restoration features by $3,420,000 and the value of these excess LERRD may be reimbursed to the non-Federal sponsor subject to the availability of funds. However, this situation is unlikely to be realized because the escalated, fully-funded cost estimate does not reflect a LERRD value that exceeds the 35% non-Federal cost share. Table 6-9 outlines the project first costs of the recommended plan at the March 2016 price level. Table 6-10 displays the cost-share information for the recommended plan based on project first costs at the March 2016 price level.

Table 6-9. Estimated Costs of the Recommended Plan

Project Cost Component	Project First Cost (in $1,000, Mar 2016 price level)
Construction and Real Estate	
Construction Costs	$179,157
Real Estate Costs (including relocations)	$161,489
Planning, Engineering and Design (PED)	$74,559
Construction Management (CM)	$30,025
Monitoring	$1,090
Adaptive Management	$5,307
Total Estimated Cost	**$451,627**

Table 6-10. Cost-Share Estimate of the Recommended Plan

Ecosystem Restoration	Federal Cost ($1,000, Mar 2016 price level)	Non-Federal Cost ($1,000, Mar 2016 price level)	Total Cost ($1,000, Mar 2016 price level)
LERRD	$0	$158,069	$158,069
Excess LERRDs (100% non-Federal)	$0	$3,420	$3,420
Ecosystem Restoration (65% Federal/35% non-Federal)	$290,138	$0	$290,138
Cash Contribution/Reimbursement	**$3,420**	-$3,420	$0
Total Cost Share	**$293,558**	**$158,069**	**$451,627**
Overall Cost Share Percentage	65%	35%	100%

Table 6-11 provides an economic summary of the recommended plan. Interest during construction was computed using estimated project costs at the March 2016 price level, anticipated construction durations for each of the three sites (they range from two to six years each), and the current Federal discount rate (3.125% for fiscal year 2016), bringing total investment costs to $528,147,000. Operations and maintenance expenses have been estimated for the three sites and detailed OMRR&R manuals will be developed for each site during the PED phase. Annual costs were updated using the current cost estimate at the March 2016 price level. Total average annual cost is estimated at $21,880,000, with an average annual cost of $31,000 per AAHU. Table 6-12 summarizes site-specific costs and benefits. Note that total annual cost computed at the site-specific level is different from the annual cost of the recommended plan. This is based on the computation of interest during construction over the two to six year construction periods for each site versus 10-year overall construction of the recommended plan.

First costs for authorization purposes are estimated at $451,627,000 (March 2016 price level) and the fully funded cost estimate to the mid-point of construction is estimated at $539,839,000.

Table 6-11. Economic Summary of the Recommended Plan

	Cost and Benefit Summary of Recommended Plan (Oct 2015 price level)
Interest Rate (Fiscal Year 2016)	3.125%
Interest Rate, Monthly	0.26%
Construction Period, Months	120
Period of Analysis, Years	50
Estimated Cost	$451,627,000
Interest During Construction	$76,520,000
Investment Cost	$528,147,000
Average Annual Cost	
Amortized Cost	$21,017,000
Annualized OMRR&R	$863,000
Total Annual Cost	$21,880,000
Average Annual Benefits	
Average Annual Habitat Units (AAHUs)	716.5
Average Annual Cost/AAHU	$31,000

Note: OMRR&R costs have been estimated for the three sites in the recommended plan Detailed OMRR&R manuals will be developed for each site during the PED phase.

Table 6-12. Site-Specific Costs and Benefits of the Recommended Plan (Oct 2015 price level, 3.125% discount rate)

Site	Total Project Cost	Annual OMRR&R	Total Annual Cost	Acres Restored	AAHU
Duckabush	$90,523,000	$122,000	$3,711,000	38.1	12.3
North Fork Skagit River Delta	$99,299,000	$36,000	$4,070,000	256.1	53.7
Nooksack River Delta	$261,805,000	$705,000	$11,427,000	1807	650.5
Total	$452,286,000	$863,000	$19,208,000	2101.2	716.5

6.8 Implementation Requirements

The following sections outline the requirements for implementation of the recommended plan.

6.8.1 Non-Federal Sponsor

The Washington Department of Fish and Wildlife (WDFW) is the non-Federal sponsor for the feasibility phase of the Nearshore Study. After project authorization, it is anticipated that the Corps will partner with WDFW to construct the three sites authorized in this study. Once a non-Federal partner is confirmed for construction, work-in-kind (WIK) credit provisions will be established and funding summaries will be developed for each year of design and construction.

6.8.2 Institutional Requirements

The schedule for project implementation is dependent on project authorization. After project authorization, the project would be eligible for construction funding. The project would be considered for inclusion in the President's budget based on national priorities, magnitude of the Federal commitment, economic and environmental feasibility, level of local support, confirmation that the non-Federal sponsor's cost share funding is available , and the budget constraints at the time of funding. Once Congress appropriates Federal construction funds, the Corps and the non-Federal partner(s) would enter into a Design Agreement (DA) and eventually a Project Partnership Agreement (PPA). The DA would define the Federal and non-Federal responsibilities for completion of final designs for the project. The PPA would define the Federal and non-Federal responsibilities for implementing, operating, and maintaining the project.

6.8.3 Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) Requirements

After completion of construction, the non-Federal sponsor(s) will assume operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) responsibility for the entire project footprint. OMRR&R costs have been estimated for the three sites included in the recommended plan; these estimates and a summary of OMRR&R activities for each site are included in Appendix B. The OMRR&R cost includes maintenance of all the infrastructure (levees, roads, bridges, etc.) that are included in the project. Although they are being modified, many of these features are already being maintained currently by local entities. Detailed OMRR&R manuals will be developed for each site during the PED phase.

6.9 Tiered Implementation Master Plan: Sites for Additional Study

As described in section 4.3, a tiered implementation approach was developed for all 36 sites identified across Puget Sound deemed critical to restore the connectivity and size of large river delta estuaries, restore the number and quality of coastal embayments, and restore the size and quality of beaches and bluffs. The tiered strategy allows for a more diversified scope of projects to be implemented under various restoration authorities and partners. The implementation master plan identifies various approaches for implementation of the 36 projects: GI projects to be recommended for construction (three sites), GI projects recommended for additional study (nine sites), projects to be completed under existing Corps construction authorities (CAP) or Puget Sound and Adjacent Waters Program (PSAW) (12 sites), and projects to be completed by others (12 sites).

The nine sites recommended for additional GI studies are the following:

- Big Beef Creek Estuary
- Big Quilcene River
- Chambers Bay
- Dugualla Bay
- Everett Marshland
- Lilliwaup River Estuary
- Tahuya River Estuary
- Snohomish River Estuary
- Telegraph Slough

More information about these nine sites is summarized in Appendix K. Table 6-13 also summarizes key details for the nine sites that require additional study under the General Investigations Program.

Table 6-13. Sites for Future General Investigation Study

Site Name	Sub-Basin	Strategy	Project Description	Acres Restored	Total Project Cost[1]
Dugualla Bay	Whidbey	Barrier Embayment	Restore tidal inundation to Dugualla Bay by removing levees, excavating tidal channels, and creating two small barrier beaches.	572	$88,355,000
Everett Marshland	Whidbey	River Delta	Restore floodplain habitat connectivity along the west bank of the Snohomish River by removing levees, excavating tidal channels, filling drainage ditches, and reconnecting streams to the tidal area.	829	$296,905,000
Telegraph Slough	San Juan	River Delta	Restore tidal inundation to Padilla Bay by removing levees and tide gates as well as excavating distributary channels to the Bay.	832	$256,124,000
Chambers Bay	South	Open Coastal Inlet	Restore tidal hydrology at the mouth of Chambers Bay by removing the Chambers Creek dam, removing armoring and fill, as well as daylighting and restoring creeks.	288	$298,002,000
Big Beef Creek Estuary	Hood Canal	Barrier Embayment	Restore historical spit and tidal inundation to Little Beef harbor by relocating the Seabeck Highway and excavating tidal channels in the estuary.	91	$37,376,000
Tahuya River Estuary	Hood Canal	Open Coastal Inlet	Restore tidal inundation to the Tahuya River estuary by replacing a roadway with a bridge and removing fill.	29	$30,305,000
Lilliwaup River Estuary	Hood Canal	Open Coastal Inlet	Restore tidal connectivity in the Lilliwaup River estuary by replacing the existing Highway 101 causeway with an elevated structure, removing accumulated sediment in the channel, and excavating tidal channels in the estuary.	19	$36,994,000
Big Quilcene River	Hood Canal	Open Coastal Inlet	Restore tidal hydrology at the mouth of the Big Quilcene River by removing dikes and fill, reconnecting distributary channels, and excavating pilot channels.	28	$37,600,000
Snohomish River Estuary	Whidbey	River Delta	Restore tidal hydrology in the Snohomish River estuary by removing levees, fill, and tide gates to reconnect the distributary channel to Union Slough (at the north end) and the Snohomish River (south end).	68	$126,593,000

[1]Estimated construction cost plus estimated $3 million feasibility study cost; prices presented in March 2016 dollars

The tiered implementation approach also identifies sites to be completed under the CAP or PSAW authority. Puget Sound and Adjacent Waters (Section 544, WRDA 2000) directs the Secretary to conduct studies and implement critical restoration projects in the area of Puget Sound, Washington and adjacent waters in consultation with the Secretary of Commerce, the Secretary of the Interior, the Governor of the State of Washington, tribal governments, and other stakeholders. According to the authority, selection of critical projects shall consider existing studies and plans.

The PSNERP study team, which included representatives from other federal and state agencies, Tribes, NGOs, academia, etc. went through a comprehensive process of identifying, screening, and selecting critical restoration projects within Puget Sound as detailed in Chapter 4. That process mirrors the directive included in the PSAW authority. Accordingly, the tiered implementation plan that resulted from the PSNERP study identifies the critical restoration projects in Puget Sound, and specifically identifies 4 of those projects for execution under the PSAW authority (Spencer Island, Quilceda Estuary Restoration, Twanoh State Park Beach Restoration and Twin Rivers). This PSNERP study also identifies the cost, acreage, and habitat units of these site-specific projects. Therefore, this study and the tiered implementation strategy meets the requirements identified by OMB (memo to ASA(CW) dated 15 June 2006).

The authorized appropriation for Section 544 is $40,000,000 with the Federal share of a single project limited to $5,000,000. Accordingly, the projects identified in the tiered implementation strategy will not exceed the remaining capacity under the PSAW authority.

Table 6-14 summarizes key details for the nine sites that require additional study under the General Investigations Program.

Table 6-14. Sites for PSAW or CAP Study

Site Name	Sub-Basin	Strategy	Project Description	Acres Restored[1]	Habitat Units[1]	Total Project Cost[1]
Chuckanut Estuary	San Juan	Open Coastal Inlet	Reconnect the Chuckanut Bay Estuary to Bellingham Bay by replacing an existing railway berm with a bridge.	88	5	$16,300,000
Deepwater Slough	Whidbey	River Delta	Restore tidal wetlands by lowering and breaching dikes, planting native vegetation and reconnecting tidal and distributary channels to Freshwater, Deepwater, and Steamboat Sloughs.	270	90	$9,900,000
Everett Riverfront Wetland	Whidbey	River Delta	Improve connectivity between the mainstem Snohomish River and large freshwater wetland complexes by excavating distributary channels, removing bulkheads, and planting native vegetation.	55.5	30	19,500,000
Harper Estuary	Hood Canal	Open Coastal Inlet	Restore unrestricted tidal exchange in Harper Estuary by removing bulkheads and hardened debris as well as restoring tidal channels in the estuary.	6.2	2	$12,200,000
Livingston Bay	Whidbey	Barrier Embayment	Restore large area of salt marsh and mudflats by excavating starter channels to initiate tidal marsh development, filling internal drainage ditches, lowering internal dikes, and planting native vegetation.	239	40	$13,100,000
McGlinn Island	Whidbey	River Delta	Improve the hydraulic connection between the North Fork Skagit River and the Swinomish Channel by creating a new distributary channel from Dunlap Bay to the Swinomish Channel.	940	0.2	$10,000,000
Quilceda Estuary	Whidbey	River Delta	Restore historic marsh by removing berms along Quilceda Creek, excavating fill material, eliminating old agricultural ditches, creating new tidal channels, and planting native vegetation.	9	3	$2,600,000
Sequalitchew Creek	South	Open Coastal Inlet	Restore the stream mouth and open coastal inlet morphology by removing armor and nearshore fill around the mouth of the Sequalitchew Creek ravine.	3.5	0.5	$14,000,000
Spencer Island	Whidbey	River Delta	Restore tidal exchange to Spencer Island by breaching an existing dike and creating a tidal channel network in the interior of the island	313	136	$3,700,000

Site Name	Sub-Basin	Strategy	Project Description	Acres Restored[1]	Habitat Units[1]	Total Project Cost[1]
Twanoh Beach	Hood Canal	Barrier Embayment	Restore valuable coastal embayment by removing shoreline armoring, allowing sand and gravel beach restoration to support spawning grounds for forage fish.	4	2	$2,600,000
Twin Rivers	Strait	Beach	Remove rock armoring and sheet pile walls, and fill to restore sand and gravel beaches that serve as spawning grounds for forage fish.	4	0.15	$3,600,000
WDNR Budd Inlet Beach	South	Beach	Restore sediment supply and transport by removing armor and debris, placing large woody debris, channel rehabilitation, and beach nourishment.	2	1	$10,400,000

[1]Estimates for acres restored, habitat units, and total project costs are conceptual estimates only. Costs, benefits, and acres restored will be refined when additional studies are completed for each site.

7 ENVIRONMENTAL COMPLIANCE OF THE RECOMMENDED PLAN*

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

7.1 NATIONAL ENVIRONMENTAL POLICY ACT OF 1969

The National Environmental Policy Act (NEPA) (42 U.S.C. §4321 et seq.) commits Federal agencies to considering, documenting, and publicly disclosing the environmental effects of their actions. NEPA-required documents must provide detailed information on the proposed action and alternatives, environmental effects of the alternatives, mitigation measures, and any adverse environmental effects that cannot be avoided if the proposal is implemented. Agencies must demonstrate that decision makers have considered these factors prior to undertaking actions.

The Corps published a Notice of Intent to prepare an EIS in the Federal Register on October 2, 2009, and held four scoping meetings around the Puget Sound area. All comments received during scoping phase were considered in determining whether it will be in the public interest to proceed with the proposed project. The Draft FR/EIS was published for a public comment period initially from October 10, 2014 through November 24, 2014. Responding to public request, the comment period was extended through January 8, 2015. Public comments and agency responses appear in Appendix H. The Final FR/EIS will be published for a 30-day period, followed by a Record of Decision. This is intended to achieve NEPA compliance for the proposed project.

7.2 ENDANGERED SPECIES ACT OF 1973

The Endangered Species Act (ESA) (16 U.S.C. §1531-1544), Section 7(a) requires that Federal agencies consult with the NMFS and USFWS to ensure that proposed actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their critical habitats.

ESA consultation was conducted via the Fish Passage and Restoration Projects Biological Opinion issued to the Corps' Seattle District in 2008, and coverage of species under USFWS under this Biological Opinion has been extended through 2018. The Corps received letters from NMFS and USFWS indicating their support for using this process for ESA consultation in 2012. The USFWS provided an approval letter for the Recommended Plan on February 4, 2016. NMFS provided a Biological Opinion to specifically cover the actions proposed by the Nearshore Study. The issuance of this consultation with explicit inclusion of all Nearshore Study sites and features was provided to the Corps on February 11, 2016.

7.3 FEDERAL WATER POLLUTION CONTROL ACT OF 1972 (CLEAN WATER ACT)

The Clean Water Act (33 U.S.C. §1251 et seq.) requires Federal agencies to protect waters of the United States. The regulation implementing the Act disallows the placement of dredged or fill material into water unless it can be demonstrated there are no practical alternatives that are less environmentally damaging. The sections of the CWA that apply to the Nearshore Study proposal are 401 regarding discharges to waterways, 402 regarding discharges of storm water, and 404 regarding fill material in waters and wetlands.

The assumptions for water quality and CWA compliance were that all data shown on WDOE's website are the best available information, none of the water quality conditions at any site would prevent a feasible restoration action, standard BMPs employed during construction would be sufficient to avoid significant impacts, and that WDOE would be able to issue 401 certification upon receiving the required level of detail in site designs. The vast acreages of wetland restoration are assumed to have only temporary, minor negative effects on water quality and will improve water quality conditions in the long term, especially in cases where buffers between a waterbody and agricultural land are established or increased.

Section 401

Any project that involves placing dredged or fill material in waters of the United States or wetlands, or mechanized clearing of wetlands requires a water quality certification from the state or tribal agency as delegated by EPA. For most sites of the Nearshore Study, the delegated authority is WDOE. For the Nooksack site, the EPA has delegated authority to the Lummi Nation for their lands while Ecology maintains jurisdiction over state and private lands. The Corps initiated coordination with WDOE and the Lummi Nation in 2014 for their certification that the proposed Federal action will not violate established water quality standards. The Corps received a letter from WDOE on January 8, 2016 stating their support for the Corps to continue pursuing these projects and continued coordination in formal permit phase (see Appendix J). The Lummi Nation referenced their letter in support of the project, which they provided on November 25, 2014, and requested that the Corps reinitiate coordination for 401 certification when more detailed designs are available prior to construction. The Corps will submit the 401 water quality certification request at the 65% design phase and will receive the certification before completion of the 95% design package. Based on Seattle District experience, WDOE typically issues a 401 certification within a 6-9 month period. The Corps has anticipated standard best management practices that are typically required by WDOE for similar ecosystem restoration projects and have accounted for those in the design and associated cost estimate.

Section 402

The National Pollutant Discharge Elimination System (NPDES), controls discharges into waters of the United States. In 1987, the Clean Water Act was amended to require the EPA to establish a program to address storm water discharges. In response, the EPA promulgated the NPDES storm water permit application regulations. The Corps will ensure that each restoration site is covered by a Section 402 Construction Storm water General Permit. Best management practices for erosion and sedimentation control will be included in the design for each restoration site.

Section 404

In 1972, Section 404 established a program to regulate the discharge of dredged or fill material into the navigable waters of the United States. Much earlier, the Rivers and Harbors Act of 1899 (33 U.S.C. §403) defined navigable waters of the United States as "those waters that are subject to the ebb and flow of the tides and/or are presently used, or have been used in the past, or may be susceptible to use to transport interstate or foreign commerce." The Clean Water Act built on this and defined waters of the United States to include tributaries to navigable waters, interstate wetlands, wetlands that could affect interstate or foreign commerce, and wetlands adjacent to other waters of the United States. To comply with Section 404, it is necessary to avoid negative effects to wetlands wherever practicable, minimize effects where they are unavoidable, and compensate for effects in some cases. The Nearshore Study's Recommended Plan has undergone a Section 404(b)(1) evaluation. See Appendix J.

7.4 NATIONAL HISTORIC PRESERVATION ACT

The National Historic Preservation Act (NHPA) of 1966 (16 U.S.C. §470), as amended through 1992 (Public Law 102-575), establishes preservation as a national policy and directs the Federal government to provide leadership in preserving, restoring, and maintaining the nation's historic and cultural environment. Section 106 of NHPA requires Federal agencies to account for the indirect, direct, and cumulative effects of their undertakings on historic properties (i.e., archaeological sites, Traditional Cultural Properties, buildings, structures, objects, districts, and landscapes listed in or eligible for listing in the National Register). Section 106 and its implementing regulations at 36 CFR 800 establish procedures for Federal agencies to follow in identifying historic properties and assessing and resolving effects of their undertaking on them, in consultation with State Historic Preservation Officers (SHPO), Indian tribes, Native Hawaiians, and the Advisory Council for Historic Preservation (ACHP), as appropriate. Other parties may participate in the Section 106 consultation process, including but not limited to applicants for Federal assistance, permit and license applicants, certified local governments, and other groups or individuals with an economic, social, or cultural interest in the project. Maximum public involvement in the process is encouraged.

The Corps consulted with the SHPO, ACHP, interested Tribes, and the public on a Programmatic Agreement (PA; see Appendix D) regarding the three sites of the recommended plan (Nooksack River Delta, North Fork Skagit River Delta, and Duckabush Estuary). The PA was fully executed in June 2016. The PA provides for deferred identification and evaluation for Section 106 under 36 CFR § 800.4 (b) (2) and 36 CFR § 800.14 (b) and provides a framework under which the Corps will comply with Section 106 once Congressional approval and authorization is granted. Letters were sent on March 5, 2013 to the SHPO and ACHP detailing the project. The letter stated that the Corps was exploring the possibility of developing a PA or MOA to defer identification and evaluation until specific aspects or location of alternatives were more fully defined, but also requested advice and guidance on the appropriate mechanism to fulfill the agency's Section 106 responsibilities. The SHPO responded April 3, 2013 stating that they looked forward to consulting with Corps. The ACHP responded March 22, 2013 stating that they would participate in consultation. Follow-up letters were sent on September 30, 2015 to the ACHP, SHPO and interested Tribes providing a project update and stating that the Corps elected to defer identification and evaluation under Section 106 of the NHPA. Emails were sent to interested members of the public that may have an interest in the restoration sites in the recommended plan. The ACHP reiterated their interest in participating in the development of a PA by email on October 30, 2015. The PA was completed in 2016 to include the three sites of the Recommended Plan. The PA outlines the Section 106 procedures that will be undertaken once Congressional approval and authorization is granted. Procedures include which Section 106 tasks need to occur prior to construction (e.g. fieldwork), how Section 106 consultation will occur, how determinations of eligibility will be made, how findings of no adverse effect will be determined, how findings of adverse effects will be made, and how the PA will be implemented and dispute resolution procedure. In addition, the PA provides for a variety of treatment measures that can be used for mitigation of an adverse effect (See Appendix E of the PA). The treatment measures are standard types of mitigation actions used for adverse effects and the costs of these treatment measures have been taken into account during cost estimation for this project. Signatories to the PA include the Corps, the Washington SHPO, the ACHP, WDFW, and the Lummi Nation. The Lummi Nation is a signatory due to the Nooksack restoration project extending onto the reservation and because the Lummi Nation has a recognized Tribal Historic Preservation Officer (THPO) who has assumed the responsibilities of the State Historic Preservation Officer (SHPO) on tribal lands. The Washington Department of Transportation (WSDOT) is an invited signatory due to their interest in the Duckabush Bridge located in the Duckabush restoration site. For any other sites that receive authorization and funding, these will undergo a separate consultation process for compliance with NHPA.

7.5 FEDERAL TREATY OBLIGATIONS

The Federal trust responsibility to Native American Tribes arises from the treaties signed between them. Under Article VI, Clause 2 of the U.S. Constitution, treaties with the Tribes are the supreme law of the land, superior to State laws, and equal to Federal laws. In these treaties, the United States made a set of commitments in exchange for tribal lands, including the promise that the United States would protect the tribe’s people. The Supreme Court has held that these commitments create a trust relationship between the United States and each treaty tribe, and impose upon the government “moral obligations of the highest responsibility and trust.” The scope of the Federal trust responsibility is broad and incumbent upon all Federal agencies. The government has an obligation to protect tribal land, assets, and resources that it holds in trust for the Tribes, and a responsibility to ensure that its actions do not abrogate Tribal treaty rights.

Tribes have had representation in the Nearshore Study planning phase through the Northwest Indian Fisheries Commission, as well as the Lummi Nation’s participation on the Steering Committee. The Nearshore Study team anticipates that the proposed ecosystem restoration would have significant benefits to salmonid and shellfish resources, which are of economic and cultural value to the tribes within the project area. Implementation of the recommended plan would improve the affected nearshore areas, ultimately benefiting Puget Sound tribes and consistent with the Federal government's trust responsibility to them.

7.6 EXECUTIVE ORDER 13175, CONSULTATION AND COORDINATION WITH INDIAN TRIBAL GOVERNMENTS

Executive Order 13175 (6 November 2000) reaffirmed the Federal government's commitment to a government-to-government relationship with Indian tribes, and directed Federal agencies to establish procedures to consult and collaborate with tribal governments when new agency regulations would have tribal implications. The Corps has a government-to-government consultation policy to facilitate the interchange between decision makers to obtain mutually acceptable decisions. In accordance with this Executive Order, the Corps has engaged in regular and meaningful consultation and collaboration with Puget Sound's federally recognized tribes throughout the course of the study.

7.7 BALD AND GOLDEN EAGLE PROTECTION ACT

The Bald and Golden Eagle Protection Act (16 U.S.C. §668-668c), enacted in 1940 and amended several times since then, prohibits anyone without a permit issued by the Secretary of the Interior from "taking" eagles including their parts, nests, or eggs and applies criminal penalties to persons. The Act defines "take" as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." Construction activities associated with the proposed actions may disturb bald and golden eagles due to elevated noise levels and presence of heavy machinery. The Corps would avoid and minimize impacts through construction timing windows for each site identified containing or in close proximity to a breeding area, and, if nests and/or roosts are nearby, monitor and coordinate with USFWS.

7.8 CLEAN AIR ACT

The Clean Air Act (CAA) as Amended (42 U.S.C. §7401, et seq.) prohibits Federal agencies from approving any action that does not conform to an approved State or Federal implementation plan. Three agencies have jurisdiction over air quality in the project area: EPA, WDOE, and the Puget Sound Clean Air Agency. The EPA sets standards for concentrations of pollutants in outdoor air and the State establishes regulations that govern contaminant emissions from air pollution sources. In accordance with the CAA and its amendments, National Ambient Air Quality Standards (NAAQS) have been established by EPA for several criteria pollutants including lead (Pb), ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulates with aerodynamic diameters of less than 10 and less than 2.5 microns (PM_{10} and $PM_{2.5}$). Construction activities associated with the proposal will create air emissions, but these are not expected to affect implementation of Washington's CAA implementation plan.

Washington uses air-monitoring data to determine whether air quality in the State meets the national standards. Areas where the standards are met are designated as attainment areas, and areas where the standards are exceeded are designated as nonattainment areas (NAA). This will not be a concern on this project, as none of the proposed actions would occur in Washington's single nonattainment area. Construction sites of the magnitude included in the Recommended Plan are not typically a concern in attainment areas. The estimated emissions for the sites included in the proposed project are expected to meet the standards set forth by the EPA and implemented by Washington State.

7.9 COASTAL ZONE MANAGEMENT ACT

The Coastal Zone Management Act (CZMA) of 1972 as amended (16 U.S.C. §1451-1464) requires Federal agencies to carry out their activities in a manner that is consistent to the maximum extent practicable with the enforceable policies of the approved State Coastal Zone Management Program. The aim of the act is to "preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone." The delegated authority for review of consistency with the law is WDOE. In compliance with State law, each of the 15 coastal counties in Washington has developed its own Shoreline Master Program in compliance with the State Shoreline Management Act. The Corps has prepared a CZMA Consistency Determination for each site according to the relevant county or local code and has determined that the Recommended Plan is substantively consistent with the enforceable polices of the State Coastal Zone Management Program. Those enforceable policies include compliance with the Clean Water Act. Therefore, the Corps will submit the CZMA Consistency Determination along with the 401 Water Quality Certification Request to WDOE at the 65% design phase and will receive the CZMA consistency concurrence before completion of the 95% design package. In Seattle District's experience, CZMA consistency concurrence does not include any conditions on the proposed work.

7.10 FISH AND WILDLIFE COORDINATION ACT

The Fish and Wildlife Coordination Act of 1934 as amended (16 U.S.C. §661-667e) ensures that fish and wildlife conservation is given equal consideration as is given to other features of water-resource development programs through planning, development, maintenance, and coordination of wildlife conservation and rehabilitation. Whenever the waters of any stream or other body of water are proposed to be impounded, diverted, deepened or otherwise controlled or modified, the Corps shall consult with the USFWS and NMFS as appropriate, and the agency administering the wildlife resources of the state. Any reports and recommendations of the wildlife agencies shall be included in authorization documents for construction or modification of projects. The Corps shall consider the reports and recommendations of the wildlife agencies and include such justifiable means and measures for wildlife mitigation or enhancement as the Corps finds should be adopted to obtain maximum overall project benefits. Recommendations provided by the USFWS in Coordination Act Reports must be specifically addressed in Corps feasibility reports.

The Corps initiated consultation with USFWS in 2002 shortly after the start of the Nearshore Study's Feasibility Phase. USFWS has provided three Planning Aid Letters in 2005, 2007, and 2011, and has provided a USFWS biologist to be a member of the Nearshore Science Team and the Nearshore Steering Committee. USFWS has been supportive of Nearshore Study efforts and the Corps has been incorporating USFWS technical advice into project planning, strategies, objectives, site screening, and conceptual designs. NMFS has been equally supportive of the Nearshore Study and has had representation on the Nearshore Study's Steering Committee and has been a participating organization since early in the Feasibility Phase. In addition, NMFS contributed to an analysis of affected threatened and endangered species and provided conservation measures to implement during restoration work. The Corps received a Draft Coordination Act Report (CAR) from USFWS on January 21, 2016. USFWS and NMFS submitted a joint Final CAR and provided this to the Corps on March 4, 2016 (see Appendix J).

The complete list of recommendations appears in the Draft and Final CARs in Appendix J. Several key recommendations are summarized below. Through coordination prior to receiving the Draft CAR, the Corps was aware of these recommendations and incorporated them into project design development. The Corps' response follows each USFWS recommendation:

- Use best management practices (BMPs) and conservation measures to minimize short-term construction impacts
    - The Corps will apply standard BMPs for minimizing environmental impacts during construction. BMPs and conditions received in the Clean Water Act 401 certification and ESA consultation documents will be incorporated into site designs during PED.
- Avoid pile driving for bridge replacement features
    - The current level of design includes only cast-in-place piers for bridge replacement and no pile driving. Some vibratory pile removal may be necessary, but this will be held to the minimum noise impacts possible.
- Follow NMFS guidelines for riparian buffers
    - Wherever possible, the maximum available width of riparian buffer has been designed into the site-specific plans.
- Apply creativity and flexibility in working with landowners to maximize ecosystem benefits
    - Lands, easements, and rights-of-way are the responsibility of the non-Federal sponsor, who will conduct landowner outreach regarding the project. The Corps will assist with this effort wherever appropriate.
- Continue coordinating with tribal governments and representatives
    - The Corps solicited input throughout the NEPA process from all stakeholders, which included directly contacting Puget Sound tribes multiple times. The Corps will continue tribal coordination throughout PED and looks forward to having tribal input.
- Continue coordinating with USFWS through the next design phase
    - The Corps will continue coordinating with all relevant natural resource agencies including but not limited to USFWS, NMFS, and WDFW throughout PED.

7.11 MAGNUSON-STEVENS SUSTAINABLE FISHERIES AND CONSERVATION ACT

The Magnuson-Stevens Fishery Conservation and Management Act (MSA), (16 U.S.C. §1801 et. seq.) requires Federal agencies to consult with NMFS on activities that may adversely affect Essential Fish Habitat (EFH). The objective of an EFH assessment is to determine whether the proposed action(s) “may adversely affect” designated EFH for relevant commercial, federally managed fisheries species within the proposed action area. The assessment also describes conservation measures proposed to avoid, minimize, or otherwise offset potential adverse effects to designated EFH resulting from the proposed action.

EFH consultation has been completed via the Biological Opinion provided by NMFS on February 11, 2016, included in Appendix J. This Biological Opinion states that the temporary and spatially constrained increases in turbid water during construction will adversely affect EFH for Pacific Coast salmon. The measures required in the ESA consultation to minimize the effects of construction on water quality would have a similarly conservative effect on EFH. Therefore, NMFS recommends implementing Term and Condition 1(a)(1) as described in the Biological Opinion found in Appendix J. NMFS stated that implementing the minimizations measures as described in ESA consultation for restoration actions in Washington State (NWS-2008-3598),including the use of isolation devices, avoiding the need for pile driving, monitoring of water quality, and providing NMFS with additional information on design and construction as the project proceeds, would protect by avoiding or minimizing the adverse effects to approximately 20 acres of EFH for Pacific Coast salmon.

7.12 MARINE MAMMAL PROTECTION ACT

The Marine Mammal Protection Act (MMPA) of 1972 (16 U.S.C. §1361-1407) restricts harassment of marine mammals and requires interagency consultation in conjunction with the ESA consultation for Federal activities. All marine mammals are protected under the MMPA regardless of whether they are endangered, threatened, or depleted. Marine mammal species that are observed in Puget Sound include harbor seal (*Phoca vitulina*), killer whale (*Orcinus orca*), Steller sea lion (*Eumetopias jubatus*), Northern elephant seal (*Mirounga angustirostris*), California sea lion (*Zalophus californianus*), harbor porpoise (*Phocoena phocoena*), Dall’s porpoise (*Phocoenoides dalli*), Minke whale (*Balaenoptera acutorostrata*), and gray whale (*Eschrichtius robustus*) (Orca Network 2011). The primary concern for protection of marine mammals will be underwater noise from construction sites, which is described in detail in section 5.1.8. The Corps consulted with NMFS on effects to marine mammals in conjunction with the ESA Section 7 consultation. The Corps anticipates implementing all practicable conservation measures. For all restoration sites in which the sound levels are predicted to be louder than the acoustic thresholds for harassment of marine mammals, the Corps will use BMPs as described in section 5.7.4. as appropriate for each site and will coordinate with NMFS to determine whether a Marine Mammal Monitoring Plan is needed.

7.13 MIGRATORY BIRD TREATY ACT

The Migratory Bird Treaty Act of 1918 (16 U.S.C. §703-712), as amended in 1989, implements various treaties and conventions between the U.S. and Canada, Japan, Mexico, and the former Soviet Union for the protection of migratory birds. Under the Act, it is unlawful to hunt, take, capture, or kill; attempt to take, capture, or kill; possess, offer to sell, barter, purchase, deliver or cause to be shipped, exported, imported, transported, carried or received any migratory bird, part, nest, egg or product, manufactured or not. The proposed work will not result in the hunt, take, capture, or killing of migratory birds. Construction activities may disturb migratory birds due to noise and presence of large machinery. These effects will be minimized by avoiding disruptive work during the typical nesting season, and surveying the sites for nests.

7.14 HAZARDOUS, TOXIC, AND RADIOLOGICAL WASTE LAWS

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) is designed to clean up sites contaminated with hazardous substances; remediating abandoned hazardous waste sites, by establishing legal liability, as well as a trust fund for cleanup activities, called “Superfund”. The Resource Conservation and Recovery Act (RCRA) gives the EPA the authority to control hazardous waste from "cradle-to-grave." This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. The Toxic Substances Control Act (TSCA) of 1976 provides EPA with authority to require reporting, record-keeping, and testing requirements, and restrictions relating to chemical substances and/or mixtures. TSCA addresses the production, importation, use, and disposal of specific chemicals including polychlorinated biphenyls (PCBs), asbestos, radon, and lead-based paint. None of the proposed restoration sites are on the EPA National Priorities List, and there are no known HTRW sites identified within the project footprints. If chemical contaminants or regulated substances are found on a particular site proposed for restoration, the Corps will comply with current policies and coordinate with the local sponsor to ensure that remediation actions are taken as necessary prior to project implementation.

7.15 THE GENERAL BRIDGE ACT

The General Bridge Act of 1946 (33 U.S.C. §525-533) prohibits the construction of any bridge across navigable waters of the United States unless first authorized by the Coast Guard. The Coast Guard approves the location and clearances of bridges through the issuance of bridge permits or permit amendments, under the authority of the General Bridge Act of 1946, Section 9 of the Rivers and Harbors Act of 1899, and other statutes. New construction, reconstruction, or modification of a bridge or causeway over navigable waters of the United States requires permit issuance from the Coast Guard. A bridge permit is the written approval of the location and plans of the bridge or causeway to be constructed or modified. One of the sites in the Recommended Plan will involve replacement of a bridge, which will require a permit from the Coast Guard. The Corps will design and build the bridge according to Coast Guard regulations, and the permit will be obtained when the final design is available.

7.16 FARMLAND PROTECTION POLICY ACT

The FPPA is intended to minimize the impact Federal programs and actions have on the unnecessary and irreversible conversion of farmland to nonagricultural uses. It assures that to the extent possible Federal programs and actions are administered to be compatible with state, local units of government, and private programs and policies to protect farmland. The FPPA does not authorize the Federal Government to regulate the use of private or non-Federal land or, in any way, affect the property rights of owners. For the purpose of FPPA, farmland includes prime farmland, unique farmland, and land of statewide or local importance. Farmland subject to FPPA requirements does not have to be in use as cropland. It can be forestland, pastureland, cropland, or other land, but not water or urban built-up land.

The Corps initiated the process for compliance by providing the Farmland Conversion Impact Rating Forms to the Natural Resources Conservation Service (NRCS) for their review and input in October 2015. NRCS responded with their evaluation in October 2015. The rating forms were finalized in July 2016 and provided to the NRCS to complete the compliance process.

Although there will be conversion of farmland to tidal wetland, it is necessary to restore ecosystem processes at the project sites. Historic conversion of wetlands to farmland was commonplace along Puget Sound rivers due to fertile soil and flat topography. Impacts to farmland at a regional scale are minimal, as the total acreages are a small fraction of the total acreage in the counties where the projects are located.

7.17 EXECUTIVE ORDER 12898 ENVIRONMENTAL JUSTICE

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" provides that each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations. Environmental justice concerns may arise from impacts on the natural and physical environment, such as human health or ecological impacts on minority populations, low-income populations, and Indian tribes or from related social or economic impacts.

The Corps evaluated the location and design of each restoration site to determine whether they would affect minority populations, low-income populations, and Indian tribes. The EPA Environmental Justice Viewer was used to determine whether protected groups are present in the proposed restoration areas. This evaluation found that the sites are either within park limits with no residents nearby or the demographics of the nearby populations were mostly non-minority and above poverty levels, with one exception. One site is located within Lummi Nation lands. Coordination of the proposed site with key stakeholders including the Lummi Nation has occurred throughout the planning process. In the case of the Indian tribal land, the proposed restoration would improve the affected nearshore area to the benefit of the tribe and would be designed to avoid negative effects to tribal resources. Therefore, in accordance with Title III of the Civil Rights Act of 1964 and Executive Order 12898, it has been determined that the project would not directly or through contractual or other arrangements, use criteria, methods, or practices that discriminate on the basis of race, color, or national origin, nor would it have a disproportionate effect on minority or low-income communities.

7.18 EXECUTIVE ORDER 11988 FLOODPLAIN MANAGEMENT

Executive Order 11988 requires Federal agencies to recognize the significant values of floodplains and to consider the public benefits that would be realized from restoring and preserving floodplains. It is the general policy of the Corps to formulate projects that, to the extent possible, avoid or minimize adverse impacts associated with use of the base floodplain and avoid inducing development in the base floodplain unless there is no practicable alternative that meets the project purpose. Per the procedures outlined in ER 1165-2-26 (Implementation of Executive Order 11988 on Flood Plain Management), the Corps has analyzed the potential effects of the recommended plan on the overall floodplain management of the study area.

There are eight steps reflecting the decision making process required in this Executive Order. The eight steps and responses to them are summarized below.

1. **Determine if the proposed action is in the base floodplain.**
   The proposed actions are located within the base floodplain for the Duckabush River, Nooksack River, and North Fork Skagit River.

2. **If the action is in the floodplain, identify and evaluate practicable alternatives to locating in the base floodplain.**
   As the primary objective of the project is aquatic ecosystem restoration, there are no practicable alternatives completely outside of the base floodplain for the three sites that would achieve this objective.

   As described in section 6.1.3.7 and section 6.1.2.8, the study team completed an induced flooding analysis to determine whether mitigation for induced flooding (e.g., inclusion of setback levees) is justified as part of this ecosystem restoration project. Compared to acquisition of property, flowage easements, or other non-structural measures, the analysis indicates that setback levees are the preferred method to achieve the ecosystem restoration benefits at the Nooksack River Delta and North Fork Skagit River Delta. The study team also completed a qualitative evaluation of different levels of flood risk management for the setback levees. The team evaluated setback levees that provide a higher level of flood risk management than the existing levees, setback levees that provide an equivalent level of flood risk management as the existing levees, and setback levees that provide a lower level of flood risk management compared to the existing levees. Setback levees that provide equivalent levels of flood risk management to the existing levees are the minimum cost effective structure necessary to realize ecosystem restoration outputs at the site.

3. **Provide public review.**
   The proposed project has been coordinated with the public, government agencies, and interested stakeholders. The Draft FR/EIS was released in October 2014 and a public meeting was held in November 2014. Numerous comments were received on the Draft FR/EIS, which have been included and responded to in this Final FR/EIS (Appendix H).

4. **Identify the impacts of the proposed action and any expected losses of natural and beneficial floodplain values.**
   Chapter 4 of this document presents an analysis of alternatives. Practicable measures and alternatives were formulated and potential impacts and benefits were evaluated. The anticipated impacts associated with the recommended plan are summarized in Chapters 4, 5, and 6 of this report. While construction of project features would result in mostly minor and temporary adverse impacts to the natural environment, the proposed restoration would result in a substantial and long-term increase in habitat values including an increase in the quantity and quality of riparian and aquatic habitat. For each resource analyzed in Chapter 5, wherever there is a potential for adverse impacts, appropriate best management practices or other environmental considerations were identified. As there is a net benefit to biological resources, no biological mitigation is required for the recommended plan.

5. **Minimize threats to life and property and to natural and beneficial floodplain values. Restore and preserve natural and beneficial floodplain values.**
   Implementing the recommended plan would have no significant flooding impacts on human health, safety, and welfare.

6. **Reevaluate alternatives.**
   Chapter 4 of this document presents an analysis of alternatives. There are no practicable alternatives completely outside of the base floodplain for the three sites that would achieve study objectives.

7. **Issue findings and a public explanation.**
   The public will be advised that no practicable alternative to locating the proposed action in the floodplain exists, as indicated in Item 3 above.

8. **Implement the action.**
   The proposed project does not contribute to increased development in the floodplain and does not increase flood risk, but rather it restores “natural and beneficial values.” The recommended plan is consistent with the requirements of this Executive Order.

7.19 EXECUTIVE ORDER 11990 PROTECTION OF WETLANDS

Executive Order 11990 entitled Protection of Wetlands, dated May 24, 1977, requires Federal agencies to avoid adversely affecting wetlands wherever possible, to minimize wetlands destruction and to preserve the values of wetlands, and to prescribe procedures to implement the policies and procedures of this Executive Order. One of the primary goals of this project is to restore wetlands along the Puget Sound shoreline that have been lost due to dikes, fill, and armoring. The proposed actions would be largely beneficial to wetlands. The exception is potential change to freshwater wetlands that have established due to interrupted tidal flow. Once stressors such as dikes and berms are removed, salt water will inundate these freshwater wetlands and they would slowly transition to emergent brackish marsh. This transition would likely cause a functional increase in habitat and water quality. Any action potentially causing a conversion of wetland type will be evaluated by the Corps and coordinated with WDOE.

7.20 EXECUTIVE ORDER 13045 PROTECTION OF CHILDREN FROM ENVIRONMENTAL HEALTH RISKS AND SAFETY RISKS

Executive Order 13045, requires each Federal agency to "identify and assess environmental risks and safety risks [that] may disproportionately affect children" and ensure that its "policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks." The Corps has analyzed the project footprint and surrounding area for the project's potential to cause health and safety risks to children. The project sites where construction activity will occur are more than one mile away from any schools, parks, libraries, and grocery stores. Infants and children are not expected to be exposed to any health or safety risks because of these actions; therefore, this project has no environmental or safety risks that may disproportionately affect children. The plan is in compliance.

8 PUBLIC INVOLVEMENT & PEER REVIEW

Stakeholder involvement and agency coordination have been vital components of the Nearshore Study since its start in 2001. The relationships among the Study team and the many member organizations are an important facet of a collaborative planning approach to stakeholder involvement. Stakeholders are integral in helping provide input for defining restoration opportunities, objectives, and constraints, and for developing restoration strategies, which ultimately support development of the range of alternatives to be analyzed for feasibility and environmental compliance. Federal and state agencies have also participated in the NEPA process, including a process to integrate State Environmental Policy Act (SEPA) requirements with the NEPA process. In accordance with Engineering Circular 1105-2-409 (Planning in a Collaborative Environment; USACE 2005), representatives of Federal and state agencies have been invited to be members of the Project Delivery Team and the other Nearshore Study teams.

8.1 PROJECT DELIVERY TEAM

The Project Delivery Team (PDT) is a multi-disciplinary, multi-agency team responsible for the successful development and execution of all aspects of the study. The PDT comprises six standing teams, with agency, non-governmental organization and other representatives serving on the Executive Committee (EC), Steering Committee (StC), Project Management Team (PMT), Nearshore Science Team (NST), Implementation Team (IT), and Stakeholder Involvement Team (SIT). The PDT facilitates the interagency collaboration and coordination necessary for study execution and successful delivery of a quality product. In addition to formal review requirements prescribed in Corps policy, NEPA-required coordination with Federal and State agencies and tribes is facilitated through the PDT. The PDT can expand and contract as necessary to include all necessary expertise, ad hoc teams, and work groups for study execution.

8.1.1 Executive Committee

The role of the Executive Committee is to oversee implementation of the project; to receive progress reports from the Steering Committee; and to serve as an advocate for the Nearshore Study in international, Federal, State, tribal, and local government forums. The Executive Committee provides broad policy oversight and interagency/governmental coordination at executive levels of leadership.

8.1.2 Steering Committee

The role of the Steering Committee is to guide implementation of the project management plan, to develop any proposed changes to the project management plan, to advise and recommend actions to the project managers related to the implementation of the project management plan, to maintain a set of policies and procedures, and to report to the Executive Committee. The Steering Committee works to provide operational support and guidance to the PMT in completing the Nearshore Study, as well as insuring effective integration of products and results into activities outside of the Nearshore Study.

8.1.3 Nearshore Science Team

The NST is an interdisciplinary team comprised of senior scientists representing various fields. The NST works to ensure that the Nearshore Study is informed by best available science. They have also helped ensure that peer-review is effectively implemented for rigorous evaluation of study technical products and the program's use of internally and externally developed scientific information.

8.1.4 Implementation Team

The role of the Implementation Team (IT) is to develop an approach to the identification, evaluation, and assessment of potential restoration and protection projects and actions, and to identify opportunities at specific geographic locations to apply and test Nearshore Study products, guidance, and principles. The IT works to transfer scientific and technical products to the implementation of the Nearshore Study, including selection and evaluation of potential sites, and to restoration and protection work external to the Nearshore Study.

8.1.5 Project Management Team

The Project Management Team (PMT) comprises leads from the Implementation Team, Nearshore Science Team, and the Federal and local project managers. This group works to ensure coordination of activities across the program and make collective decisions on allocation of program resources toward critical path tasks.

8.1.6 Stakeholder Involvement Team

The role of the Stakeholder Involvement Team is to implement the Stakeholder Involvement Plan, which has four objectives: 1) fostering broad program understanding and support, 2) developing and reviewing restoration and protection goals and objectives, 3) involving stakeholders in the NEPA process, and 4) developing and advancing a Puget Sound Nearshore Study project site list.

8.2 AGENCY COORDINATION

Preparation of this report was coordinated with appropriate congressional, Federal, State, and local interests as well as environmental groups and other interested parties. Since the original cost-sharing agreement was signed in September 2001, many Federal, local, and State agencies, as well as non-governmental organizations beyond the Corps and WDFW have joined the Nearshore Study team as shown in section 8.1. Their participation has broadened the base of Federal and local support, and expanded the technical and financial resources being applied to the general investigation and the broader activities of the Nearshore Study.

8.2.1 Federal Cooperating Agencies

The Council for Environmental Quality regulations for implementing NEPA encourage agencies to formally agree to "cooperating agency" status, thus ensuring their expertise will be applied when formulating feasible alternative plans. While many Federal agencies have extensively participated in early Nearshore Study activities, there is no formal cooperating agency for this study. The EPA declined to be a cooperating agency upon formal invitation from the Corps.

8.2.2 Tribal Coordination

The Corps has engaged in formal and informal coordination with the federally recognized tribes of the Puget Sound throughout the feasibility phase. Coordination with tribes is ongoing and the Corps will continue to offer opportunities to meet informally or through government-to-government meetings. Appendix J shows which tribes and what dates the Corps met with and copies of letters that the Corps sent and received from the tribes. Tribal coordination will continue throughout the feasibility phase, PED, and construction in accordance with Executive Order 13175 Consultation and Coordination with Indian Tribal Governments.

8.2.3 Agency Views

Many Nearshore Study partners, the Washington State Governor, and five Congress members have provided letters that express their perspectives on the study, including the following in order of receipt:

- U.S. Environmental Protection Agency (EPA)
- Washington State Department of Ecology (WDOE)
- Skagit County (Skagit)
- U.S. Fish and Wildlife Service (USFWS)
- Washington Department of Fish and Wildlife (WDFW)
- People For Puget Sound (PFPS)
- Northwest Straits Commission (NWSC)
- The Nature Conservancy (TNC)
- Washington State Department of Natural Resources (DNR)
- University of Washington (UW)
- King County (King)
- Puget Sound Salmon Recovery Lead Entities (LE)
- U.S. Geological Survey (USGS)
- Puget Sound Partnership (PSP)
- Washington State Recreation and Conservation Office (RCO)
- Governor Christine Gregoire, State of Washington
- Representatives Inslee, Dicks, Reichert, McDermott, and Smith

8.3 PUBLIC INVOLVEMENT ACTIVITIES

8.3.1 Study Website

The Nearshore Study maintains a website (*www.pugetsoundnearshore.org*), which serves as the primary resource for information including study background, events, technical reports, program documents, and progress of the study. The site is updated as new products and reports are released. The site underwent a major update in June 2012 to make it more interesting and more usable by the public. The Nearshore Data Site (*www.psnerp.ekosystem.us/*) is a complementary website that includes a geospatial mapping feature to view proposed activities and relevant data layers derived from Nearshore Study technical products.

8.3.2 Stakeholder Involvement and Site Visits

The success of Corps planning efforts depends to a great extent on establishing partnerships with project proponents and other key stakeholders. Since the inception of the Nearshore Study, team members have met and developed relationships with public officials, congressional members and staff, members of non-governmental organizations, Federal partners, tribal government representatives, and local and State agencies. During the site selection process, the Nearshore Study team conducted site conversations with proponent(s) to ground-truth and fact-check project details. Prior to development of the conceptual designs for 36 sites, Nearshore Study team members as well as design consultants and project proponents met onsite to view and tour accessible lands to gain an understanding of on-the-ground conditions and constraints.

Project proponents were included in review of the draft conceptual design reports and their comments were incorporated into the final product. In early June 2012, project proponents and associated salmon recovery lead entity coordinators were notified via U.S. mail of their project's status with regard to the TSP for the Draft FR/EIS. Project proponents were offered an opportunity to meet with Nearshore Study team to better understand what it means for their project site to be part of the TSP. Next steps include a more comprehensive landowner and public outreach plan tailored to each of the TSP sites. This outreach work will use input from each project proponent and advocates and will follow the Nearshore Study's Stakeholder Outreach and Involvement Plan for Potential Restoration Projects (ESA 2011a).

8.3.3 Media Coverage

The Nearshore Study and its partner agencies have received positive media coverage since project inception. Coverage includes feature articles from the *Associated Press, Seattle Times, Seattle PI, Daily Olympian,* and *Daily Journal of Commerce*. In 2003, the Study team organized a project-specific media event, which highlighted new technology being used to obtain bathymetric data to improve nearshore zone mapping in Puget Sound. Since the establishment of the Puget Sound Partnership (PSP) in 2007, the Study team has coordinated media contact and other broad stakeholder engagement with PSP staff to ensure consistency of messaging, aligning the concerted work to support broader Puget Sound recovery actions.

8.3.4 Conferences/Workshops

Nearshore Study team members and associates have represented the Nearshore Study at numerous national and local conferences, ensuring that the Nearshore Study remains relevant and current in ecosystem-based restoration. This participation has brought positive recognition for the science-base and technical rigor of the Nearshore Study. Conference participation includes the Restore America's Estuaries Conference, the Salish Sea Ecosystem Conference (formerly the Puget Sound - Georgia Basin Conference), the International Conference on Ecology and Transportation, the Corps' and TNC's National Partnership Conference, the National Conference for Ecosystem Restoration, Coastal Habitats in Puget Sound (U.S. Geological Survey sponsored workshops), Salmon Recovery Conference (WA Recreation and Conservation Office sponsored), and the Coastal Zone Conference. Additionally, Nearshore Study team members have given informational presentations to the Mason County Shoreline Technical Advisory Group and the Pacific Coast Joint Venture Steering Committee.

8.3.5 Nearshore Study Sponsored Workshops

The Nearshore Study has held several meetings and workshops, including a Science Symposium, three Strategic Science Peer Review Panels, Valued Ecosystem Component Workshops, Shoreline Armoring Work Group, Navigating the Nearshore Workshop, Problems and Opportunities, Existing and Future Conditions Workshop, Informational Day for Restoration Practitioners, Evaluation and Screening Criteria Workshop, and a Restoration Strategies and Alternative Development Workshop. These workshops are typically organized as "all-hands" events, providing an opportunity for integrating the diverse perspectives and expertise represented by the membership of the Steering Committee, Nearshore Science Team, and Implementation Team. Many workshops have included participation from outside these Nearshore Study teams, helping to broaden the input that has informed the Nearshore Study.

The Nearshore Study team held workshops throughout the Puget Sound in September 2009 that were attended by city and county planning staff, tribal government representatives, non-profit staff, and some consultants. The purposes of these workshops were to: 1) engage the Puget Sound restoration community; 2) provide an overview of the Nearshore Study and its approach to delivering nearshore zone analyses and strategies; and, 3) share the results of the Nearshore Study's Change Analysis, which are useful to a broader audience beyond the Nearshore Study.

8.3.6 NEPA Scoping *

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

Scoping is a critical component of the overall public involvement program to solicit input from affected Federal, State, and local agencies; tribes; and interested stakeholders. The NEPA scoping process is designed to provide an early and open means of determining the scope of issues (problems, needs, and opportunities) to be identified and addressed in the environmental impact statement (EIS). The Nearshore Study NEPA/SEPA scoping process was conducted jointly with the WDFW.

An initial scoping meeting was held in October 2001 after completion of the Reconnaissance Phase. However, the NEPA/SEPA scoping process formally commenced on October 26, 2009. A Notice of Intent was published in the Federal Register on October 2, 2009 (Vol. 74, No. 190). The public comment period ran from October 26 to December 10, 2009. The Corps and WDFW held four public meetings in strategic locations around Puget Sound, and placed public notices in prominent sections of 14 major newspapers. The notice was emailed to a broad range of stakeholder groups and posted on the Nearshore Study and Puget Sound Partnership websites. The public scoping meetings were held in the evening to minimize conflicts with standard work schedules. An open house preceded the formal presentation where eight displays and a handout were available, followed by a question and answer period that was recorded and transcribed. The dates and locations of the public scoping meetings were as follows:

- Oct. 26, 2009: Des Moines, Highline Community College (14 people)
- Oct. 28, 2009: Port Townsend, Fort Worden State Park (7 people)
- Nov. 3, 2009: Lacey, Lacey Community Center (15 people)
- Nov. 10, 2009: Mount Vernon, Skagit Station (24 people)

During the comment period, 35 comments were received, of which one was in a letter, nine in comment cards submitted during the scoping meetings, and 25 articulated during the scoping meetings. Comments were evaluated for recurring themes, which were identified as key issues to address in the EIS. The 12 identified themes are listed in Table 8-1.

Following publication of the Notice of Intent, the Corps received a scoping letter from the EPA on December 10, 2009, pursuant to EPA's responsibilities under NEPA and Section 309 of the Clean Air Act. This letter states that Puget Sound recovery is a priority for EPA and that the agency fully supports this effort. The major points in EPA's support letter recommended that the Nearshore Study team do the following: use Valued Ecosystem Components to identify objectives, optimize benefits at multiple scales while developing priorities, consider climate change in project planning, and benefit from lessons learned from other regional coastal restoration initiatives. As identified throughout this document and other supporting documents completed for the Nearshore Study, each of these recommendations has been implemented.

Table 8-1. Summary of Type of Scoping Comments Received

Theme	Number of Comments
General project questions	20
Shoreline management	5
Floodplain development	1
Harvesting energy	1
Water quality	1
Removal of armoring	1
Participation in prioritization of restoration actions	1
Impacts of railroads on nearshore habitats	1
Projects should increase jobs	1
Funding for projects with multiple purposes	1
Global warming should be considered	1
Sustainability of beaches where sediment is brought in	1

8.3.7 Draft EIS Public Comment Period*

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

The public comment period, during which any person or organization may comment on the Draft FR/EIS, is mandated by state and Federal laws. For the Nearshore study, the Draft FR/EIS public comment period formally ran for 90 days beginning in October 2014 and ending in January 2015. The Study team hosted one public hearing in November 2014. In addition to accepting comments during the public hearings, comments were accepted via mail, fax, and email. The Corps recorded and considered all comments received during the comment period. The complete list of comments regarding the Draft FR/EIS and the Corps' responses appears as Appendix H of this Final FR/EIS.

The Corps sent notices of availability to a long list of interested stakeholders, local entities, and all Native American Tribes within the study area with the location of electronic and hard copies. The following is a list of agencies that directly received either an electronic or a hard copy of the Draft FR/EIS for review (other entities received electronic or paper notice of availability):

- Bureau of Indian Affairs
- Environmental Protection Agency
- National Marine Fisheries Service
- National Oceanic and Atmospheric Administration – Restoration Center
- National Park Service
- Natural Resource Conservation Service
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- U.S. Navy Region Northwest
- Puget Sound Partnership
- Washington Department of Archaeology & Historic Preservation
- Washington Department of Ecology
- Washington Department of Fish & Wildlife
- Washington Department of Natural Resources
- Washington State Department of Transportation

- Washington State Recreation and Conservation Office
- Northwest Indian Fisheries Commission
- The Nature Conservancy
- The Northwest Straits Commission
- Skagit County
- City of Everett
- Port of Edmonds
- Port of Everett
- Orca Straits District – Aquatic Region
- Skagit River System Cooperative
- Orcas Island Library District
- Whatcom County Library
- Skagit County Library
- Sno-Isle Libraries
- King County Library

8.3.8 Environmental Protection Agency Review*

*These headings and all sub-sections therein are required by the National Environmental Policy Act.

The EPA reviewed the Draft FR/EIS in accordance with the EPA's responsibilities under NEPA and Section 309 of the Clean Air Act. Section 309 specifically directs the EPA to review and comment in writing on the environmental impacts associated with all major Federal actions. Review of the Draft FR/EIS considers the expected environmental impacts of the proposed action and the adequacy of the EIS in meeting the procedural and public disclosure requirements of NEPA. The EPA recognizes Puget Sound as an estuary of national significance and has approved the Puget Sound Partnership’s Action Agenda as the Comprehensive Conservation and Management Plan of the Puget Sound National Estuary Program.

The EPA states that the Draft FR/EIS responded to their scoping comments and addressed each recommendation. The EPA made further recommendations for the Final FR/EIS and the Corps incorporated much of this into the Final FR/EIS as described in Table 8-2. Full text of the EPA’s review letter to the Corps appears in Appendix J, Environmental Compliance.

Table 8-2. The EPA's recommendations for the Final FR/EIS and the Corps' responses on how the information was incorporated.

EPA recommendation	Corps response
Include additional information relating project benefits to ecological outcomes for identified VECs and how benefits may influence trends	The Corps added statements regarding the significance of the resources, including VECs, that would benefit and more detail on how the proposed action would benefit specific fish and wildlife. Data on trends of most of the VECs are still under development and unavailable before finalization of this report.
Optimize benefits at multiple scales and aim for geographic representation of the entire study area, primarily by selecting the alternative that has a greater number of restoration sites with a broader geographic spread and wider range of types of benefits	While the Recommended Plan has fewer sites proposed for construction under this authorization, the Corps and the non-Federal sponsor formulated a comprehensive strategy for restoration at all 36 sites that were under initial consideration at the outset of the conceptual level design phase. These would be constructed under existing authorities or receive further study before authorization and implementation.

Report on lessons learned from other coastal restoration projects, both local and nationwide	One of the technical documents prepared during the Nearshore Study was specifically for the purpose of learning from other large-scale ecosystem restoration projects, titled *Application of the "Best Available Science" in Ecosystem Restoration Project Efforts in the USA* (Van Cleve et al. 2004). While the Corps continues to refer to this document for guidance, the information is not explicitly reiterated in this report, but is available at *www.pugetsoundnearshore.org*. The Corps will seek updated information on lessons learned during the next design phase.
Discuss how climate resiliency factored into the formulation of the final array of alternatives	Climate resiliency of sites was not necessarily a strong criteria for formulation of the final array of alternatives; however, risk of reduction in restoration benefits at each site was analyzed prior to final site selection. Additionally, site features are designed according to the Corps' sea level change analysis as described in section 3.6.5.

8.4 PEER REVIEW

From early in this general investigation, the Puget Sound Nearshore Study team built a rigorous peer review process into all elements – study planning, technical reports, and report development – and plans to continue these practices as an integral component of the plan's implementation. Peer review was designed to meet all pertinent Corps policies (e.g. Engineering Circulars (EC) including EC 1165-2-214). In 2007, the "Peer Review Plan for Feasibility Study of Puget Sound Marine Nearshore Habitat Restoration, WA" (Peer Review Plan; USACE 2007) was developed by the Nearshore Study's Nearshore Science Team and approved by the Corps Ecosystem Restoration Planning Center of Expertise (ECO-PCX). This plan requires external review of the project's technical reports, as well as more comprehensive strategic science and programmatic peer review that includes external review of the sufficiency of science used in the Nearshore Study and the application of science by an independent Strategic Science Peer Review Panel (SSPRP; refer to section 8.4.3).

8.4.1 Corps Review Policy

EC 1165-2-214 identifies specific procedures that must be followed to ensure the quality and credibility of Corps decision documents (USACE 2012). The Nearshore Study has adhered to this guidance and completed multiple rounds of District Quality Control (DQC) and Agency Technical Review (ATR) on feasibility phase deliverables. The Draft FR/EIS went through DQC, ATR, and Independent External Peer Review (IEPR). The DQC, ATR, and IEPR review reports will be submitted to Corps headquarters with the Final FR/EIS.

In accordance with guidelines set by the Corps for planning and ecosystem output models (e.g., ER 1165-2-501 [USACE 1999c] and EC 1105-2-412 [USACE 2011b]), Seattle District has received approval for one-time use of a planning model. The Puget Sound Nearshore Ecosystem Output Model is a regional model developed by members of the Nearshore PDT and the NST.

The model was used to generate net benefit scores for the array of actions under consideration. A documentation report (Appendix G) that explains the model has undergone peer review by the SSPRP. The model review plan was submitted to the ECO-PCX in June 2012 and received one-time use approval in November 2012.

8.4.2 Technical Report Peer Review

Consistent with the Peer Review Plan, primary program documents developed during the Nearshore Study have undergone peer review. Typically for draft technical reports, two to four subject matter experts outside of the project are engaged as anonymous reviewers by a member of the PDT, who provides the reviewers' comments to the report's primary author. Following revisions to address comments, the technical report is assigned a document number and published on the Nearshore Study's website. On the website, supporting documents used to inform the Nearshore Study, but did not receive those peer review procedures, are clearly distinguished from peer-reviewed technical reports.

8.4.3 Strategic Science Peer Review Panel

Integral to the Nearshore Study, a continuous peer-review process provides guidance to ensure that the Nearshore Study is following the best available science. To provide a broad overview of application of scientific principles and information in completing the Nearshore Study, the NST recommended that potential panel members have experience in large-scale coastal restoration actions and the following disciplines be explicitly represented in external review:

- coastal geomorphology
- estuarine/coastal ecology
- restoration planning, monitoring, and assessment
- landscape ecology
- coastal/estuarine oceanography/sediment transport
- social science

The SSPRP convened in the summer of 2008 to provide independent review and input to the Nearshore Study. In convening the SSPRP, the NST and PMT identified potential panel chairpersons. The SSPRP Chair was selected based on international recognition for scientific excellence and extensive experience in other national ecosystem restoration programs. SSPRP members were selected based on each person's identified area of expertise, in consultation with the SSPRP Chair. The role of the SSPRP is based on the Nearshore Study's Peer Review Plan with modifications based on recommendations from the SSPRP and experience from other large-scale restoration programs.

Procedures and schedules for the SSPRP review are coordinated through the Chair. The SSPRP Chair communicates annually with the rest of the Panel to determine which Nearshore Study documents were due for review and who among the Panel members would take the lead for each, based on their expertise. In addition to review of the program's application of science, the SSPRP reviewed complex program documents, including the Ecosystem Output Model and the Feasibility Scoping Meeting submittal package. Drafts were distributed to the Panel members with at least two months allowed for review; the Chair coordinated the review summary in all cases, usually with a conference call among the SSPRP members. Additional full-group reviews were provided during periodic on-site, multi-day SSPRP programmatic workshops with the Nearshore Science Team and Project Management Team, which included attendance by other members of the Nearshore Study team, such as the Steering Committee. These comprehensive SSPRP workshops were convened in June 2008, May 2009, and November 2011.

9 RECOMMENDATIONS

The following language outlines the Corps' recommendations for project approval and authorization for implementation.

I recommend that the recommended plan for ecosystem restoration for the Puget Sound Nearshore project area as generally described in this report be authorized for implementation as a Federal project, with such modifications thereof as in the discretion of the Commander, USACE may be advisable. The estimated project first cost of the recommended plan is $451,627,000 (March 2016 price level), which includes monitoring costs of $1,090,000 and adaptive management costs of $5,307,000. Operations, maintenance, repair, rehabilitation, and replacement (OMRR&R) expenses are estimated at $863,000 per year. The Federal portion of the estimated first cost is $293,558,000. The non-Federal sponsors' portion of the required 35% cost share of total project first costs is $158,069,000. The LERRD estimate exceeds the 35% non-Federal cost share for restoration features by $3,420,000 and the value of these excess LERRD may be reimbursed to the non-Federal sponsor subject to the availability of funds. However, this situation is unlikely to be realized because the escalated, fully-funded cost estimate does not reflect a LERRD value that exceeds the 35% non-Federal cost share. The non-Federal partners shall agree, prior to implementation, to perform the following items of local cooperation:

a. Provide 35 percent of total ecosystem restoration costs as further specified below:

    1. Provide the required non-federal share of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

    2. Provide, during the first year of construction, any additional funds necessary to pay the full non-federal share of design costs;

    3. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the government to be required or to be necessary for the construction, operation, and maintenance of the project;

    4. Provide, during construction, any funds necessary to make its total contributions equal to 35 percent of total project costs.

b. Provide work-in-kind during final design and construction as well as providing the post-construction monitoring. The value of LERRDs needed for the project are credited against the non-federal sponsors' cost-sharing requirement;

c. Shall not use funds from other federal programs, including any non-federal contribution required as a matching share therefore, to meet any of the non-federal obligations for the project unless the federal agency providing the federal funds verifies in writing that such funds are authorized to be used to carry out the project;

d. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities that might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;

e. Shall not use the project or lands, easements, and rights-of-way required for the project as a wetlands bank or mitigation credit for any other project;

f. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

g. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable federal and state laws and regulations and any specific directions prescribed by the federal government;

h. Give the federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-federal sponsors own or control for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

i. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

j. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

k. Comply with all applicable federal and state laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c et seq.);

l. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the federal government determines to be required for construction, operation, and maintenance of the project. However, for lands that the federal government determines to be subject to the navigation servitude, only the federal government shall perform such investigations unless the federal government provides the non-federal sponsors with prior specific written direction, in which case the non-federal sponsors shall perform such investigations in accordance with such written direction;

m. Assume, as between the federal government and the non-federal sponsors, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the federal government determines to be required for construction, operation, and maintenance of the project;

n. Agree, as between the federal government and the non-federal sponsors, that the non-federal sponsors shall be considered the operators of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

o. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

The recommendations contained herein reflect a proposal for construction authorization at three sites across Puget Sound (Duckabush River Estuary, Nooksack River Delta, and North Fork

Skagit River Delta). While the recommended plan includes restoration at these three sites, the National Ecosystem Restoration (NER) Plan is a 36-site master plan intended to restore a more diversified scope or projects to be implemented under various restoration authorities and partners. This 36-site plan reasonably maximizes ecosystem restoration benefits and restores over 8,000 acres across all seven Puget Sound sub-basins. The NER Plan includes 16 river delta sites, 10 coastal inlet sites, 6 barrier embayment sites, and 4 beach sites. Of the 36 sites included in the NER Plan, there are nine projects recommended for additional study. These sites and their estimated costs including $3,000,000 for feasibility plus conceptual construction cost estimated at the March 2016 price level are as follows: Dugualla Bay at $88,355,000, Everett Marshland at $296,605,000, Telegraph Slough at $256,124,000, Chambers Bay at $298,002,000, Big Beef Creek Estuary at $37,376,000, Tahuya River Estuary at $30,305,000, Lilliwaup River Estuary at $36,994,000, Big Quilcene River at $37,600,000, and Snohomish River Estuary at $126,593,000. Every effort should be made to pursue authorization at these additional sites.

The recommendations contained herein reflect the information available at this time and current departmental policies governing the formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of the national civil works construction program or the perspective of higher levels within the executive branch. Consequently, the recommendations may be modified before they are transmitted to Congress for authorization and/or implementation funding. However, prior to transmittal to Congress, the State of Washington, interested Federal agencies, and other parties will be advised of any significant modifications in the recommendations and will be afforded an opportunity to comment further.

JOHN G. BUCK
COL, EN
Commanding

10 LIST OF PREPARERS *

The following individuals participated in the preparation of this integrated FR/EIS:

Name	Education/Experience	Responsibility
U.S. Army Corps of Engineers		
Valerie Ringold	B.S. Fisheries & Wildlife Biology, M.S Management, 26 years exp.	Chief of Planning Branch
Jessie Winkler	B.A. Biology, M.M.A. (Marine Affairs); 14 years exp.	Chief of Civil Projects (Project Manager 2011-2013)
Lynn Wetzler	M.P.A.; 7 years exp.	Project Manager 2013-present
Rachel Mesko	B.A. Economics; 6 years exp.	Plan Formulation
Nancy Gleason	B.A. Environmental Studies, M.E.S. Salmonid Ecology; 16 years exp.	Environmental Coordinator
Chemine Jackels	B.S. Biological Sciences, M.S. Biological Science; 13 years exp.	Aquatic Ecology; Cumulative Effects
Fred Goetz	B.S. Environmental Studies/Geography, M.S. Fisheries Science, PhD Fisheries Science; 25 years exp.	Climate Change
Charyl Barrow	B.S. Applied Economics; 8 years exp.	Economics
David Clark	B.A. Political Science, M.M.A (Marine Affairs); 4 years exp.	Hazardous Waste/Contaminated Sites
Maleena Lemiere	B.S. Civil Engineering, M.S. Civil Engineering; 7 years exp.	Greenhouse Gases/Air Quality
Kara Kanaby	M.A. Anthropology/Archaeology; 10 years exp.	Cultural Resources
Zachary Wilson	B.S. Ecology; 4 years exp.	Cumulative Effects
Glenn Kato	B.S. Civil Engineering; 30 years exp.	Civil Design
Scott Brown	B.S. & M.S. Ocean Engineering; 7 years exp.	Hydrology & Hydraulics
Catherine Petroff	PhD. Civil Engineering; 31 years exp.	Hydrology & Hydraulics; Climate Change
Seth Klein	B.S. Civil Engineering; 6 years exp.	Geotechnical Engineering
Diane Hintz	B.S. Industrial Engineering; 22 years exp.	Real Estate
Scott Campbell	M.S. Geographic Information Systems; 12 years exp.	GIS Development
WDFW		
Theresa Mitchell	B.A. Marine Biology, M.M.A. (Marine Affairs); 10 years exp.	Project Manager (2014-present) Assistant Project Manager (2011-2014)
Other Contributors		
Curtis Tanner, USFWS	B.S. Aquatic Science/Environmental Studies, M.M.A. (Marine Affairs); 25 years exp.	Project Manager for WDFW, 2005-2013
Anchor QEA	Varies	Existing Conditions
Environmental Science Associates (ESA)	Varies	Conceptual Design Reports

11 REFERENCES

Angell, T., and K.C. Balcomb, III. 1982. Marine Birds and Mammals of Puget Sound. University of Washington Press. Seattle.

Babcock, R., and J. Keesing. 1999. Fertilization biology of the abalone *Haliotis laevigata*: laboratory and field studies. Canadian Journal of Fisheries and Aquatic Sciences, 56(9):1668-1678.

Bailey, H., B. Senior, D. Simmons, J. Rusin, G. Picken, and P.M. Thompson. 2010. Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Marine Pollution Bulletin 60(6):888-897

Bain, D.E., B. Kriete and M. Dahlheim. 1993. Hearing abilities of killer whales (*Orcinus orca*). The Journal of the Acoustical Society of America 94(3):1829

Bassett, C. 2010. Underwater Ambient Noise at a Proposed Tidal Energy Site in Puget Sound. Master's Thesis. University of Washington, Seattle.

Beamer, E. and R.A. Henderson. 1998. Juvenile Salmonid Use of Natural and Hydromodified Stream Bank Habitat in the Mainstem Skagit River, Northwest Washington. Prepared for the U.S. Army Corps of Engineers, Seattle, Washington

Beamer, E., and K. Larsen. 2004. The Importance of Skagit delta habitat on the growth of wild ocean-type Chinook in the Skagit Bay: Implications for delta restoration. 6p. Available: *www.skagitcoop.org/index.php/documents*

Beamer, E., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larsen, C. Rice, and K.L. Fresh. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: Linking estuary restoration to wild Chinook salmon populations. 94p. Appendix D of Skagit River System Cooperative and Washington Department of Fish and Wildlife. 2005. Skagit Chinook Recovery Plan. Available: *www.skagitcoop.org/index.php/documents*

Beamer, E.M., A. McBride, R. Henderson, J. Griffith, K. Fresh, T. Zackey, R. Barsh, T. Wyllie-Echeverria, and K. Wolf. 2006. Habitat and fish use of pocket estuaries in the Whidbey Basin and north Skagit County Bays, 2004 and 2005. 76p. Available: *www.skagitcoop.org/index.php/documents*

Beaudreau, A.H. 2009. The Predatory Role of Lingcod (*Ophiodon elongates*) in the San Juan Archipelago, Washington. Partial Doctoral Dissertation. University of Washington

Beissinger, S.R., and N. Nur. 1997. Population trends of the marbled murrelet projected from demographic analysis. Appendix B *in* U.S. Fish and Wildlife Service. Recovery plan for the marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon and California. Portland, Oregon. 203p.

Bell, S. S., M. S. Fonseca, and L. B. Motten. 1997. Linking restoration and landscape ecology. Restoration Ecology 5:318-323.

Berry, H.D., T.F. Mumford Jr., and P. Dowty. 2005. "Using historical data to estimate changes in floating kelp (*Nereocystis luetkeana* and *Macrocystis integrifolia*) in Puget Sound, Washington." Proceedings of the 2005 Puget Sound Georgia Basin Research Conference. Available: *depts.washington.edu/uwconf/2005psgb/2005proceedings/papers/F7_BERRY.pdf*

Betke, K., M. Schultz-von Glahn, and R. Matuschek. 2004. Underwater noise emissions from offshore wind turbines. *In:* Proceedings of the joint congress CFA/DAGA'04, 591-592, Strasbourg 2004. Available: *www.itap.de/daga04owea.pdf.* (Accessed 15 May 2012).

Bilkovic, D.M., and M.M. Roggero. 2008. Effects of coastal development on nearshore estuarine nekton communities. Marine Ecology Progress Series 358:27-39.

Bird, E. 2000. Coastal Geomorphology: An Introduction. John Wiley & Sons. New York, New York. 322 p.

Blaxter, J.H.S. and D.E. Hoss. 1981. Startle response in herring Clupea harengus: The effect of sound stimulus. Journal of the Marine Biological Association of the United Kingdom. 61:871-880

Bledsoe, L.J., D.A. Somerton, and C.M. Lynde. 1989. The Puget Sound runs of salmon: An examination of the changes in run size since 1896. In: C.D. Levings, L.B. Holtby, and M.A. Henderson (eds.), Proceedings of the National Workshop on Effects of Habitat alteration on Salmonid Stocks, May 6-8, 1987, Nanaimo, B.C. p. 50-61. Canadian Special Publication of Fisheries and Aquatic Sciences 105.

Boesch, D.F., and R.E. Turner. 1984. Dependence of fishery species on salt marshes. Estuaries 7:460-468.

Bolte, J., and K. Vache. 2010. Envisioning Puget Sound Alternative Futures: PSNERP Final Report. Produced for the Puget Sound Nearshore Ecosystem Restoration Project. 50p. Available:
www.pugetsoundnearshore.org/supporting_documents/FRAP%20final%20report.pdf

Bottom, D.L., K.K. Jones, T.J. Cornwell, A. Gray, and C.A. Simenstad. 2005a. Patterns of Chinook salmon migration and residency in the Salmon River estuary (Oregon). Estuarine, Coastal, and Shelf Science 64:79-93.

Bottom, D.L., C.A. Simenstad, J. Burke, A.M. Baptista, D.A. Jay, K.K. Jones, E. Casillas, and M.H. Schiewe. 2005b. Salmon at river's end: the role of the estuary in the decline and recovery of Columbia River salmon. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-68, 246 p.

Bower, J.L. 2009. Changes in Marine Bird Abundance in the Salish Sea: 1975 to 2007. Marine Ornithology 37:9-17.

Brannon, E., and A. Setter. 1989. Marine distribution of a hatchery fall Chinook salmon population. Pages 63-69 *in* E. Brannon and B. Jonsson (eds). Proceedings of the Salmonid Migration and Distribution Symposium, School of Fisheries, University of Washington, Seattle.

Brennan, J.S. 2007. Marine Riparian Vegetation Communities of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-02. Published by Seattle District, U.S. Army Corps of Engineers. Seattle, Washington.
Available: *www.pugetsoundnearshore.org/technical_papers/riparian.pdf*

Buchanan, J.B. 2006. Nearshore Birds in Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-05. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.
Available: *www.pugetsoundnearshore.org/technical_papers/shorebirds.pdf*

BEA (Bureau of Economic Analysis). 2010. Regional Economic Information System, Table SA04. Available: *www.bea.gov/regional*

Busby, P.J., T.C. Wainwright, B.J. Bryant, L.J. Lierheimer, R.S. Waples, and I.V. Lagomarsino. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum. NMFS-NWFSC-27. P1-255

Calambokidis, J. and G.H. Steiger. 1990. Sightings and movements of humpback whales in Puget Sound, Washington. Northwestern Naturalist 71:45-49

Canning, D.J., and M. Stevens. 1989. Wetlands of Washington: a resource characterization. Washington Department of Ecology, Olympia, Washington. 45pp.

Carlton, J.T. and J. Hodder. 2003. Maritime mammals: terrestrial mammals as consumers in marine intertidal communities. Marine Ecology Progress Series 256:271-286

Cereghino, P., J. Toft, C. Simenstad, E. Iverson, S. Campbell, C. Behrens, and J. Burke. 2012. Strategies for nearshore protection and restoration in Puget Sound. Puget Sound Nearshore Report No. 2012-01. Published by Washington Department of Fish and Wildlife, Olympia, Washington, and the U.S. Army Corps of Engineers, Seattle, Washington. Available: *www.pugetsoundnearshore.org/technical_papers/psnerp_strategies_maps.pdf*

Cederholm, C.J., M.D. Kunze, T. Murita, and A. Sibatani. 1999. Pacific salmon carcasses: Essential contributors of nutrients and energy for aquatic and terrestrial ecosystems. American Fisheries Society 24(10):6-15.

Cheng, T. K., Hill, D. F., Beamer, J., and García-Medina G.,2015), Climate change impacts on wave and surge processes in a Pacific Northwest (USA) estuary, Journal of Geophysical Research - Oceans, Vol 120(1), pps. 182–200. WDFW (Washington Department of Fish and Wildlife, formerly Washington Department of Fisheries). 1975. A Catalog of Washington Streams and Salmon Utilization: Puget Sound.

Clancy, M., I. Logan, J. Lowe, J. Johannessen, A. MacLennan, F.B. Van Cleve, J. Dillon, B. Lyons, R. Carman, P. Cereghino, B. Barnard, C. Tanner, D. Myers, R. Clark, J. White, C.A. Simenstad, M. Gilmer, and N. Chin. 2009. Management Measures for Protecting the Puget Sound Nearshore. Puget Sound Nearshore Ecosystem Restoration Project Report No. 2009-01. Published by Washington Department of Fish and Wildlife, Olympia, Washington. Available: *www.pugetsoundnearshore.org/technical_papers/mangement_measure.pdf*

Clarke, D.G., C. Dickerson, and K.J. Reine. 2002. Characterization of Underwater Sounds Produced by Dredges. US Army Engineer Research and Development Center. Vicksburg, MS

Clearwater Research, Inc. 2007. 2006 Outdoor Recreation Survey. Final Report. Prepared by Clearwater Research for Washington State Recreation and Conservation Office. Available: *www.rco.wa.gov/documents/rec_trends/2006RecSurveyFull.pdf*

Climate Impacts Group. 2008. Climate Change Scenarios. Available: *www.cses.washington.edu/cig/fpt/ccscenarios.shtml* (Accessed February 14, 2013)

Climate Impacts Group. 2009. The Washington Climate Change Impacts Assessment, M. McGuire Elsner, J. Littell, and L Whitely Binder (eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington.
Available: *www.cses.washington.edu/db/pubs/allpubs.shtml*

Coen, L.D., R.D. Brumbaugh, D. Bushek, R. Grizzle, M.W. Luckenbach, M.H. Posey, S.P. Powers, and S.G. Tolley. 2007. Ecosystem services related to oyster restoration. Marine Ecology Progress Series 341:303-307.

Cohen, A.N. 2004. An Exotic Species Detection Program for Puget Sound. San Francisco Estuary Institute, Oakland, CA. 52p.

Cordell, J.R., H. Higgins, C. Tanner, and K. Aitkin. 1998. Biological status of fish and invertebrate assemblages in a breached-dike wetland site at Spencer Island, Washington. FR-UW-9805. Fisheries Research Institute. University of Washington, Seattle, Washington.

Council on Environmental Quality (CEQ). 2010a. Memorandum for Heads of Federal Departments and Agencies: Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions. Issued February 18, 2010. Available: *www.whitehouse.gov/sites/default/files/microsites/ceq/20100218-nepa-consideration-effects-ghg-draft-guidance.pdf*

Council on Environmental Quality. 2010b. Final Recommendations of the Interagency Ocean Policy Task Force July 19, 2010.
Available: *www.whitehouse.gov/files/documents/OPTF_FinalRecs.pdf*

Cummins, Andrea. 2009. Personal communication. U.S. Army Corps of Engineers. October 9, 2009.

Dawson, C. and B. Wilkins. 1980. Social Considerations Associated With Marine Recreational Fishing Under FCMA. Marine Fisheries Review 42(12):12-17.

Dethier, M.N. 1990. A Marine and Estuarine Habitat Classification System for Washington State. Natural Heritage Program, Washington Department of Natural Resources. Olympia, Washington. 56p.
Available: *www.dnr.wa.gov/Publications/amp_nh_marine_class.pdf*

Dethier, M.N. 2006. Native Shellfish in Nearshore Ecosystems of Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-04. Published by Seattle District, U.S. Army Corps of Engineers. Seattle, Washington.
Available: *www.pugetsoundnearshore.org/technical_papers/shellfish.pdf*

Dethier, M.N. and G.C. Schoch. 2005. The consequences of scale: assessing the distribution of benthic populations in a complex estuarine fjord. Estuarine, Coastal and Shelf Science 62:253-270.

Dickerson, C., K.J. Reine and D.G. Clarke. 2001. Characterization of Underwater Sounds Produced by Bucket Dredging Operations. US Army Engineer Research and Development Center. DOER Technical Notes Collection (ERDC TN-DOER-E14). Vicksburg, MS

Dowling, J.L., D.A. Luther, and P.P. Marra. 2011. Comparative effects of urban development and anthropogenic noise on bird songs. Behavioral Ecology 23(1):201.

Downing, J. 1983. The Coast of Puget Sound: Its Processes and Development. Puget Sound Books, Washington Sea Grant Program, University of Washington, Seattle. 126p.

Duffy, E. 2009. Factors during early marine life that affect smolt-to-adult survival of ocean-type Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*). Dissertation. University of Washington, Seattle.

Earth Economics. 2008. A New View of the Puget Sound Economy: The Economic Value of Nature's Services in the Puget Sound Basin. Available: *www.eartheconomics.org/FileLibrary/file/Reports/A_New_View_of_the_Puget_Sound_Economy.pdf* (Accessed June 7, 2012)

Eissinger, A.M. 2007. Great Blue Herons in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-06. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.
Available: *www.pugetsoundnearshore.org/technical_papers/herons.pdf*

Emmett, R., R. Llanso, J. Newton, R. Thom, M. Hornberger, C. Morgan, C. Levings, A. Copping, and P. Fishman. 2000. Geographic signatures of North American west coast estuaries. Estuaries 23:765-792

EPA (Environmental Protection Agency). 1999. Consideration of cumulative impacts in EPA review of NEPA documents. EPA Report 315-R-99-002, Washington, D.C.

EPA. 2005. Office of Transportation and Air Quality. Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel. EPA420-F-05-001.

ESA (Environmental Science Associates). 2011a. Puget Sound Nearshore Ecosystem Restoration Project: Stakeholder Outreach and Involvement Plan for Potential Restoration Projects. Prepared by ESA for Washington Department of Fish and Wildlife, Olympia, WA

ESA. 2011b. Puget Sound Nearshore Ecosystem Restoration Project: Strategic Restoration Conceptual Engineering – Final Design Report. March 2011. Prepared by ESA, ESA PWA, Anchor QEA, Coastal Geologic Services, KPFF, and Pacific Survey & Engineering for Washington Department of Fish and Wildlife, Olympia, WA. Available: *www.pugetsoundnearshore.org/cdr.html*

FAA (Federal Aviation Administration). 2007. Hazardous Wildlife Attractants on or near Airports. Advisory Circular No. 150/5200-33B. Available online: *http://www.faa.gov/documentLibrary/media/advisory_circular/150-5200-33B/150_5200_33b.pdf* (Accessed September 12, 2014)

Fahrig, L. and G. Merriam. 1994. Conservation of fragmented populations. Conservation Biology 8:50-59.

Farina, A. 2000. Principles and Methods in Landscape Ecology, Kluwer Academic Publishers, Netherlands.

Feely, R.A., S.R. Alin, J. Newton, C.L. Sabine, M. Warner, A. Devol, C. Krembs, and C. Maloy. 2010. The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. Estuarine, Coastal and Shelf Science 88:442-449.

Federal Emergency Management Agency (FEMA). 1982. Flood Insurance Study. Jefferson County, Washington Unincorporated Areas. Community Number 530069.

Federal Emergency Management Agency (FEMA). 1985. Flood Insurance Rate Map. Skagit County (Unincorporated areas), Washington. Panel Number 530151 0425C.

Federal Emergency Management Agency (FEMA). 2007. Flood Insurance Study. Whatcom County, Washington Unincorporated Areas. Flood Insurance Study Number 53073CV000A.

Finlayson, D. 2006. The Geomorphology of Puget Sound Beaches. Puget Sound Nearshore Partnership Report No. 2006-02. Washington Sea Grant Program, University of Washington. Seattle, Washington.
Available: *www.pugetsoundnearshore.org/technical_papers/geomorphology.pdf*

Finlayson, D. and H. Shipman. 2003. Puget Sound drift cells: The importance of waves and wave climate. Puget Sound Notes 47:1-4.

Ford, J.K.B. 1989. Acoustic behaviour of resident killer whales (*Orcinus orca*) off Vancouver Island, British Columbia. Canadian Journal of Zoology 67(3): 727-745

Forman, R.T.T. and M. Godron. 1986. Landscape ecology. John Wiley & Sons, New York, New York, USA.

Fresh, K.L. 2006. Juvenile Pacific Salmon in Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-06. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.
Available: *www.pugetsoundnearshore.org/technical_papers/pacjuv_salmon.pdf*

Fresh, K., C. Simenstad, J. Brennan, M. Dethier, G. Gelfenbaum, F. Goetz, M. Logsdon, D. Myers, T. Mumford, J. Newton, H. Shipman, and C. Tanner. 2004. Guidance for protection and restoration of the nearshore ecosystems of Puget Sound. Puget Sound Nearshore Partnership Report No. 2004-02. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington.
Available: *www.pugetsoundnearshore.org/technical_papers/guidance.pdf*

Fresh, K., M. Dethier, C. Simenstad, M. Logsdon, H. Shipman, C. Tanner, T. Leschine, T. Mumford, G. Gelfenbaum, R. Shuman, and J. Newton. 2011. Implications of Observed Anthropogenic Changes to the Nearshore Ecosystems in Puget Sound. Prepared for the Puget Sound Nearshore Ecosystem Restoration Project. Technical Report 2011-03. Available: *www.pugetsoundnearshore.org/technical_papers/implications_of_observed_ns_change.pdf*

Glick, P., J. Clough, and B. Nunley. 2007. Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. National Wildlife Federation.

Goetz, F., C. Tanner, C.S. Simenstad, K. Fresh, T. Mumford, and M. Logsdon. 2004. Guiding restoration principles. Puget Sound Nearshore Partnership Report No. 2004-03. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington. Available: *www.pugetsoundnearshore.org/technical_papers/nearshore_guiding_principles.pdf*

Goetz, Fred. 2009. Personal communication. U.S. Army Corps of Engineers. October 14, 2009.

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Department of Commerce NOAA Technical Memo. NMFS-NWFSC-66, 598 p.

Gordon, J. and A. Moscrop. 1996. Underwater Noise Pollution and its Significance for Whales and Dolphins, pp. 282-319 *in:* The Conservation of Whales and Dolphins, M.P. Simmonds and J.D. Hutchinson, eds. John Wiley & Sons Ltd.

Greiner, C.M. 2010. Principles for Strategic Conservation and Restoration. Puget Sound Nearshore Ecosystem Restoration Project Report No. 2010-01. Published by the Washington Department of Fish and Wildlife, Olympia, WA and the U.S. Army Corps of Engineers, Seattle, WA. Available: *www.pugetsoundnearshore.org/technical_papers/conservation_and_restoration_principles.pdf*

Griggs, G.B. 2005. The impacts of coastal armoring. Shore and Beach 73:13-22.

Griggs, G.B., J.F. Tait, and W. Corona. 1994. The interaction of seawalls and beaches—Seven years of monitoring, Monterey Bay, California. Shore and Beach 63(2):31–36.

Grossman, E., G. Hood, E. Beamer and R. Kayen. 2005. Characterizing natural vs. human-related change in Puget Sound deltaic habitats. Proceedings of the 2005 Puget Sound Georgia Basin Research Conference, Seattle. Puget Sound Action Team, Olympia, Washington.

Gustafson, R.G., M.J. Ford, D. Teel, and J.S. Drake. 2010. Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-105, 360 p.

Haley, D. 1986. Marine Mammals: Second Edition. Pacific Search Press. Seattle, Washington.

Hall, J.D. and C.S. Johnson. 1971. Auditory thresholds of a killer whale *Orcinus orca* (Linnaeus). The Journal of the Acoustical Society of America 51:515-517

Harbo, R.M. 2006. Whelks to Whales: Coastal Marine Life of the Pacific Northwest. Harbour Publishing, Madeira Park: British Columbia, Canada.

Hard, J.J., J.M. Myers, M.J. Ford, R.G. Cope, G.R. Pess, R.S. Waples, G.A. Winans, B.A. Berejikian, F.W. Waknitz, P.B. Adams. P.A. Bisson, D.E. Campton, and R.R. Reisenbichler. 2007. Status review of Puget Sound steelhead (*Oncorhynchus mykiss*). U. S. Department of Commerce NOAA Tech. Memo. NMFS-NWFSC-81, 117 p.

Hastings, M.C. 1995. Physical effects of noise on fishes. Inter-noise 95, the 1995 International congress on noise control Engineering Vol 2: 979-984

Hauser, D.D.W., M.G. Logsdon, E.E. Holmes, G.R. VanBlaricom, and R.W.Osborne. 2007. Summer distribution patterns of southern resident killer whales *Orcinus orca*: core areas and spatial segregation of social groups. Marine Ecology Progress Series 351: 301-310

Hayden-Spear, J. and D. Gunderson. 2007. "Nearshore habitat associations of young-of-year copper (*Sebastes caurinus*) and quillback (*S. maliger*) rockfish in the San Juan Channel, Washington." Pages 367-382 *in* J. Heifetz, J. DiCosimo, A. J. Gharrett, M. S. Love, V. M. O'Connell, R. D. Stanley (eds.) Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant College Program, AK-SG-07-01.

Healey, M.C. 1982. Juvenile Pacific salmon in estuaries: the life support system. Pages 315-341 *in* V.S. Kennedy (ed.), Estuarine comparisons. Academic Press, New York.

Henning, J.A., R.E. Gresswell, and I.A. Fleming. 2006. Juvenile salmonid use of freshwater emergent wetlands in the floodplain and its implications for conservation management. North American Journal of Fisheries Management 26:367-376.

Hood Canal Dissolved Oxygen Program. 2009. Available: *www.hoodcanal.washington.edu/aboutHC/brochure.html*

Hood, W.G. 2004. Indirect environmental effects of dikes on estuarine tidal channels: thinking outside the dike for habitat restoration and monitoring. Estuaries and Coasts 27: 273-282

Hood, W.G. 2005. Sea Level Rise in the Skagit Delta. Skagit River Tidings. Skagit Watershed Council, Mount Vernon, Washington.

Hruby, T. 2004. Washington State wetland rating system for western Washington – Revised. Washington State Department of Ecology Publication #04-06-025.

Hueckel, G.J. and R.M. Buckley. 1987. The influence of prey communities on fish species assemblages on artificial reefs in Puget Sound, Washington. Environmental Biology of Fishes 19(3):195-214

Huff, M.H., M.G. Raphael, S.L. Miller, S.K. Nelson, and J. Baldwin. 2006. Northwest Forest Plan—The first 10 years (1994-2003): status and trends of populations and nesting habitat for the marbled murrelet. Gen. Tech. Rep. PNW-GTR-650. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 149 p.

Illingworth & Rodkin, Inc. 2007. Compendium of Pile Driving Sound Data. Prepared for the California Department of Transportation. Available: *www.dot.ca.gov/hq/env/bio/files/pile_driving_snd_comp9_27_07.pdf* (Accessed 23 May 2012)

Industrial Economics, Inc. 2006. Economic Impacts Associated with Critical Habitat Designation for the Southern Resident Population of Killer Whales. Prepared for NOAA Fisheries Northwest Fisheries Science Center, Seattle, WA.

IAC (Interagency Committee for Outdoor Recreation). 2003. Estimates of Future Participation in Outdoor Recreation in Washington State. Available: *www.rco.wa.gov/documents/rec_trends/Est_Future_Participation_Outdoor_Rec_3-03.pdf*

IPCC. 2007. Climate Change 2007. The physical science basis, Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change: Cambridge University Press, Cambridge, United Kingdom and New York, N.Y., USA.

Jay, D.A. and C.A. Simenstad. 1996. Downstream effects of water withdrawal in a small, high-gradient basin: erosion and deposition on the Skokomish River delta. Estuaries 19:501-517.

Johannessen, J. and A. MacLennan. 2007. Beaches and Bluffs of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-04. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington

Johnson, O.W., W.S. Grant, R.G. Kope, K. Neely, F.W. Waknitz, and R.S. Waples. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Department of Commerce NOAA Technical Memo. NMFS-NWFSC-32, 280 p.

Johnson P., D.L. Mock, A. McMillan, L. Driscoll, and T. Hruby. 2002. Washington State Wetland Mitigation Evaluation Study Phase 2: Evaluating Success. Washington State Department of Ecology Shorelands & Environmental Assistance Program, Lacey, WA. Publication No. 02-06-009. Available: *www.ecy.wa.gov/pubs/0206009.pdf* (Accessed February 8, 2013).

Jordan, S.J., L.M. Smith, and J.A. Nestlerode. 2008. Cumulative effects of coastal habitat alterations on fishery resources: toward prediction at regional scales. Ecology and Society 14:16. Available: *www.ecologyandsociety.org/vol14/iss1/art16/*

Kiehl, J.T. and K.E. Trenberth. 1997. Earth's annual global mean energy budget. Bulletin of the American Meteorological Society 78(2):197–208.

Knudsen, F.R., P.S. Enger, and O. Sand. 1992. Awareness reactions and avoidance responses to sound in juvenile Atlantic salmon, *Salmon salar* L. Journal of Fish Biology 40:523-534

Kozloff, E.A. 1973. Seashore Life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago. University of Washington Press. Seattle, Washington. 282 pp.

Kozloff, E. 1993. Seashore Life of the Northern Pacific Coast. University of Washington Press. Seattle, Washington.

Kriete, B. 2007. Orcas in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-01. Published by U.S. Army Corps of Engineers Seattle District. Seattle, Washington. Available: *www.pugetsoundnearshore.org/technical_papers/orcas.pdf*

Krueger, K.L., K.B. Pierce, Jr., T. Quinn, and D.E. Penttila. 2010. Anticipated effects of sea level rise in Puget Sound on two beach-spawning fishes, *in* Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010, Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009: U.S. Geological Survey Scientific Investigations Report 2010-5254, p. 171-178.

Lance, M.M., S.A. Richardson, and H.L. Allen. 2004. Washington State Recovery Plan for the Sea Otter. Washington Department of Fish and Wildlife, Olympia, WA. 91p. Available: *wdfw.wa.gov/publications/00314*

Lane, R.C. and W.A. Taylor. 1997. Washington's wetland resources: Tacoma, Wash., U.S. Geological Survey. Available *wa.water.usgs.gov/pubs/misc/wetlands/* based on Lane, R.C., and Taylor, William A., 1996, Washington wetland resources, *in* Fretwell, Judy D., Williams, John S., and Redman, Phillip J., comps., National water summary on wetland resources: U.S. Geological Survey Water-Supply Paper 2425, p.393-397

Leschine, T.M. and A.W. Petersen. 2007. "Valuing Puget Sound's Valued Ecosystem Components." Puget Sound Nearshore Partnership Report No. 2007-07. Published by U.S. Army Corps of Engineers Seattle District. Seattle, Washington. Available: *www.pugetsoundnearshore.org/technical_papers/social_values.pdf*

Levy, D.A. and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River Estuary. Canadian Journal of Fisheries and Aquatic Sciences 39:270-276.

Lincoln. J. 2000. The Puget Sound Model Summary. University of Washington. Seattle, Washington.

Littell, J.S. and L.W. Binder. 2007. PNW Climate Change and Implications for Forest Ecosystems. Climate Impacts Group, Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington. Washington State Forests Planning/Adaptation Work Group (Forests PAWG), July 17, 2007.

Lourie, S.A. and A.C.J. Vincent. 2004. Using biogeography to help set priorities in marine conservation. Conservation Biology 18:1004-1020.

Love, M.S., M. Yaklavich, and L. Thorsteinson. 2002. The Rockfishes of the Pacific Northwest. University of California Press. Berkeley, California.

Lummi Nation. 2008. Lummi Nation Wetland and Habitat Mitigation Bank Prospectus. Prepared for Lummi Indian Business Council. Prepared by Lummi Natural Resources Department Water Resources Division and ESA Adolfson.

Lusseau, D., D. Bain, R. Williams, and J. Smith. 2009. Vessel traffic disrupts foraging behaviour of southern resident killer whales *Orcinus orca*. Endangered Species Research 6:211-221

Mantua, N.J., I. Tohver, and A.F. Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. Climatic Change. 102(1-2):187-223. DOI: 10.1007/s10584-010-9845-2.
Available: *www.cses.washington.edu/db/pubs/allpubs.shtml*

Martin, Stephen G. PhD. Personal communication. May 23, 2012. U.S. Army Corps of Engineers.

Mass, C. 2008. The Weather of the Pacific Northwest. Univ. Wash. Press, Seattle, WA.

May, C.W. 1996. Assessment of cumulative effects of urbanization on small streams in the Puget Sound lowland ecoregion: implications for salmonid resource management. Seattle, University of Washington, Department of Civil Engineering, Ph.D. dissertation, 383 p.

Meacham, P. 2001. Washington State Aquatic Nuisance Species Management Plan. Washington State Department of Fish and Wildlife, Olympia, WA. 128 pp.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington, DC.

Mitsch, W.J., and J.G. Gosselink. 2007. Wetlands. 3rd Ed., John Wiley & Sons, New York.

Mofjeld H.O. and L.H. Larsen. 1984. Tides and tidal currents of the inland waters of western Washington. Technical Report NOAA Technical Memorandum ERL PMEL-56, Pacific Marine Environmental Laboratory.

MRLC (Multi-Resolution Land Characteristics Consortium). 2006 Land Cover. Available: *www.mrlc.gov/viewerjs/*. (Accessed September 19, 2012)

Mumford, T.F. 2007. Kelp and Eelgrass in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-05. Published by U.S. Army Corps of Engineers Seattle District. Seattle, Washington.
Available: *www.pugetsoundnearshore.org/technical_papers/kelp.pdf*

Mumford, Thomas. 2010. Personal Communication with a member of the Nearshore Science Team. September 2010.

Mumford, Thomas and Megan Dethier. 2010. Personal Communication with members of the Nearshore Science Team. September 2010.

Newton, J.A., E. Siegel, and S.L. Albertson. 2003. Oceanographic changes in Puget Sound and the Strait of Juan de Fuca during the 2000-01 drought. Canadian Water Resources Journal 28(4):715-728.

Newton, J., C. Bassin, A. Devol, M. Kawase, W. Ruef, M. Warner, D. Hannafious, and R. Rose. 2008. Hypoxia in Hood Canal: an overview of status and contributing factors. *In*: Proceedings of the 2007 Georgia Basin Puget Sound Research Conference. Available: *www.depts.washington.edu/uwconf/2007psgb/2007proceedings/papers/9a_newton_comp.pdf*

NMFS. 2005a. Endangered and Threatened Wildlife and Plants: Endangered Status for Southern Resident Killer Whales. Final rule. Federal Register 70(222):69903-69912.Available: *ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A0IL*

NMFS. 2005b. Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs: Final rule. Federal Register 70(123):37160-37204.

NMFS. 2006. Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon. Final rule. Federal Register 71(67):17757-17766. Available: *ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=E09K*

NMFS. 2006b. Endangered and Threatened Species; Designation of Critical Habitat for Southern Resident Killer Whale. Final rule. Federal Register 71(229):69054-69070.

NMFS. 2007a. Endangered and Threatened Species: Final Listing Determination for Puget Sound Steelhead; Final Rule. 72 FR 26722-26735. Available: *www.gpo.gov/fdsys/pkg/FR-2007-05-11/pdf/E7-9089.pdf*

NMFS. 2007b. Office of Protected Resources: Species of Concern (Northern Abalone). Available online: *www.nmfs.noaa.gov/pr/pdfs/species/pintoabalone_detailed.pdf*

NMFS. 2009a. Endangered and Threatened Wildlife and Plants: Final Rulemaking to Designate Critical Habitat for the Threatened Southern DPS of North American Green Sturgeon; Final Rule. 74(195) FR 52300-52351.

NMFS. 2009b. Endangered and Threatened Wildlife and Plants: Proposed Endangered, Threatened, and Not Warranted Status for Distinct Population Segments of Rockfish in Puget Sound. 74(77) FR 18516-18542.

NMFS. 2009c. Species of Concern: Puget Sound/Strait of Georgia Coho Salmon. Available: *www.nmfs.noaa.gov/pr/pdfs/species/cohosalmon_detailed.pdf*.

NMFS. 2010. Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of Eulachon. Final rule. Federal Register 76(203):65324-65352.

NMFS. 2011. Endangered and Threatened Species; Designation of Critical Habitat for the Southern Distinct Population Segment of Eulachon. Federal Register 76(203):65324-65352

NMFS. 2012. U.S. Commercial Landings for 2009 and 2010. Available: *www.st.nmfs.noaa.gov/st1/fus/fus10/02_commercial2010.pdf* (Accessed June 4, 2012)

NMFS. 2013. Office of Protected Resources: Humpback Whales. Available: *www.nmfs.noaa.gov/pr/species/mammals/cetaceans/humpbackwhale.htm*

NMFS and USFWS. 2008. Endangered Species Act Section 7 Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation: Washington State Fish Passage and Habitat Enhancement Restoration Programmatic Consultation.

National Research Council. 1987. Responding to Changes in Sea Level: Engineering Implications. Committee on Engineering Implications of Changes in Relative Mean Sea Level, Marine Board, Commission on Engineering and Technical Systems, National Research Council. National Academy Press, Washington DC. 148pp.

NWF (National Wildlife Federation). 2007. Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. Available: *www.nwf.org/~/media/PDFs/Wildlife/PacificNWSeaLevelRise.pdf?dmc=1&ts=20130208T1639506718*

Nedwell, J.R., B. Edwards, A.W.H. Turnpenny, and J. Gordon. 2004. Fish and Marine Mammal Audiograms: A Summary of Available Information. Subacoustech Report #534R0214. Available: *www.subacoustech.com/information/downloads/reports/534R0214.pdf* (Accessed 18 April 2012)

Nehlsen, W.J., J.E. Williams, and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16:4-21

Olesiuk. P.F. 1993. Annual prey consumption by harbor seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia. Fisheries Bulletin 91: 491-515

The Olympian. 2007 (January 12). History of Puget Sound cleanup efforts. Available: *www.theolympian.com/2006/08/06/45317/history-of-puget-sound-cleanup.html* (Accessed April 27, 2012)

Orca Network. 2011. Marine Mammals of Puget Sound. Available: *www.orcanetwork.org/marinemammals/interp1.pdf* (Accessed July 30, 2012).

PCSGA (Pacific Coast Shellfish Growers Association). 2012. Shellfish Production on the West Coast. Available: *pcsga.net/wp-content/uploads/2011/02/production_stats.pdf* (Accessed June 3, 2012)

Pacific Northwest Hatchery Reform Project. 2008. Welcome to Hatchery Reform. Available: *www.hatcheryreform.us/hrp/welcome_show.action*

Partyka, M.L. and M.S. Peterson. 2008. Habitat quality and salt-marsh species assemblages along an anthropogenic estuarine landscape. Journal of Coastal Research 24: 1570-1581.

Pearson, S.F., M.G. Raphael, M.M. Lance, and T. D. Bloxton, Jr. 2011a. Washington 2010 at-sea marbled murrelet population monitoring: Research Progress Report. Washington Department of Fish and Wildlife, Wildlife Science Division and USDA Forest Service Pacific Northwest Research Station, Olympia, WA.

Pearson, S.F., N. Hamel, S. Walters, and J. Marzluff (eds). 2011b. Impacts of Natural Events and Human Activities on the Ecosystem *in* Puget Sound Science Update, April 2011. Puget Sound Partnership, Tacoma, WA. Available: *www.psp.wa.gov/downloads/pssu2011/PSSU_042011_3.pdf*

Penttila, D. 2007. Marine Forage Fishes in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-03. Published by Seattle District, U.S. Army Corps of Engineers Available: *www.pugetsoundnearshore.org/technical_papers/marine_fish.pdf*

Perrin, W.F. and S.B. Reilly. 1984. Reproductive parameters of dolphins and small whales of the family Delphinidae. *In* W.F. Perrin, R. L. Brownell, Jr. and D. P. DeMaster (eds.), Reproduction in whales, dolphins, and porpoises, p. 97-134. International Whaling Commission (Special Issue 6), Cambridge, U.K. 490 p.

Peterson, M.S., and M.R. Lowe. 2009. Implications of cumulative impacts to estuarine and marine habitat quality for fish and invertebrate resources. Reviews in Fisheries Science 17:505-523.

Pilkey, O.H., and H.L. Wright, III. 1988. Seawalls versus beaches. Journal of Coastal Research, Special Issue 4:41-64.

Plummer, Mark. 2009. NOAA Fisheries Northwest Fisheries Science Center, Personal Communication with Northern Economics. October 21, 2009.

Pressey, R.T. 1953. The sport fishery for salmon on Puget Sound. Fisheries Research Papers, Washington Department of Fish. 1:33-45.

PSP (Puget Sound Partnership). 2008. Puget Sound Action Agenda Protecting and Restoring the Puget Sound Ecosystem by 2020. December 1, 2008. Available: *www.psp.wa.gov/downloads/ACTION_AGENDA_2008/Action_Agenda.pdf*

PSP. 2009. Ecosystem Status and Trends: A 2009 Supplement to State of the Sound Reporting. November 2009. Appendix C to the 2009 State of the Sound Report. Available: *www.psp.wa.gov/sos2009.php*

PSP. 2012. The 2012/2013 Action Agenda for Puget Sound. Available: *psp.wa.gov/downloads/AA2011/083012_final/Action%20Agenda%20Book%202_Aug%2029%202012.pdf*

PSRC (Puget Sound Regional Council). 2010. Transportation 2040. Available: *www.psrc.org/assets/4838/4web_FINALT2040es.pdf*

Puget Sound Restoration Fund. 2009. Pinto Abalone Recovery. Available: *www.restorationfund.org/projects/pintoabalone*

PSWQAT (Puget Sound Water Quality Action Team). 2002. 2002 Puget Sound Update: Eighth Report of the Puget Sound Ambient Monitoring Program. Available: *wdfw.wa.gov/publications/01029/wdfw01029.pdf*

Radtke, H.D. 2011. Washington State Commercial Fishing Industry Total Economic Contribution. Prepared for Seattle Marine Business Coalition. Available online: *www.fishermensnews.com/attachmentsPDF/RadtkeReport.pdf* (Accessed June 6, 2012)

Reeves, G.H., F.H. Everest, and J.R. Sedell. 1993. Diversity of juvenile anadromous salmonid assemblages in coastal Oregon basins with different levels of timber harvest. Transactions of the American Fisheries Society 122(3):309-317.

Rice, C.A. 2006. Effects of shoreline modification on a northern Puget Sound beach: Microclimate and embryo mortality in surf smelt (*Hypomesus pretiosus*). Estuaries and Coasts 29:63-71.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, Inc. San Diego, CA

Rieman, B.E. and J.D. McIntyre. 1993. Demographic and Habitat Requirements for Conservation of Bull Trout. Gen. Tech. Rep. INT-302. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID. 38 p. Available: *www.fs.fed.us/rm/pubs_int/int_gtr302.pdf*

Rothaus, D.P., B. Vadopalas, C.S. Friedman. 2008. Precipitous declines in pinto abalone (*Haliotis kamtschatkana kamtschatkana*) abundance in the San Juan Archipelago, Washington, USA, despite statewide fishery closure. Canadian Journal of Fisheries and Aquatic Sciences. 65(12):2703-2711.

SAIC. 2011. Final Summary Report: Environmental Science Panel for Marbled Murrelet Underwater Noise Injury Threshold. Panel Conducted July 27-29, 2011 in Lacey Washington. Document prepared for U.S. Navy NAVFAC

Schiel, D.R., S.A. Wood, R.A. Dunmore, D.I. Taylor. 2006. Sediment on rocky intertidal reefs: Effects on early post-settlement stages of habitat-forming seaweeds. Journal of Experimental Marine Biology and Ecology 331(2):158-172

Schlenger, P., A. MacLennan, E. Iverson, K. Fresh, C. Tanner, B. Lyons, S. Todd, R. Carman, D. Myers, S. Campbell, and A. Wick. 2011a. Strategic Needs Assessment Report (SNAR). Puget Sound Nearshore Ecosystem Restoration Project Report No. 2011-02. Published by the U.S. Army Corps of Engineers, Seattle, Washington, and Washington Department of Fish and Wildlife, Olympia, Washington. Available: *www.pugetsoundnearshore.org/technical_papers/strategic_needs_assessment_final.pdf*

Schlenger, P., A. MacLennan, E. Iverson, K. Fresh, C. Tanner, B. Lyons, S. Todd, R. Carman, D. Myers, S. Campbell, and A. Wick. 2011b. Strategic Needs Assessment: Analysis of Projected Future Nearshore Ecosystem Process Degradation in Puget Sound. Prepared for the Puget Sound Nearshore Ecosystem Restoration Project. Addendum to Rpt No. 2011-02. Available: *www.pugetsoundnearshore.org/technical_papers/strategic_needs_assessment_final.pdf*

Schusterman, R.J., R.F. Balliet, and J. Nixon. 1972. Underwater audiogram of the California sea lion by the conditioned vocalization technique. Journal of the Experimental Analysis of Behavior 17(3):339-350.

Shared Strategy. 2007. Puget Sound salmon recovery plan and National Marine Fisheries Service's (NMFS) final supplement to the Shared Strategy plan. Available: *www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Puget-Sound/PS-Recovery-Plan.cfm*

Shipman, H. 2008. A Geomorphic Classification of Puget Sound Nearshore Landforms. Puget Sound Nearshore Partnership Report No. 2008-01. Published by Seattle District, U.S. Army

Corps of Engineers, Seattle, Washington and Washington Department of Fish and Wildlife, Olympia, Washington. Available: *www.pugetsoundnearshore.org/technical_papers/geomorphic_classification.pdf*

Shipman, H., M.N. Dethier, G. Gelfenbaum, K.L. Fresh, and R.S. Dinicola (eds). 2010. Puget Sound Shorelines and the Impacts of Armoring-- Proceedings of a State of the Science Workshop, May 2009. U.S. Geological Survey, Scientific Investigations Report 2010-5254. 262 p. Available: *pubs.usgs.gov/sir/2010/5254/*

Short, F. 1999. The effects of climate change on seagrasses. Aquatic Botany 63:169-196

Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function, pp. 343-364. In: V. S. Kennedy (ed.), Estuarine comparisons. Academic Press, New York.

Simenstad, C.A., M. Logsdon, K. Fresh, H. Shipman, M. Dethier, and J. Newton. 2006. Conceptual model for assessing restoration of Puget Sound Nearshore Ecosystems. Puget Sound Nearshore Partnership Report No. 2006-03. Washington Sea Grant Program, University of Washington, Seattle, Washington. Available: *www.pugetsoundnearshore.org/technical_papers/conceptual_model.pdf*

Simenstad, C.A., M. Ramirez, J. Burke, M. Logsdon, H. Shipman, C. Tanner, J. Toft, B. Craig, C. Davis, J. Fung, P. Bloch, K. Fresh, S. Campbell, D. Myers, E. Iverson, A. Bailey, P. Schlenger, C. Kiblinger, P. Myre, W. Gerstel, and A. MacLennan. 2011. Historical Change and Impairment of Puget Sound Shorelines. Puget Sound Nearshore Ecosystem Restoration Project Report No. 2011-01. Published by Washington Department of Fish and Wildlife, Olympia, Washington, and U.S. Army Corps of Engineers, Seattle, WA. Available: *pugetsoundnearshore.org/technical_papers/change_analysis.pdf*

Skalski, I.W., W.H. Pearson, and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (*Sebastes* spp.). Canadian Journal of Fisheries and Aquatic Sciences 49: 1357-1 365

Sound Science. 2007. Sound Science: Synthesizing ecological and socioeconomic information about the Puget Sound ecosystem. Mary H. Ruckelshaus and Michelle M. McClure, coordinators; prepared in collaboration with the Sound Science collaborative team. U.S. Department of Commerce, National Oceanic & Atmospheric Administration (NMFS), Northwest Fisheries Science Center. Seattle, Washington. 93 p. Available: *www.nwfsc.noaa.gov/research/shared/sound_science/index.cfm*

Snover, A.K., P.W. Mote, L. Whitely Binder, A.F. Hamlet, and N.J. Mantua. 2005. Uncertain Future: Climate Change and its Effects on Puget Sound. A report for the Puget Sound Action Team by the Climate Impacts Group (Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle). Available: *www.cses.washington.edu/db/pubs/allpubs.shtml*

Stick, K.L. and A. Lindquist. 2009. 2008 Washington Herring Stock Status Report. Stock Status Report No. FPA 09-05. Washington Department of Fish and Wildlife, Olympia, WA. Available: *wdfw.wa.gov/publications/00928/*

Szymanski, M.D., D.E. Bain, K. Kiehl, S. Pennington, K.R. Henry. 1999. Killer whale (*Orcinus orca*) hearing: auditory brainstem response and behavioral audiograms. Journal of the Acoustical Society of America. 106(2):1134-1141

TCW Economics. 2008. Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State. Prepared for the Washington Department of Fish and Wildlife. Available: *wdfw.wa.gov/publications/pub.php?id=00464*

TCW Economics. 2012. March 2012 errata to the Final Report: Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State. December 2008. Sacramento, CA. with technical assistance from The Research Group, Corvallis, OR. Prepared for Washington Department of Fish and Wildlife *wdfw.wa.gov/publications/00464/wdfw00464.pdf*

Thom, R. 1992. Accretion rates of low intertidal salt marshes in the Pacific Northwest. Wetlands 12(3):147-156

Thom, R.M, K.E. Buenau, C. Judd, and V.I. Cullinan. 2011. Eelgrass (*Zostera marina* L.) Stressors in Puget Sound. Prepared for Washington State Department of Natural Resources, U.S. Department of Energy, Pacific Northwest National Laboratory Sequim, Washington

Toft, J.D., J.R. Cordell, C.A. Simenstad, and L.A. Stamatiou. 2007. Fish distribution, abundance, and behavior along city shoreline types in Puget Sound. North American Journal of Fisheries Management 27:465-480.

TRG (The Research Group). 2008. Final: Washington Commercial Fisheries Economic Value in 2006. Prepared by The Research Group, Corvallis OR, in association with TCW Economics, Sacramento, CA. Prepared for Washington Department of Fish and Wildlife.

Turner, M.G. 1989. Landscape ecology: the effect of pattern on process. Annual Review of Ecology and Systematics 20:171-197.

Turner, M.G., R.H. Gardner, and R.V. O'Neill. 1995. Ecological dynamics at broad scales. BioScience 45:29-35.

U.S. Navy. 2010. Bird/Animal Aircraft Strike Hazard (BASH) Manual, Published by Commander Navy Installations Command Air Operations Program Director, January 2010

USACE. 1985. Engineer Circular 405-1-04. Real Estate Handbook. May 20, 1985. Department of the Army, Washington, D.C.

USACE. 1999a. Engineer Pamphlet 1165-2-502, Ecosystem Restoration – Supporting Policy Information. 30 September 1999, Department of the Army, Washington, D.C.

USACE. 1999b. Engineering Regulation 1110-2-1150, Engineering and Design Civil Works Projects. 31 August 1999, Department of the Army, Washington, D.C.

USACE. 1999c. Engineering Regulation 1165-2-501, Civil Works Ecosystem Restoration Policy. 30 September 1999, Department of the Army, Washington, D.C.

USACE. 2000a. Engineering Regulation 1105-2-100, Planning Guidance Notebook. 22 April 2000, Department of the Army, Washington, D.C.

USACE. 2000b. Engineering Regulation 1105-2-100 Appendix E-37, Significance of Ecosystem Outputs. 22 April 2000, Department of the Army, Washington, D.C.

USACE, 2003. Lower Duckabush River, Channel Migration Report, Floodplain Management Services program, prepared for Jefferson County, 25 pps.

USACE. 2004. Puget Sound and Adjacent Waters Ecosystem Restoration Plan – Phase I Report. U.S. Army Corps of Engineers, Seattle District

USACE. 2005. Engineering Circular 1105-2-409, Planning In a Collaborative Environment. 31 May 2005, Department of the Army, Washington, D.C. (*http://planning.usace.army.mil/toolbox/library/ECs/ec1105-2-409.pdf*)

USACE. 2007. Peer Review Plan for Feasibility Study of Puget Sound Nearshore Habitat Restoration, WA. Seattle District U.S. Army Corps of Engineers

USACE. 2009a. Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007) - Monitoring Ecosystem Restoration. Civil Works Directorate Memorandum for Commanders and major subordinate commands, dated 31 August 2009. Available: *cw-environment.usace.army.mil/restore/riverrestoration/pdfs/WRDA%20Sec_2039.pdf*

USACE. 2011b. Engineering Circular 1105-2-412, Assuring Quality of Planning Models. 31 March 2011, Department of the Army, Washington, D.C.

USACE. 2012a. CorpsMap: Corps Puget Sound Project. Available: *corpsmap.nws.usace.army.mil:7777/pls/apex/cm2.cm2.map?map=CPSP*

USACE. 2012b. Engineering Circular 1165-2-209, Civil Works Review Policy. 31 January 2012, Department of the Army, Washington, D.C. *planning.usace.army.mil/toolbox/library/ECs/EC1165-2-209_31Jan2012.pdf*

USACE. 2013 Engineering Regulation 1100-2-8162, Incorporating Sea Level Change in Civil Works Programs. December 2013, Department of the Army, Washington D.C. www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1100-2-8162.pdf

U.S. Census Bureau. 2010. Available: *www.census.gov/2010census/*

USFWS (United States Fish and Wildlife Service). 1977. Endangered and Threatened Wildlife and Plants; Determination that the Southern Sea Otter is a Threatened Species. 42 FR 2965-2968.

USFWS. 1992. Endangered and threatened wildlife and plants; Threatened status for the Washington, Oregon, and California population of the marbled murrelet; Final Rule. 57 FR 45328-45337.

USFWS. 1997. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for *Castilleja levisecta* (Golden Paintbrush). 62 FR 31740-31748.

USFWS. 1999. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for Bull Trout in the Coterminous United States: Final Rule. 50 FR 589110-58933.

USFWS. 2004. Endangered and threatened wildlife and plants; Listing of the Southwest Alaska Distinct Population Segment of Northern Sea Otter as Threatened. 69 CFR 6600-6621.

USFWS. 2009. 5 Year Review for the Marbled Murrelet. Washington Fish and Wildlife Office. Lacey, WA.

USFWS. 2012. Strategic Restoration Conceptual Design – Preliminary Environmental Contaminant, Cultural Resource, and Endangered Species Site Evaluations. Prepared by the U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Puget Sound Coastal Program in support of the Puget Sound Nearshore Ecosystem Project

Van Cleve, F.B., C. Simenstad, F. Goetz, and T. Mumford. 2004. Application of the "Best Available Science" in Ecosystem Restoration: Lessons Learned from Large-Scale Restoration Project Efforts in the USA. Puget Sound Nearshore Partnership Report No. 2004-01. Published by Washington Sea Grant Program, University of Washington

WDFW (Washington Department of Fish and Wildlife, formerly Washington Department of Fisheries). 1975. A Catalog of Washington Streams and Salmon Utilization: Puget Sound.

WDFW (formerly Washington Department of Fisheries). 1993. 1992 Washington State Salmon and Steelhead Stock Inventory, prepared by the Washington Department of Fisheries and the Washington Department of Wildlife, with the Western Washington Treaty Indian Tribes. Olympia, Washington. Available online: *wdfw.wa.gov/publications/pub.php?id=00194*

WDFW. 2002. Washington State Salmon and Steelhead Stock Inventory, prepared by the Washington Department of Fish and Wildlife, with the Western Washington Treaty Indian Tribes. Olympia, Washington. Available online: *wdfw.wa.gov/conservation/fisheries/sasi/*

WDFW. 2009. Draft Environmental Impact Statement for the Puget Sound Rockfish Conservation Plan. Olympia, WA. Available: *wdfw.wa.gov/publications/00035/*

WDFW. 2012a. Recreational Crab Fishing – Yearly Harvest Estimates. Available online: *wdfw.wa.gov/fishing/shellfish/crab/estimates.html* (Accessed June 5, 2012)

WDFW. 2012b. Threatened and Endangered Wildlife in Washington: 2011 Annual Report. Endangered Species Section, Wildlife Program. Washington Department of Fish and Wildlife, Olympia, WA. 180 pp. Available: *wdfw.wa.gov/publications/01385/*

WDFW, Washington State Recreation and Conservation Office, U.S. Fish and Wildlife Service. 2012. Habitat Work Schedule – Lead Entity Public Portal. Available: *hws.ekosystem.us/*

WDOE (Washington State Department of Ecology). 1992a. 1992 Statewide water quality assessment, 305(b) report: Olympia, Wash., Department of Ecology pub No. 92-04, 245 p.

WDOE.1992b. Focus--Wetlands in Washington State: Olympia, Wash., Washington State Department of Ecology publication F-S-92-108, 2 p.

WDOE. 2008. Focus on Puget Sound: economic facts. Publication Number: 06-01-006. Olympia, Washington. Revised October 2008. Available: *fortress.wa.gov/ecy/publications/publications/0601006.pdf*

WDOE. 2009a. Water Quality Assessment map tool for Washington. Available: *apps.ecy.wa.gov/wqawa2008/viewer.htm*

WDOE. 2009b. Washington Shoreline Public Access Project. Available: *www.ecy.wa.gov/programs/eap/beach/shoreline_public_access_project.html*

WDOE. 2009c. Shoreline Management. Available: *www.ecy.wa.gov/programs/sea/shorelines/index.html* (Accessed February 14, 2013)

WDOE. 2011. Control of Toxic Chemicals in the Puget Sound: Phase 3: Primary Sources of Selected Toxic Chemicals and Quantities Released in the Puget Sound Basin. Washington State Department of Ecology, Olympia, WA. Publication No. 11-03-024. Available: *www.ecy.wa.gov/biblio/1103024.html*

WDNR (Washington State Department of Natural Resources). 2009. Field Guide to Selected Rare Plants of Washington. Available: *www1.dnr.wa.gov/nhp/refdesk/fguide/htm/fgmain.htm*

WSDOT (Washington State Department of Transportation). 2012. Online Project Database. Available: *www.wsdot.wa.gov/projects/* (Accessed July 19, 2012).

WSDOT. 2014. 2014 Annual Traffic Report. Available: *http://www.wsdot.wa.gov/mapsdata/travel/pdf/Annual_Traffic_Report_2014.pdf* (Accessed Oct 30, 2015).

Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. Status review of Coho salmon from Washington, Oregon, and California. U.S. Department of Commerce. NOAA Technical Memorandum NMFS-NWFSC-24, Northwest Fisheries Science Center, Seattle, Washington. 258 p. Available: *www.nwfsc.noaa.gov/assets/25/4237_06172004_123333_coho.pdf*

Weitkamp, L. and K. Neely. 2002. Coho salmon (*Oncorhynchus kisutch*) ocean migration patterns: insight from marine coded-wire tag recoveries. Canadian Journal of Fisheries and Aquatic Sciences 59(7): 1100-1115

Wiens, J. 2002. Central concepts and issues of landscape ecology. In: K. J. Gutzwiller (ed.) Applying Landscape Ecology in Biological Conservation. Springer, New York, p 3-21.

Wiens, J., B. Horne, and B. Noon. 2002. Integrating landscape structure and scale into natural resource management, pp. 23-67. *In* J. Liu and W.W. Taylor (eds.) Integrating Landscape Ecology into Natural Resource Management. Cambridge University Press, New York.

Williams, G.D. and R.M. Thom. 2001. Marine and Estuarine Shoreline Modification Issue. Battelle Marine Sciences Laboratory, Pacific Northwest National Laboratory, Sequim, WA.

Williams, P., and P. Faber. 2001. Salt marsh restoration experience in San Francisco Bay. Journal of Coastal Research 27:203-211.

Willson, M.F. and K.C. Halupka. 1995. Anadromous fish as keystone species in vertebrate communities. Conservation Biology 9:489-497

Wonham, M. and J. Carlton. 2005. Cool-temperate marine invasions at local and regional scales: The Northeast Pacific Ocean as a model system. Biological Invasions 7(3): 369-392

Woodroffe, C. 2002. Coasts: Form, Process, and Evolution. Cambridge University Press. 623p.

Wright, L.D. 1985. River deltas. Pages 1-76 *in* R.A. Davis, Jr. (ed.), Coastal Sedimentary Environments. Springer-Verlag, New York.

Zhang, Z., A. Campbell, and J. Lessard. 2007. Modelling Northern Abalone, *Haliotis kamtschatkana*, population stocks and recruitment in British Columbia. Journal of Shellfish Research 26:1099-1107.

12 ANNOTATED BIBLIOGRAPHY

These documents are available upon request by sending an e-mail request to *pugetsoundnearshore@dfw.wa.gov* except for those whose distribution is prohibited. When an electronic version is available, a hyperlink to the document will be included below. All of these documents are incorporated by reference according to 40 CFR 1502.21 except for those denoted by an asterisk (*) as they are not available for public distribution, or in the cases of appendices that are summarized herein.

Puget Sound Nearshore Ecosystem Restoration Project Technical Reports

Principles for Strategic Conservation and Restoration

This report summarizes principles of landscape ecology and conservation biology that are applicable to the conservation and restoration of nearshore ecosystems in Puget Sound and are intended to guide the prioritization of sites and actions by the Nearshore Study team and others. The result is 11 principles derived from the literature organized into three hierarchical scales: 1) Overarching Principles; 2) Landscape Level Principles; and 3) Site-Specific Principles. Available at:
www.pugetsoundnearshore.org/technical_papers/conservation_and_restoration_principles.pdf

Historical Change and Impairment of Puget Sound Shorelines: Atlas and Interpretation of Puget Sound Nearshore Ecosystem Restoration Project Change Analysis

This report is a comprehensive, spatially explicit analysis (Change Analysis) of net changes to nearshore ecosystems of Puget Sound—its beaches, estuaries, and deltas—since its earliest industrial development. These quantified changes in the structure of Puget Sound's shorelines are indicators of qualitative change to ecosystem processes. Because historical documentation of nearshore ecosystem processes does not exist per se, we used the observed physical changes to the shoreline, Nearshore Study conceptual models, and other sources of understanding about the relationship among nearshore ecosystem processes, structures, and functions to interpret the levels and types of impairment of nearshore ecosystem processes. Our approach was to systematically quantify historical change in the physical structure of Puget Sound's shorelines over the past approximately 150 years, between the earliest land surveys of the General Land Office and U.S. Coast and Geodetic Survey (1850s–1890s) and present conditions (2000–2006).

Historical change was analyzed in four categories: Tier 1) Landform Transition, changes in landform class, either among natural geomorphic classes or to classifications of artificial or absent; Tier 2) Shoreline Alterations, changes in historically documented attributes such as wetlands or current anthropogenic modifications (considered stressors) along the shoreline; Tier 3) Adjacent Upland Change, anthropogenic changes within 200 meters of the adjoining uplands; and Tier 4) Watershed Area Change, anthropogenic changes in the drainage area. The four categories of nearshore change (tiers) were related to shifts in the benefits of natural nearshore ecosystems to humans and their communities. The results of this analysis can be used to inform

restoration and preservation planning about the types, extent, and consequences of changes to Puget Sound's shoreline.
Available at: *www.pugetsoundnearshore.org/technical_papers/change_analysis.pdf*

Implications of Observed Anthropogenic Changes to the Nearshore Ecosystems in Puget Sound

This report by the Nearshore Study Nearshore Science Team presents a synthesis of the most significant physical changes to the nearshore ecosystems of Puget Sound and implications of these changes to ecosystem functions, goods, and services. Documented historical changes to the shoreline environment of Puget Sound have caused widespread losses in connectivity, increased fragmentation of the landscape and simplification of nearshore landscapes. These impacts have disrupted many nearshore ecosystem processes that support important species and have impaired the system's capacity to support biological diversity and production.
Available at:
www.pugetsoundnearshore.org/technical_papers/implications_of_observed_ns_change.pdf

Strategic Needs Assessment: Analysis of Nearshore Ecosystem Process Degradation in Puget Sound

This report characterizes the impacts of shoreline and watershed alterations on nearshore ecosystem processes, identifies the potential causes of observed ecosystem degradation, and assesses which of the identified problems most need to be addressed through restoration and protection actions. To support this strategic needs assessment, a spatially explicit evaluation framework was created and applied to characterize the extent to which the observed distribution of stressors has degraded each of the 11 nearshore ecosystem processes evaluated.
Available at:
www.pugetsoundnearshore.org/technical_papers/strategic_needs_assessment_final.pdf

Strategies for Nearshore Protection and Restoration in Puget Sound

This report, commonly called the "Strategies Report" integrates change analysis and estimated process degradation, under a simple restoration and protection planning model. This model offers a framework for the management of Puget Sound nearshore ecosystems. We identify a set of delta, beach, barrier embayment and coastal inlet sites. Sites differ in their historical potential to provide ecosystem services. Restoration and protection planning should consider the operation of critical ecosystem processes at the site scale. The intensity and character of site degradation both indicates the potential for restoration, but creates risk in that restoration efforts may be undermined by degradation of critical ecosystem processes. The development of landscape strategies and conservation actions can be informed by these large-scale assessments. We provide suggestions for incorporating Nearshore Study data into restoration planning. Our framework and assessments point to groups of large complex sites, where there may be exceptional opportunities for large-scale ecosystem restoration or protection.

Available at:
www.pugetsoundnearshore.org/technical_papers/psnerp_strategies_maps_lowres.pdf

U.S. Fish and Wildlife Service Reports

This is a series of four documents produced by the USFWS with contractor support to supplement Nearshore Study conceptual design work and includes the following:

PSNERP Strategic Restoration Conceptual Design Preliminary Environmental Contaminants, Cultural Resource, and Endangered Species Site Evaluations.

This report provides baseline information on environmental contaminants, cultural resources, endangered species and conservation measures for 36 candidate restoration sites under consideration by the Nearshore Study team. Environmental Site Assessment Level 1 Survey Checklists were also completed for each of the 36 sites.

A Cultural Resources Assessment of the Puget Sound Nearshore Ecosystem Restoration Projects (PSNERP) Area, NW Washington, Task 1. Literature and Data Review and Synthesis*

This report presents the results of cultural resource record/literature searches for 36 candidate restoration sites under consideration by the Nearshore Study team. An assessment of the potential for cultural resources within each project area is made based on a review of the environmental, cultural, and archaeological data, and recommendations are provided on where future archaeological efforts should be made for each of the 36 action areas. By law, sensitive cultural resource information is not available for public release.

A Cultural Resources Assessment of the Puget Sound Nearshore Ecosystem Restoration Projects (PSNERP) Area, NW Washington, Task 2: Historic Context of Agricultural Dikes.

This report is a regional-scale historic context of late 19th and early 20th century agricultural development within the Puget Sound region of NW Washington. This effort documents the history of development of dikes built in the region, and proposes evaluation criteria to use as a management tool for the USFWS and others to use for compliance with NHPA Section 106.

Cultural Resources Field Inventory for 15 Action Areas within the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) Area, NW Washington*

This presents the findings surface surveys and subsurface investigations concentrated on project components within areas previously determined to have high to moderate probabilities for cultural resources. The purpose of the inventory was to provide (1) descriptions of cultural resources in the area of potential effect (APE) for Nearshore Study undertakings, (2) determinations concerning the eligibility of cultural resources to the National Register and the Washington Heritage Register (WHR), and (3) recommendations on how to avoid or mitigate impacts to historic properties. This report was completed for subset of the 36 candidate restoration sites, and only on lands where access had been granted by the landowner. By law, sensitive cultural resource information is not available for public release.