# Cumulative Effects Analysis
# Eastern Shore of Central Puget Sound
# Washington

**Final**

February 7, 2014

US Army Corps
of Engineers ®

Cover photo: Port of Everett 1940. Credit: USACE.

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U.S. Army Coprs of Engineers
Seattle District
4735 East Marginal Way South
Seattle. WA 98134

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# DOCUMENT READING TIPS

## 1. References

Cited sources and sources that provide additional information are listed in Section 7 Sources. The sources are separated by section.

## 2. “Web Viewer” User Information

### *2.1 Data Sources*

USACE Puget Sound Program (CPSP) web viewer is developed from the Corps Map, a web-based, cross-platform GIS portal. Corps Map is built using open standards interfaces and an Oracle database. Major technologies used include Oracle and Oracle Spatial for data storage, PL/SQL and JavaScript for application development, OSGEO MapServer and OpenLayers for geospatial interface, and MapFish/ext for the AJAX web 2.0 interface.

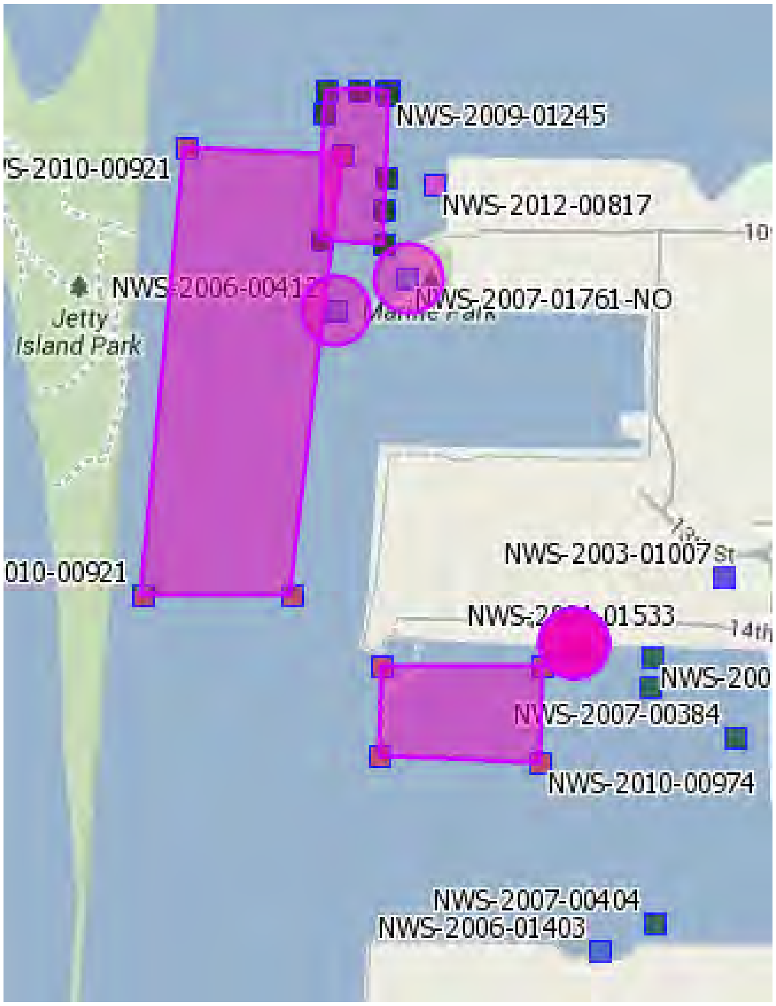
Data shown throughout the document as “USACE Regulatory Permits” originates in the national OMBIL Regulatory Module (ORM) database and Seattle District-specific data is extracted nightly into a local database. Views are created within the local database to feed the various layers in the viewer’s table of contents. No modifications are made to the underlying data.

“Fish Distribution” and “Forage Fish Spawning” data is compiled by the Washington Department of Fish and Wildlife and ”Critical Habitat” data is from the National Marine Fisheries Service. These layers are updated as the source data is changed by the providers.

“Puget Sound Nearshore Ecosystem Restoration Project” (PSNERP) data originates in the 3.0 release.

### *2.2 USACE Regulatory Permit Data*

Figures in this document showing regulatory permit data represent ORM database entries at the time of capture. Users should be aware of the following: (a) The square icons can represent one or more permit actions, however approximately 72% of the actions listed in the ORM database represent one permit; (b)the square icons do not represent completed activities, only permit applications submitted. Applications may subsequently be withdrawn and these can be identified by looking at the query results. Additionally, a set of icons may represent boundaries of a larger project. The figure below shows multiple icons representing the boundaries of one project (i.e., project area), that may appear to be four separate permit actions. Approximately 5% of actions in Washington State are represented by an area rather than a single icon. The figure also shows single icons that represent a single project.


NWS-2009-01245
S-2010-00921
NWS-2012-00817
NWS-2006-00412
NWS-2007-01761-NO
Jetty
Island Park
NWS-2003-01007
010-00921
NWS-2007-00384
NWS-2010-00974
NWS-2007-00404
NWS-2006-01403

# 1. Introduction

## 1.1. Purpose

The purpose of this cumulative effects study is to provide regulatory and natural resource agencies in the Puget Sound with more complete information regarding past trends to better inform regulatory and environmental planning decision making. Information provided herein about altered function, habitat, and resources in the study area will support future individual regulatory permit decisions. The cumulative effects assessments that occur during regulatory review disclose the relative contribution that the proposed activity will have on the overall effects to the resources within the scope of the analysis.

Therefore, the intended outcome of this report is that regulatory agencies will use the results of this study to support more informed cumulative impact assessments for their respective programs. Cumulative impact assessments are a part of USACE Regulatory program under both the NEPA and CWA regulations. While there is a focus in this report on USACE Clean Water Act (CWA) authority, any agency—local, State or Federal—that is involved in natural resource decision making in the area may find the information useful.

## 1.2. Scope

For this study, resources of concern are first broadly defined as any resources that could experience any of the cumulative impacts to "waters of the U.S" and the associated aquatic ecosystem within the study area. From a practical standpoint, this study focuses on changes to "special aquatic sites" (wetlands, mudflats, and vegetated shallows) within the study area and their associated functions and aquatic organisms that are dependent on these habitats. As the literature describes, there are a wide variety of fauna that for some portion of their life cycle utilize wetlands, mudflats, and submerged aquatic vegetation (in vegetated shallows) such as eelgrass. While this study does not evaluate all of these, there are a few indicator species as well as species that are listed under the Endangered Species Act that can provide insight about changes occurring in the aquatic environment within the study area. Regionally important species include fish such as migratory salmon (Chinook, chum, and coho, for example); marine mammals such as orca (killer whale) and harbor seals; migratory marine bird species such as scoters, goldeneye, and scaups; and several invertebrates that serve as prey resources for many of these species.

## 1.3. Study Area

The study area is focused on a portion of the Puget Sound nearshore area (Figure 1-1). It extends from Brown's Point at Commencement Bay, north of Tacoma (this was the end of the previous cumulative impact study), to Tulalip Point on the north side of the Snohomish River mouth, north of Everett. The study area includes the Duwamish River and Snohomish River estuaries (to the extent of salt water intrusion). It focuses on a narrow shoreline strip defined as 650 feet upland (landward) of the mean higher high-water (MHHW) datum and 30 feet waterward of the mean lower low-water (MLLW) datum observed over the National Tidal Datum Epoch. The 30-foot waterward portion (-30 ft MLLW) represents the approximate depth of the photic zone (Figure 1-2). The landward distance of 650 feet (+ 650 ft. MHHW) was chosen due to the quantity of information available and the large GIS database from the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) study. For environmental parameters that are watershed-focused (such as impervious surface, road density, etc.), "process units," defined as the upper watersheds that drain to specific shoreline segments, were also examined. To facilitate data analysis, the study area is separated into the following seven subsections: Subsection 1 – Federal Way, Subsection 2 – Burien/West Seattle, Subsection 3 – Elliott Bay, Subsection 4 – Duwamish Estuary, Subsection 5 – Edmonds, Subsection 6 – Everett, Subsection 7 – Snohomish.

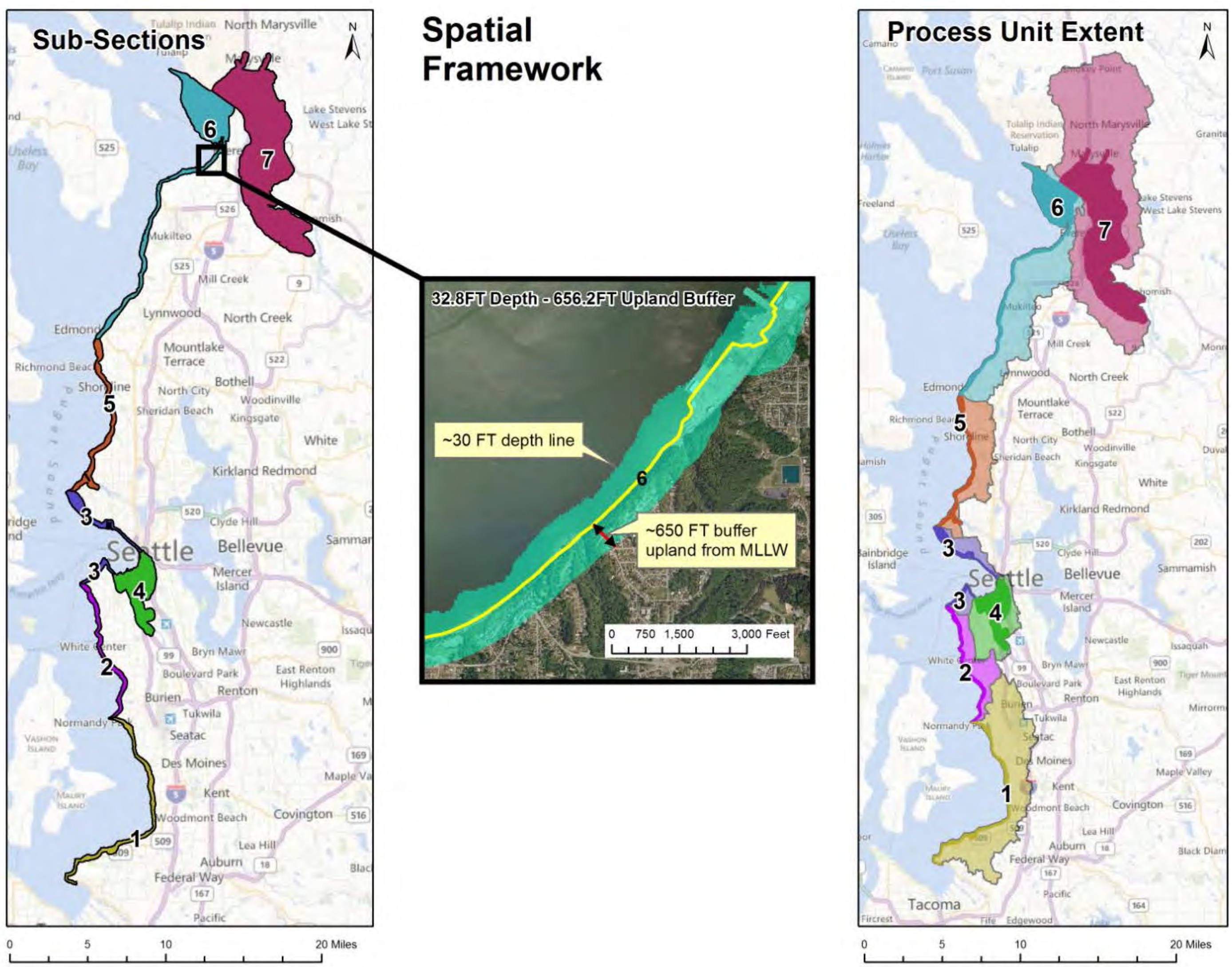



**Figure 1-1 Study area, including subsections and process units.** The map on the left shows the study area including associated subsections. The width of the study area is shown on the photo in the middle (i.e., the zone 30ft waterward of the MLLW and 650 feet landward from the MHHW). The map on the right portrays the extent of the "process" units that drain to the study area and associated subsections.

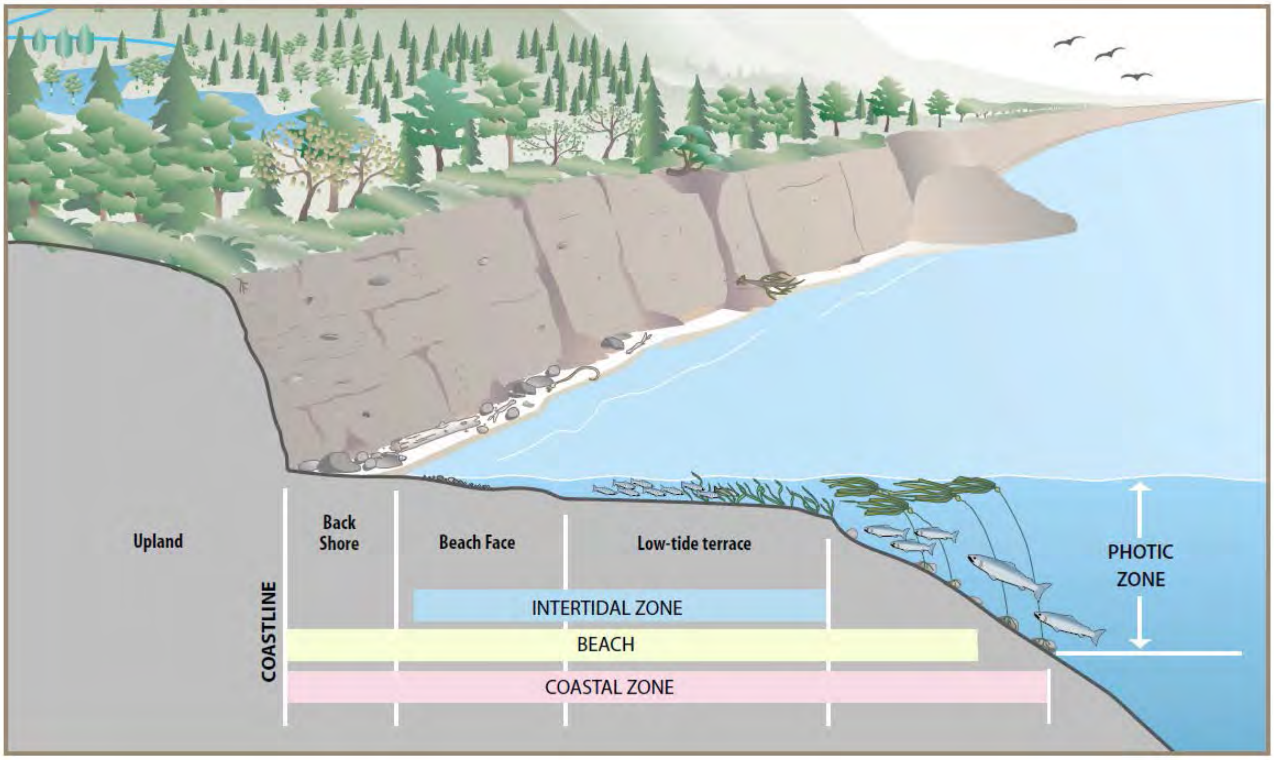



**Figure 1-2. Nearshore habitats in Puget Sound.** The study area focuses on the nearshore areas of the eastern shoreline of Central Puget Sound. This area is typified with steep bluffs and narrow, sandy beaches. Figure courtesy of King County.

## 1.4. Cumulative Effects Defined

Cumulative effects encompass both direct (primary) and indirect (secondary) effects attributable to proposed actions along with environmental effects of other past, present, and reasonably foreseeable future actions. Both direct and indirect effects of past actions, current actions, and future conditions, as predicted based on recent trends, were evaluated. A cumulative effects evaluation can be part of a 404 CWA permit action or can be the focus of a National Environmental Policy Act (NEPA) assessment. The definition of cumulative effects is different under the two different statutes but the permit evaluation process under Section 404 of the CWA must also consider NEPA.

Terminology is slightly different in CWA Section 404 and in NEPA, and their implementing regulations. In particular, the broad term under CWA Section 404 is "cumulative effects," while under NEPA the broad term is "cumulative impacts," although the NEPA regulations go on to define "effects." Following are specific definitions of cumulative effects and related terms from the regulations.

1. From the CWA Section 404(b)(1) Guidelines[1] (40 CFR 230):

   a. Primary (direct) **cumulative effects** – "*… are the changes in the aquatic ecosystem that are attributable to the collective effect of a number of individual discharges of dredged or fill material. Although the impact of a particular discharge may constitute a minor change in itself, the cumulative effect of numerous such piecemeal changes can result in a major impairment of the water resources and interfere with the productivity and water quality of the existing ecosystem.*" (40 CFR 230.11(g)(1)

      *The regulation goes on to explain, "Cumulative effects attributable to the discharge of dredged or fill material in waters of the United States should be predicted to the extent reasonable and practical. The permitting authority shall collect information and solicit information from other sources about cumulative impacts on the aquatic ecosystem. This information shall be documented and considered during the decision making process concerning the evaluation of individual permit applications, the issuance of a General permit, and the monitoring and enforcement of existing permits."* (40 CFR 230.11(g)(2))*"*

   b. Secondary (indirect) **cumulative effects** – "*… effects on an aquatic ecosystem that are associated with a discharge of dredged or fill materials, but do not result from the actual placement of dredged or fill material.*" (40 CFR 230.11(h)(1))

      "*Some examples of secondary effects on an aquatic ecosystem are fluctuating water levels in an impoundment and downstream associated with the operation of a dam, septic tank leaching and surface runoff from residential or commercial developments on fill, and leachate and runoff from a sanitary landfill located in waters of the U.S. Activities to be conducted on fast land created by the discharge of dredged or fill material in waters of the United States may have secondary impacts within those waters which should be considered in evaluating the impact of creating those fast lands.*" (40 CFR 230.11(h)(2))

   c. **Aquatic ecosystem** – "*… waters of the United States, including wetlands, that serve as habitat for interrelated and interacting communities and populations of plants and animals.*" (40 CFR 230.3(c))

2. From NEPA implementing regulations (40 CFR 1508):

   *a.* *"**Cumulative impact**" is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."* (40 CFR 1508.7)

   b. *"**Direct effects** … are caused by the action and occur at the same time and place."* (40 CFR1508.8(a))

   c. ***"Indirect or secondary effects** … are caused by the action and are later in time or farther removed* in *distance, but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems."* (40 CFR1508.8(b))

[1] Although officially titled "Guidelines," these regulations are binding in the same way as other implementing regulations including the Council on Environmental Quality regulations for implementing NEPA.

3. From the CWA Section 404(b)(1) Guidelines :
    a. **Special aquatic sites** – *"…geographic areas, large or small possessing special ecological characteristics of productivity, habitat, wildlife protection, or other important and easily disrupted ecological values. These areas are generally recognized as significantly influencing or positively contributing to the general overall environmental health or vitality of the entire ecosystem of a region."* (40 CFR 230.3(q-1))

The Section 230.10(a)(3) goes on to say,

> *"Where the activity associated with a discharge which is proposed for a special aquatic site (as defined in subpart E) does not require access or proximity to or siting within the special aquatic site in question to fulfill its basic purpose (i.e., is not "water dependent"), practicable alternatives that do not involve special aquatic sites are presumed to be available, unless clearly demonstrated otherwise. In addition, where a discharge is proposed for a special aquatic site, all practicable alternatives to the proposed discharge which do not involve a discharge into a special aquatic site are presumed to have less adverse impact on the aquatic ecosystem, unless clearly demonstrated otherwise."*

As noted above, the definitions of cumulative effects differ under CWA and NEPA regulations. The NEPA interpretation focuses on evaluating historical changes within the environment and the CWA definition emphasizes dredging and filling aspects. For this study we will evaluate cumulative impacts using both definitions. It is important to be cognizant and inclusive of both approaches since NEPA is one of the regulations that must be considered when evaluating and approving Federal actions.

## 1.5. Analysis Approach

This study is similar to the Commencement Bay Cumulative Impact study completed in 1991. The current study area extends from Brown's Point to Tulalip Point and includes the Duwamish River and Snohomish River estuaries. The study summarizes the historical landscape and changes that occurred to create the present day existing condition. Major changes in the study area are documented, followed by a description in of the response of various study area resources to existing stressors.

This study relies on relevant peer-reviewed literature for background information about Puget Sound and the study area as well as several specific data evaluations initiated previously and completed as part of this study. These include analysis of data for (1) the diversity and abundance of Puget Sound marine birds (Subsection 4.3), (2) road density (including impervious surface and fragmentation analysis) in the study area (Subsection 3.4), and (3) USACE regulatory permits in the study area, Puget Sound, and Washington State (Section 5).

Section 1 introduces the study area and describes the purpose and scope of this study. Section 2 describes the existing conditions of the study area by individual subsection. Section 0 describes the major changes to different environments in the study area. Section 4 describes resources affected in the study area. Section 5 summarizes the evaluation of Regulatory permits for the study area and discusses other aspects of the Regulatory program. Section 0 summarizes the impacts to study resources and characterizes identified trends.

### *1.5.1. Weight of Evidence*

Similar to the Commencement Bay study, this study uses a "weight of evidence: approach. The weight of evidence approach is described by Linkov et al. (2009):

*"Developing individual lines of evidence from available data to address a specific question requires describing the degree to which those lines of evidence support a specific conclusion or alternative conclusions. Weight of evidence (WOE) can be defined as a framework for synthesizing individual lines of evidence, using methods that are either qualitative (examining distinguishing attributes) or quantitative (measuring aspects in terms of magnitude) to develop conclusions regarding questions concerned with the degree of impairment or risk. In general, qualitative methods include presentation of individual lines of evidence without an attempt at integration, or integration through a standardized evaluation of individual lines of evidence based on qualitative considerations."*

The weight of evidence approach involves a narrative process in which individual lines of evidence (e.g., scientific understanding of environmental parameters) such as wetland quantity, wetland quality, and their effects on fish and wildlife resources are considered in combination to evaluate environmental impact. This study did not assign different ranks or weights to individual attributes but treated each line of evidence as equal.

### *1.5.2. Thresholds of Concern*

Thresholds of concern are established for some activities that could result in a significant effect; sometimes these thresholds are referred to as "triggers." Most of the triggers discussed in the main text of this report have been identified from the literature. Triggers are specific to certain types of activities and once these levels are exceeded an impact to the environment is assumed based on impacts demonstrated in similar conditions. A trigger (threshold of concern) is specific to the type of impact. For instance, a common threshold of concern for impervious surface is 10% coverage; i.e., 10% of all surface within the watershed covered with some type of impervious surface. Literature suggests that once this level has been exceeded there are demonstrable impacts to the aquatic environment (Booth, D.B. and Jackson, C.R. 2007).

### *1.5.3. Impact Assessment*

Diffenderfer (2012) describes the distinction and the overlap between the impact analyses required under NEPA, CWA, and ESA: "Because the goals of the cumulative and secondary/indirect impact analyses under each statute [CWA and NEPA] are distinct, when applied they can lead to quite different results. The NEPA analysis is the broadest; CWA concerns the effects caused by construction of a project. Today there are few cases that draw distinctions between the impact analysis under the CWA versus the NEPA and ESA [Endangered Species Act] statutes. Courts seem to blend the impact analysis under NEPA with that of CWA, which is understandable given that full consideration is required by the 404(b)(1) guidelines and USACE of Engineers public interest review under CWA."

The terms "effects" and "impacts" are used interchangeably in this study. Effects can be ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health-related, whether direct, indirect, or cumulative. Effects of actions can be beneficial or detrimental.

This study is not focused on any particular project but instead evaluates whether thresholds of concern for cumulative effects within the study area has been exceeded.

While the term cumulative effects has been defined it is also important to identify how cumulative effects occur. Beanlands et al. (1986) summarized five ways in which effects could accumulate:

1. Time-crowded perturbations. Disturbances that occur sufficiently close in time that the system does not recover during the time in between.
2. Space-crowded disturbances. Disturbances that overlap in space such that their effects are not dissipated in the distance between locations. These can also overlap in time.
3. Synergism. The interactions of different types of disturbances produce effects qualitatively and quantitatively different from the individual disturbances.
4. Indirect effects. Disturbances initiate a chain of events that produce effects delayed in time or space from the original disturbance.
5. Nibbling. Disturbances produce effects by small changes, i.e., incremental or decremental effects.

Ultimately, the aggregate influence on the total resource must be considered.

The approach developed for this cumulative impact study uses a hybrid framework as noted by Diffendorfer 2012, which uses the 404(b)(1) Guidelines with inclusion of Council of Environmental Quality (CEQ) guidance from a NEPA perspective. It is also important that spatial scale at which the impacts occur and spatial scale at which cumulative effects are realized are incorporated.

The CEQ principles of cumulative effects analysis are:

1. Cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions.
2. Cumulative effects are the total effect and include both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken no matter who has taken the actions.
3. Cumulative effects need to be analyzed in terms of specific resources, ecosystem, and human community being affected.
4. It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful.
5. Cumulative effects on a given resource, ecosystem, and human community are rarely aligned with political or administrative boundaries.
6. Cumulative effects may result from the accumulation of similar effects or the synergistic interaction of different effects.
7. Cumulative effects may last for many years beyond the life of the action that caused the effects.

8. Each affected resource, ecosystem, and human community must be analyzed in terms of its capacity to accommodate additional effects, based on its own time and space parameters.

### 1.5.4. Trend Analysis

Similar to the approach used for the 1999 Commencement Bay study, this study employs the trend analysis and overlay mapping/GIS methods suggested by CEQ (1997) for cumulative effects evaluation.

Trends analysis includes where possible, the status of resources, ecosystems, and human communities over time and results in the projection of past and/or future conditions. For this study an effort was made to obtain historic information from original surveys. Historic aerial photos were also used in the evaluation. An emphasis was made to obtain long-term data sets where possible to identify changes over several decades.

Overlay mapping and GIS methods incorporate location information into cumulative effects analysis. Overlay mapping directly evaluates cumulative effects by identifying areas where effects are greatest. Mapping and GIS will also facilitate incorporating landscape features such as connectivity, fragmentation, and land cover.

This cumulative effects study has also been assisted by incorporating existing ecological information into the analysis. Several previous studies on historical wetland changes, fisheries, water quality, and geomorphology have occurred in the same area as this study. Where possible the results of these studies have been included. Of particular benefit to this evaluation was the extensive GIS and environmental analysis that was conducted under the Puget Sound Nearshore Ecosystem Restoration Project general investigation study that is a multiagency effort coordinated by the Seattle District USACE and Washington Department of Fish and Wildlife.

# 2. Study Area Existing Conditions

Historical condition descriptions within each subsection provide the context and timeframe in which the study area was developed and resources were impacted.

Existing conditions are described by subsection below as shown in Figure 1-1. Conditions common to the entire study area are described first, with information unique to subsections following. Conditions common to the entire study area include weather, air and water quality, some stressors and harvest restrictions, most terrestrial and marine wildlife, endangered species, and flora. Unique conditions described for each subsection include historical development, land classification and modification, water quality, physical setting, significant or special aquatic sites, fisheries, wildlife and vegetation, stressors and disturbances, public lands, manmade features, restoration activities, other relevant activities and the WDFW Marine Shoreline Habitat Assessment.

## 2.1. Conditions Common to the Entire Study Area

The Puget Sound Region is an inland area of the Pacific Northwest that lies west of the Cascade Range and east of the Olympic Mountains. It is part of a larger physiographic structure designated as the Puget Sound Trough. Dominant winds are from the south and southwest from October through March shifting to the north in July and August. The study area is somewhat protected with limited fetch restricting wave height, which is typically between1 to 2 ft with the exception of winter storms. In 2010, air quality in Puget Sound was generally good but dipped to moderate for about 10% of the year with brief periods of 'unhealthy for sensitive groups.' In addition, winter inversions can decrease air quality. In 2010, two mandatory burn bans occurred in late December and early January for 4 days each (PSCAA 2012).

The study area does not experience the stronger ocean influence that the northern Puget Sound does from the Strait of Juan de Fuca. Winds are relatively light and are frequently from the north and northwest during the summer. During the winter, a relatively stationary low-pressure region often develops in the Aleutian Islands, regularly sending Pacific storms through British Columbia and Puget Sound. This pattern is responsible for the cloudy, rainy winters for which Puget Sound is noted. Winds are generally from the southwest in inclement weather and from northwest during fair weather, but are strongly influenced by local terrain. While microclimate conditions may apply within the study area they do not significantly influence data analysis and are not discusses further.

The annual average temperature range in the study area is approximately 44.8-59.8 degrees Fahrenheit (ºF). The area experiences a winter temperature range of approximately 35.9-50.2ºF and a summer temperature range of 64.4-75.6 ºF, with lower average temperatures occurring farther north. Total precipitation in the study area averages approximately 37 inches annually. Precipitation occurs mostly during the winter and relatively infrequently during the summer (NOAA data from 1971-2000).

For several decades sea level rise in Puget Sound has been recorded with an increasing rate shown in recent years. Sea level is expected to rise over the next fifty years by approximately 6 inches (Mote et al. 2008).

The major source of sediment into Puget Sound is coastal bluff erosion. However, in the study area much coastal bluff erosion does not reach the shoreline due to roads, railroads, waterfront homes, bluff development, and other human interference. Johannessen and MacLennan (2007) states:

*"The cumulative impact of human modifications conditions to the shoreline (currently one-third of Puget Sound's shoreline has been armored) may be far-reaching in terms of both habitat and existing human activities, particularly in the face of anticipated increases in the rate of sea level rise."*

A variety of mammal and bird species are common throughout the study area. Red-tailed hawks, eagles, osprey, and other raptors nest and roost along coastal bluffs and inland areas. Small songbirds such as pine siskins, chickadees, song sparrow, hooded Oregon junco, swallows, house finch and warblers (Wilson's and yellow rumped) inhabit the upland hillsides and wooded bluffs. The occasional western sandpiper and dunlin can be found on beaches during migration. Marine birds typical of this area include black brant, goldeneye, harlequin duck, scoter, mergansers, buffleheads, goldeneye, marbled murrelet, and rhinocerous auklet. With the exception of black brant (which prefer eelgrass and algae), many of these birds feed primarily on crustaceans, mollusks, and small fish. Common alcids on the shoreline include the common murre and pigeon guillemot. Dabbling ducks, geese, and gulls are commonly found. Pisciverous birds such as cormorants, grebes, loons, and great blue herons are found in the area. Some of these species are protected under the Neotropical Bird Conservation Act, Migratory Bird Treaty Act and/or the Bald and Golden Eagle Protection Act.

Bird diversity in the study area is greater during the winter. Of the birds present in the summer season most are year round residents. Of the resident birds, most have the ability to nest close to areas frequently disturbed and heavily altered by human activities. Total bird densities measured during the summer season range from 45 to 125 individuals per square mile with the highest densities being found off shore (Nysewander et al. 2005).

Mammals in the study area consist of coyotes, foxes, voles, rabbits, field mice, moles, rats and other small mammals. Furbearers such as raccoon, otter, mink, and opossum, feed, mate and take refuge along the shorelines and nearshore hillsides. Deer are also known to frequent much of the area. Additional information on wildlife in the study area can be found on the Washington Department of Fish and Wildlife (WDFW) Priority Habitats and Species databases which contain information on important fish and wildlife species to be considered in land use planning.

Marine mammals that occasionally haul out on some of the beaches include harbor seals and California sea lions. Orca, gray, minke and pilot whales as well as Dalls porpoise are occasionally spotted in deeper waters. All marine mammals are provided some protection under the National Atmospheric and Oceanic Agency's Marine Mammal Protection Act and the Endangered Species Act.

Harbor seal and California sea lion are common and occur in the nearshore around various piers and other structures (Gretchen and Calambokidis1986; Osborne et al. 1999).

The intertidal area provides habitat for a variety of invertebrates and shellfish important to both humans and wildlife. These include clams, crabs, the occasional little red octopus, mysids and other shrimp-like species, amphipods, copepods, snails, polychaetes, and nematodes (Dethier 2006).

Invertebrates that are present in this subsection include various species of cnidarians (anemones), poriferans (sponges), mollusks (gastropods), anthropods (crustaceans), echinoderms (starfish and allies), and terrestrial insects, which are often an important prey item for juvenile salmonids.

Zooplankton is an extremely diverse group of animals that include the larval stage of dozens of marine and estuarine phyla. In Puget Sound copepods dominate the zooplankton composition, while amphipods, mysids, various species of fish larvae, and euphausiids are all in abundance (Toft and Cordell 2006). Many of these species are prey resources for listed juvenile salmon species such as Chinook.

Many marine fishes use the nearshore for feeding and migration. For example, shiner perch, flatfishes (sole and flounder), and sculpins use shallow water for feeding and protection from predators.  Forage fish including pacific herring, sand lance and surf smelt are typically found in large schools and are foraged upon by larger predatory fish such as salmon and trout.  All three of these species actively spawn on beaches within the study area depending upon physical parameters such as temperature, grain size, tidal heights and vegetation. While spawning can occur year round it is most common between the months of October and April.

Of particular importance, are the salmonids.  Figure 2-1 shows distribution of Bull Trout and Chinook critical habitat in the study area. The line for Bull trout critical habitat is in orange and in blue for Chinook.

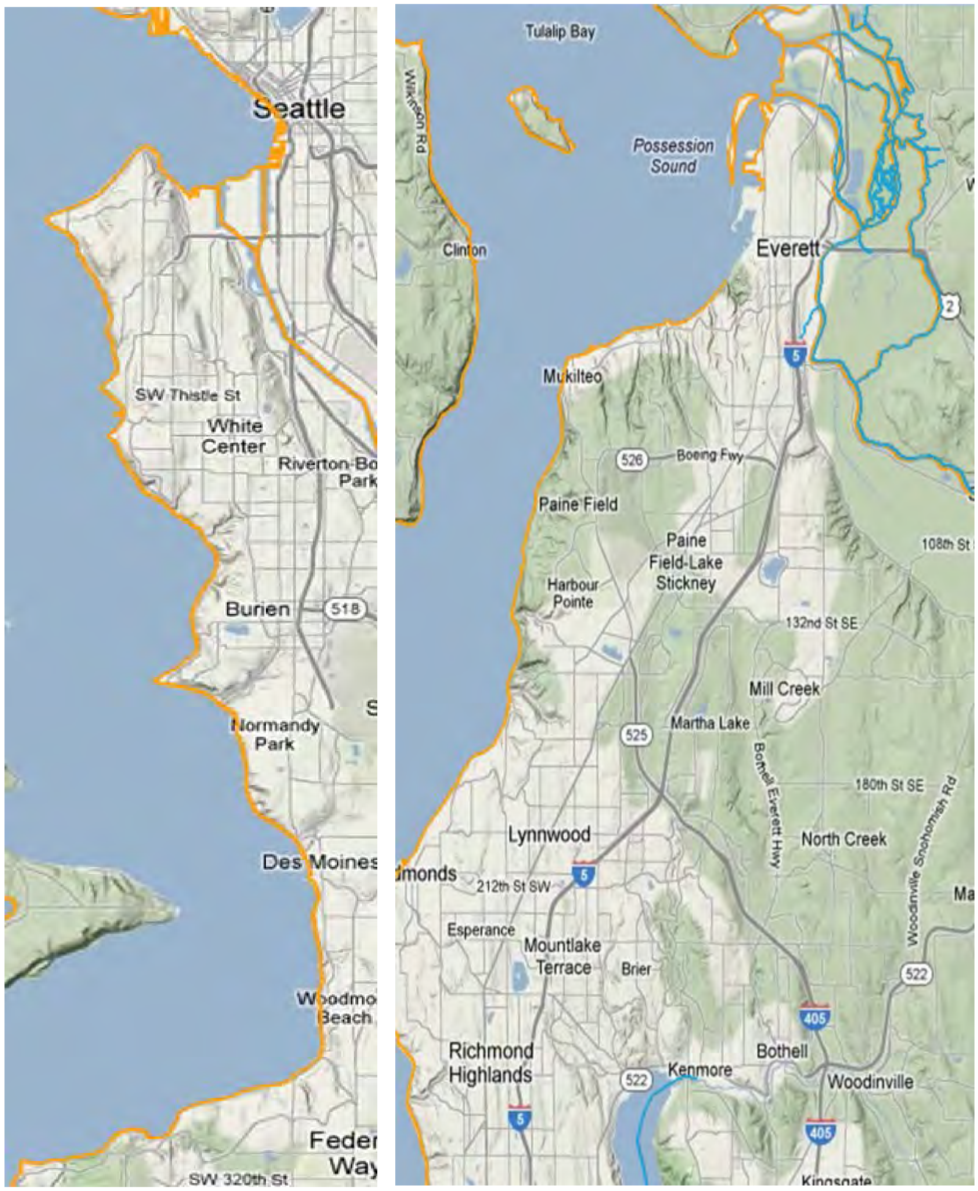



**Figure 2-1 Critical habitat in the study area. Critical habitat for Bull trout is in orange and in blue for Chinook.**

A wide variety of juvenile salmonids can be found in the nearshore study area. Between February and July, juvenile anadromous salmon out-migrate from their native streams and move into the nearshore area in search of food and refuge. The closest major sources of salmon out migrants to the study area are the Puyallup, Duwamish and Snohomish Rivers. These river systems, along with small creeks along the shoreline, provide a consistent source of juvenile salmon to the study area. Salmon migrants are predominantly Chinook, pinks, chum, coho, and sea-run cutthroat trout. Adult Chum, sockeye, pinks, steelhead, and bull trout also pass through the study area in much deeper water on their return to spawn. (Brennan et al. 2004) Table 2-1 lists the endangered species in the study area and by subsection.

**Table 2-1 Endangered Species and Critical Habitat status. Subsection 1 – Federal Way, Subsection 2 – Burien/West Seattle, Subsection 3 – Elliott Bay, Subsection 4 – Duwamish Estuary, Subsection 5 – Edmonds, Subsection 6 – Everett, Subsection 7 – Snohomish Estuary.**

| Listed species | ESA Status | Designated Critical Habitat | Subsection |
|---|---|---|---|
| Chinook salmon (Onchorhynchus tshawytscha) | Threatened | Yes- Natal Streams and Rivers | All |
| Bull trout (Salvelinus confluentus) | Threatened | Yes- Near shore area of most of Puget Sound (Critical habitat exists along the shorelines of entire study area. See Figure 2-1) | All |
| Puget Sound Steelhead (Onchorhynchus mykiss) | Threatened | No | All |
| Puget Sound Southern Killer Whale (Orcinus orca) | Endangered | Yes- Most of Puget Sound | All except, Subsection 4 – Duwamish Estuary and Subsection 7 – Snohomish Estuary |
| Marbled Murrelet (Branchyramphus mamoratus) | Threatened | No- Occasionally found offshore | |
| Bocaccio (Sebastes paucispinis) | Endangered | No | All except, Subsection 4 – Duwamish Estuary and Subsection 7 – Snohomish Estuary |
| Canary Rockfish (Sebastes pinniger) | Threatened | No | All except, Subsection 4 – Duwamish Estuary and Subsection 7 – Snohomish Estuary |
| Yelloweye Rockfish Sebastes ruberrimus | Threatened | No | All except, Subsection 4 – Duwamish Estuary and Subsection 7 – Snohomish Estuary |

Tree species in the study area include big leaf maple, black cottonwood, Douglas fir, grand fir, willow, Pacific dogwood, red alder, shore pine, Sitka spruce, western hemlock, western red cedar and madrone. Typical native shrubs include Indian plum, Oregon grape, nootka rose, oceanspray, rhododendron, snowberry and twinberry. Native vegetative ground cover includes; bleeding heart, sword fern, bracken fern, foam flower, fringecup, and kinnikinnik. Immediately adjacent to the shoreline beach strawberry, gumweed, Oregon iris, seaside plantain and Douglas aster are found. Typical ground cover species in more disturbed areas include blackberry, butterfly bush, scotch broom, Canadian thistle, bull thistle, fireweed, pearly everlasting, english plantain, stinging nettle, prickly lettuce, tansy, dog fennel and cow-parsnip.

### *2.1.1. Stressors and Impacts upon the Study Area*

Urban development is the major stressor impacting the study area. Major effects of urban development include degraded water quality, sediment process disruption, toxic input, and loss or fragmentation of habitat. The Washington State Department of Health advises against any shellfish harvest on any beach on the eastern shores of Puget Sound between Everett and Tacoma due to public health concerns related to biotoxins (red tide blooms) and pollution (mainly fecal coliform).

## 2.2. Shoreline Conditions in the Study area

The Washington Depatment of Fish and Wildlife (WDFW) (Wilhere et al. 2012) recently developed a habitat assessment for the Puget Sound Partnership's Watershed Characterization Project. Of the three habitats assessed, marine shorelines provided the most comprehensive and accurate data for fish, wildlife and habitats. Two assumptions were made in this assessment:

1. The belief that the relative value of shorelines for the conservation of fish and wildlife habitat is predominantly a function of the presence of the species and habitats for which we collect occurrence data. Data was collected for species and habitats most significant, so that the results will indicate which locations we should me most concerned about for the conservation of fish and wildlife habitats.
2. The relative value of a place for the conservation of fish and wildlife habitats can be accurately quantified, and that relative value can be expressed through a single comprehensive number, an index.

   The main product of the assessment was a quantitative index that indicates the relative value of shorelines for fish and wildlife habitat conservation. For this analysis the shoreline was separated into smaller spatial units by intersecting shoreform and shorezone classification systems to produce a shoreline composed of 10,178 segments. Boundaries between segments correspond to mapped changes in shoreform, morphology, or substrate, all of which significantly influence plant, fish, and wildlife habitats. To include the most data, the shoreline was buffered approximately ¼ mile in the landward direction and approximately ¼ mi or to extreme low tide, whichever was farther, in the seaward direction (Wilhere et al. 2012). One-quarter mile was chosen as the buffer width because it was believed to best represent the area affected by shoreline development.

   Two indices were used that summarize data on the occurrence or abundance of 41 species: species groups and habitat types. The indices are used to show the relative value of marine shoreline segments based on habitat function. Higher scores indicate shoreline segments with relatively more habitat functions than segments with lower scores. The composite index is the sum of the 41 species; hence, it mainly reflects the quantity of habitat functions at shoreline segments (Wilhere et al. 2012). In general, shoreline segments with many habitat functions obtain the highest scores for the composite index; however, the composite index alone misrepresents segments with a small number of habitat functions, but high relative value. The high relative value is important but not represented by the number of habitat functions. Therefore, a top-5 index was created to provide that information and should be used in conjunction with the composite index. Within each subsection below, both the composite index and the top 5 have been included. In addition, pie charts were created to show the same information as the maps in order to better compare indices among subsections. The Marine Shoreline Habitats Assessment as well as index data for the seven subsections in the study area can be found in Appendix A.

Review of the index scores showed a repeated pattern of shorelines along developed urban areas tending to have low scores and shorelines along less developed areas known to have high ecological value with high scores. There were two noted exceptions to this pattern, the mouths of the Puyallup and Duwamish Rivers (which is part of this study area). These river mouths are heavily degraded but the presence of salmon species resulted in these shorelines having high relative value. Scores for the composite and top-5 indices were highly correlated, ρ=0.81, but there were obvious differences between the two.

Lastly, land use and land modification was classified and evaluated as described in 3.4Urbanization to show changes in land use over time. Specific subsections contain a tabulation of land classification and percent cover, and the type and percent of modification.

### *2.2.1. Subsection 1 – Federal Way*

Subsection 1 – Federal Way starts at Brown's Point and ends at Three Tree Point (Figure 1-1) with a total land area of 2,564 acres. It includes the city of Federal Way, the City of Des Moines and a portion of Normandy Park. Landscape features that occur in this section include; Joe's Creek, Lakota Creek, Dumas Bay, Des Moines Creek, Miller Creek and Walker Creek. Aerial photographs from 1977 and 2006 near Dumas Bay do not indicate large scale changes in shoreline development (Figure 2-2 and Figure 2-3).


**Figure 2-2 Air photo from 1977 near Dumas Bay. Courtesy of Washington Department of Ecology**


**Figure 2-3 Federal way shoreline near 30th Avenue Southwest in 2006 near Dumas Bay. Courtesy of Washington Department of Ecology.**

## Brief History of Federal Way

The area that is now Federal Way had many explorers and settlers travel through before a small trading post was established in 1840 along a trail going north and south. By 1860 this road had been extended and improved for military use so that it spanned from Pierce County north to Seattle. The first homestead was established in 1871 and Poverty Bay was named. Additional settlers arrived and the first school was opened in 1880. During this time, commercial developments were scarce, with only a few sawmills around the lakes in the area. It was not until 1904 that the first actual store opened in Federal Way.

In 1906, the city developed a plan to become a recreational destination. About 10 years later a bowling alley, dance hall, and skating rink were built. The hopes of becoming a recreational area were diminishing when news came of a potential highway that would travel the entire western coast of the United States. Construction of Highway 99 began in 1915 and the section between Seattle and Tacoma was opened in 1928. However, the depression of the 1930’s and World War II hindered development aside from a few gas stations.

By the 1950’s, tourists and travelers from outside Washington began to drive through Federal Way on Highway 99. This stimulated restaurant growth as well as making possible the feasibility of the Federal Shopping Way Mall and amusement park in 1955. A section of I-5 opened a mile east of Highway 99 bringing more development including houses and schools. In 1968 the Weyerhaeuser Corporation, one of the largest producers of pulp and paper, chose Federal Way as the location of its headquarters and began construction.

In 1975 and 1976, two more shopping centers opened. By the end of the 1980’s the Federal Way population had grown considerably with the addition of condominium complexes, businesses, and a water park. Attempts were made in 1971, 1981, and 1985 to incorporate as a city, but were overwhelmingly voted down. Finally in 1990, incorporation was approved by voters and Federal Way became Washington's sixth largest city with a population of 67,554. By 2010, the population had risen to 89,306.

## Brief History of Des Moines

The city of Des Moines is located midway between Seattle and Tacoma and has been settled since 1867. Shingle and lumber mills were the first commerce to develop in town and shortly thereafter a wharf was built. While its location between two major cities attracted entrepreneurs, it was not until near 1890 that more substantial development took place.

In 1890, Des Moines boasted hotels, a chair and tin factory, a boat yard, a school, and churches. When an economic downturn occurred in 1893 the town lost a quarter of its population, going from 216 in 1890 to 162 in 1900. A small economic upturn raised the population to 357 by 1906 and by 1920 the number of residents had risen to 751.

After 1910, the roads in Des Moines were gravel and brick, allowing for better transportation. A car ferry made trips between the towns of Portage and Des Moines starting 1916, but stopped in 1921. By 1920, improved roads and the interurban Seattle-Tacoma light-rail ran past Des Moines five miles to the east provided the ability to drive through Des Moines. In 1930, the number of residents rose to almost 2,000 as visitors decided to move to Des Moines for its lower cost and location. Commerce rose in the 1930's as the construction of Highway 99 completed the connection between the two bigger cities. New businesses catering to drivers such as hotels, eateries, and service stations opened. The new transportation network also connected small berry growers and chicken farms in Des Moines to markets in Tacoma and Seattle.

Des Moines incorporated in 1959, giving residents more ability to determine the future of their city as the population increased after World War II. In 1961 the first community college in King County, Highline Community College, opened in Des Moines. The Des Moines Marina opened in 1970 with wet and dry moorage for 838 small vessels. In 1980, a 670 foot fishing pier was built on the north end of the marina. In 1990, Des Moines had approximately 17,283 residents and by 2000 it had 29,409, only a few hundred less than what it is today in 2011.

## Land Classification and Modifications

Table 2-2 and Table 2-3 show the tabulated land classification and percent cover, and the type and percent of modifications in Subsection 1 – Federal Way.

**Table 2-2 Land classification and percent cover for Subsection 1 – Federal Way.**

| Land Classification | Percent Cover |
|---|---|
| Barren/open space | 20% |
| Developed (high, medium, low intensity) | 26% |
| Open water | 24% |
| Herbaceous | 1% |
| Shrub/scrub | 0.2% |
| Wetland (herbaceous and woody) | 14% |

| | |
|---|---|
| Forested (deciduous, evergreen, mixed) | 11% |

**Table 2-3 Type and percent of modifications in Subsection 1 – Federal Way.**

| Modification | Percent cover in the sub area |
|---|---|
| Marinas | 3% |
| Percent of area occupied by railroad | 0% |
| Impervious surface- 0 to 10% | 70% (70% of the area has 10% or less impervious surface) |
| Impervious surface- 10 to 30% | 10% |
| Impervious surface- 30to 50% | 9 % |
| Impervious surface- 50 to 100% | 9% |
| Shoreline armoring | 70% of the area has shoreline armor |
| Overwater structures | 2% |

## Water Quality

There are several active municipal and industrial wastewater discharge permits in the area, including permits for the Federal Way wastewater treatment facility, Weyerhaeuser Technology Center, and Des Moines sewer district. There are three water bodies classified as Category 5 in Subsection 1 – Federal Way; two classified for the presence of PCBs and one for fecal coliform. Category 5 classified water bodies are polluted waters that require a Total Maximum Daily Load (TMDL). Placement in this category means that Ecology has data showing that the water quality standards have been violated for one or more pollutants, and there is no TMDL or pollution control plan.

## Physical Setting

Much of the shoreline within Subsection 1 – Federal Way includes bluff-backed beach and barrier beach. Some of the bluff-backed beaches are slopes ≥ 25% that present landslide hazards. There are approximately 16 miles of shoreline in Subsection 1 – Federal Way, which includes six drift cells and one region of negligible drift as shown in Table 2-4.

**Table 2-4 Drift Cells within the study area Data Source: Johannessen et al. 2005**

| Drift Cell Name[a] | Length (miles)[b] | Percent of the drift cell modified (current)[c] | Historic Change | Notes |
|---|---|---|---|---|
| KI-7-3 (starts north of Des Moines Ck. | 4.5 | 40.3% | Reduced sediment supply by 65% | |
| KI-8-2 Des Moines Ck. | 0.2 | 68% | 100% loss of sediment sources | Long riprap revetment, wave shadow effect from Des Moines Marina |
| KI-8-2/8-3 NAD | 0.5 | 100% | 100% loss of accretion shoreform | Long breakwater at marina precludes nearshore drift |
| KI-8-3 south of Des Moines | 2.1 | 55% | 63% loss of sediment source | Suburban residential development atop bluffs |
| KI-9-2 south of Saltwater Park | 4.8 | 59% | 45% loss of sediment source | |
| KI-10-2 mainly Dumas Bay | 0.3 | 4% | 0% loss | |
| KI10-3 terminates at Dash Point | 0.5 | 27% | 30% loss of sediment source | |

a. Data source: Johannessen et al. 2005, Table 7

b. Data source: Johannessen et al. 2005, Table 8, Conversion unit 1 mile=5280ft

c. Data source: Johannessen et al. 2005, Table 8, MOD=Percent of drift cell modified (current)

## Significant or Special Aquatic Sites

There are a few wetlands within Subsection 1 – Federal Way. Most of these are smaller than 10 acres and adjacent to the shoreline. There are a few larger wetlands that appear on the National Wetlands Inventory (NWI) including a 7.5 acre wetland (PEM/SSF) at Dumas Bay, a mudflat with associated eelgrass at the mouth of Des Moines creek, a 4 acre PEM/SSF wetland on the shoreline north Marine View Park (west of 200th and 509), and a 5.1 acre PEM/PFOC at the Normandy Park Community club just north of Normandy Terrace SW and just south of Sylvester SW in Normandy park on Walker Creek (Cowardin 1979). Eelgrass has been identified throughout the entire shoreline of the subsection (Figure 3-13). In some areas such as Dumas Bay there are thick robust beds of eelgrass while other parts of the shoreline within this subsection include thin patchy eelgrass near the low tide line.

## Fisheries, Wildlife and Vegetation

Coho and cutthroats are the most likely spawners in the smaller streams of the study area such as Joe's Creek, Des Moines Creek, Miller Creek and Walker Creek. Coho salmon usually return within the months of October and November to their natal streams and complete spawning by January. Cutthroat trout would typically spawn in late winter to early spring. Chum salmon spawn in some of the creeks in this subsection such as Miller and Walker creek. Many of the streams in this subsection display the effects of poor water quality probably from runoff from nearby neighborhoods. Creeks such as Des Moines (63% mortality), Miller (23% mortality) and Walker creeks have a significant incidence of measured prespawn mortality (Scholz et al. 2011).

Much of the shoreline and bluff tops are in urban residential neighborhoods dominated by horticultural plants and expansive lawns. However, native species can be found on undisturbed nearshore and bluffs and cliffs. Just above the tide line, American dune grass and gumweed are commonly foundbeach pea and sea rocket can be found further up the shoreline. On bluffs and cliffs away from the spray zone, Douglas fir, big leaf maple, western hemlock and madrone exist.

## Stressors/ Disturbances

Stressors and disturbances in Subsection 1 – Federal Way include changes to sediment dynamics from dredging bulkheads, landslides, marinas, altered water chemistry, surface water runoff, altered hydrology, alteration to bluffs, altered habitat from filling, dredging, bankline armoring, riparian vegetation removal. Much of the shoreline in this subsection has been hardened. The Des Moines Marina requires regular dredging and maintenance. In 2007, 9,000 cy of material was dredged from the marina (permit # NWS-2007-01762N0) and in 2008 a timber bulkhead and other repairs were made at the marina.

Washington State Department of Ecology prepared a shoreline inventory and characterization report for the City of Federal Way that discussed the conditions of the shoreline resources. They describe some of the shore modifications they observed in the following statement (WADOE 2007).

*"It appears that filling has taken place at several locations in Federal Way. The most obvious are at the estuaries in Dumas Bay and Dash Point State Park. The marsh in western Dumas Bay was historically considerably larger, but appears to have been reduced in size for residential development. The estuary in Dash Point State Park also appears to have been filled and channelized, possibly to reduce flooding and facilitate parking and recreational areas. Backfilling of bulkheaded shoreline appears to have occurred near Adelaide, where a historic accretion shoreform previously occurred, and at the base of bluffs east of Dash Point State Park"*

## Public Lands

Public lands Subsection 1 – Federal Way include Marine View Park and Normandy Beach Park in Normandy Park, Saltwater State Park in Des Moines, and Redondo Beach, Dash Point Park and Dumas Bay in Federal Way.

## Manmade Features

Man made features within the shoreline in Subsection 1 – Federal Way include large piers at Dash Point and Redondo Beach; a large marina in Des Moines; a seawall at Redondo beach, and; bankline hardening in Dumas Bay. Restoration activities in the subsection have been focused around public areas such as Saltwater State Park in Des Moines and Des Moines Creek, which, is adjacent to the Marina.

## Restoration Activities

Table 2-5 shows the location and type of activity for restoration projects in Subsection 1 – Federal Way.

**Table 2-5 Habitat restoration in Subsection 1 – Federal Way**

| Location | Type of activity |
|---|---|
| Salt Water State Park | Rock fill for bull kelp |
| Saltwater State Park | unknown |
| Des Moines | unknown |
| Des Moines Creek | Fish habitat enhancement |
| Des Moines Creek | Fill and excavation for fishery enhancement |

## Other Relevant Activities

There are no USACE congressionally authorized projects in this subsection.

## WDFW Marine Shoreline Habitat Assessment

Subsection 1- Federal Way shows the highest habitat values within the study area. The Top Five index shows 85% of the shoreline having high habitat values (Figure 2-5). The composite index (Sum all) shows 74% of the shoreline with high habitat values (green and yellow) (Figure 2-4 and Figure 2-6). The habitat values increased when only the top 5 component for each segment were observed. The increased values for the Top 5 index show that the Top 5 components are what contribute most to the high habitat values for the composite index. Geoduck, Dungeness crab, Smelt, and Hardshell clams were the most common in the top 5 for this subsection. This aligns with what we already know that the majority of Federal Way shoreline has been armored and development includes individual housing with approximately 15% of riparian area remaining.

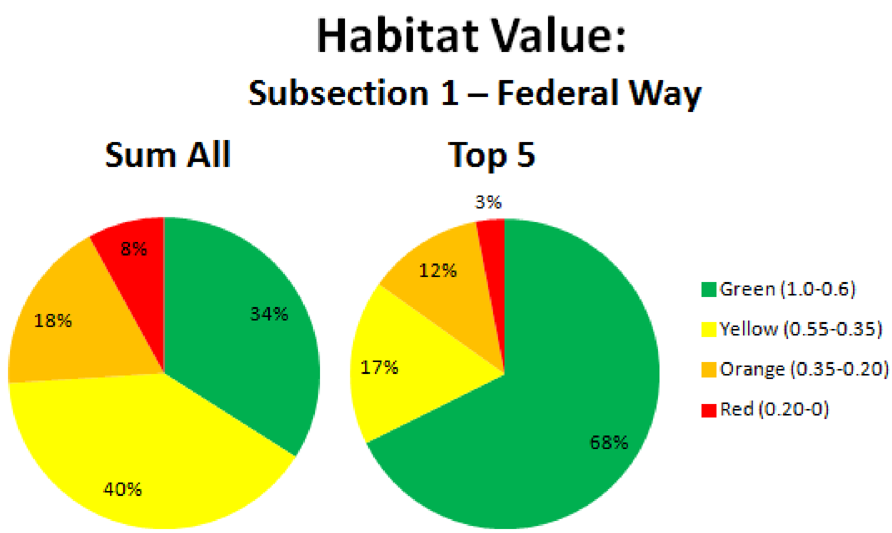



**Figure 2-4 Habitat Values for Subsection 1- Federal Way**

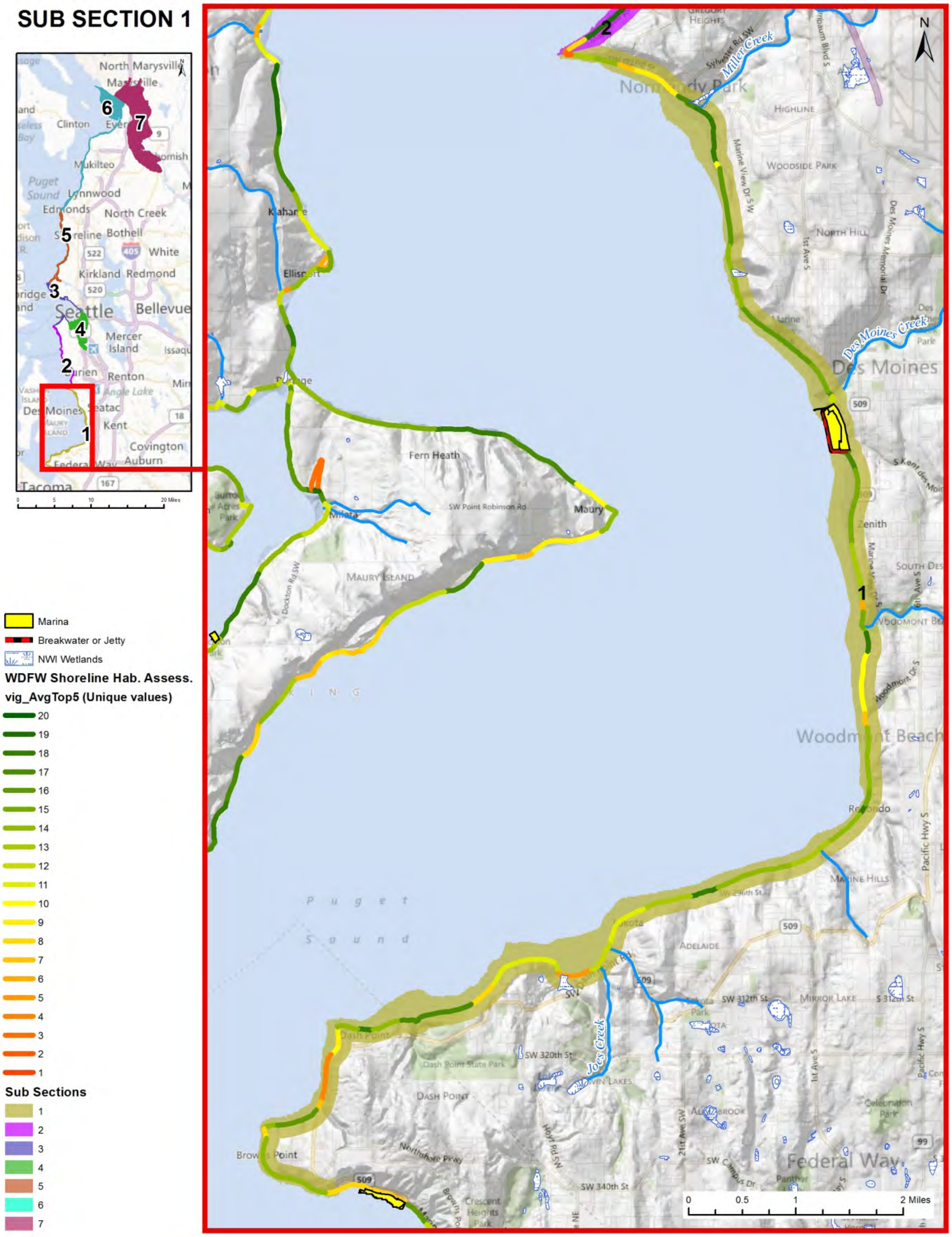



**Figure 2-5 Subsection 1 – Federal Way WDFW Shoreline Habitat Quantitative Assessment Index. Top-5 index indicating relative value of shorelines for fish and wildlife habitat conservation.**

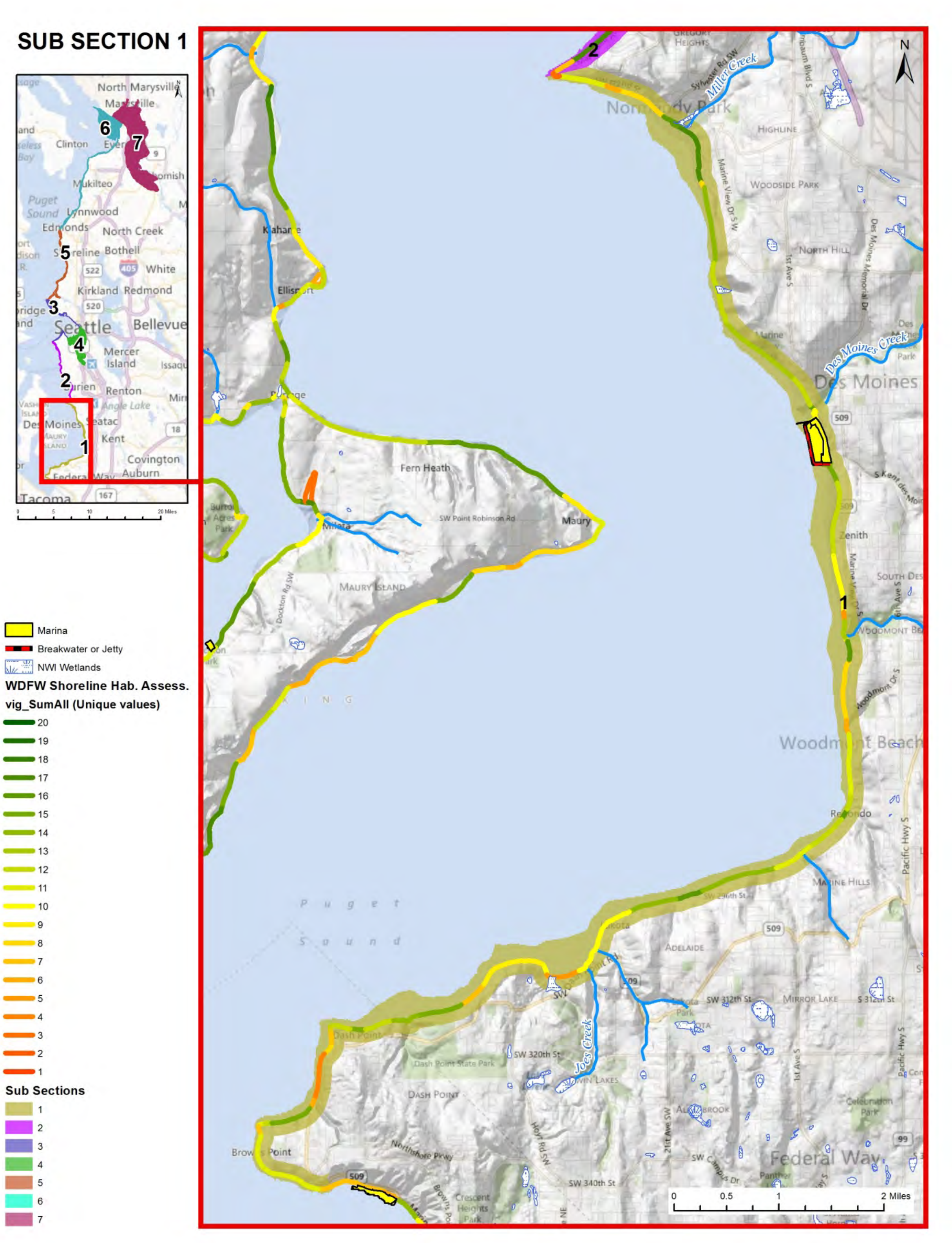



**Figure 2-6 Subsection 1 – Federal Way WDFW Shoreline Habitat Quantitative Assessment Index. Composite index indicating relative value of shorelines for fish and wildlife habitat conservation.**

## *2.2.2. Subsection 2 – Burien/West Seattle*

Subsection 2 – Burien/West Seattle is between Three Tree Point and Alki Point with a total land area of 1,616 acres. It includes Brace point, Seahurst Park, the Fauntleroy ferry terminal, and the shorelines of Normandy Park, Burien, and West Seattle (Figure 1-1). Aerial photographs from 1977 and 2006 do not suggest large scale changes in shoreline development during this period (Figure 2-7 and Figure 2-8).


**Figure 2-7 Air photo of west Seattle just south of the Fauntleroy Ferry dock in 1977. Courtesy of Washington Department of Ecology**


**Figure 2-8 West Seattle, just south of the Fauntleroy Ferry in 2006. Courtesy of Washington Department of Ecology**

## History of Burien

Settlement in what would one day become Burien started in the early 1870's when a very small community slowly started, comprising of only foot trails and small houses. Burien did not become a defined community until the 1880's when an intrepid German immigrant built an estate office and started attracting more residents to the area. Burien grew and in the 1890's the Seattle Mosquito Fleet started making trips to Three Tree Point where a dock was constructed on its north beach along with a tennis court, dance floor, and clubhouse.

The Interurban light-rail was completed in Burien in 1915, connecting it to Seattle, Everett, and Tacoma along a north-south corridor, but was shortly closed. After that, the city grew slowly, much along the lines of the other small cities in the area, increasing in population during the post World War Two years with the introduction of major roads. Between 1972 and 1975 a seawall was built to stabilize the public access beach in what is now Seahurst Park. Burien did not officially incorporate until 1993, and in 1998 it annexed the Manhattan and Woodside Park areas gaining another 2,500 residents. As Burien and Seattle expanded, Burien started servicing many South Seattle residents with grocery and similar stores. In 2003 the city revitalized its downtown with enhanced parking, street safety, landscaping, crosswalks, and public art. In 2010 another 14,000 residents was gained through the annexation of Highline.

## Land Classification and Modifications

Table 2-6 and Table 2-7 below show the tabulated land classification and percent cover, and the type and percent of modifications in Subsection 2 – Burien/West Seattle.

**Table 2-6 Land classification and percent cover for Subsection 2 – Burien/West Seattle.**

| Land Classification | Percent Cover |
|---|---|
| Barren/open space | 19% |
| Developed (high, medium, low intensity) | 24% |
| Open water | 28% |
| Herbaceous | 0.2% |
| Shrub/scrub | 0.2% |
| Wetland (herbaceous and woody) | 12.5% |
| Forested (deciduous, evergreen, mixed) | 15.5% |

**Table 2-7 Type and percent of modifications in Subsection 2 – Burien/West Seattle.**

| Modification | Percent cover in the sub area |
|---|---|
| Marinas | 0% |
| Percent of area occupied by railroad | 0% |
| Impervious surface- 0 to 10% | 72% of the area has impervious surfaces between 0 to 10% |
| Impervious surface- 10 to 30% | 10% of the area has impervious surfaces between 10 to 30% |

| | |
|---|---|
| Impervious surface-30 to 50% | 8% of the area has impervious surfaces between 30 to 50% |
| Impervious surface- 50 to 100% | 10% |
| Shoreline armoring | 88% |
| Overwater structures | 0.2% |

## Water Quality

Subsection 2 – Burien/West Seattle includes the cities of Normandy Park, Burien, and the Seattle neighborhood of West Seattle. The Fauntleroy ferry terminal is also located in this subsection. There are few active industrial wastewater discharge permits. Category 5 waters in the area classified for fecal coliform. There is a discharge outfall pipe from the Renton treatment facility south of Alki Point. Salmon and Fauntleroy creeks have a 37 % incidence of prespawn mortality

## Physical Settings

Three Tree Point and Alki Point that bound this subsection are the two most prominent coastal features. Subsection 2 – Burien/West Seattle contains mainly bluff-backed and barrier beaches and a cove at Lincoln Park. There are also a few small creeks that empty to the Sound such as Salmon creek and Fauntleroy creek. There are two drift cells located in Subsection 2 – Burien/West Seattle (Table 2-8) (Johannessen et al 2005).

**Table 2-8 Drift Cells within Subsection 2 – Burien/West Seattle Data Source: Johannessen et al 2005**

| Drift Cell name[a] | Length (miles)[b] | Percent of the drift cell modified (current)[c] | Historic Change | Notes |
|---|---|---|---|---|
| KI-7-2 | 1.6 | 76% | 98% loss of sediment sources in this drift cell | Heavily modified by residential bulkheads. Less than 1% of drift cell is contributing sediment to down drift beaches. |
| KI-5-1 | 11.2 | 59% | 13% loss of historic accretion shoreform | Predominantly modified by riprap and bulkheads |

a. Data source: Johannessen et al. 2005, Table 7

b. Data source: Johannessen et al. 2005, Table 8, Conversion unit 1 mile=5280ft

c. Data source: Johannessen et al. 2005, Table 8, MOD=Percent of drift cell modified (current)

## Significant or Special Aquatic Sites

A review of the National Wetland Inventory (NWI) shows the entire shoreline mapped as estuarine, intertidal unconsolidated bed (E2US). DNR eelgrass mapping shows a band of eelgrass along the shoreline (deep intertidal to shallow subtidal) with some areas patchy and in other areas it is continuous.

NWI does not display any wetlands adjacent to the shoreline in this subsection. There is also bull kelp in many places in deeper water.

## Fisheries, Wildlife and Vegetation

A variety of mammals and many bird species can be found in this subsection. Red-tailed hawks, eagles and other raptors nest and roost along the bluffs and mature trees. Small songbirds such as pine siskins, chickadees, song sparrow, Oregon junco, swallows, house finch and warblers (Wilson's and yellow rumped) inhabit the upland hillsides and wooded bluffs. The occasional western sandpiper and dunlin can be found on beaches during migration.

Juvenile cutthroat trout, Chinook, chum, coho, and pink salmon feed and rear in nearshore areas of this subsection. Juvenile salmonids feed on epibenthic invertebrates in the intertidal zone. Between February and July, juvenile anadromous salmon out-migrate from their native streams and move into the nearshore area in search of food and refuge. The closest large sources of salmon out migrants to this subsection are the Puyallup River to the south and the Duwamish River to the north Adult salmonids migrate along the shoreline during the late summer to early winter months. Salmon and Fauntleroy creeks support a runs of coho and cutthroat. Brennan et al. (2004) provides an excellent detailed discussion on juvenile salmon use in the study area. In addition to salmonids, many marine fishes use the nearshore for feeding and migration. Marine fish such as a variety of surfperch, flatfish, gunnel, prickleback, and rockfish species typically occur along Puget Sound shorelines. Common species that likely to be found in this subsection also include striped perch, staghorn sculpin, English sole, and cabezon. As with salmonids, the benthic invertebrate resources in nearshore areas provide abundant prey for marine fish.Forage fish are typically smaller fish that usually can be found in large schools and are foraged upon by larger predatory fish such as salmon and trout. In Puget Sound forage fish usually include pacific herring, sand lance and surf smelt. All three of these species actively spawn on the beaches in the study area. Physical parameters such as temperature, grain size, tidal heights and vegetation influence where spawning will occur. Spawning can occur year round but is most common between the months of October and April. It appears there are several forage fish spawning locations south of Lincoln Park (WDFW 2003; WDFW 2008). (GIS viewer WDFW. 2003; HerrSpwn, 2008 Documented Sand Lance Spawning, 2008 Documented Smelt spawning).

## Stressors/ Disturbances

Stressors/disturbances in this sub area include changes to sediment dynamics from, dredging bulkheads, landslides and marinas, altered water chemistry from outfalls, urbanization runoff, changed hydrology from shoreline armoring, alteration to bluffs, altered habitat from filling, dredging, bankline armoring, riparian vegetation removal, dredging.

## Public Land

Public land in the area includes Eagle landing Park, Seahurst Park, Salmon Creek Ravine and Seola Parks in Burien and Lincoln Park in West Seattle.

## Manmade Features

The largest manmade structures that dominate the shoreline in this subsection are the Fauntleroy Ferry Terminal and a large condominium pier on Beach Drive near Cormorant Cove.

## Restoration Activities

The largest habitat restoration project in this subsection occurred at Seahurst Park in Burien in 2007 where a concrete bulkhead was removed and restored to 2000 linear feet of natural shoreline. Additional restoration at Seahurst Park is planned but no firm date exists.

The Port of Seattle constructed a 7.4 acre underwater reef off of West Seattle as mitigation.

## Other Relevant Activities

USACE provides recurring sand placement along 2,300ft of seawall at Lincoln Park.

## WDFW Marine Shoreline Habitat Assessment

The Burien/West Seattle subsection shows some of the highest habitat values within the study area. The composite index (Sum all) shows more than 70% of the shoreline with high habitat values (green and yellow) (Figure 2-9 and Figure 2-11). The Top Five index shows even higher habitat values (Figure 2-10). The results for the Top 5 index are very similar to that of Subsection 1 – Federal Way. The higher Top 5 index indicates that only a few components are contributing to the high habitat values in the composite index. This subsection also has shoreline hardening and is mostly urban.

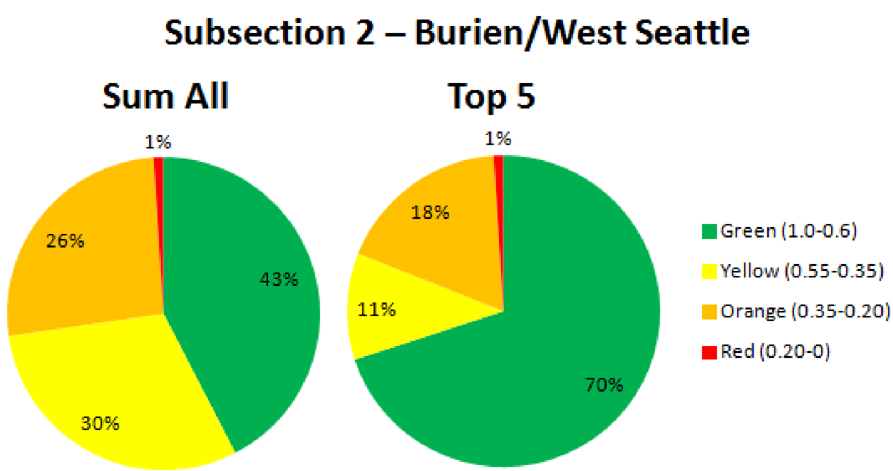



**Figure 2-9 Habitat Values for Subsection 2 – Burien/West Seattle**

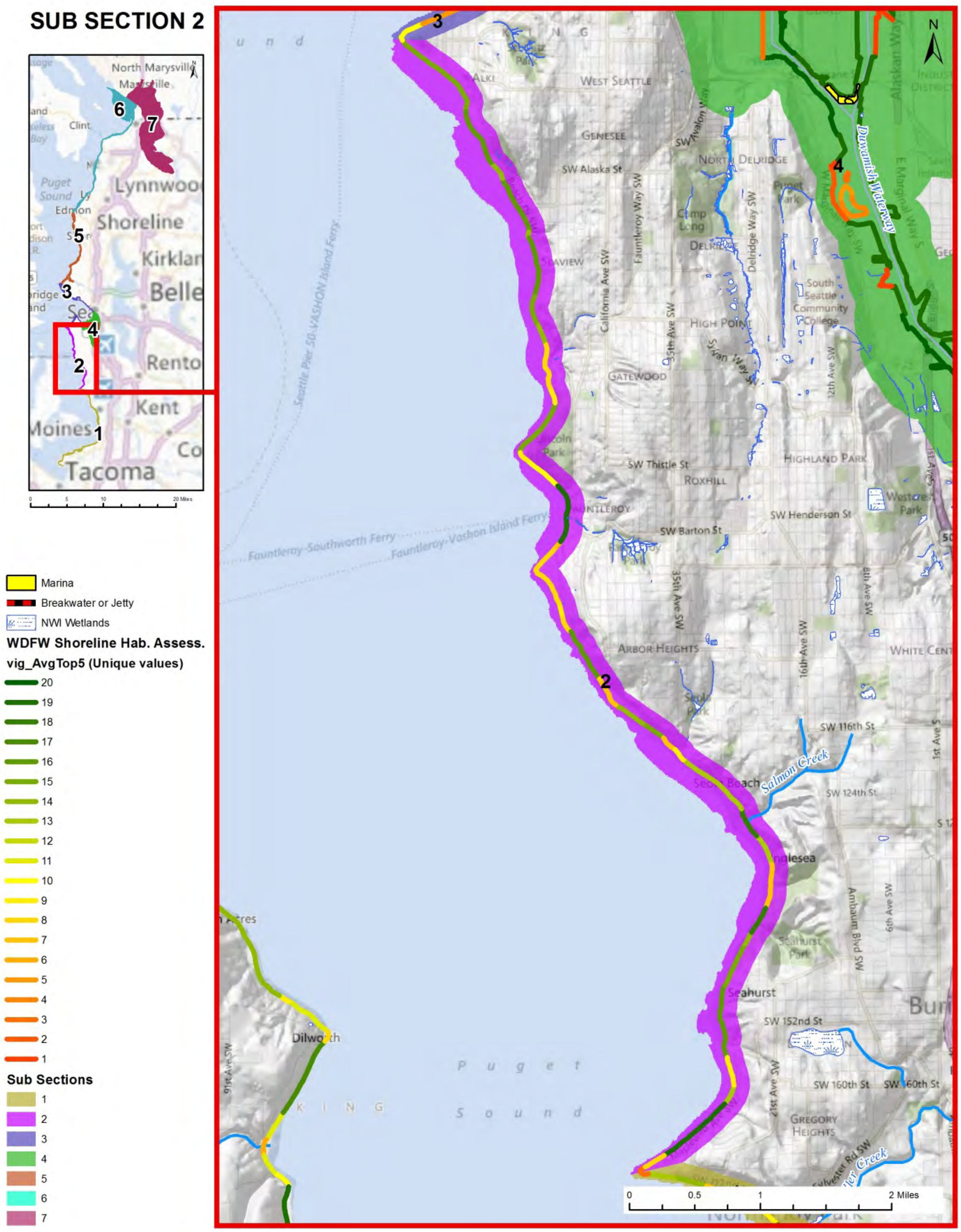



**Figure 2-10 Subsection 2 – Burien/West Seattle WDFW Shoreline Habitat Quantitative Assessment Index. Top-5 index indicating relative value of shorelines for fish and wildlife habitat conservation.**

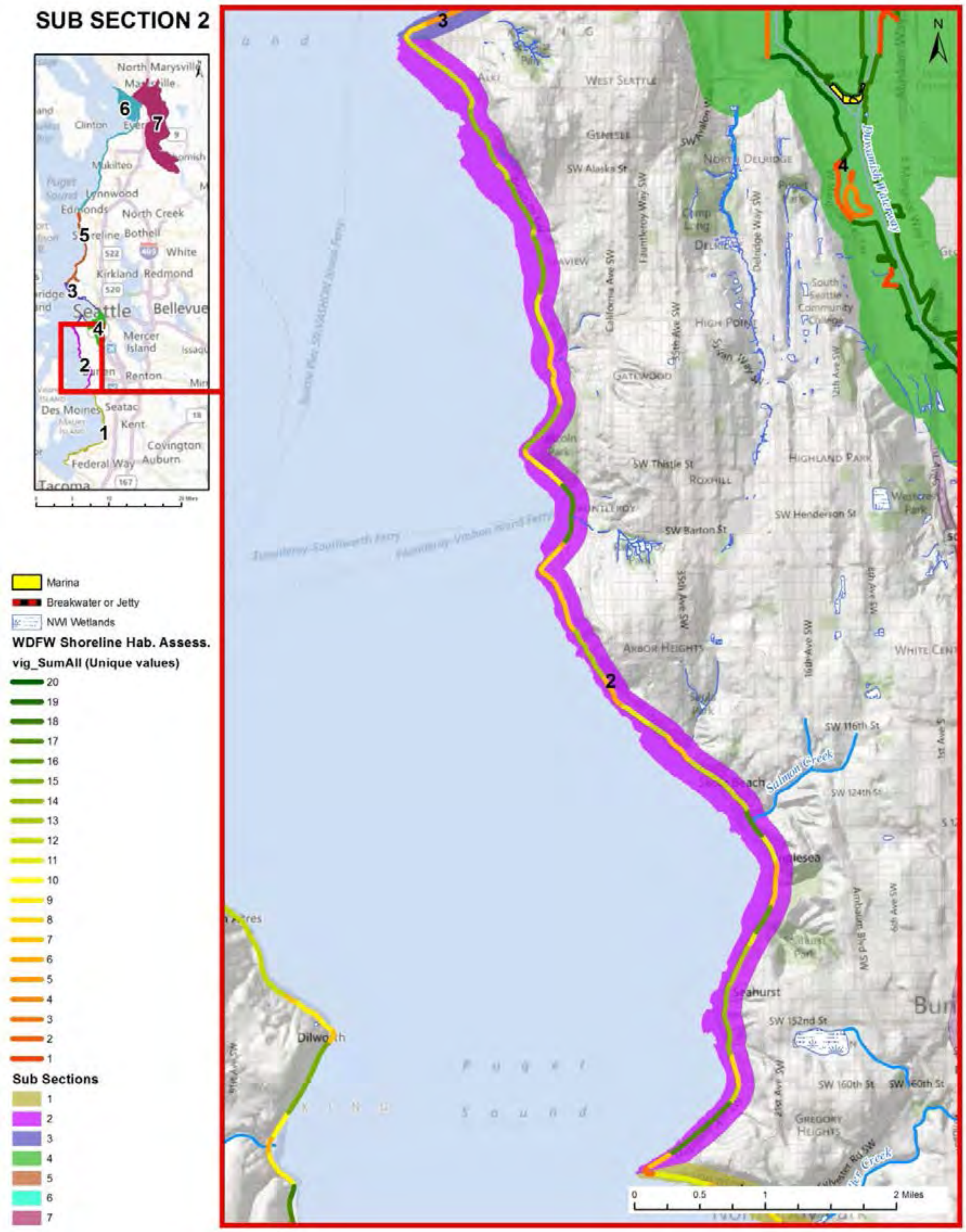



**Figure 2-11 Subsection 2 – Burien/West Seattle WDFW Shoreline Habitat Quantitative Assessment Index. Composite index indicating relative value of shorelines for fish and wildlife habitat conservation.**

## 2.2.3. Subsection 3 – Elliott Bay

Subsection 3 – Elliott Bay starts at Alki Point and West Point (Figure 1-1) with a total land area of 1,909 acres. It includes Alki Beach, Duwamish head, downtown Seattle, Magnolia Bluff and WestPoint. Aerial photographs from 1977 and 2006 near South Magnolia indicate large scale changes in shoreline development (Figure 2-12 and Figure 2-13).


**Figure 2-12 Shoreline in the South Magnolia area in 1977. Courtesy of Washington Department of Ecology.**

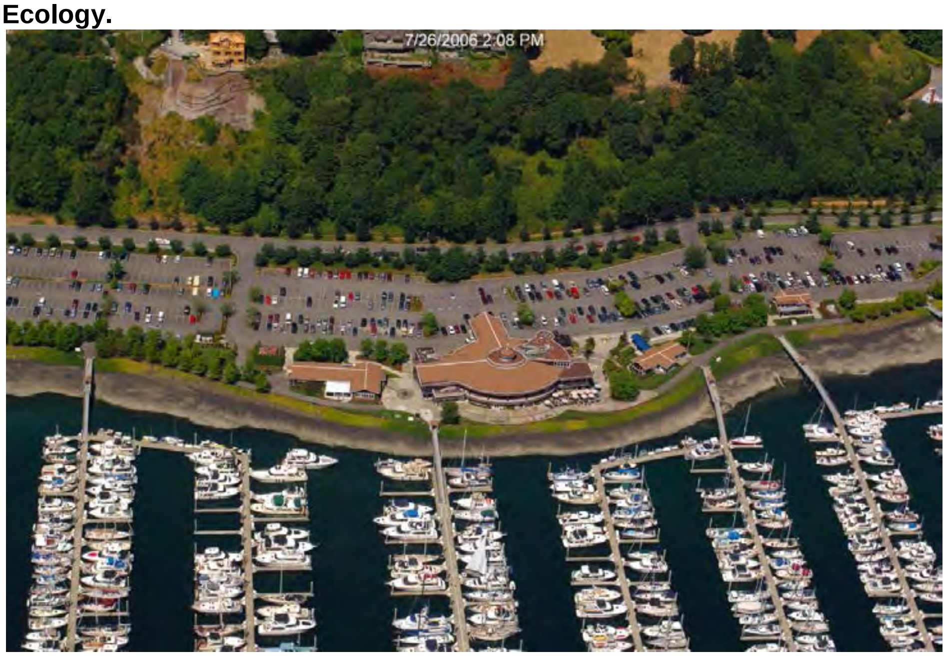



**Figure 2-13 Shoreline of South Magnolia showing part of the Elliott Bay marina in 2006. Courtesy of Washington Department of Ecology.**

## History of Seattle

In 1851, four American families settled the area that is now West Seattle. They hoped to build a trading post to sell and load lumber to ships heading south to San Francisco on what is now Alki Point. However, this location proved to be a poor port and so in 1852 the settlers moved to Elliott Bay where deep water extended right up to the beach and plentiful large firs met the water's edge. There they staked their claims north of the Duwamish River in a small clearing between giant evergreens in what is now Pioneer Square. A major portion of the south end of Elliott Bay included broad, intertidal flats and shallows. In 1853, with a population of 170, 111 of which were male, a sawmill and the beginnings of a wharf were built. Coal was discovered in 1853, not far from present day Renton, which would later play a major role in Seattle's future.

By 1860 there was further wharf development in the port, facilities to supply fresh water to ships, a business supplying pack trains heading to newly discovered eastern Washington gold fields, rudimentary banking services, a clothing store, and even a cabinet shop.

With a population of 303 people in 1860 Seattle saw the construction of roads connecting the city to eastern Washington. The first telegraph line reached Seattle in 1864, in time for Seattle to hear about Lincoln's assassination. By the late 1860's the wharf had grown to 200 feet. In 1869 Seattle was granted the status of a city by the territorial legislature. At this time Seattle established regular connections with various other smaller towns, settlements, and farms in the area supporting the movement of logs, people, and other goods to the centrally located port of Seattle.

Seattle's population grew to over 1,000 in 1870. The next two decades were a boom for Seattle and its growing population expected the city to be a major terminus for the railroads. The city and its suburbs expanded northward to Queen Anne Hill and plans even existed to build a canal between Lakes Washington and Union. However, in 1873 it was announced that the location of the Northern Pacific Railroad terminus would be in Tacoma. Seattle called an emergency meeting and decided to build its own railway connecting Elliott Bay to the coal mines near Renton. By 1877 this railroad, as well as a greatly expanded wharf, and the first shipyard, were completed and Seattle began to export coal until California began producing cheap oil in 1907.

The 1880 census counted 3,533 inhabitants in Seattle and 29 manufacturing establishments employing 174 people. Another sawmill was constructed, Providence Hospital (Seattle's first major medical facility), and the first salmon-canning company opened in the city. During this decade new business and institution construction increased in value and volume. By 1886 Seattle's population soared to 20,000. Near the end of the 1880's, Seattle was announced to be the terminus for the Great Northern Railroad that traversed the northern states connecting it to the rest of the country.

In the spring of 1889 The Great Seattle Fire tore through its commercial section, burning it to the ground. Five days after the fire, merchants were back on the streets selling their goods in tents, and within two years the city had rebuilt the burned areas with brick buildings. During this rebuilding, thousands of people were attracted to King County and Seattle. The census of 1890 records 42,837 people living in Seattle, a figure 11 times the population of 1880. Four months after the fire Washington gained statehood becoming the 42nd state. During reconstruction, the city took the chance to improve infrastructure such as widening streets from 66 to 90 feet and rebuilding sidewalks using pavement. The area of the city doubled in size in 1891 after annexing Magnolia, Green Lake, and University District neighborhoods. By 1891, construction was finished on railroad connecting British Columbia with King County and in 1893 the first cross-country Great Northern train arrived in Seattle. An agreement between the Japan Steamship Company and the Great Northern Railway Company, provided Seattle with a major trans-Pacific shipping line increasing its profile over that of Tacoma, San Francisco, and other port cities vying to be the gateway to the Orient. This decade also saw the improvement of Seattle's water supply, its sewer system, the drastic regrading of Seattle's hills into tamer less restricting topography through the sluicing of soil into Elliott Bay, and the realignment of all wharves and piers. Tidal mud flats along Elliott Bay's waterfront were filled above high tide after 1894 using excavated material from canal construction. This caused the heart of the waterfront to move southward, allowing for shipyards, loading docks, several foundries, a brewery, railroad marshaling yards, military shipping, and other industries to establish. In 1895 the Duwamish River was dredged to create the East Waterway. The dredged material was then used as fill to create Harbor Island.

At the turn of the century, Seattle had a population numbering 80,761, a figure nearly double that of 10 years earlier. The Fort Lawton military installation (the modern day Discovery Park) was established in Magnolia in 1900. Major fires in 1914 destroyed the Madison Park pavilion and the Grand Trunk Dock and on May 30 of that year a barge loaded with dynamite heading to Russia exploded in Elliott Bay destroying property. Sabotage was suspected but never proven. The years leading up to World War 1 were bleak but industry continued to grow. In 1917, the same year the United States officially entered into World War I, the Boeing Airplane Company was established and received an order from the US Army for 200 planes. Seattle's industries had been growing steadily before the war, but now an estimated 40,000 men alone worked in the shipyards producing both wooden and steel ships. By 1917 Seattle had more than 250,000 people.

Between 1901 and 1904, Beacon Hill elevation was lowered through hydraulic sluicing and the resulting fill was placed in the intertidal area of the Duwamish River to raise land and decrease the potential for flooding. After years of planning and debate, ground was broken for the construction of the Lake Washington Ship Canal and the Chittenden Locks in 1911 and was opened for navigation on May 8, 1917. When opened, the lake's level dropped almost 9 feet resulting in the drying up of the Black River. Elliott Bay and the Duwamish Estuary also underwent dramatic changes. By 1917 the east and west navigation channels and Harbor Island on the lower Duwamish were constructed, replacing 9.3 miles of naturally meandering river with 5.3 miles of straightened federal navigation channel. In 1919, private and county levees were finished on the Duwamish waterways to protect and encourage productive farming.

The 1920's saw little development. Manufacturing and wage earning jobs decreased and population rose. As the 1930's arrived, this slump developed into the Great Depression. The depression years saw creation of Shanty towns filled with the homeless and unemployed and depression strikes. However, the onset of World War II brought both people and jobs back to the area. Between 1940 and 1943 alone, Seattle's population grew from 368,302 to approximately 480,000. Ship and plane building increased, lumber and other raw materials were harvested or mined in greater amounts, and food production employed an evergrowing number of workers. Overseas shipments increased, another Pier was built, and in 1943 plans for the Seattle-Tacoma airport was initiated. Boeing's employees grew to 30,000 as it built flying fortresses and other planes needed for the war. By 1944, the Boeing Company's peak, they employed 50,000 people in Seattle. After the war ended the economy declined once more with key industries on the low. Boeing's workforce dropped from 40,000 to 11,000. However, the economy recovered and by 1954 Boeing began producing commercial airplanes. The Alaskan Way Viaduct, Highway 99, new office buildings, and government facilities were built or improved, and colleges enrolled more students with the enactment of the GI Bill. In 1958 Seattle passed a measure to construct wastewater treatment plants and new sewer lines, cleaning up Seattle's waterways and reopening swimming beaches.

On April 21, 1962 Seattle hosted the World's Fair giving the city an Opera House, Coliseum, Science Center, the Space Needle, theaters, and a sports arena. The years after the fair were prosperous and the Seattle skyline grew taller, construction of roads and bridges increased including the floating SR 520 Bridge in 1963 and I-5 cut through Seattle. Extensive levee building by local and federal government took place during the 1960's, further channelizing the Duwamish River. The oldest buildings in Seattle, the brick buildings of Pioneer Square, had been largely abandoned for newer construction in other areas of the city. However, by 1970 Pioneer Square was restored and hundreds of restaurants, businesses, and offices sprung up. Pikes Place was also restored, being saved from demolition. Between 1970 and 1972, however, Boeing dismissed 43,200 of its employees, decreasing its workforce from 80,400 to 37,200 workers, causing a citywide recession and saving the company from bankruptcy. Meanwhile, construction continued in downtown Seattle and the Port experienced one of its greatest upsurges in its history improving and installing containerized cargo equipment. In 1976 the sports stadium known as the Kingdome (to be replaced by CenturyLink Field in 2002) was completed.

In 1980 Seattle's population dropped to below 500,000 while in all of King County it rose to 1,250,000. In 1985 the county approved bonds to finance updating of the Woodland Park Zoo and also saw the completion of Seattle's tallest building, Columbia Center. The metro bus tunnel under downtown Seattle was completed in 1988 as well as the Washington State Trade and Convention Center.

Seattle's population rose to 516,259 by 1990. In 1999 the new home of the Mariners, Safeco Field, opened in response to pressure from the baseball team. In 2000, with Safeco finished and a new football stadium secured, the Kingdome was demolished. Seattle's population has continued to grow, albeit slowly, to 563,374 today. In 2011 the first phase of the Alaskan Way Viaduct replacement began with completion slated for 2015. Removal of the viaduct will provide the downtown waterfront with revitalization potential not possible while the elevated highway exists.

## Land Classification and Modifications

Table 2-9and Table 2-10 below show the tabulated land classification and percent cover and the type and percent of modifications in Subsection 3 – Elliott Bay.

**Table 2-9 Land use classification and percent cover in Subsection 3 – Elliott Bay.**

| Land Classification | Percent Cover |
|---|---|
| Barren/open space | 23% |
| Developed (low intensity) | 3% |

| Land Classification | Percent Cover |
|---|---|
| Developed ( medium intensity) | 8% |
| Developed (high intensity) | 74% |
| Open water | 33% |
| Herbaceous | 1% |
| Shrub/scrub | 0.2% |
| Wetland (herbaceous and woody) | 6% |
| Forested (deciduous, evergreen, mixed) | 3% |

**Table 2-10 Type and percent of modifications in Subsection 3 – Elliott Bay.**

| Modifications | Percent cover in the subsection |
|---|---|
| Marinas | 12% |
| Percent of area occupied by railroad | 2% |
| Impervious surface- 0 to 10% | 64% of the area has impervious surfaces between 0 to 10% |
| Impervious surface- 10 to 30% | 6% of the area has impervious surfaces between 10 to 30% |
| Impervious surface-30 to 50% | 5% of the area has impervious surfaces between 30 to 50% |
| Impervious surface- 50 to 100% | 24% of the area has impervious surfaces between 50 to 100% |
| Shoreline armoring | 89% |
| Overwater structures | 11% |

## Water Quality

The City of Seattle and Elliott Bay are the most developed areas in the State of Washington. As noted in the brief history described above much of the Seattle's shoreline has been greatly modified over the past 150 years. Subsection 3 – Elliott Bay is dominated by a mix of uses including residential, maritime activities (such as shipping, boat building/repair and ferry), industrial and railroad all of which affect water quality. Within this subsection, industrial and municipal discharges, groundwater seepage, urban runoff, atmospheric deposition, and resuspension of sediments all play a part in diminishing water quality. Pollutants found in Elliott Bay include petroleum products, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and polychlorinated dibenzo-dioxins (PCDDs); heavy metals; fertilizers, animal wastes, pesticides, surfactants, hormones, medications, and sediment from construction sites. One dramatic example of water quality in this area is Longfellow creek, an urban stream located within this subsection that discharges into the west waterway of the Duwamish River and Elliott Bay. Over the last several years, prespawn mortality of Coho salmon in this creek has been measured at over 72% (Feist et al. 2011). This research has linked the amount of impervious surface and the amount of PAHs in surface water run-off during storm events to fish mortality.

Stormwater runoff in particular, is a leading cause of trace metal pollution in the water bodies around Seattle. In many areas that have separate storm-sewer systems, stormwater receives minimal treatment, if any, before being discharged directly into Elliott Bay. Combined sanitary and storm sewers, which are prevalent throughout the Seattle area, often discharge a mixture of stormwater and raw sewage directly into Elliott Bay during heavy rainstorms. The 303(d) list from 2012 designated various areas of Elliott Bay, shown in Figure 2-14, as Category 5 (WADOE 2012).

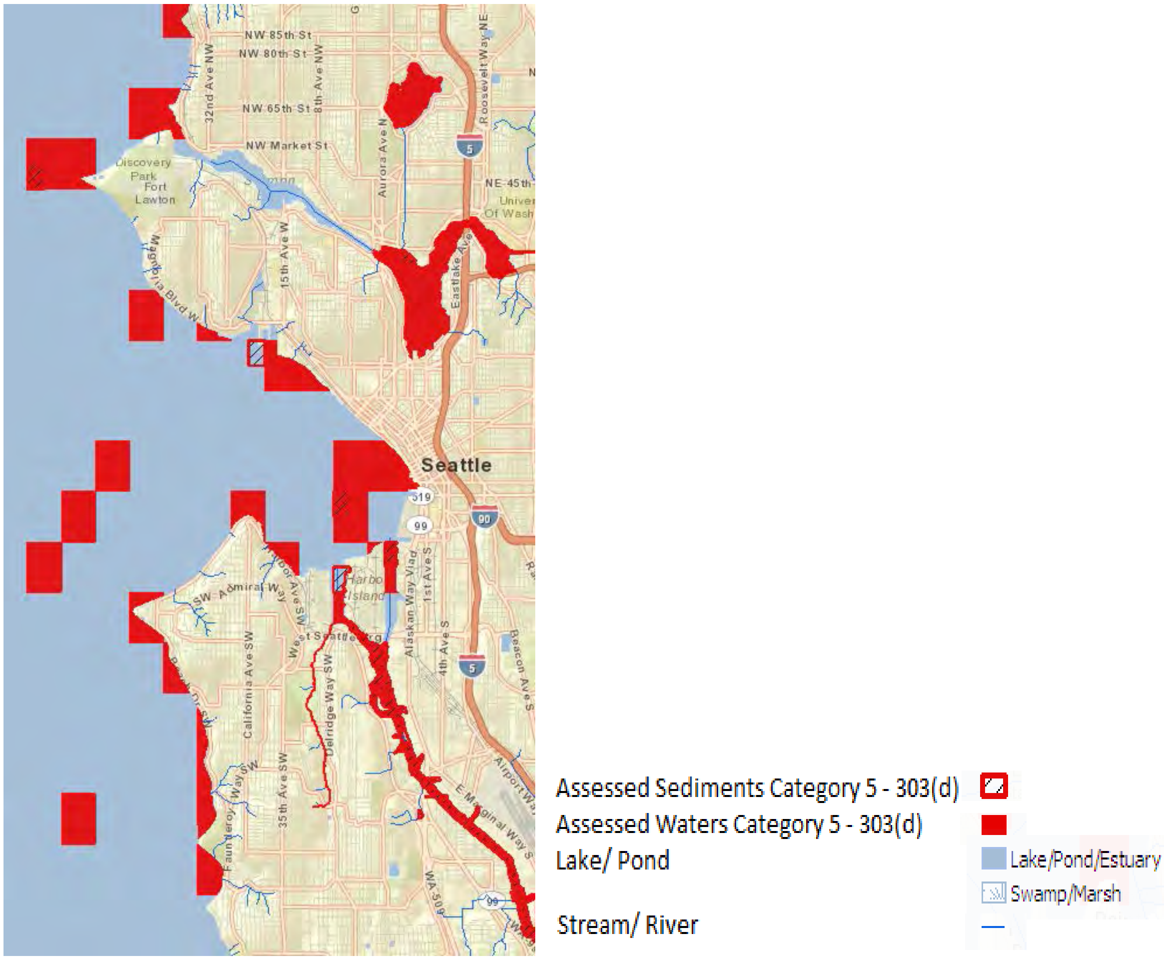



**Figure 2-14 Category 5 waters in Elliott Bay and nearby waters including the Lower Duwamish Waterway. Source: Washington State Department of Ecology.**

The sediments in Elliott Bay have been listed on the 303(d) list for numerous pollutants including mercury, silver, and multiple organic compounds. Often, sediments in the nearshore of Elliott Bay are laden with toxic materials washed into the bay from the heavily urbanized and industrialized surroundings (STCE 1988; McLaren and Ren 1994, Ebbesmeyer et al. 1995; Romberg et al. 1995; Michelsen et al. 1998).

## Physical setting

In general, the currents of Elliott Bay tend to circulate in a weak, counterclockwise gyre through the inner and outer bay (Ebbesmeyer et al. 1998). This persistent flow is thought to be driven by the consistent north-bound movement of water in Puget Sound spanning from the Tacoma Narrows, north through Colvos Passage. This flow is split, sending roughly half of the volume northward mostly bypassing Elliott Bay. Despite this, enough volume flows into the Bay to continually circulate its waters (Ebbesmeyer et al.

1998). This flow influences the development of an eddy, which pushes the currents to spin around Alki Point and Duwamish Head into inner Elliott Bay. These currents initially flow through a submarine canyon but branch into an ever-changing network of eddies once they reach the inner Bay (Ebbesmeyer et al. 1998)

The waters of Elliott Bay emanate from two major sources; subsurface saltwater from Puget Sound flowing in large volume into the bay and a relatively small freshwater discharge from the Duwamish River and other minor sources. It should be noted that stormwater runoff, while significant in terms of increasing levels of toxins found in the nearshore (Michelsen et al. 1998), supplies less than 0.4% of the Duwamish River water volume (Curl et al. 1988). Relative to other rivers in the area, the Duwamish has a relatively low total output averaging only 1,790 cubic feet per second (Curl et al. 1988).

Wave energy in Elliott Bay, which is a sheltered embayment protected from open water and southerly winds, is much lower than that seen in more exposed areas of Puget Sound. Under moderate winds, waves in Elliott Bay tend to have relatively short wave periods ranging from 2 to 2.5 seconds, low energy, and increase little in intensity during storms (Downing 1983). As a result, natural wave action is usually very light in Elliott Bay and at the Alaskan Way Seawall and usually has little impact on the nearshore environment compared to less sheltered environments.

Unlike relatively weak natural tidal currents of the nearshore (Ebbesmeyer et al. 1998), those created by vessel traffic are sufficient to resuspend and redistribute sediments. Contaminated sediments along the waterfront can be resuspended and redistributed allowing for potential exposure (Curl et al. 1988).

Tides in Elliott Bay are mixed semi-diurnal with two high and two low tides of unequal magnitude occurring each day. Because Elliott Bay is a tidal marine environment, water elevation is entirely determined by daily tides and is independent of the hydrology of its tributaries. In 2007, the average tidal range between mean higher-high water (MHHW) and mean lower-low water (MLLW) is 11.6 ft (NOAA 2008).

The majority of influx of sediment into this subsection is from the Duwamish River. One hundred percent of the shoreline area in this subsection has been heavily modified and there is a limited amount of sediment reaching the nearshore from feeder bluffs. Table 2-11 lists the four drift cells and shows three of the four have been significantly modified.

**Table 2-11 Drift Cells within Subsection 3 – Elliott Bay. Data Souce:Johannessen et al. 2005**

| Drift Cell name[a] | Length (miles)[b] | Percent of the drift cell modified (current)[c] | Historic Change | Notes |
|---|---|---|---|---|
| KI3-2/2-3-NAD | 1.4 | 100%, most of area is on fill | 100% loss of nearshore sediment | Near southern boundary of Magnolia near Smith Cove Marina. Breakwaters preclude nearshore drift. |
| KL-3-3 | 0.25 | 89% | 100% | Most of shore is in |

| Drift Cell name[a] | Length (miles)[b] | Percent of the drift cell modified (current)[c] | Historic Change | Notes |
|---|---|---|---|---|
| | | | | rip rap. |
| KI-4-1-NAD | 1.1 miles | 100% | 100% loss of nearshore sediment | Water depth and piers preclude and significant longshore transport |
| KI-5-1 | 11.2 | 59% | 13% loss of historic accretion shoreform | Predominantly modified by riprap and bulkheads. Only a couple miles of this drift cell, along the western portion of Alki beach is in this subsection |

a. Data source: Johannessen et al. 2005, Table 7

b. Data source: Johannessen et al. 2005, Table 8, Conversion unit 1 mile=5280ft

c. Data source: Johannessen et al. 2005, Table 8, MOD=Percent of drift cell modified (current)

## Significant or Special Aquatic Sites

The PSNERP database of current wetlands identifies 32 different wetlands within this subsection using four salinity-based categories: euryhaline, unvegetated, estuarine mixing, and tidal freshwater. Many of these are concentrated along Alki beach and Alki head and there are several along the toe of the Magnolia Bluff up to Discovery Park. Eelgrass can be found along the shoreline from Duwamish head to Alki point throughout the photic zone. Eelgrass can also be found from Magnolia to WestPoint. Eelgrass is not found along the central waterfront but there are occasional patches of bull kelp in this area.

## Fisheries, Wildlife and Vegetation

Elliott Bay is regarded as one of the most heavily urbanized areas in Puget Sound. The majority of terrestrial, nearshore, and offshore habitats that naturally occurred in the area either no longer exist or are degraded. Many species have been affected by extensive development of the shoreline including those that are now federally or state listed, or state priority species. In addition, the terrestrial landscape surrounding this subsection area is dominated by industrial and commercial development that produces solid wastes, noise, and air and water pollution.

Studies specific to the Elliott Bay waterfront identified, hairy crabs, coonstripe shrimp, and Pacific octopus are often present around Pier 59 in the central waterfront (USACE Seattle District 2008). Sunflower star, bat star, and Pacific herring are also present along the central waterfront in the protected waters, such as those found at the Bell Street Marina, near Pier 66. Occasionally, Dungeness crab, spider crab, shore crab, and helmet crab, are also found in this area (WSDOT 2004; Toft and Cordell 2006; USACE Seattle District 2008).

Studies conducted just north of the Alaskan Way Seawall on fish assemblages documented many resident species in the nearshore (Toft et al. 2004; Toft and Cordell 2006). Shiner perch was found to be the most abundant fish in the area, while pile perch and striped sea perch were also common. Pacific sand lance and Pacific herring were also found in relatively high densities, albeit only during the summer months. Similarly, larval fish were most abundant during the summer months. Predatory species which have been known to prey on salmonid fry were found to be rare. Examples of these species are bay pipefish, penpoint gunnel, kelp perch, lingcod, ratfish, buffalo sculpin, and tube-snout. Other species found in the areas of deeper water along the Seawall are English sole, rock sole, starry flounder, and various rockfish and smelt, and (Toft et al. 2004). In 2012 pacific herring were found to have spawned in the northeastern portion of the bay near the Sculpture Park. The Alki beach shoreline also supports spawning by sand lance and smelt as do many beaches in Puget Sound.

Eight species of native anadromous salmon and trout occur in Elliott Bay and are known to utilize the nearshore and offshore as both juveniles and adults (WSDOT 2004). These include Chinook salmon, chum salmon, pink salmon, sockeye salmon, coho salmon, steelhead trout, bull trout, and sea-run coastal cutthroat trout (Toft et al. 2004; WSDOT 2004; Brennan and Higgins 2004; Toft and Cordell 2006; Fresh 2006). Juvenile salmon are especially prevalent in the nearshore and overlaps in emigration and residence timing of juvenile salmon essentially ensure that at least one species can be found in the nearshore environment any time of year (Brennan and Higgins 2004).

Various marine mammals that use the waters of Elliott Bay have been shown to have elevated levels of various anthropogenic toxins in their systems (Ross et al. 1998; Calambokidis et al.1999; Cullon et al. 2001; Lambourn et al. 2001). The high levels of persistent organic pollutants such as PCBs (polychlorinated biphenyls), DDT (dichloro-diphenyl-trichloroethane), and PBDE (polybrominated diphenyl ethers) that persist in the study area are most likely the cause of unusual physical problems seen in these mammals; such as compromised immune and reproductive systems that often leads to reduced fecundity and increased mortality rates (Ross et al. 1998; Calambokidis et al. 1999; Cullon et al. 2001; Lambourn et al. 2001).

Water bird species composition and density varies widely by season in Elliott Bay. A few species, however, can be found around the nearshore year round with some of the most common being herring gull, California gull, and ring-billed gull (Eissinger 2007; USACE Seattle District 2008). Examples of other common species that can be found in the study area most of the year are double-crested cormorant, pigeon guillemot, common and Barrow's goldeneye, surf scoter, common merganser, and western grebe.

Winter at Elliott Bay typically hosts the highest numbers of water birds with total densities often ranging from 125 to 250 individuals per square mile (Nysewander et al. 2005; USACE Seattle District 2008). These high densities are attributed to the large influx of migrant species that seek shelter and feeding habitat in the mostly protected waters of Elliott Bay, particularly south of Pier 86 (USACE Seattle District 2008). Some species common to the Elliott Bay during the winter season are red-necked grebe, scaup, American widgeon, hooded merganser, glaucus gull, pigeon guillemot, common murre, rhinoceros auklet, and Canada goose.

The shoreline of Elliott Bay has a wide variety of habitats and associated vegetation. Much of the study area has been modified with hardened shoreline and either paved or grassy upland adjacent to the shoreline. The Magnolia side of the bay is heavily treed with residences on steep bluffs. The Central waterfront is heavily urbanized with mainly paved surfaces with a few trees.

The waters of Elliott Bay host a wide diversity of marine algae; a pattern tied to the presence of three major substrate types and somewhat protected waters throughout the area. Multiple species of green, brown, and red algae reside throughout the littoral zone around the Seawall. Man made substrates such as floating docks and pilings are dominated by two algae species; sea lettuce and rockweed. Mats of bull kelp are present in small pockets at various locations along the waterfront. There are long patchy bands of eelgrass along Alki beach and to the north along Magnolia bluff. As part of the mitigation for Elliott Bay marina, eelgrass was planted outside the breakwater.

## Stressors/disturbances

There are a wide variety of disturbances to the nearshore area within this subsection. These include the wastewater treatment facility at WestPoint, regular dredging in the Duwamish River, the ferry terminal at Coleman dock (prop wash dominates the nearshore wave dynamics in the central waterfront) (Ebbesmeyer et al. 1995; Michelsen et al. 1998), shoreline hardening which provides a physical barrier between upland and the marine environment, and there is a considerable road network and other imperious surfaces near the water/land interface.

## Public Land

Public access to the shore area has long been a priority for planning within the city of Seattle. As a result there are several parks and viewing and fishing access areas. Parks include; Alki beach, Seacrest park (near Alki head), waterfront park on the central waterfront, Olympic Sculpture Park, and Discovery park at WestPoint.

## Manmade Features

Nearly all of the Elliott Bay shoreline is hardened by riprap, bulkheads or seawalls. Elliott Bay hosts a wide variety of large structures that intrude into the nearshore area. Over 60% of the central waterfront has overwater structures such as piers and wharfs. The Port of Seattle operates several marine terminals for shipping and cruise lines, including terminals 89-90 in Smith Cove and along the east waterway in downtown Seattle. There is a seawall that runs the length of the central waterfront and another along Alki beach. There are two marinas in the Bay, the very large Elliott Bay marina and a smaller Port of Seattle marina on the central waterfront. There is a large ferry terminal with several ferry routes originating at Colman Dock in the central waterfront.

## Restoration Activities

One of the most significant restoration projects in Elliott Bay is the Olympic Sculpture Park near pier 70. This project consisted of removing riprap and re-shaping the shoreline to create an intertidal bench and small embayment. Monitoring over the past several years has shown the subtidal and intertidal restoration actions have restored habitat function. At West Point a beach nourishment project placed approximately 60,000 cubic yards of sand and gravel were with some shoreline plantings (beach grass). Additionally, two pocket beaches with associated beach grasses were created along the shoreline of the Pacific Sound Resources Superfund Site shoreline at the west side of the mouth of the Duwamish River.

The Port of Seattle completed a non- compensatory restoration site of 0.7 acres along the central waterfront. Additionally, two superfund sites completed shoreline/intertidal restoration activities in conjunction with remediation.

## Mitigation

A large mitigation project associated with construction of the Elliott Bay Marina consists mainly of several acres of planted eelgrass and kelp. Additional eelgrass mitigation planting occurred off shore of the West point treatment facility.

The Port of Seattle has several small mitigation sites in Elliott Bay including 3.2 acres excavation, fill, and intertidal plantings at Smith cove/T-91 and 0.6 acres in the East Waterway that consisted of overwater structure removal.

## Other Relevant Activities

The Seattle District USACE activities in this subsection include the Seattle Harbor project (initiated in 1919) which provides navigation (dredging) in the east and west waterways of the Lower Duwamish River.

In 1998, USACE also participated in a nearshore restoration project under the Green Duwamish General Investigation near Alki head. The project consisted of placement of new substrate materials in the shallow subtidal of Elliott Bay. The overall goals of the project were to enhance the productivity of benthic fauna, increase the distribution and density of macro algae (bull kelp) and other primary producers, and improve the attributes that support resident and migratory marine and estuarine fish species.

## WDFW Marine Shoreline Habitat Assessment

The Elliott Bay subsection shows the lowest shoreline habitat values within the study area (Figure 2-15, Figure 2-16 and Figure 2-17). Both indices show that approximately 60% of the habitat is of low value (red and orange). The most common components in the Top 5 for this subsection were the same as Subsection 1 – Federal Way and Subsection 2 – Burien/ West Seattle, but lower habitat values for the Top 5 index show that the all components have a somewhat equal contribution to the composite index. Much of Seattle’s shoreline is highly degraded habitat and each component is similar to the other in that they aren’t flourishing. Habitat improves along the western part of Alki beach and the shoreline from Magnolia up to West Point.

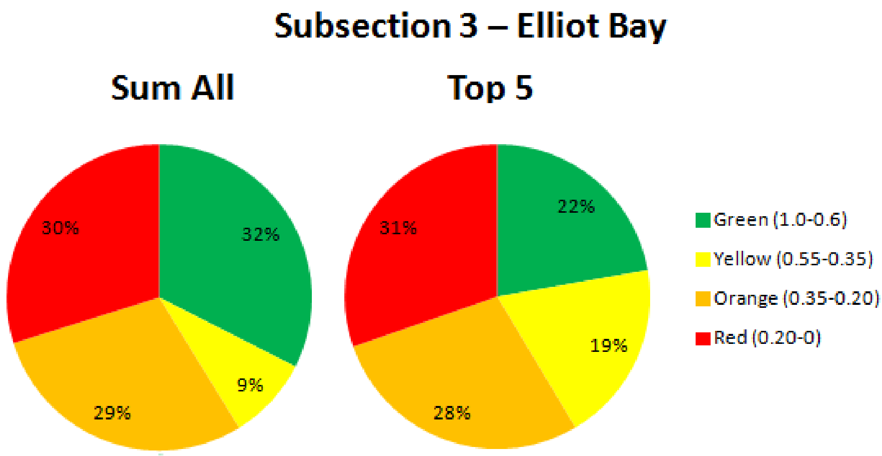



**Figure 2-15 Habitat Values for Subsection 3 – Elliott Bay**

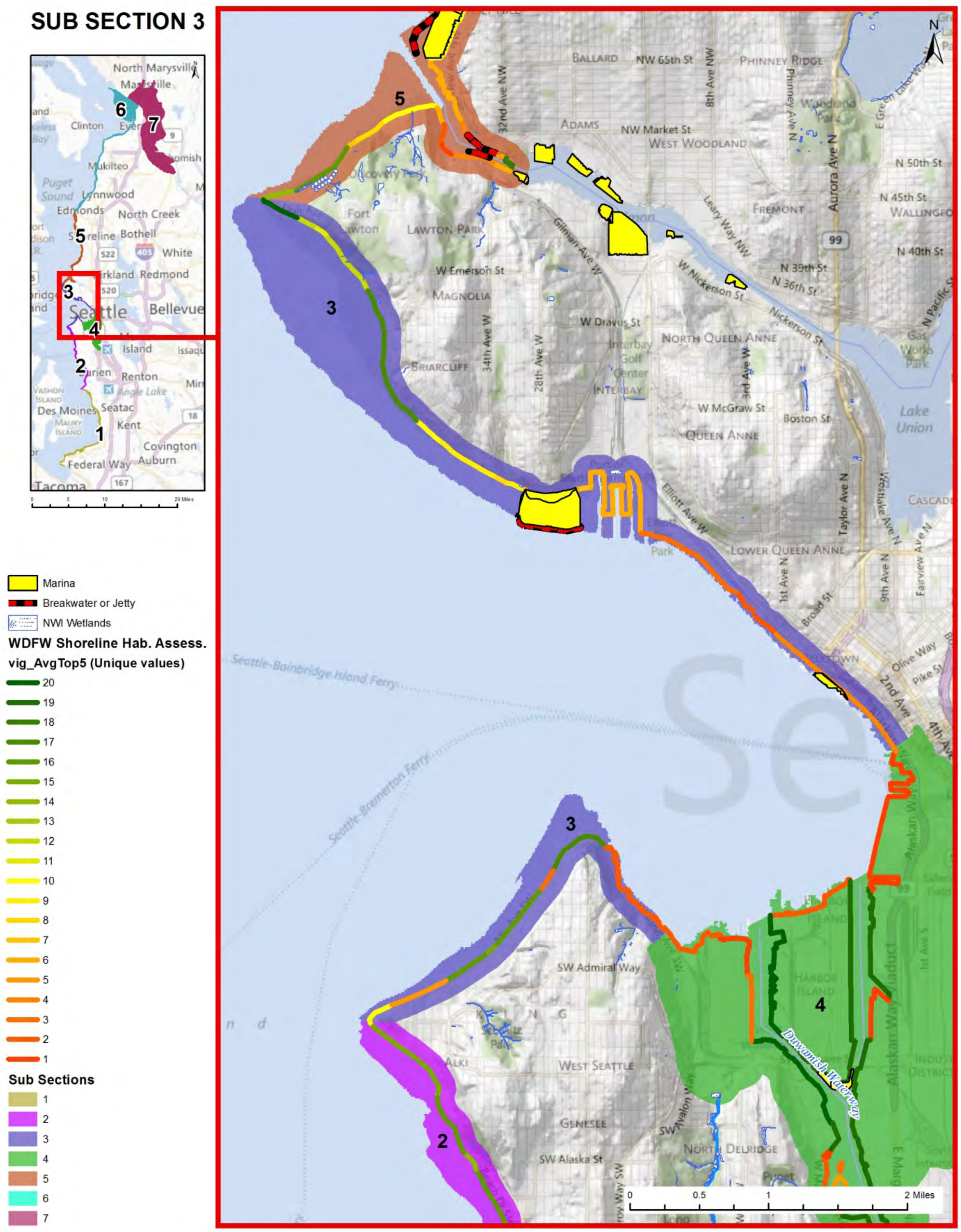



**Figure 2-16 Subsection 3 – Elliott Bay WDFW Shoreline Habitat Quantitative Assessment Index. Top-5 index indicating relative value of shorelines for fish and wildlife habitat conservation.**

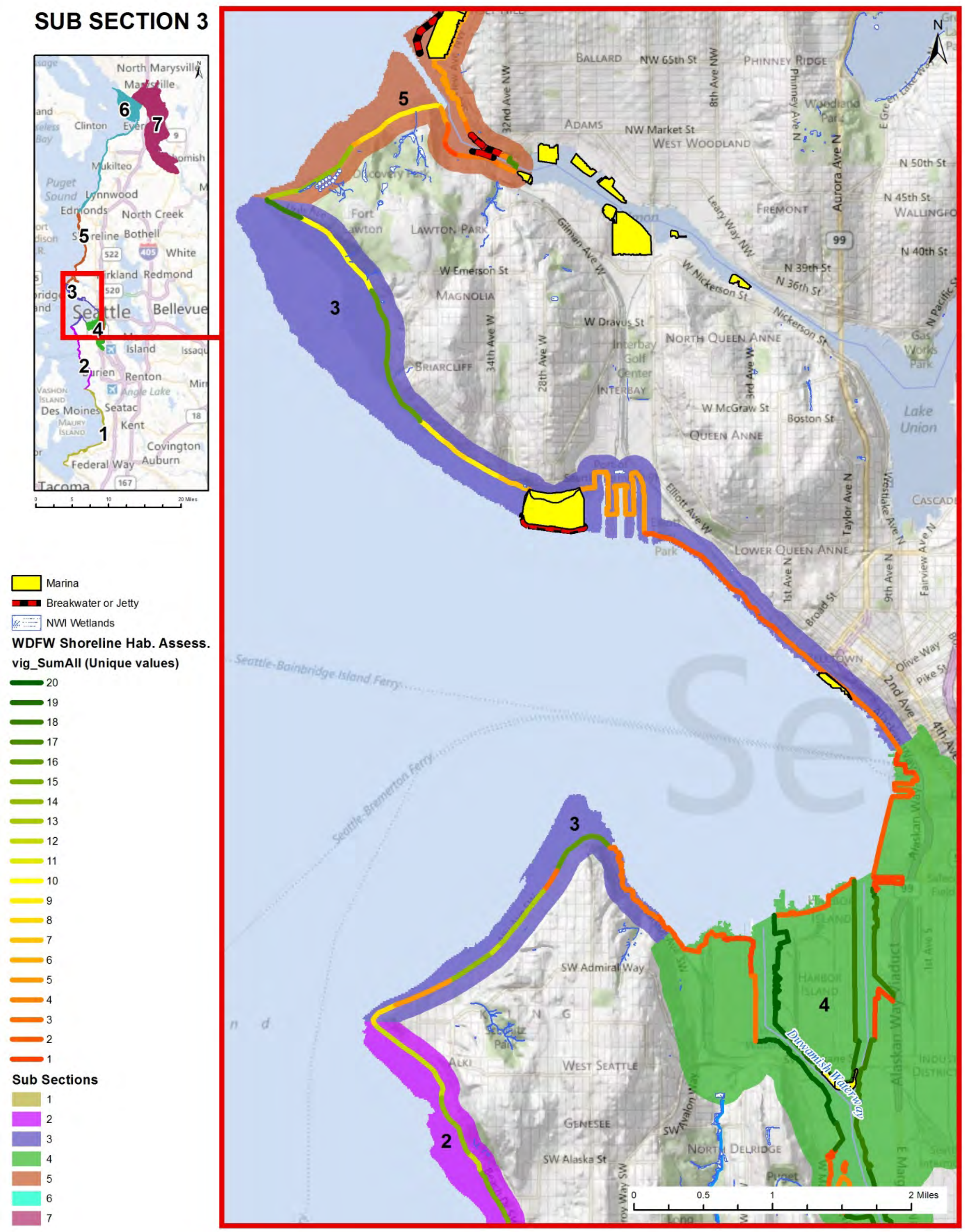



**Figure 2-17 Subsection 3 – Elliott Bay WDFW Shoreline Habitat Quantitative Assessment Index. Composite index indicating relative value of shorelines for fish and wildlife habitat conservation.**

## 2.2.4. Subsection 4 – Duwamish Estuary

Subsection 4 – Duwamish Estuary is located between Harbor Island and the historic North Wind weir at approximately river mile 7 (Figure 1-1), which is the extent of salt water intrusion. Subsection 4 – Duwamish Estuary has a total land area of 4,682 acres. Aerial photographs from 1977 and 2006 near First Avenue South Bridge indicate most large scale changes in shoreline development were complete by 1977 (Figure 2-18 and Figure 2-19).


**Figure 2-18 Air photo of the Duwamish Waterway looking southeast towards the First Avenue South Bridge in 1977. Courtesy of Washington Department of Ecology.**

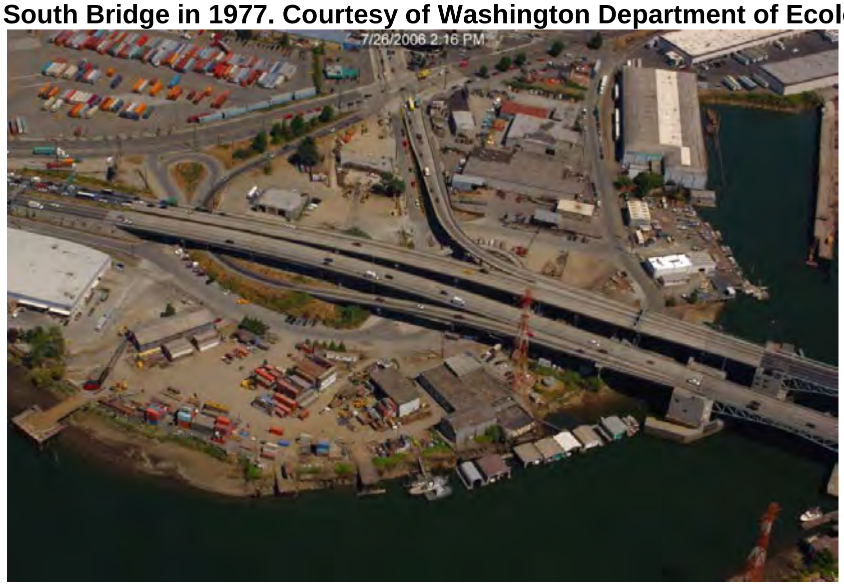



**Figure 2-19 Close-up view of the First Avenue South Bridge on the Duwamish in 2006. Courtesy of Washington Department of Ecology**

## Brief History of the Duwamish

The first 70 years (beginning in 1850) of Euro-American settlement and development in Subsection 4 – Duwamish Estuary fundamentally shaped the conditions found today. The initial Euro-American settlement and subsequent development of the river basin was integrally related to logging, mining, railroad construction and agriculture. The first permanent Euro-American settlement in what was to later become King County was recorded along the Duwamish River.

Historically, the Green/Duwamish River Basin was nearly four times its present size because it included the White River and all of the Lake Washington drainages. The Green River flowed west to the present location of Auburn where it was joined by the White River. The combined river, then called the White River, meandered for about 12 miles to the junction with the Black River. From the junction, the combined waters flowed onward to Elliott Bay as the Duwamish River (Duwamish means "many colors" to the local Native Americans). The undeveloped Duwamish drainage area of approximately 1,640 square miles contributed an estimated 2,500 to 9,000 cubic feet per second of fresh water to the estuary environment.

Early records indicate that the Duwamish estuary was characterized by a river meandering through significant areas of tidal marshes and swamp lands. Fresh water entered Puget Sound via three main distributor channels. The estimated area of the Duwamish Estuary prior to development was about 4.3 square miles

Dredging of the mouth of the estuary and construction of Harbor Island by the City and Port of Seattle began in the early 1900s. In 1919, Congress funded a navigation project to deepen, widen, and straighten the estuary portion of the Duwamish River to be completed by USACE when dredged sediment was placed in the estuary. Subsequent dredged material was side cast immediately adjacent to the mainstem, eliminating hydrologic connectivity to a once extensive floodplain. The Duwamish delta at one time had over 4,000 acres of tidal and intertidal habitat, which was important for a number of fish and wildlife species. By the mid-1940s, much of the estuary was filled; only about 2 percent of the estuary now remains.

In 1912, the City of Tacoma constructed the Tacoma Diversion Dam at Palmer (RM 61.0) to create a municipal water supply. On average, the city withdraws 113 cubic feet per second (cfs) continually from the river. The diversion dam blocks over 200 miles of upstream mainstem and tributary salmonid spawning and rearing habitat.

In 1916, the Lake Washington Ship Canal and Hiram Chittenden Locks were constructed lowering the level of Lake Washington by 9 feet, and eliminating flows from the lake to the Black River and hence, the Duwamish River. Additionally, the Cedar River was redirected to Lake Washington, disconnecting it as well and reducing flow in the Green/Duwamish River Basin by 70 percent, with subsequent adverse effects on the anadromous fishery. In 1961, Howard Hanson Dam was constructed as a flood control project at Eagle Gorge just upstream of the Tacoma diversion dam.

The lower Duwamish is the most highly developed and altered portion of the system of the Green/Duwamish basin. The former floodplain has been highly urbanized. The mainstem channel configuration has lost complexity and currently resembles a large ditch that facilitates passage of tidal waters. Most of the small tributaries have been channelized and culverted. A once extensive estuary has been all but filled in, eliminating 98 percent of the most productive habitats, such as mudflats, emergent marshes, and tidal sloughs (Blomberg et al. 1988). The Duwamish Estuary is estimated to have had a shoreline of 93,000 feet and 3,950 acres of tidal mudflat, marsh, and swamp. By 1986, there was a total of 45 acres of tidal mudflat and tidal marsh, and no tidal swamps. The estuary shoreline had been reduced to 72,000 feet with only 19,000 feet in riparian vegetation and the remaining 53,000 feet in developed shoreline. Approximately 21,000 feet of shoreline was lost in straightening the channel (Blomberg et al. 1988)

Industrialization and urbanization have caused widespread pollution in river sediments. The lower five miles of the Duwamish River was declared a superfund site in 2001. Low summer flow and lack of riparian vegetation to provide shade to the river cause a temperature barrier to occur, which decreases fish migration in the lower river during the late summer months. Given the known loss of habitat, flow diversion, industrialization, and other disturbances, perhaps it is not a coincidence that one of the major runs of salmon, spring Chinook, has gone extinct in the Green/Duwamish basin.

Table 2-12 identifies some specific events and results of changes to the river and riparian zone in the latter half of the nineteenth century and into the twentieth century.

**Table 2-12 Chronology of Events in the Green/Duwamish River Basin 1850-1963**

| Date | Event | Result |
|---|---|---|
| 1850 | Oregon Donation Land Act | Land granted to settlers after 5 years homesteading |
| 1851 | First Euro-American settlers arrive in the Duwamish area | Land clearing begins - three claims filed |
| 1853 | Extension of Land Act through 1855 | Seventeen claims filed along the river |
| 1854 | First road built in King County | Road built through the river valley |
| 1855-58 | Removal of debris from river for navigational purposes. | |
| 1856 | Land clearing resumes | Duwamish area gardens planted, orchards established, timber cutting begins |
| 1858 | Drainage Laws | County passes laws permitting ditches for drainage, swamp land drainage begins |
| 1862 | Homestead Act | Settlement of territory encouraged |
| 1866 | Population of valley starts to grow in earnest | |
| 1867 | First railroad bridge built across Black River | Local railroad construction begins in Green/Duwamish River basin |
| 1870 | 277 settlers living in valley | |
| 1870's | Major railroads build lines | Pace of logging increases in Green/Duwamish River watershed |

| Date | Event | Result |
|---|---|---|
| 1875 | Channel Improvement Act | County road funds used for improvement of rivers |
| 1880-1910 | Extensive logging occurs in the watershed | |
| 1895 | Duwamish East Waterway construction begins | East Duwamish Waterway dredged and used for Harbor Island fill |
| 1902 | Green River Hatchery | State operated Green River Hatchery opens on Soos Creek |
| 1901-04 | Hydraulic sluicing of Beacon Hill | Fill placed in the intertidal area of the Duwamish River to raise land and decrease flooding potential |
| 1910 | Tacoma Water Diversion authorized | City of Tacoma Diversion Dam on the Green River construction is begun for municipal water |
| 1911 | White River Diversion | White River completely diverted to Puyallup River to reduce flooding problems |
| 1916 | Black and Cedar Rivers diverted from Green/Duwamish River | Ship Canal cut to Lake Union draining Lake Washington to Puget Sound. Reduced flooding in Green/Duwamish Basin |
| 1917 | East/West Duwamish Waterways finished | Dredging of channel completed, 2.2 sq. miles of Duwamish intertidal area filled, flooding reduced. |
| 1960s | Extensive levee building by local and federal government | Channelization of the river |
| 1963 | Howard Hanson Dam completed | Reduces maximum flow of Green River to 12,500 cfs at Auburn to reduce flooding |

## Land Classification and Modification

Table 2-13and Table 2-14 show the tabulated land classification and percent cover, and the type and percent of modifications in Subsection 4 – Duwamish Estuary.

**Table 2-13 Land use classification and percent cover in Subsection 4 – Duwamish Estuary.**

| Land Classification | Percent Cover |
|---|---|
| Barren/open space | 2 |
| Developed high | 74 |
| Developed medium | 3 |
| Developed low | 7 |
| Open water | 22 |
| Herbaceous | 0 |
| Shrub/scrub | 0 |

| | |
|---|---|
| Wetland (herbaceous and woody) | 0 |
| Forested (deciduous, evergreen, mixed) | 0.4 |

**Table 2-14 Type and percent of modifications in Subsection 4 – Duwamish Estuary.**

| Modifications | Percent cover |
|---|---|
| Marinas | 0.6 |
| Percent of area occupied by railroad | 2 |
| Impervious surface- 0 to 10% | 15 |
| Impervious surface- 10 to 30% | 2 |
| Impervious surface-30 to 50% | 2 |
| Impervious surface- 50 to 100% | 80 |
| Shoreline armoring | 98 |
| Overwater structures | 43 |

## Water Quality

Subsection 4 – Duwamish Estuary of the study area includes the Duwamish River from Harbor Island upstream to approximately River Mile 7. This portion of the Duwamish River is lined by industrial and manufacturing facilities. Port of Seattle shipping terminal is located at Harbor Island. Maintenance dredging occurs in this area to accommodate commercial shipping. A large portion of the Duwamish River in this area is classified under EPA's National Priorities List. Historic pollution from industrial, stormwater and sewage has contributed to contamination of river sediment. Pollutants include PCBs, dioxins and furans, carcinogenic PAHs, and arsenic. There are several Early Action areas that have already been remediated for contaminated sediment. A final remediation action is currently being selected for future design and implementation. Figure 2-14 shows most of the Subsection 4 – Duwamish Estuary is listed as Category 5waters (WADOE 2012)

## Air Quality

Wind patterns in the Duwamish are dominated by winds from the South and southwest from October through March shifting to the North in the late summer (July August). The high density of industry as well as autos has caused some air quality problems in the Duwamish. Motor vehicles are the largest source of most air pollutants in King County. Local inputs from cement plants and steel mills can also be significant with mercury being a pollutant of concern. Again, most problems occur during the dry portion of late summer when weather patterns are very stable and there are only slight on-shore or off-shore winds. Particulates, sulfur dioxide, ozone and carbon monoxide are the pollutants of concern. The area is still within attainment measures. Puget Sound Clean Air Agency records show over 200 businesses registered as active sources of air pollution in the Duwamish Valley, an area of mixed industrial and residential land use.

## Physical Setting

Since the retreat of glaciation, the Green River has been carving out a floodplain from sedimentary, volcanic, and glacial deposits. The most significant recent geologic event was a massive landslide triggered by seismic or volcanic activity on Mount Rainier approximately 5,000 years ago. The largest landslide is known as the Osceola mudflow and it spilled down the White River valley burying the Enumclaw area and flowed on into the Duwamish valley. In some places, several hundred feet of mud were deposited. This mudflow diverted the White River northward to join the Green River and the combination of the two rivers deposited vast quantities of alluvial material to form the wide flat lower Green River valley which was now exclusively freshwater.

The soils along the lower Green/Duwamish River are not well known because extensive filling and industrial development in this area have largely covered the native delta soils. However, it is likely that the underlying native soils are similar to soils found in other tidal deltas, such as the Nisqually River delta. The Duwamish Estuary was once a vast tidally influenced swampland and marsh area. The soils in this area were likely fine materials from alluvium mixed with organic materials from the vast amounts of plant material produced in the estuarine marshes. These soils are generally very deep, poorly drained, and subject to being compacted and destabilized when disturbed (Perkins 1993).

The lower Duwamish experiences a diurnal tide with two daily high tides and two daily lows. The lower Green/Duwamish River has been dredged for most of its length and saltwater now intrudes between river mile (RM) 7 during normal flow and RM 10 during summer low flows and high tides. The relocation of the Renton Sewage Plant effluent outfall from the Black River to Elliott Bay has reduced summer low flows and enabled saltwater to move further upstream in the Duwamish River. Saltwater tidal soils in this segment of the river are very fine mud and clays that form hardened banks. The lower Duwamish Estuary is an area of very low gradient. Most of the larger sediment had been deposited in the middle river, and the lower river had primarily sand and mud substrate. There is a sediment trap at the 3rd Turning basin (RM 5.5) that captures course grained sands as they move through the system. Some of the soils in the industrially developed Duwamish Estuary have received heavy metal, petroleum, and organic chemical contamination. Most of the lower reach of the river was affected by tidal influence, whether freshwater tidal or brackish tidal. It is known that the river had several historic distributary channels spread over the broad delta floodplain. But today the river acts more like a canal, there is not much lateral movement within the system and bank line armoring and fill has disconnected the river from its former floodplain.

There are no drift cells in Subsection 4 – Duwamish Estuary. Sediments are under riverine and tidal influence.

## Significant or Special Aquatic Sites

The PSNERP data base identifies 9 small wetlands in Subsection 4 – Duwamish Estuary (NWI also identifies many of the same sites). With the exception of an emergent marsh at Kellogg Island most of these wetlands are either mitigation sites or restoration projects that have been constructed in this portion of the study area. More information on mitigation and restoration in 5.4 Habitat Restoration and 5.5 Mitigation. There are several mudflats that area exposed at low tides within the Duwamish and these have not been mapped so site specific investigations should be pursued at a low tide (like -1 or -2 MHHW) for permit actions in this area. Mudflats can be found at Kellogg Island, Diagonal way, GSA and the third turning basin to name a few.

## Fisheries, Wildlife and Vegetation

Seven species of salmonids travel up the Duwamish to their spawning areas in the upper basin they include; Chinook, coho, pink, chum, steelhead, cutthroat, and Bull trout. Wild salmonid stocks are augmented with plants from several regional hatcheries. Several species and stocks have been established, or are maintained, in the Green/Duwamish River system through extensive stocking efforts. Resident estuarine fish also include; starry founder, c-o sole, several species of perch including the shiner, several species of sculpins and three spined stickleback to name a few.

As degraded as the Duwamish appears to be it still provides as an essential rearing area for many estuarine dependent species such as “ocean type” juvenile salmonids (mainly Chinook and chum). The estuarine environment is important in providing both food and refuge for juvenile salmonids. Juvenile salmonids prey preferentially on certain species of crustaceans including amphipods (e.g., Corophium sp., Anisogammarus, Eogammarus), and some species of harpacticoid copepods (e.g., Harpacticus uniremis, Tisbe sp.), cumaceans, and midges. According to Cordell et al. (2011), annelids and chironomids (both adult and pupae) were a significant diet component of juvenile Chinook.

Mammal usage of the Duwamish Estuary has been limited because the site is surrounded by industrial development and roads. Mammals inhabiting the estuary include raccoon, Townsend voles, rabbits, muskrats, rats and probably coyote. Voles and muskrats likely consume insects and fleshy plant material from the high and low marsh areas. Raccoons consume fish, turtles, small mammals, birds, eggs, insects, and plant material, especially berries. California sea lion, harbor seals, beaver and river otters have been observed in the Duwamish Estuary.

A number of birds utilize the Duwamish waterway especially during spring and fall shorebird migration. Species such as dunlin, sandpiper and yellow legs of small flocks can be found. Shorebirds inhabit the mudflats and low marsh areas within the waterway feeding on small invertebrates, insects and some plant material. Both osprey and eagles forage and nest along the way with several nest boxes constructed for their use. Western grebes historically used the Kellogg Island area as a staging area prior to nesting but now are only rarely observed. Several species of waterfowl (mallards, widgeon, goldeneye and bufflehead to name a few) are usually seen more in winter months. The high marsh and upland areas of Kellogg Island and other areas currently are overwhelmingly dominated by nesting and feeding Canada geese. These geese compete with other species in the area.

The entire shoreline of the Duwamish is critical habitat for Bull trout. The river from the upper Green Basin down to the third turning basin is mapped as critical habitat for Chinook.

The existing vegetation in the Duwamish estuary is extremely limited due to very extensive industrial development that filled most of the intertidal and freshwater tidal marshes and swamps. In the remnant intertidal areas, there are marsh communities dominated by Lyngbys sedge, salt grass, Baltic rush, brass buttons, and hardstem bulrush. The invasive common reed dominates the marsh plant community in at least two locations. Reed canary grass can be found throughout most of this subsection. On upland sites, the vegetation is dominated by weedy species such as Scot's broom, dog fennel, Himalayan blackberry, and tansy ragwort.  A few sites have been planted with native vegetation in an attempt to restore habitat to the waterway and these sites are dominated by willows, alders, cottonwood, and shrubs such as red-flowering currant.

## Stressors/ Disturbances

There is an entire litany of disturbances in this subsection.  This is the most industrialized area in all of Washington State with many cement plants, metal recycling, airplane and boat manufacturing as well as a whole host of other industries.  Stressors include; bankline armoring, dredging, contaminated sediment, poor water quality, noise, excessive wake from boat traffic, an overabundance of impervious surfaces, and fill.

## Public Land

There are several public access and parks in the area including Duwamish Waterway, Puget and Riverview parks, T-107 public access area and a large green belt on the east side bluff of West Seattle.

## Manmade Features

The waterway is replete with piers, wharfs, marinas and riprap to list here but the GIS viewer has them all cataloged.

## Restoration activities

Starting over twenty years ago there was a flurry of non- compensatory restoration activities within the Duwamish with many agencies (USACE, EPA, USFWS, NMFS, King County, The City of Seattle and the Port of Seattle) working collaboratively to implement restoring some of the lost habitat types (mudflats, marsh and tidal sloughs) that were filled in the past.  There has been a lot of monitoring of these projects over time and all has been successful in restoring some of the historic functions that had been lost within the context of an urbanized estuary.  While the restoration has proved beneficial it represents less than 1% of the total amount of habitat lost historically. Table 2-15 is a list of the restoration projects that have been constructed:

**Table 2-15 Restoration Activities with related acreage in Subsection 4 – Duwamish Estuary**

| Restoration Project | Approximate size of intertidal habitat (acres) |
|---|---|
| Site one | 2.5 |
| GSA site | 0.25 |
| T-105 | 0.6 |
| Turning Basin III (CA and POS) | 0.6 |
| Hamm Creek | 0.8 |
| Puget Creek | 0.6 |
| Herring House | 2.1 |
| North wind's weir | 1.0 |

| Restoration Project | Approximate size of intertidal habitat (acres) |
|---|---|
| Kenco marine | 0.8 |
| Turning Basin II | 1.3 |
| First Ave. South | 2.1 |
| Duwamish Waterway park | 0.02 |
| Total acres of intertidal restoration | 10.7 |

## Mitigation

There are a few 404 related mitigation projects in this subsection as well that are associated with past filling projects. Mitigation projects this area included; 0.28 acres of intertidal habitat at Ralph Island at the end of Diagonal Way (Port of Seattle), 1.9 acres of intertidal habitat at the third turning basin (Port of Seattle) and the 509 marsh at the First South Bridge (Department of Transportation).

## Other Relevant Activities

There are a few USACE projects in Subsection 4 – Duwamish Estuary. The largest is the navigational dredging of the waterway from the third turning basin to Harbor Island (approximately rivermile 6). USACE also constructed some restoration projects in this subsection, a few are listed in Table 2-16.

**Table 2-16 Restoration Activities performed by USACE Seattle**

| Restoration Project Name | Authority |
|---|---|
| Puget Creek | Section 1135 of WRDA |
| Hamm Creek | Section 1135 of WRDA |
| Site 1 | Green Duwamish General Investigation |

## WDFW Marine Shoreline Habitat Assessment

Subsection 4 – Duwamish Estuary is an anomaly in terms of the habitat values identified in the WDFW assessment. While the actual shoreline habitat is degraded (almost completely armored with very little riparian vegetation) it is an important migratory corridor for salmon and trout which affects the index scoring showing that two thirds of the area is of high habitat value (green) in both indices (Figure 2-20, Figure 2-21 and Figure 2-22).

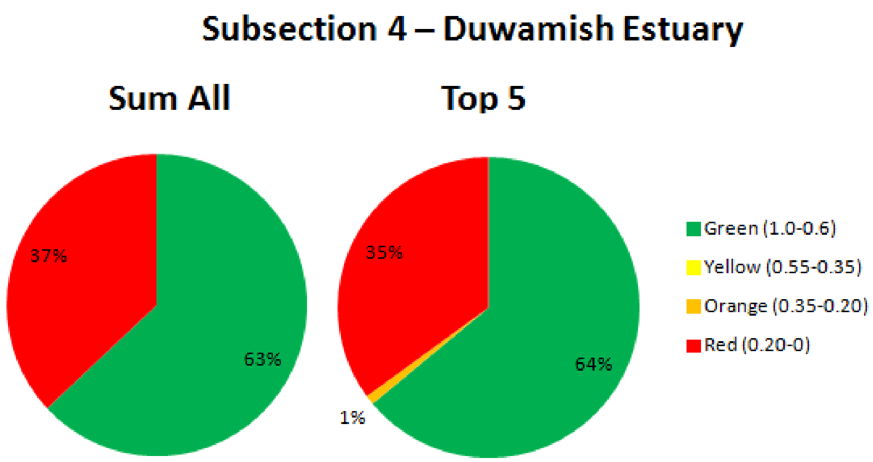



**Figure 2-20 Habitat Values for Subsection 4 – Duwamish Estuary**

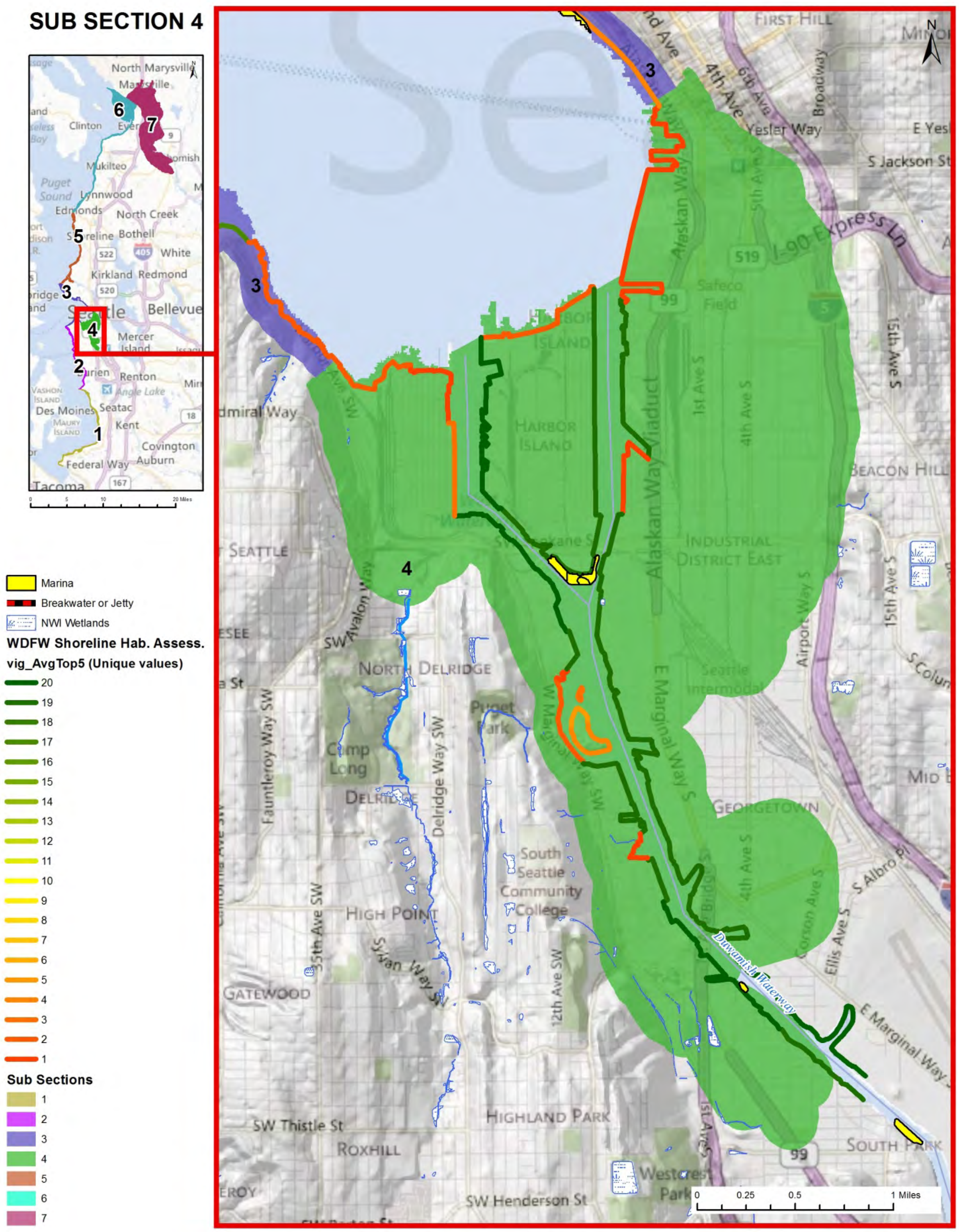



**Figure 2-21 Subsection 4 – Duwamish Estuary WDFW Shoreline Habitat Quantitative Assessment Index. Top-5 index indicating relative value of shorelines for fish and wildlife habitat conservation.**

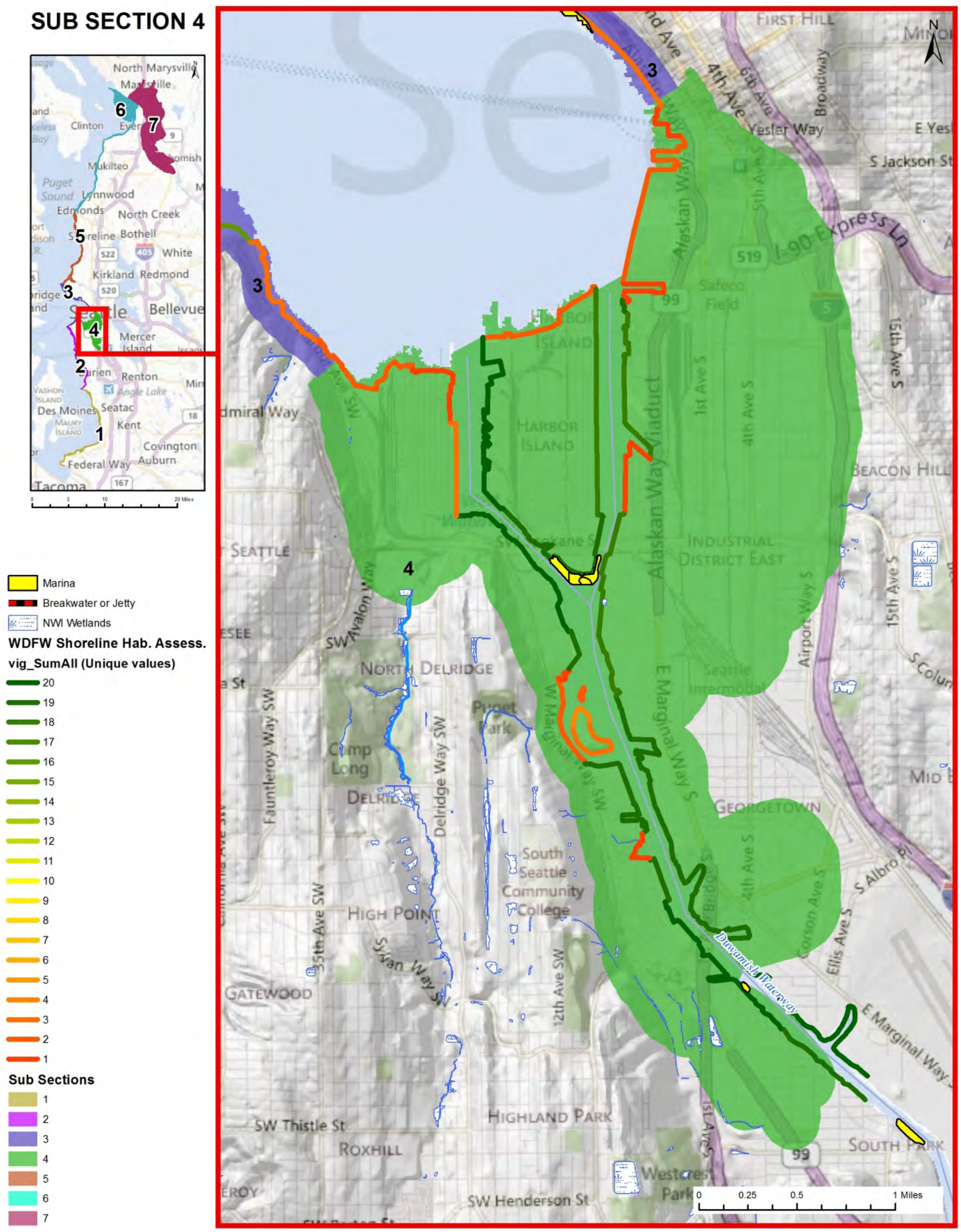



**Figure 2-22 Subsection 4 – Duwamish Estuary WDFW Shoreline Habitat Quantitative Assessment Index. Composite index indicating relative value of shorelines for fish and wildlife habitat conservation.**

## 2.2.5. Subsection 5 – Edmonds

Subsection 5 – Edmonds starts at WestPoint (Discovery Park) in the south and continues to Edwards point (Edmonds marina) in the North (Figure 1-1) with a total land area of 2,494 acres. This subsection includes Shilshole marina, Carkeek Park, Wells Point, and Edmonds Marina (Figure 2-25). Municipalities in this subsection include city of Seattle neighborhoods such as Ballard and Shoreline, The Highlands, Richmond Beach, and Edmonds. Creeks in this area include Pipers, Boeing and Deer creeks. Aerial photographs from 1977 and 2006 do not suggest large scale changes along the shoreline (Figure 2-23 and Figure 2-24).


**Figure 2-23 Air photo from 1977 just north of Richmond Beach. Courtesy of Washington Department of Ecology.**


**Figure 2-24 Shoreline oblique air photo just north of Richmond Beach in 2006. Courtesy of Washington Department of Ecology.**


**Figure 2-25 Edmonds Marina with Edmonds marsh in the background (top center of the picture) from 2006. Courtesy of Washington Department of Ecology.**

Two of the larger municipalities in Subsection 5 – Edmonds are the cities of Edmonds and Shoreline. The following is a brief overview of their history.

## History of Edmonds

The first settler in Edmonds was George Brackett who, in 1880, opened a general store. Logging would be Edmonds mainstay like most settlements and in 1889 the first sawmill was built on the waterfront. A year later in 1890 Edmonds was incorporated, a wharf was constructed, and in 1891 the Great Northern Railroad reached the town. Downtown Edmonds by 1908 had over 50 businesses, 4 churches, and had a population of 1,546. In 1923 the first car ferry began operation between Edmonds and Kingston on the existing wharf. Shingle production remained the main economic force in the town until 1951 when the last shingle mill closed. At its lumber peak, Edmonds was running 10 mills.

When the Great Depression hit all but two mills closed down, but the town was able to cope well. Business continued to open on Main Street, local projects such as road and high school improvements continued, and residents raised their own vegetables, fruits, and chickens. Life in Edmonds continued on its customary pace. During the years of World War II Edmonds would lose many men, but after the war ended a new period of growth was ushered in. Population rose past that of Snohomish to become the second most populous city in Snohomish County, right behind Everett.

In 1962, the Port of Edmonds was under way for construction and was finished by 1969, providing the only public boating access in the highly populated 30-mile stretch between Shilshole Bay and the Port of Everett and the state's first public saltwater fishing pier. The Port of Edmonds was located in the newly made Edmonds Port District formed in 1948.

By 1970 the population of Edmonds rose to just below 24,000 and would rise another 5,000 by the end of the decade. Edmonds became the 19th largest city in the state in 2000, still second to Everett in the immediate area, with a population of 39,544 reaching 40,560 in 2007. Most of Edmonds residents would live outside the city center as its boundaries extended, with surrounding cities, such as Lynwood, Mountlake Terrace, and Woodway creating an almost contiguous urban area. In 2011 the Edmonds/Kingston ferry dock is one of the busiest in the Washington State Ferries system.

## History of Shoreline

The first settlers to live in the Shoreline area arrived in the 1880's to clear land for timber and farming. But large settlement did not occur until 1890 when a small town was planned in anticipation of the Great Northern Railroad. One year later in 1891 this railroad would be completed, passing through Shoreline to Seattle. The arrival of the railroad spurred growth and interest in the town. Shoreline was close to Seattle and attracted many residents looking to live in a rural area yet still commute to work in Seattle.

By 1906 a light-rail interurban system had been completed and in 1913 Trunk Road was paved over with bricks. Commuters could travel by train, boat, or light-rail between Seattle and Shoreline and by 1914 even bus. These centers of transportation initiated commercial growth and the population grew. In 1907 a small shipyard was constructed by the Portland Ship Building Company. Lumber mills cleared forests that in turn attracted farmers who then grew crops and livestock. By the 1930's America was turning to the car and the Interurban was reduced to scrap and sold by 1939 and paved roads were soon crisscrossing the community. Development and growth slowed during the Depression and World War II (1930-1945). The only growth during the depression occurred along Aurora Street in which the newly constructed Highway 99 ran through.

After World War II demand for family housing dramatically increased. In the 1960's I-5 was constructed, replacing Highway 99 as the main arterial north-south road. In 1995 Shoreline was incorporated into a city by King County with a population of 50,352 people, the 10th largest city in Washington.

The railroad is a dominant feature within the nearshore area (in most places adjacent to the shoreline) of Subsection 5 – Edmonds so a brief history is included here as well.

## History of Railroads in the Seattle Area and North

The development of Seattle and the surrounding area is closely tied with the emergence of railroads. Since its founding in 1851 Seattle has been a city dependent on commerce, relying on the natural deepwater port to facilitate transportation of trade along its waterfront. Mass transport dominates economically and physically in Seattle's waterfront where transcontinental rail lines and transoceanic routes converge. The first transcontinental railroad to reach the northwest was the Northern Pacific where it had begun construction westward in Duluth and eastward from Kalama, with eventual lines moving north and south. The Northern Pacific had many promising cities to choose from for its western terminus; Olympia, Steilacoom, Seattle, Tacoma, and Mukilteo all fought for the Northern Pacific terminus that would bring assured wealth and trade with it.

Despite Seattle's offer, Tacoma was chosen by the Northern Pacific. Seattle was rocked by the loss of the terminus, but in spite of this the city survived and grew, thanks to its centrally located position in the Puget Sound and excellent deepwater port. But the port alone would not suffice for the areas visionary populace. The city gathered together and acted proactively, choosing to fund and build Seattle's own rail, the Seattle & Walla Walla railroad, linking it to the rich farmlands of Eastern Washington. Funded and built almost completely from the pockets and labor of Seattle's population, construction started at the mouth of the Duwamish River atop of piers and trestles over the tidelands in 1874 and finishing in 1877. Track never reached Walla Walla or King County but went as far as the coal mine in Renton after 12 miles of track was laid. In time this road would be extended to Newcastle using Chinese workers, but no further. By connecting the large lucrative coal mines of Renton to the port of Seattle, an outlet for coal emerged to satiate the high demands in burgeoning California. This coal output allowed and further cemented Seattle's place in becoming no longer just the geographical center of the Puget Sound but the economic center as well. In 1880 the Seattle & Walla Walla railroad and its generous waterfront franchise was bought up by Henry Villard, owner of the Oregon and Eastern Washington railroads and steamships that were filling the void left behind by the Northern Pacific during its financial crisis. Villard renamed Seattle's railroad the Columbia & Puget Sound Railroad and erected Seattle's first train depot, barely more than a shed, not far from where Union Station would be built 20 years later.

In 1885 the Lake Shore & Eastern Railroad was incorporated with the eventual goal to connect Seattle to a transcontinental railway. Piers were sunk, planks laid, and tracks placed north between Elliott Bay and Ballard along a 120 foot-wide waterfront right of way. This new track was adjacent to the Northern Pacific owned tracks on the previously filled "Railroad Avenue", effectively separating the city from its harbor by a wide strip of piers, rail, fill, and pilings. Track was also laid eastward from Seattle to Bothell and Woodinville. Railroad Avenue truly began taking shape in 1887 when 26,000 piles cut from nearby forests, were driven into the Elliott Bay mud. When the great fire destroyed part of this stretch in 1889, it was rebuilt and extended further to support more streets, rail, and buildings atop its trestles.

The Great Northern Railway extended westward across Montana and Idaho. Owned by James Hill the "Empire Builder", his grand vision was to gain access to trade and transport with the Orient. The news of this transcontinental railroad sparked a new bidding war between the cities in the Puget Sound for the terminus, the apparent choice being Seattle. The Great Northern entered into the northwest in 1989 as Hill purchased the Fairhaven & Southern Railroad that ran from Bellingham Bay north to the Canadian border and extended it south to Burlington on the Skagit River. Then in 1890 Hill purchased the New Westminster & Southern Railway running from West Minster, B.C. to the Washington border. This same year he created the Seattle & Montana Railroad and announced his decision in choosing Seattle as the location of the Great Northern terminus, granting the city its long awaited transcontinental terminal. Within two short years contractors succeeded in clearing land, blasting stumps, filling cribbing on shorelines, pounding pilings, and constructing trestles along the route north of Seattle following the coastline closely. Construction north required the crossing of three major rivers, the Snohomish, Stillaguamish, and the Skagit River, and was fraught with setbacks. Tides, waves, flooding eroded soft soil and washed out tracks, wood eating worms ate at pilings in salt water, and even a draw bridge was condemned and had to be rebuilt. In some cases track laid on the shore near Edmonds and Mukilteo was only four feet above the tide line. Eventually in 1893, the first train from the Great Northern Railway arrived in Seattle north of the main harbor at Smith Cove, granting the city a transcontinental status. However, before it could extend southward to Elliott Bay it was met with opposition.

Seattle City Engineer, Reginal Heber Thomason, opposed another railroad on the already congested waterfront and proposed that the Great Northern Railway and Northern Pacific join forces and build a tunnel beneath the downtown and develop the new terminal south of Pioneer Square. Before any work could be done, the national economy fell taking with it the Northern Pacific and Union Pacific. The Great Northern Railway survived and Hill temporarily gained control of the Northern Pacific, granting him the opportunity to build the proposed tunnel in 1903 and completing it in 1906. The southern end of the tunnel opened into the Great Northern and Northern Pacific's new grand terminal Union Depot, now called King Street Station.

## Land Classification and Modification

Table 2-17 and Table 2-18 show the tabulated land classification and percent cover, and the type and percent of modifications in the Edmonds subsection.

**Table 2-17 Land classification and percent cover for Subsection 5 – Edmonds.**

| Land Classification | Percent Cover |
|---|---|
| Barren/open space | 6% |
| Developed low intensity | 9% |
| Developed medium intensity | 8% |
| Developed high intensity | 4% |
| Open water | 33% |
| Herbaceous | 0.6% |
| Shrub/scrub | 0.2% |
| Wetland (herbaceous and woody) | 10% |
| Forested (deciduous, evergreen, mixed) | 11% |

**Table 2-18 Type and percent of modifications in Subsection 5 – Edmonds.**

| Modification | Percent cover in the sub area |
|---|---|
| Marinas | 16% |
| Percent of area occupied by railroad | 4% |
| Impervious surface- 0 to 10% | 79% |
| Impervious surface- 10 to 30% | 5% |
| Impervious surface-30to 50% | 5% |
| Impervious surface- 50 to 100% | 10% |
| Shoreline armoring | 99% |
| Overwater structures | 3% |

## Water Quality

Subsection 5 – Edmonds includes the Seattle neighborhoods of Ballard, the Highlands, and the City of Shoreline. Shilshole marina is also located in this sub area. Category 5 waters are classified in this area for fecal coliform and PCBs. There are also Category 5 offshore sediments for exceedence of the Sediment Management Standards bioassay criterion. The abandoned tank farm at Wells point has exceeded State standards for sediment, groundwater and surface water. Pipers Creek has exceedances for fecal coliform. Piper's creek also exhibits about 58% mortality in coho due to pre spawning mortality (PSM).

## Physical Setting

Much of the upland area of Edmonds lies at the terminus of the Seattle drift plain, a plateau that drops towards the Sound. The surficial geology of the subsection consists mainly of Pleistocene glacial, alluvial, and marine sediments and little or no bedrock is exposed. Major Quaternary stratigraphic units in the area include nonglacial sand, silt, and clay. The steep bluffs in the area are susceptible to landslide. In the nearshore area the substrate is dominated by sands while mixed course grained (sand and gravel) material is frequently encountered throughout this subsection (Woodruff et al. 2001). There are four drift cells identified in Subsection 5 – Edmonds (Table 2-19)

**Table 2-19 Drift Cells within the study area Data Source: Johannessen et al. 2005**

| Drift Cell name[a] | Length (miles)[b] | Percent of the drift cell modified (current)[c] | Historic Change | Notes |
|---|---|---|---|---|
| SN-2/SN-3-NAD | 2.6 | 100% | 81% loss | Edmonds Marina and Ferry Terminal impede net shore drift |
| SN-3 | 6.2 | 71% | 100% loss of pre-development sediment KI-2-1sources | Modified by Railroad |
| KI-2-1 | 2.8 | 78% | 100% loss of bluff sediment | Modified by railroad |
| KI-2-1/2-2-NAD | 3.3 | 96% | 82% | Includes modification from Shilshole marina |

a. Data source: Johannessen et al. 2005, Table 7

b. Data source: Johannessen et al. 2005, Table 8, Conversion unit 1 mile=5280ft

c. Data source: Johannessen et al. 2005, Table 8, MOD=Percent of drift cell modified (current)

## Significant or Special Aquatic Sites

Woodruff et al. (2001) provides a very detailed report about eelgrass and kelp distribution within Subsection 5 – Edmonds. For the most part, there is dense to moderate eelgrass along the entire shoreline in this subsection and some patchy areas of kelp. Wetlands (according to NWI) in the area include a palustrine forested wetland at Pipers Creek, palustrine forested on the north side of Wells Point and the large Edmonds marsh just shoreward of the marina, which includes palustirine emergent and palustrine forested.

## **Fisheries, Wildlife and Vegetation**

Waterfowl typically observed in Subsection 5 – Edmonds include Canada goose, mallard, widgeon, northern shoveler, scaup, godeneye pintail, bufflehead and merganser. Sea duck and marine birds consist of loons, grebes, scoter guillemot cormorant and gulls with the occasional marbled murrelet loafing off the shoreline. Purple martins nests on pilings at the mouth of Boeing Creek (WADOE 2010). Raptors include Bald eagles, red tailed hawks and the occasional peregrine falcon.

Juvenile cutthroat trout and Chinook, chum, coho, and pink salmon feed and rear in nearshore areas of Subsection 5 – Edmonds. Juvenile salmonids feed on epibenthic invertebrates in the intertidal zone. Woodruff et al. (2001) documented a variety of fish in the nearshore during their survey work in 2000. Fish observed included perch (4 species) with shiner perch as the most frequent, herring and sand lance, flat fish (such as starry flounder) were also present as well at rat-fish. A steel-pile dam is present on Boeing creek about 2,300 feet from the mouth at Puget Sound and acts as a up- stream barrier to migratory fish (WSDE 2010). Even with the barrier it is still used by Chinook, coho, chum and cutthroat.

Forage fish such as sand lance, herring and smelt can be found in the nearshore area throughout this subsection. Sandlance spawn at both Wells Point and Golden Gardens. Smelt have been known to spawn at Wells Point and Richmond Beach.

Geoduck is found in most of shoreline beach areas near Wells Point. Other macro invertebrates include littleneck, horse, butter and sand clams, shore, Dungeness and red rock crabs, cockle, softshell and bay mussels. The most common anemone in Subsection 5 – Edmonds is the White-Plumed anemone Washington State Department of Health advises against any shellfish harvest on any beach on the eastern shores of Puget Sound between Everett and Tacoma due to public health concerns related to biotoxins (red tide blooms) and pollution (mainly fecal coliform).

Mammals in the area consist of coyotes, foxes, voles, rabbits, and other small mammals (field mice, moles and the occasional rat). Furbearers such as raccoon, otter, mink, opossum, also feed, mate and take refuge along the beach and hillsides. Deer are known to frequent some of the area. The DNR Priority Habitat Database has locations for some of the States sensitive species.

Marine mammals that occasionally haul out on some of the beaches include harbor seals and California sea lions. Whales such as orca, minke and pilot and the occasional porpoise can occasionally be spotted offshore in the deeper waters. All marine mammals are protected by the Marine Mammal Protection Act. (NOAA 2013)

Flora in Subsection 5 – Edmonds is typical of most of Central Puget Sound. With the railroad so close to the shoreline many of the native emergent species are lacking and the railbed itself has weedy species. But just above the tide line you can sometimes find American dune grass and gumweed. Farther up the shore in elevation beach pea and sea rocket can be found. On bluffs and cliffs away from the spray zone, where you find more mature tree species expect to find Douglas fir, big leaf maple, western hemlock and madrone. Much of the shoreline and bluff tops are in urban residential neighborhoods where cultivated plants and expansive lawns dominate.

## Disturbances and Stressors

There is an entire litany of disturbances in this subsection which include frequent landslides during the winter along the railroad grade.  Outfall for Brightwater treatment facility is at Point Wells, shoreline hardening of 99% of the area, two large marina intrude into the nearshore., longshore sediment process is disrupted by the two large marinas (Shilshole and Edmonds) as well as the former tank farm at Wells Point.

## Public Access

In Subsection 5 – Edmonds there is public access to Golden Gardens, Carkeek Park, Richmond Beach, and Edmonds underwater park.

## Manmade features

Along the shoreline there are overwater restaurants (on piers) just southeast of Shilshole marina, Shilshole marina, the former Wells Point tank farm and Edmonds marina and the Edmonds Ferry terminal.

## Restoration activities

Restoration sites include Pipers Creek near Carkeek Park including wetland enhancement and some in stream work conducted by Seattle Public Utilities.  There has also been some native plant restoration at Richmond Beach.

## Mitigation

No mitigation sites were discovered in this subsection.

## Other Relevant Activities

In 1974, USACE constructed Shilshole Marina and in 1986 rehabilitated the breakwater at Edmonds Marina but the marina itself was constructed locally.

## WDFW Marine Shoreline Habitat Assessment

Subsection 5 – Edmonds shows average habitat values within the study area.  The composite index (Sum all) shows approximately 60% of the shoreline with high habitat values (green and yellow) (Figure 2-26 and Figure 2-28).  The Top Five index shows approximately 70% of shoreline with high habitat values (Figure 2-10).  The results for the Top 5 index are very similar to that of Subsection 1 – Federal Way and Subsection 2 – Burien/West Seattle. The higher Top 5 index indicates that only a few components are contributing to the high habitat values in the composite index. The only difference is that National Wetlands were common in the Top 5 components.  A substantial portion of the Edmonds subsection shoreline is either hardened or has railroad tracks along the shoreline with a diminished riparian corridor.

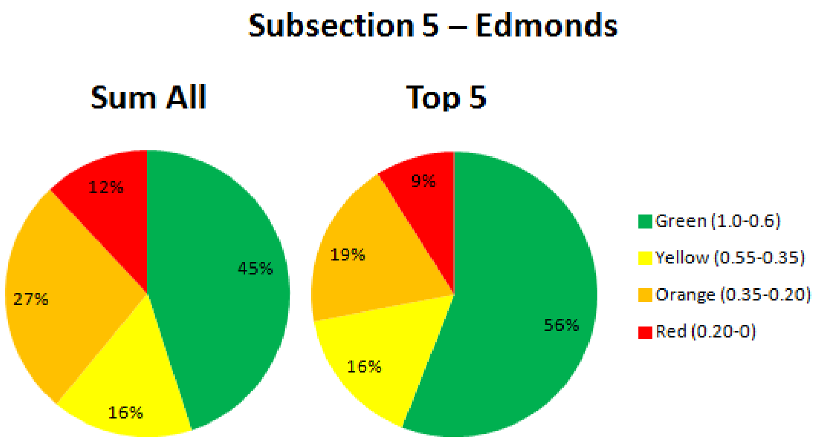



**Figure 2-26 Habitat Values for Subsection 5 – Edmonds**

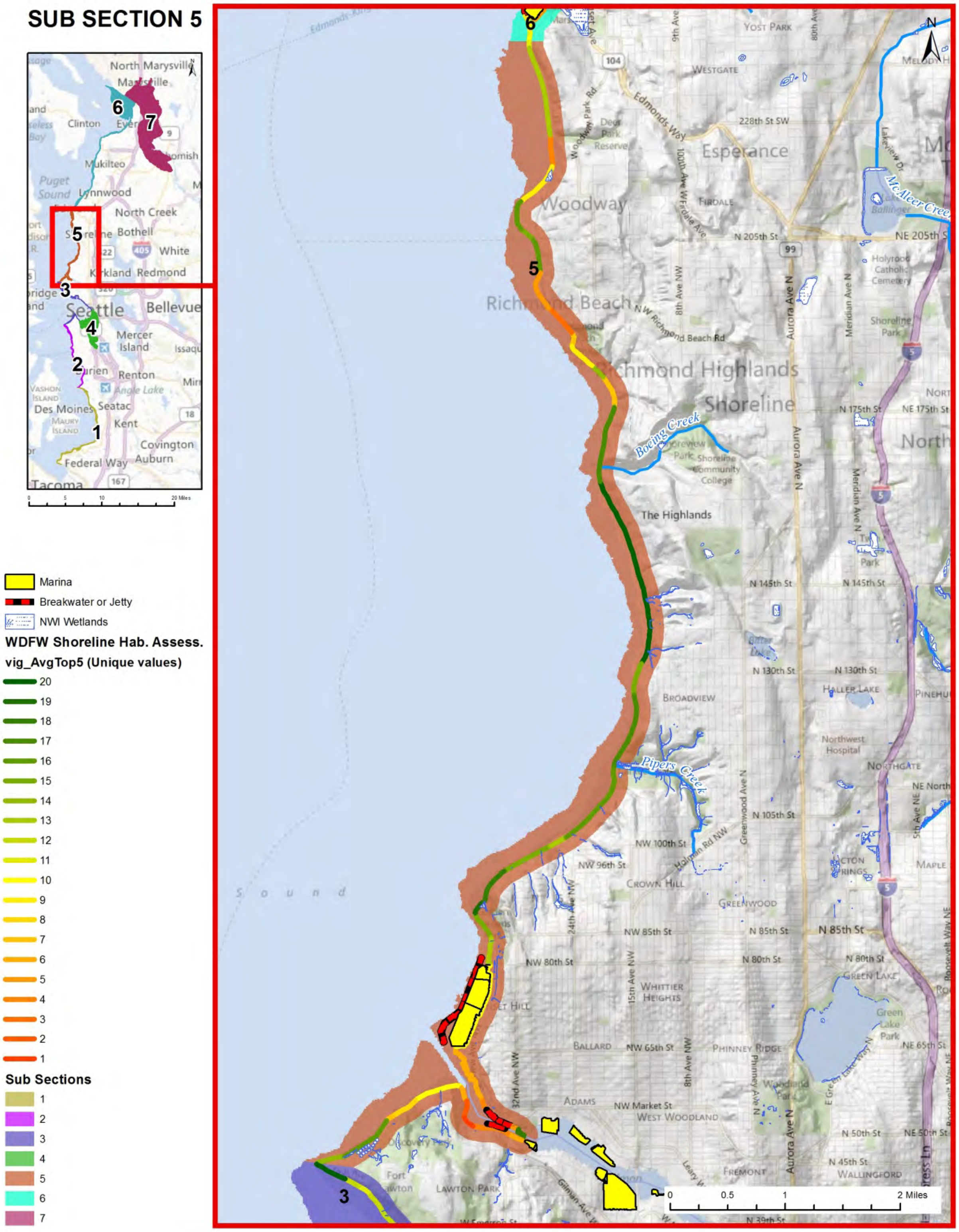



**Figure 2-27 Subsection 5 – Edmonds WDFW Shoreline Habitat Quantitative Assessment Index. Top-5 index indicating relative value of shorelines for fish and wildlife habitat conservation.**

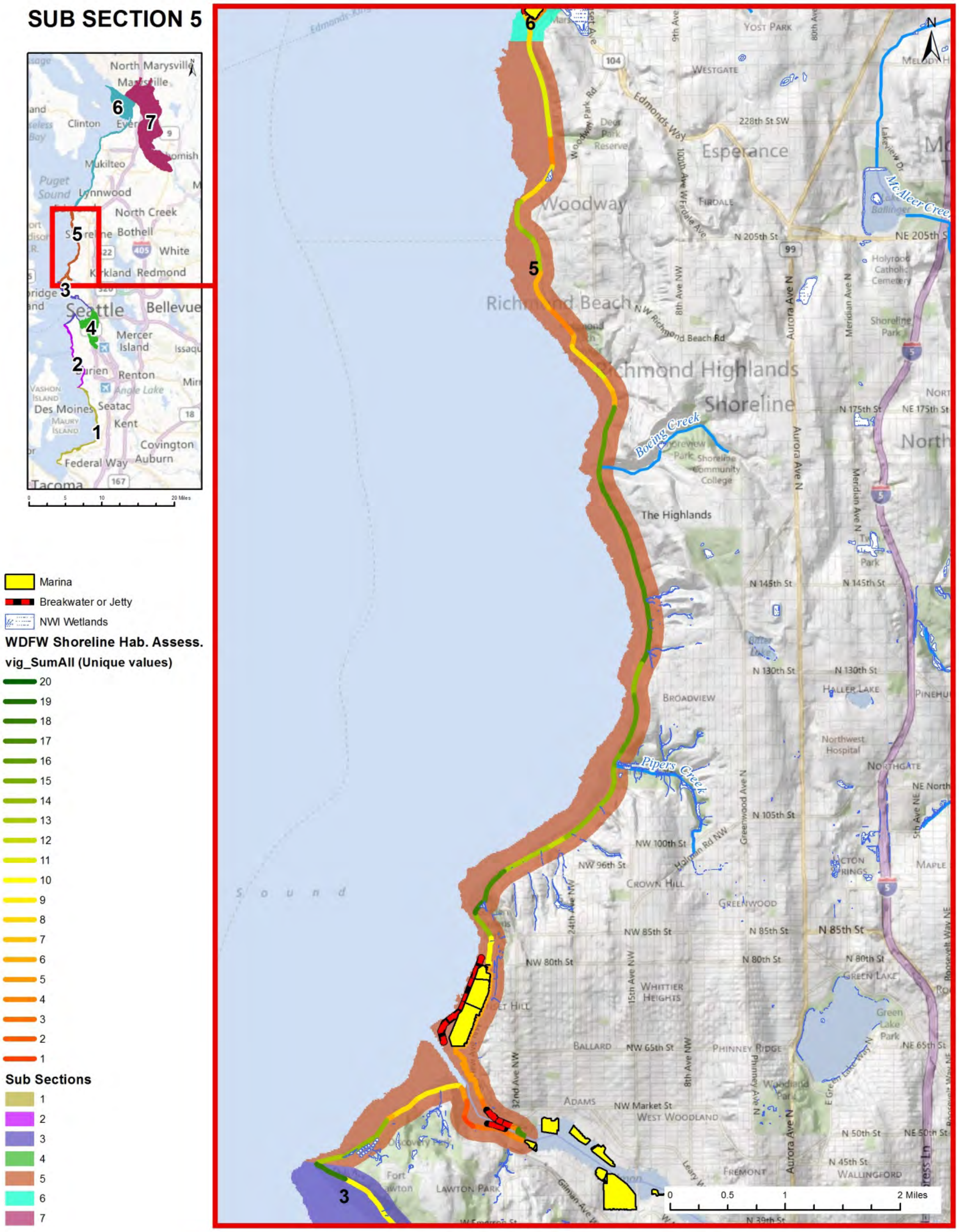



**Figure 2-28 Subsection 5 – Edmonds WDFW Shoreline Habitat Quantitative Assessment Index. Composite index indicating relative value of shorelines for fish and wildlife habitat conservation.**

### *2.2.6. Subsection 6 – Everett*

Subsection 6 – Everett extends from Edwards Point to Priest Point, with a total area of 8,801 acres (Figure 1-1). Specific features include Picnic Point, Elliott Point, the Navy homeport, Port of Everett, Port Gardner, and Jetty Island (Figure 2-31), and is inclusive of the shorelines of the municipalities of Edmonds, Mukilteo and Everett. The large mudflat and associated wetland on the right side of Figure 2-31 represents some of the last and largest special aquatic sites in the Everett area. Jetty Island wetlands and mudflats are maintained from the placement of dredged material from the Snohomish navigation projects. Aerial photos from 1977 and 2006 shows that a section of shoreline along Mukilteo did not have large scale changes (Figure 2-29 and Figure 2-30).


**Figure 2-29 This 1977 air photo shows the shoreline along Mukilteo including the tank farm and barge loading facility it's just north of the ferry terminal. Courtesy of Washington Department of Ecology.**

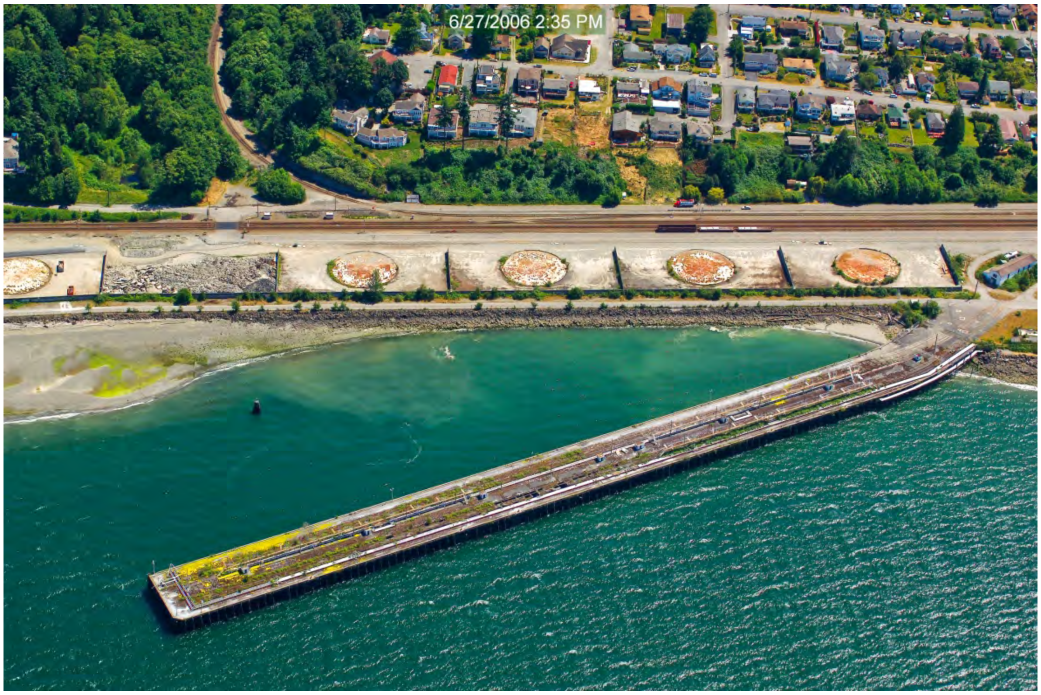



**Figure 2-30 Close-up of the same area in 2006. This area is slated for redevelopment and the U.S. Air force has removed the tanks. The barge loading facility has been closed. Courtesy of Washington Department of Ecology.**


**Figure 2-31 Jetty island and Port Garner area in 2006. Courtesy of Washington Department of Ecology.**

## History of Everett

The first permanent settlement in what would become Everett was a single log cabin in 1861. By 1870 the population rose to 400 and 1,387 by 1880. During this time, logging was the mainstay for the city and several mills were constructed. By 1872 50 acres of the Snohomish had been diked for farming. By 1889 there was talk of railroads reaching Everett increasing growth and sparking a boom. Land was cleared and a nail factory, barge works, docks, a paper mill, and a smelter were constructed by 1891. A sawmill on a large wharf, immense warehouse, and a brick hotel were also constructed. By 1892 Everett resembled a city with schools, churches, theatres, telephones, streetcar service, and a population of approximately 5,600 strong. Following Seattle's initiative, a railroad was built connecting the mines in the Cascades to the smelter in town.

In 1893 the Great Northern Railway arrived and Everett was officially incorporated, but then depression struck shortly after causing people to leave and investments to be withdrawn. In 1897 Everett won the county seat of Snohomish and by 1899 the city began to recover. By 1903 Everett boasted 10 sawmills, 12 shingle mills, a paper mill, flouring mill, foundries, machine shops, a smelter, an arsenic plant, a refinery, "creosoting" works, a brewer, a sash and door plant, an ice and cold storage plant, and a creamery. Industry employed more than 2,835 men. Population by 1911 rose to 25,000 and the number of manufacturing plants rose to 95. The Snohomish River and bay were dredged and the world's largest lumber mill was built that would produce 70 million feet by 1912. In 1927 Highway 99 was completed, connecting Everett to the main north-south arterial road. Demand for lumber grew during World War I and downtown experienced much growth but demand fell during the depression years in the 1930's.

In 1936 the cities first airfield established aviation and eventually a military presence in the area. During World War II the field's facilities were improved and became a military base. Construction of a huge shipyard started in 1942. After the war Alaska Airlines replaced and resided on the former military base, but between 1950-1953 military had returned for the Korean War. Then, once again leaving, the military moved out allowing the Seattle Boeing Corporation to move in and build the largest building by volume for plane production. In 1965 Highway 99 was replaced with I-5, spurring growth and commerce.

The 1970's saw a nosedive in the aviation industry, with massive layoffs in Boeing, Everett experienced high unemployment. In hopes of stabilizing the city's future, Everett put itself in the running for a new Naval base and was chosen. In 1987 the Naval Station in Everett started construction and in 1994 Navy personnel moved into the support and administration buildings. Today it is the US Navy's most modern facility. This firmly established financial and professional services in downtown Everett, spurring expansions in hospitals, schools, and the Port of Everett, and even the mall.

In the 1990's Everett's skyline grew skyward and the town became the homeport for the U.S.S. Lincoln aircraft carrier and several other vessels. Boeing also expanded its business on the 777 airplane. By 2002 a new train station and events center in downtown were completed and by 2007 Everett's population had reached over 100,000. In 2007 Boeing released the 787 Dreamliner and by 2011 797 Boeing 787's had been ordered.

## History of Mukilteo

In 1792 Captain George Vancouver declared possession of the land around the Puget Sound on what is now Mukilteo, Washington. Permanent settlement, however, did not start until 1858 when an exchange saloon was built trading staples for furs, feathers, and cranberries with the Indians. As it grew it became an important trade site for logging. However, the town sought to expand its commercial sector. Aside from being important for lumber, Mukilteo was a fishing village, trading post, and a port-of-entry. By 1870 a brewery and a salmon-salting business were built as well. During 1877 the salmon-salting business expanded into Washington's first salmon cannery. By 1892 Mukilteo had a population of about 300, built its first school in 1893, and started the new century with a population of 350.

The 1900's brought growth like it did to other Puget Sound cities. In 1903 a lumber company was founded followed by a gunpowder plant and a lighthouse in 1906. Ferries visited Mukilteo as early as 1911, with the first car ferries in 1919, supporting restaurants and stores. A road was built connecting surrounding settlements in 1914, lessening the dependence on water bound transportation but also increasing ferry usage.

By 1947 Mukilteo's population had grown to 775 and had voted to incorporate. Even with such a small population the town ran a ferry service to Whidbey Island, a fuel storage facility for the Air Force, and a major rail line for the Great Northern Railway. Mukilteo became an official city in 1970 after adopting state municipal code. Population stayed relatively low at 1,426 but after annexation of an area south in 1980 and subsequent annexation of Harbor Pointe in 1991, the city's population increased dramatically to over 10,000 and almost double that by 2005. Substantial development has occurred since in response to the increased population and a new ferry terminal is planned, as the Mukilteo-Clinton ferry dock is too small to accommodate the growing traffic of commuters and travelers. In 2008 the Sounder commuter rail service opened connecting Mukilteo to Everett in the North and Seattle and Tacoma to the south.

## Land Classification and Modification

Table 2-20 and Table 2-21 show the tabulated land classification and percent cover, and the type and percent of modifications in the Everett subsection.

**Table 2-20 Land classification and percent cover for the Everett subsection**

| Land Classification | Percent Cover |
|---|---|
| Barren/open space | 31 |
| Developed low intensity | 6% |
| Developed medium intensity | 4% |
| Developed high intensity | 5% |
| Open water | 38% |
| Herbaceous | 0.4% |
| Shrub/scrub | 0 |
| Wetland (herbaceous and woody) | 10% |
| Forested (deciduous, evergreen, mixed) | 6% |

**Table 2-21 Type and percent of modifications in the Everett subsection.**

| Modification | Percent cover in the subsection |
|---|---|
| Marinas | 2% |
| Percent of area occupied by railroad | 2% |
| Impervious surface- 0 to 10% | 84% |
| Impervious surface- 10 to 30% | 4% |
| Impervious surface-30to 50% | 4% |
| Impervious surface- 50 to 100% | 8% |
| Shoreline armoring | 58% |
| Overwater structures | 58% |

## Water and Sediment Quality.

This subsection includes the cities of Mukilteo, and Everett and a portion of the City of Edmonds. There are several important features that contribute to water quality and sediment quality in this area including the Port of Everett, Mukilteo Ferry Terminal and Everett naval station. Burlington Northern Santa Fe Railroad also runs adjacent to the shoreline in much of this area. The railroad system here has resulted in landslides which contribute to acute turbidity along this portion of shoreline. The former Kimberly-Clark plant in Everett is believed to have contaminated sediments and perhaps groundwater associated with the site (Sheets 2012). The only Category 5 area for water is near the city of Edmonds for fecal coliform. There is one area at the Port of Everett for Category 5 sediments exceeding the Sediment Management Standards bioassay criterion. Under Chapter 173-201A WAC, Port of Everett is classified as 'secondary contact' for recreation use due to increased levels of fecal coliform. There are relatively few wastewater discharge permits in the Everett area. There are at least two wastewater treatment facilities located along the shoreline in Subsection 6 – Everett.

## Physical Setting

Much of the Everett subsection contains steep Bluff Backed beach. While susceptible to landslides, deposition of sediment from the bluffs are intercepted by the railroad tracks that runs the entire length of this subsection. There is also limited sediment input from stream mouths as many of these are culverted under the railroad track. In the nearshore area the substrate is dominated by sands while mixed course grained (sand and gravel) material is frequently encountered throughout this subsection (Woodruff et al. 2001).

Shoreline drift cells are a compartmentalized area adjacent to the shoreline that acts similarly to a closed or nearly closed system. Typically, sediment is mobilized within the littoral zone system by waves and current. This suspended sediment load is then redistributed in a continuous cycle of deposition and erosion within the cell (Johannessen et al. 2005) Johannessen did not identify any drift cells for Subsection 6 – Everett, but did describe some of the nearshore characteristics.

*"This sub-area is characterized by the Burlington Northern Santa Fe (BNSF) railway and seawall, which runs adjacent to, and occasionally over, 73.7% of the (linear) marine shoreline. The seawall and associated backfill were constructed into the upper foreshore between 1889 and 1891 to defend the overlying railroad from wave erosion and burial by landslide colluviums from adjacent receding bluffs. As a result, the structure has eliminated the primary nearshore sediment source."*

## Significant or Special Aquatic Sites

Unlike the Subsection 5 – Edmonds that is characterized by an almost continuous band of eelgrass, Subsection 6 – Everett for the most part has sparse eelgrass when present and there are many places in the shoreline where eelgrass is absent. Woodruff (et al 2001) notes a large patch of kelp just north of the ferry terminal, but for the most part Kelp is lacking in the rest of the subsection. The NWI identifies a few wetlands adjacent or close to the shoreline (Table 2-22). The railroad tracks are a barrier to the shoreline in many of these locations.

**Table 2-22 Aquatic habitat type, size and location in Subsection 6 – Everett**

| Aquatic habitat type (Cowardin) | Size (acres) | Location |
|---|---|---|
| PEM/SSfh | 1.2 | North Edmonds (on North Edmonds quad sheet) |
| PUBH (small lake) | 4.5 | Just north of Picnic Park |
| E2USM (mudflat) | 158 | Just north of 10th street marina |
| PEMf | 17 | Just south of former Kimberly Clark |
| E2USM (mudflat) | 14 | Just north of former Kimberly Clark |
| E2USM | 60 | Adjacent to the southwest portion of Jetty Island |
| PEM | 1 | Jetty Island |
| PEM | 2 | Jetty Island |

## Fisheries, Wildlife and Vegetation

Juvenile cutthroat trout and Chinook, chum, coho, and pink salmon feed and rear in nearshore areas of Subsection 6 – Everett. Juvenile salmonids feed on epibenthic invertebrates in the intertidal zone. Woodruff et al. (2001) documented a variety of fish in the nearshore during their survey work in 2000. Fish observed included perch (4 species) with shiner perch as the most frequent, herring and sand lance, flat fish (such as starry flounder) were also present as well at rat-fish.

There are three salmon bearing streams in this subsection including Picnic Point stream (coho and cutthroat), the largest stream in this subsection which is Big Gulch Creek (coho, chum and cutthroat) and in northern Mukilteo there is Japanese Gulch creek (coho and chum). Most of these streams are in degraded condition (sedimentation and water quality issues) and enter Puget Sound through culverts that run under the railroad tracks.

There is some limited spawning by forage fish in this subsection. Sand lance spawn at the beach at Meadowdale Park, Picnic Point beach as well as near the Mukilteo Ferry dock and the railroad barge facility. Smelt have been known to spawn on the beach in Edmonds near Brown Bay, at Picnic Point and just south of Howarth Park in Mukilteo.

The Mukilteo Shoreline and Characterization reports a list of invertebrates that typically inhabit the nearshore area. Shell fish such as clams (Manila, Butter, Geoduck and littleneck), scallops, mussels and oysters are expected to be present. Crabs (Dungeness and red rock) Shrimp (coon-stripe and spot), sea urchin, sea cucumbers octopus and squid are expected to be in the nearshore area. On a site specific basis substrate type has a major influence on what species are present. The Washington State Department of Health advises against any shellfish harvest on any beach on the eastern shores of Puget Sound between Everett and Tacoma due to public health concerns related to biotoxins (red tide blooms) and pollution (mainly fecal coliform).

The entire shoreline in Subsection 6 – Everett is critical habitat for Bull Trout. Orca critical habitat is all of Puget Sound from the 20 foot contour from shoreline.

Mammals in the area consist of voles, rabbits, and other small mammals (field mice, moles and the occasional rat). Furbearers such as raccoon, otter, and opossum, also feed, mate and take refuge along the beach and hillsides. In several of the gulches and vegetated bluffs that are included in this subsection (Japanese, Big Gulch and Smuggler's Gulch) there is a variety of wildlife including deer and coyote. Birds include bald eagle, red tail and sharp shinned hawk, great horned owl, common flicker, kinglets, pine siskin and the brown creeper (Mukilteo, City of 2011). The DNR Priority Habitat Database has locations for some of the States sensitive species.

There is a variety of marine birds that utilize the shoreline of this subsection. Bird numbers and diversity change with the season with more variety of species observed in the winter. Common marine birds are cormorants, gulls, loons, goldeneye, scoters, mergansers, great blue herons, mallards and widgeon. Alcids include pigeon guillemot, murre and the occasional marbled murrelet.

Marine mammals that occasional haul out on some of the beaches include harbor seals and California sea lions. Wales such as orca, minke and pilot and the occasional porpoise can occasionally be spotted offshore in the deeper waters. The Mukilteo Shoreline Inventory and Characterization report (Mukilteo, City of 2011) notes that Stellar sea lions have been spotted in the area but the nearest haul out is in the San Juan Islands. Many of these species are provided some protection under the Marine Mammal Protection Act.

## Stressors and Disturbance

There are multiple stressors/disturbances in this subsection. The single largest stressor in this area is the railway and associated seawall the runs almost the entire length of this subsection. Impacts from the railway is loss of nearshore sediment input from the historic feeder bluffs, fill that removed adjacent beaches and intertidal habitat, culverting of streams that enter the sound, loss of riparian habitat and landslides that frequently smother intertidal sessile organisms. Other disturbances includes ferry terminal effects on sediment distribution in the area, contaminated sediments in Everett Harbor, several overwater structures in the subsection that shade the intertidal areas (Navy homeport, Everett piers, Norma beach boathouse) and impacts from urbanization (reduced water quality, increase in impervious surface).

## Public Land

Public land includes several parks and open spaces in this subsection associated with the cities of Mukilteo and Everett. Parks include; the dilapidated pier at Haines Warf park, Meadowdale Beach park, Picnic Point park, Mukilteo Lighthouse park, Marine Park in Everett s well as Jetty Island.

## Manmade Features

Man made features within the shoreline in this subsection include several large overwater structures in this subsection. In Mukilteo there is Haines Warf Park, Mukilteo Ferry terminal, the former USAF tank farm, and a railroad barge loading facility. In Everett, the Navy Home port and several piers associated with the Port of Everett dominate. Additionally, there are several marinas within the Everett harbor area and a large boathouse at Norma beach in Mukilteo.

## Mitigation

Mitigation and restoration sites in this subsection include a Navy Homeport project that created a gently sloping fish bench of 8,500 square feet between tidal elevation -3 to +5 MLLW. There is also a proposed mitigation bank for Mukilteo.

Restoration projects in this area are focused mainly on the Picnic Point beach area and re-vegetation.

## Other Relevant Activities

USACE has one large navigational/dredging project in this subsection. The Everett Harbor and Snohomish River navigation project was authorized in 1910. It included construction of a training dike and excavation of material from the federal channel.

There is also one beneficial use of dredge material/restoration project at Jetty Island which is adjacent to the navigation channel. Clean material from the navigation project is placed along the shoreline of the Island to create intertidal habitat. This project has been monitored over the years and judged successful. The island is subject to erosion and requires the continual addition of material to keep the Island intact.

## WDFW Marine Shoreline Habitat Assessment

Subsection 6 – Everett shows somewhat low habitat values compared to other subsections in the study area. The composite index (Sum all) shows approximately 50% of the shoreline with high habitat values (green and yellow) (Figure 2-32 and Figure 2-34). The Top Five index shows approximately 60% of shoreline with high habitat values (Figure 2-33). The results for the Top 5 index are very similar to that of Subsection 1 – Federal Way, Subsection 2 – Burien/West Seattle and Subsection 5 – Edmonds. The higher Top 5 index indicates that only a few components are contributing to the high habitat values in the composite index. Much of this subsection is degraded habitat, with hardened shoreline and only 6% riparian habitat remaining.

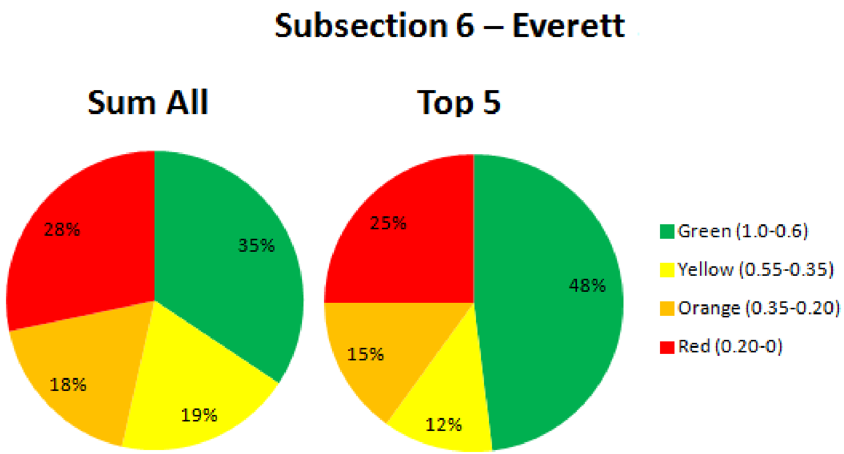



**Figure 2-32 Habitat Values for Subsection 6 – Everett**

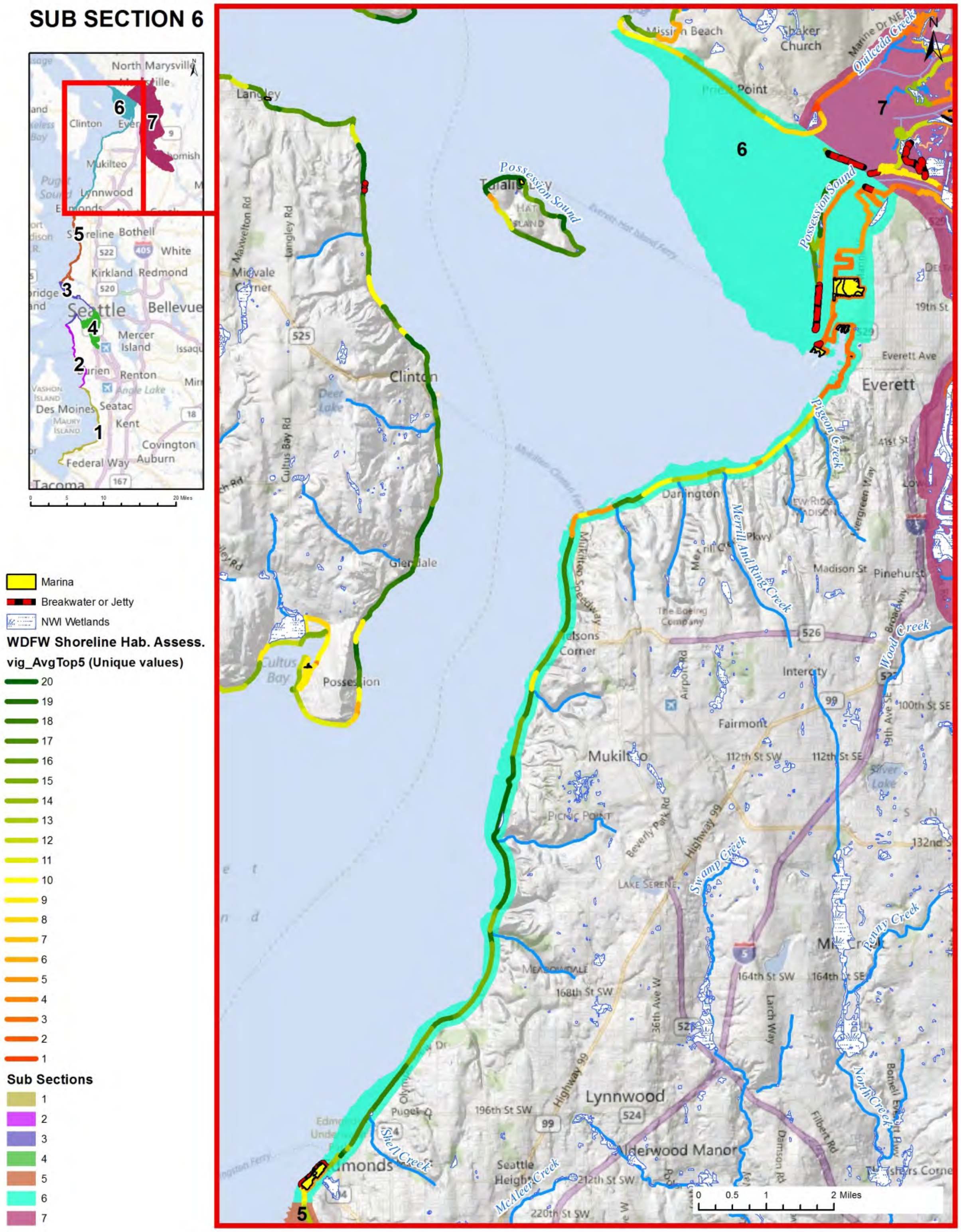



**Figure 2-33 Subsection 6 – Everett WDFW Shoreline Habitat Quantitative Assessment Index. Top-5 index indicating relative value of shorelines for fish and wildlife habitat conservation.**

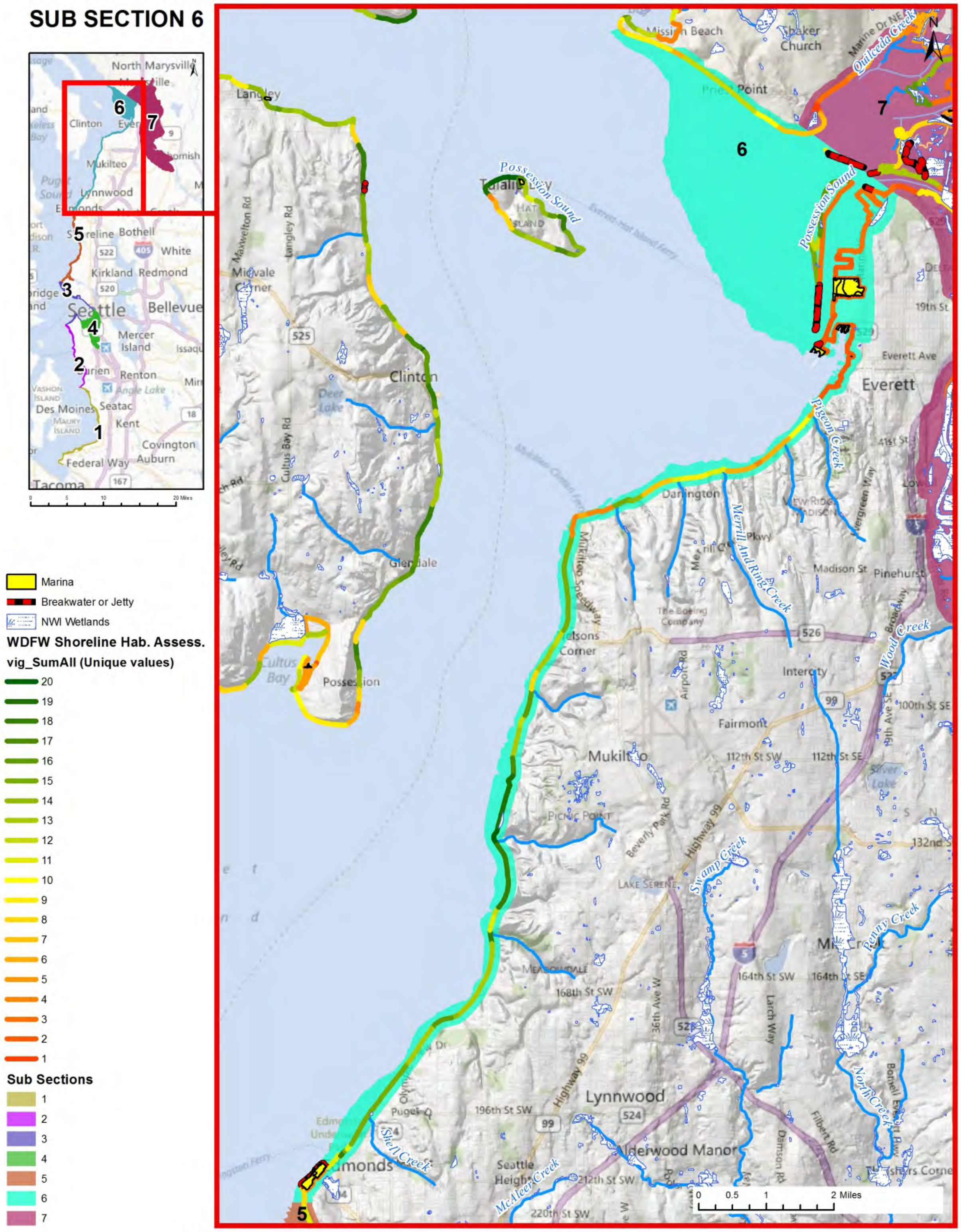



**Figure 2-34 Subsection 6 – Everett WDFW Shoreline Habitat Quantitative Assessment Index. Composite index indicating relative value of shorelines for fish and wildlife habitat conservation.**

## *2.2.7. Subsection 7 – Snohomish Estuary*

Subsection 7 – Snohomish Estuary starts at Tulalip Point and tidal influence ends near Lowell (Figure 1-1) with a total land area of 21,864 acres. It includes a portion of the City of Everett, Marysville, the Snohomish Estuary, and its distributary channels, along with Ebey, Steamboat and Union sloughs. Figure 2-35 and Figure 2-36 are 1977 and 2006 aerial photos of an area near the mouth of the Snohomish River.


**Figure 2-35 Air photo near the mouth of the Snohomish River in 1977.Note the log rafts in the lower portion of the photo. Courtesy of Washington Department of Ecology.**


**Figure 2-36 Air photo close- up of the same area in 2006 near Marysville. It is rare to see a log raft on the Snohomish anymore. Courtesy of Washington Department of Ecology.**

## History of Snohomish River

The Snohomish River is formed by the confluence of the Snoqualmie and Skykomish Rivers about 22 miles southeast of Everett, Washington.

The earliest European settlers arrived in the Snohomish Valley in the late 1850s from Seattle. They were drawn here because the broad expansive valley with associated deep soils. Many of the immigrants that arrived were from Switzerland and Scandinavia and were interested in developing dairy farms and similar agricultural pursuits that they had learned in the old country. About twenty to thirty years later the lumber industry arrived following the development of the railroads.

The 1880s and 1890's, found the development of small localized railroads to deliver the lumber harvest. Several saw mills were also built during this time. After the first cut of timber in the lower valley much of this area also was converted to agriculture. Early town sites were platted during this time coinciding with the continued development of the railroads. As timber production waned and the economy diversified many of the smaller towns in valley became bedroom communities to Everett and provided the labor force to the industries that grew within the region.

The lower Snohomish River estuary is approximately 9 miles long and three to four and a half miles broad at it’s widest. It is an area of very low gradient with a sinuous, meandering main channel and three main distributary channels (Steamboat, Union, and Ebey Sloughs) spread over the broad delta floodplain (Figure 3-9). Lower reaches of the Snohomish River, as well as Ebey, Steamboat, and Union Sloughs, and their associated complex of wetlands are estuarine areas under saltwater influence. The approximately 1,900 acres of the lower river basin was historically almost totally wetland. Prior to the mid-19th century, approximately two-thirds of the Snohomish River estuary was composed of forested wetland (Haas and Collins 2001). Currently, greater than 80 percent of the riparian zone has been cleared or is in an early successional stage. Eighty-five percent of historic tidal marsh is no longer intact (Haas and Collins 2001). The southern portion of estuary is predominately characterized as fluvial freshwater and was historically a mosaic of tidal marshes, forested wetlands, and intertidal sloughs. Today these areas are predominately diked and in agricultural production. The exceptions being the southern end of Spencer Island (just upstream of the upstream settling basin), on which the dikes have been breached to restore tidal influence, and Otter Island that was never diked. Agricultural diking, wetland loss, and the reduction of large woody debris supply to the lower river are implicated in the decline of the basin’s salmonid stocks. Logging and clearing for agricultural/residential development continue to impact the lower Snohomish River and estuary. Nearly all the upland area in the project vicinity is now used for industrial, commercial, residential, or agricultural purposes. In many instances, urban land use has been made possible by conversion of wetlands to uplands using dredged material as fill.

## Land Classification and Modification

Table 2-23and Table 2-24 show the tabulated land classification and percent cover, and the type and percent of modifications in the Subsection 7 – Snohomish Estuary.

**Table 2-23 Land classification and percent cover for the Subsection 7 – Snohomish Estuary.**

| Land Classification | Percent Cover |
|---|---|
| Barren/open space | 9% |
| Developed low intensity | 6% |
| Developed medium intensity | 4% |
| Developed high intensity | 2% |
| Open water | 6% |
| Herbaceous | 2% |
| Shrub/scrub | 1% |
| Wetland (herbaceous and woody) | 31% |
| Forested (deciduous, evergreen, mixed) | 8% |
| Cultivated Crops | 9% |
| Hay/Pasture | 20% |

**Table 2-24 Modifications and stressors in Subsection 7 – Snohomish Estuary. This information was also obtained from the PSNERP study.**

| Modification | Percent cover in the sub area |
|---|---|
| Marinas | 0 |
| Percent of area occupied by railroad | 1% |
| Impervious surface- 0 to 10% | 86% |
| Impervious surface- 10 to 30% | 6% |
| Impervious surface-30to 50% | 3% |
| Impervious surface- 50 to 100% | 5% |
| Shoreline armoring | Most of the shoreline is in levees with the exception of restoration and mitigation projects where levees have been breached. (see below for more details) |
| Overwater structures | 0.2% |

## Water Quality

Subsection 7 – Snohomish Estuary encompasses the Snohomish Estuary. There are several wastewater discharge permits in this area. Most notable are the wastewater treatment facilities for the City of Everett and the City of Marysville as well as for the Weyerhaeuser Company for discharge of stormwater containing treated landfill leachate at Smith Island. There have been some site specific concerns within the basin especially during the summer with fecal coliform and temperature. Pollutants within the Snohomish River are derived primarily from industrial point and non-point sources, storm water runoff from agricultural fields, and leakage of septic fields. Ebey Slough is 303 (d) listed (Category 5) for pH, fecal coliform, and water column bioassay and the mainstem Snohomish River is listed for dissolved oxygen and fecal coliform.

## Physical Setting

Subsection 7 – Snohomish Estuary is located within the Eastern Puget Riverine Lowland, a physiographic province characterized by unconsolidated deposits described as quaternary sediments, dominantly glacial drift, including alluvium. The main feature within this subsection is the Snohomish River which is formed by the confluence of the Skykomish and Snoqualmie rivers. This area is affected by both riverine and tidal flows. The tide is dynamic within the study area exhibiting a diurnal tide with an approximate 14 foot tidal range. There is also a significant riverine effect with large floods typically occurring in the late fall and early winter (November through January). The river has an approximate mean annual flow of 9,951 cubic feet per second (as measured at Monroe in 1985).

The lower Snohomish River estuary is approximately 9 miles long and three to four and a half miles broad at its widest point. It is an area of very low gradient with a sinuous, meandering main channel and three main distributary channels (Steamboat, Union, and Ebey Sloughs) spread over the broad delta floodplain. Lower reaches of the Snohomish River, as well as Ebey, Steamboat, and Union Sloughs, and their associated complex of wetlands are estuarine areas under both saltwater and freshwater influence. There are no drift cells identified in this section.

## Fisheries, Wildlife and Vegetation

In the last 100 years the Snohomish estuary has lost as much as 80% (Haas and Collins 2001) of the fringing marshes that provide critical benefits to fish during some portion of their life cycle. Multiple migratory runs of both native and hatchery reared salmonid stocks occur seasonally in the Snohomish River Estuary. Native trout species include steelhead, cutthroat and bull trout. The system supports a diversity of salmonid species. There are nine species of anadromous salmonids that have been documented in the Snohomish River: summer/fall Chinook salmon, fall run coho salmon, fall run chum salmon, cutthroat, and summer/winter steelhead trout, and bull trout. Pink salmon are also present in the system. The principal juvenile salmonid out-migration season occurs from mid-February through mid-June for steelhead, coastal cutthroat, coho, chum and Chinook (WDFW 1993).

The Snohomish River and its estuary support runs of eight salmonids: Chinook, coho, chum, and pink salmon, as well as steelhead trout, sea-run cutthroat trout, and bull trout. All species spawn in freshwater upstream of the estuary, and adult use of the estuary (and therefore of the proposed dredging areas) is largely limited to migration and physiological transition from salt to fresh water. In contrast, juvenile salmonids depend on estuarine environments for migration, physiological transition from fresh to salt water, feeding, and refuge from predation and displacement during migration. There is considerable variation by species in juvenile residence periods in the estuary, with coho, chum, and Chinook juveniles being relatively more dependent on the estuarine environment than pink, steelhead, sea-run cutthroat and native char, which quickly move through the estuary to marine waters.

Native char (bull trout and Dolly Varden) are believed to coexist in the Snohomish River drainage. Bull trout migrate and are captured throughout the inner bays of northeast Puget Sound from Possession Sound, Port Susan, Skagit Bay, Padilla Bay, out to Whidbey Island.

Forage fish include Pacific herring surf smelt, sand lance larvae, three spined stickleback, shiner perch, flounder, peamouth and various sculpin. Juvenile forage fish prey on epibenthic invertebrates and crustaceans and are themselves important prey items for larger juvenile salmon and for bull trout.

Common invertebrate species (which are typically preyed upon by salmonids) include: snails, polychaetes, shore crabs, isopods, ghost shrimp, Dungeness crab, and red crab. Juvenile salmonids also prey preferentially on certain species of tiny crustaceans including amphipods, some species of harpacticoid copepods, cumaceans, and midges which are also common in the intertidal mudflats and marshes of the lower estuary.

The Snohomish River is critical habitat for both Bull trout and Chinook.

Bald eagles are commonly seen flying over Possession Sound and are frequently seen perching and foraging along the lower Snohomish River. The Snohomish River estuary is recognized as regionally important during spring migrations of shorebirds and fall migrations of raptors and waterfowl. The abundant waterfowl, marine birds, and shorebirds within the lower Snohomish River provides an avian prey base for bald eagles peregrine falcons, merlins, and other raptors. Common species include ring-necked ducks, American widgeons, Canada geese, mallards, pintail, scoters, mergansers, and bufflehead. Other common species include double-crested cormorants, western grebes, American coots, brants, pigeon guillemots, and several gull species. During winter migrations, the flooded agricultural fields along the lower Snohomish River attract snow geese, trumpeter swans, snowy owls, merlins, great-horned owls, and gyrfalcons. Shorebirds are commonly observed along the lower river in the tidal mudflats and marshes or along sandy shorelines. Common species include dunlins, western sandpipers, dowitchers, black-bellied plovers, and yellowlegs. Several other bird species that inhabit the action area are either Federal Species of Concern or are listed by Washington State as Monitor, Candidate, or Sensitive species. The peregrine falcon (Federal Species of Concern and State Sensitive), osprey (State Monitor), great blue heron (State Monitor), and purple martin (State Candidate) all occur within the action area and have been observed either near the open water disposal sites or along the lower Snohomish River.

This subsection is more rural than the previous subsections and includes a more diverse mammal assemblage. Mammals in the area include raccoons, squirrels, rabbits, mice, voles, screws, moles rats, bats, deer, coyotes and probably black bear. The DNR Priority Habitat Database has locations for some of the States sensitive species.

This subsection is more riverine (although tidal) than most of the previous sections of the study area. So the occasional harbor seal and California sea lion may be observed at the River confluence with Port Garner but the majority of marine mammals would include mink, river otter and beaver.

Intertidal marshes along the lower Snohomish River are dominated by typical native estuarine emergent species including: Lyngby's sedge, pickleweed, fleshy jaumea, tufted hairgrass, hard-stem bulrush, and Pacific silverweed with generally forested and scrub-shrub wetland and upland buffers.

Riparian forests and areas of palustrine scrub-shrub wetland fringe portions of the lower river and its sloughs. These areas are dominated by Sitka spruce, Pacific willow, Scouler's willow, western red cedar and black cottonwood.

There are multiple wetlands in this subsection listed on the NWI website. NWI classifies most of these wetlands as PEM or PFOC but historically they were all estuarine wetlands. As European settlers developed the river valley they converted most of the estuarine wetland habitats into agricultural fields by developing an extensive levee system, placing tile systems and constructing pumps. While this effectually cut off tidal influence much of the converted land remains wet. Within the last several years there has been an effort to restore tidal inundation (Spencer Island, Union slough) to these areas by removing the levees and allowing the tidal influx.

## Disturbances and Stressors

Disturbances/stressors in Subsection 7 – Snohomish Estuary include tidal barriers is probably the most significant stressor in this subsection with the construction of levees, tide gates. Approximately 44 miles of dikes isolate the river from its riparian floodplain. There are also several roads adjacent to the water and an increasing amount of housing projects has added to the amount of impervious surfaces. In the upper portions of the Snoqualmie and Tolt River systems there are a few dams that deprive sediment from reaching to the lower Snohomish system. There are several bridges in this subsection that cross the River (I-5, 529 and Highway 2). Few marinas can also be found at this subsection inkling one in Marysville and one at the western tip of Ebey Island.

Much of Subsection 7 – Snohomish Estuary is still has a rural fell to it. While there are portions of the city of Everett and Marysville within the study area and conversion of former agriculture to housing open space is still common. Primary man made features includes an extensive levee system, roads and houses.

## Public Lands

Public lands in Subsection 7 – Snohomish Estuary include Spencer Island Park, Langus Riverfront Park, Star Park and Ebey Waterfront Park in Marysville. There also some large open spaces with trails on levees within this section such as Diking District 6 that is owned by Washington Department of Fish and Wildlife.

## Restoration Activities

Several restoration actions have occurred at Spencer Island in the Snohomish River including a large dike breach to provide fish access to intertidal habitat. Several other large restoration projects are currently proposed (Smith Island, Diking District 6 and Qwuloolt) but have not been completed at this time.

## Mitigation

Two mitigation projects have occurred in Union Slough: the Port of Everett has a 20 acre mitigation project, and USACE and City of Everett constructed a 100 acre intertidal restoration project to restore intertidal connectivity and provide off-channel fish rearing habitat.

## WDFW Marine Shoreline Habitat Assessment

Subsection 7 – Snohomish Estuary shows somewhat low habitat values compared to other subsections in the study area. The composite index (Sum all) shows approximately 60% of the shoreline with high habitat values (green and yellow) (Figure 2-32 and Figure 2-39). The Top Five index shows approximately 50% of shoreline with high habitat values (Figure 2-38). The results for the Top 5 index are very similar to that of Subsection 3 – Elliott Bay. The lower Top 5 index indicates that all components are contributing to the habitat values in the composite index. The most common components in the Top 5 index are National wetlands, Bull trout, Coastal Resident cut throat, and waterfowl. These are to be expected since there are some large habitat restoration projects in the subsection.

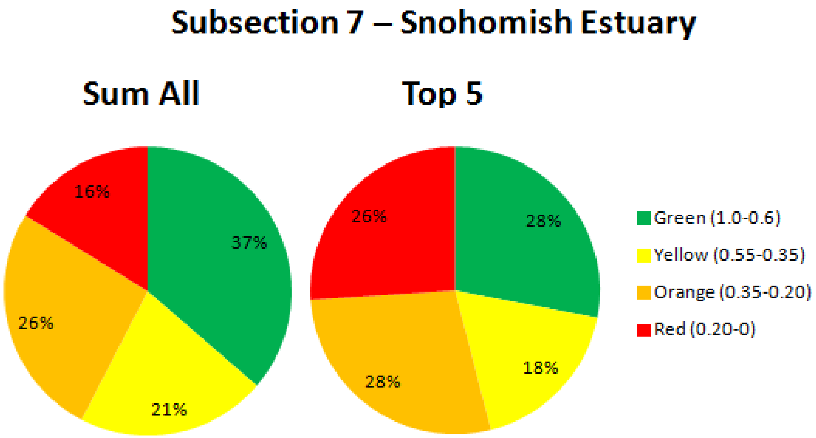



**Figure 2-37 Habitat Values for Subsection 7 – Snohomish Estuary**

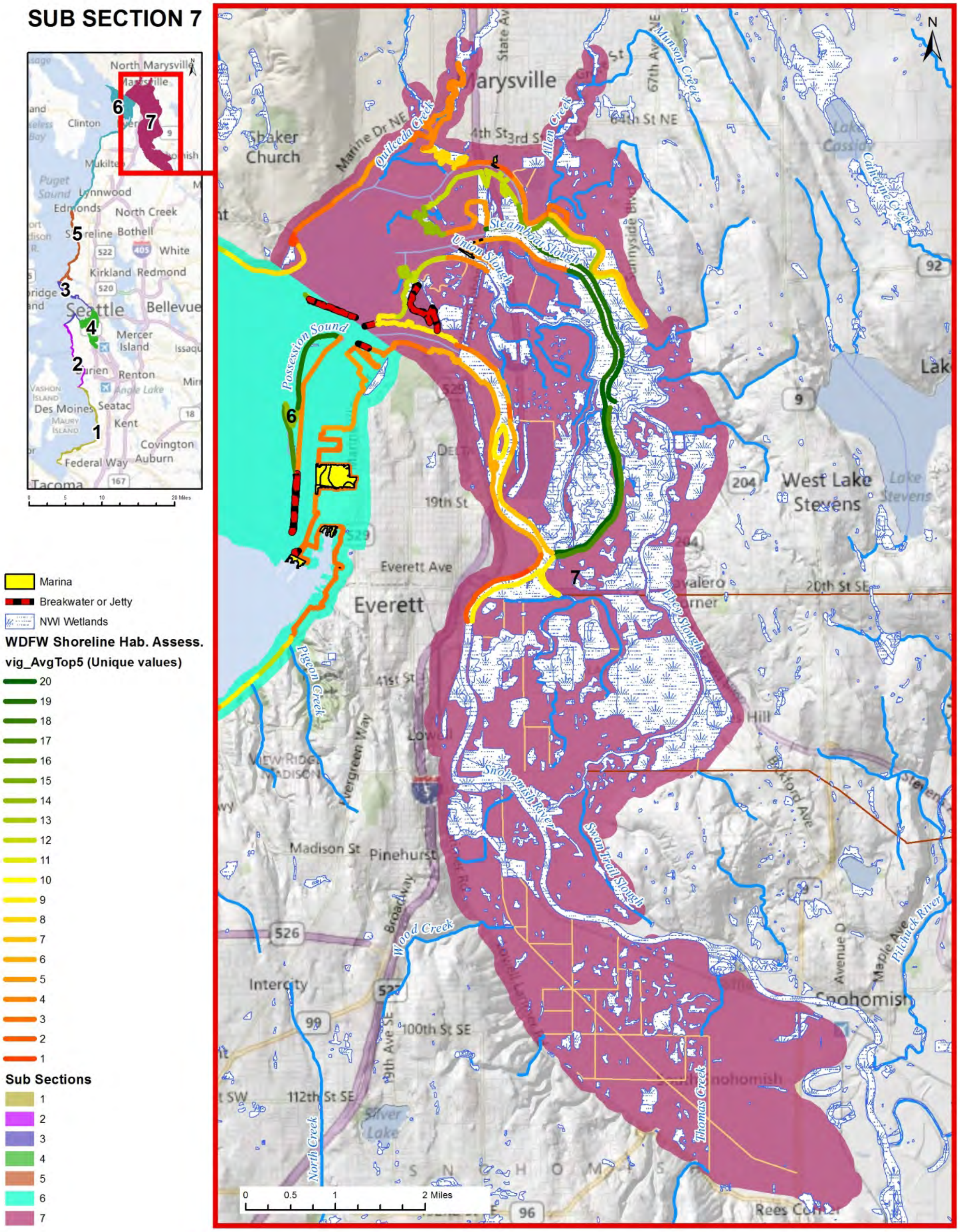



**Figure 2-38 Subsection 7 – Snohomish Estuary WDFW Shoreline Habitat Quantitative Assessment Index. Top-5 index indicating relative value of shorelines for fish and wildlife habitat conservation.**

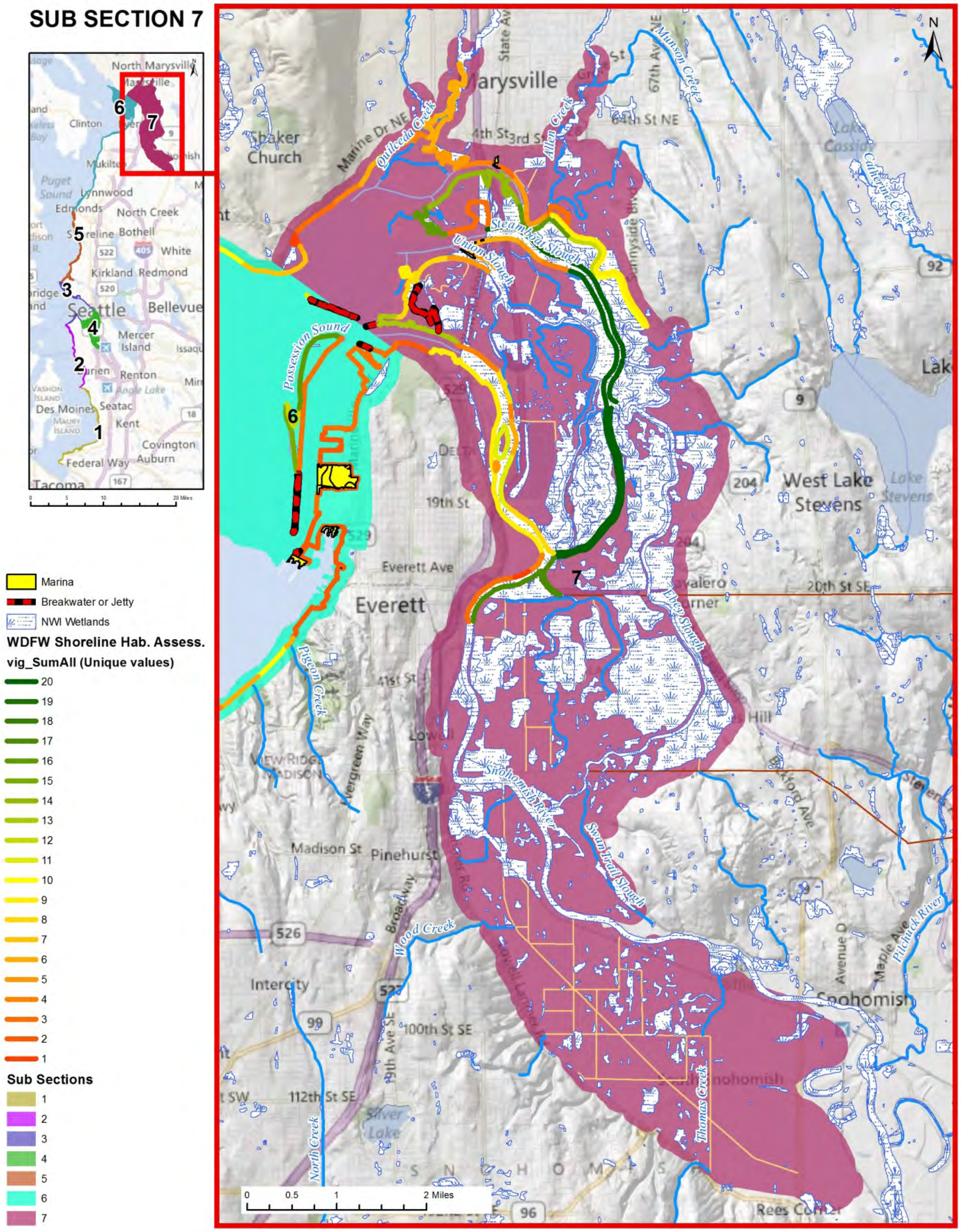



**Figure 2-39 Subsection 7 – Snohomish Estuary WDFW Shoreline Habitat Quantitative Assessment Index. Composite index indicating relative value of shorelines for fish and wildlife habitat conservation.**

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# 3. Major Changes Within Study Area

## 3.1. Nearshore Environment

### *3.1.1. Description of the Nearshore Portion of the Study Area*

Study Area Existing Conditions identified historic changes to wetlands within the study area, particularly the cumulative loss of wetlands (including mudflats) within the Snohomish and Duwamish estuaries. This section considers cumulative impacts to the nearshore portion of the study area, which is composed of the nearshore portions of the estuary subsections (Subsection 4 – Duwamish Estuary and Subsection 7 – Snohomish Estuary), and the entirety of the other five subsections. As identified in the introduction, the nearshore area for this study is defined as being between 650 ft landward of the high tide line (MHHW) and 30 feet waterward of the low tide line (MLLW). The additional 30 feet below MLLW is considered to encompass the photic zone. All area waterward of the high tide line (MHHW) is under CWA 404 jurisdiction. The entire study area, as defined, is regulated under section 404 of the CWA, as are impacts to surrounding areas that influence or are influenced by the nearshore environment. Habitats of concern and their associated functions were evaluated with regard to the nearshore environment.

Much of the study area is on the eastern shoreline of what is usually referred to as Central Puget sound or south central Puget sound and is part of Water Resource Inventory Areas (WRIA) 7 (Snohomish basin) and 9 (Duwamish Basin). It is part of the Puget Lowland Ecoregion which includes the open hills and tablelands of glacial and lacustrine deposits in the Puget Sound valley. Historically, most of the land was forested and Douglas fir was a major subclimax species (EPA 1986). Quinn (2010) briefly describes the watersheds of the Puget Sound in the following statement:

*"Characteristics of the watersheds that make up Puget Sound ecosystem vary dramatically across the region. Sharp topographic relief creates highly variable local-scale climate, and in combination with diverse soil types, results in wide variety of environmental conditions. This range in conditions supports high levels of biodiversity and other important biological phenomena. The terrestrial landscape is dominated by some of the most productive forest communities in the world, where many of the conifer species reach their maximum growth potential for height and diameter. Douglas- fir communities dominate the lowlands of Puget Sound by virtue of their tolerance to well-drained, glacially derived soils, while hemlock and true fir (genus Abies) communities dominate wetter areas in the foothills and more mountainous regions. Interspersed among the forest, particularly at lower elevations, are other notable features, such as prairie, madrone forests, oak woodlands and wetland and bog ecosystems."*

Much of the shoreline of Puget Sound that falls within the study area is composed of long narrow beaches comprised of either coarse sand or mixed gravels backed by steep bluffs. Over 60% of the Puget Sound shoreline is comprised of bluffs and the majority of the study area consists of bluff-backed beaches or barrier beaches. Historically, the bluff would have been completely forested with hemlocks, firs, big leaf maple, and madrone; now, land use in much of the area has been converted to residential housing with a significant decrease in vegetation cover in most subsections (Section 3.3).

## Habitats of Interest in the Nearshore Area

Two habitat types occur within CWA 404 jurisdiction: beaches and aquatic substrate. Banks and bluffs occur just upland of this jurisdiction.

- **Beaches**

In the study area, sandy beaches begin underwater in the subtidal area, continue up through the surf zone into the swash zone where the waves cover and uncover the sand regularly, and the upper extent of the beach approaches the toe of backing bluffs or a ripararian zone. While most people envision beaches as sandy, in Puget Sound there are extensive pebble/gravel beaches in higher energy environments. Johannessen and MacLennan (2007) describe beaches as, "…an accumulation on the shore of generally loose unconsolidated sediment that extends landward from the low water line to a definite change in material and form, such as to a bluff or dune." According to Johannessen (2010) Puget Sound beaches are shaped by wind-generated waves, with wave energy determined by the fetch (the open distance between opposite shorelines). Waves in Puget Sound are fetch-limited due to the distance from the ocean and the shelter between the sound and the ocean provided by the Olympic Mountains..

Sandflats on the other hand are broad flat or shallow sloped areas, either exposed or sheltered, that are primarily composed of coarse sandy material. Typically, sand flats are exposed at low tides and covered by shallow water at high tides. Marine organisms usually associated with sand flats include shrimp and marine worms (nematodes) that burrow into the substrate. Marine birds use sandflats as loafing and feeding areas and seals and sea lions use sand flats as haul out sites when they are exposed at lower tides.

High, upper tidal sandy beaches where there is occasional inundation are typical spawning areas for forage fish such as surf smelt and sand lance (Figure 3-1).

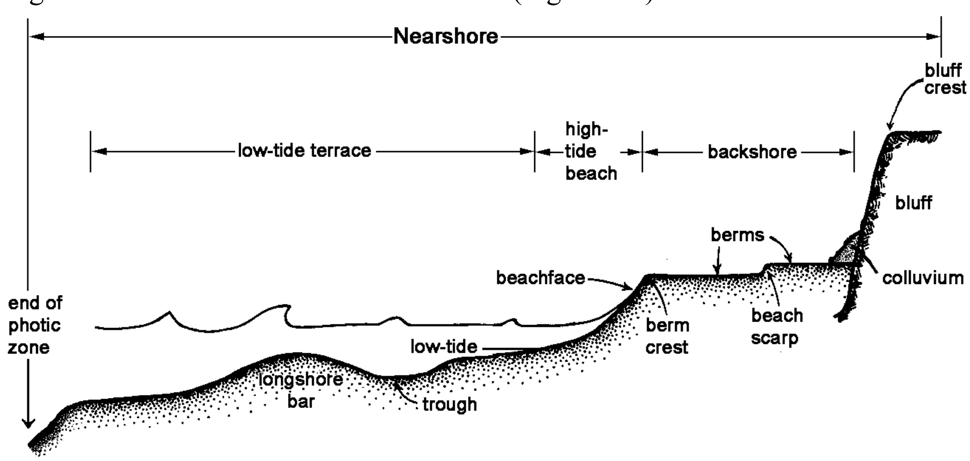



**Figure 3-1 Cross-section of a beach with terminology used in the Puget Sound area. The entire area depicted in the figure is now considered part of the nearshore zone in the Puget Sound region.** Source: Komar, 1976.

Beaches provide multiple functions including: water filtration, sediment source, depositional area, primary productivity and food chain support (permeable sand provides structure for small interstitial organisms such as bacteria, protozoans, and small metazoans, forming a distinct food web), nesting area for shorebirds, and critical foraging areas for both fish and waterfowl. Beaches also link terrestrial aquifers with coastal waters through discharge of groundwater.

Stressors include activities that change or alter circulation patterns or sediment supply including: excavation, fill, beach hardening (such as bulkheading), overwater structures, dams, and sea level rise.

- **Aquatic Substrate**

Aquatic substrate is described in the 404 (b)(1) Guidelines 230.20 (a) as;

*"The substrate of the aquatic ecosystem underlies open waters of the United States and constitutes the surface of wetlands. It consists of organic and inorganic solid materials and includes water and other liquids or gases that fill the spaces between solid particles."*

Within the study area most marine sediments are either coarse-grained (sand or cobble) or fine-grained (clays and silts). Rock outcroppings exist but are rare. A wide variety of organisms exist either within the substrate (benthic infauna) or on or above the surface of the substrate (epibenthic organisms). Tidal dynamics, water circulation, and substrate size greatly influence the species present as well as their abundance and distribution.

One way to categorize organisms within this habitat is in the way they obtain their food. There are three main groups: surface feeders focused on decomposed material (small crustaceans such as shrimp, for example), surface deposit feeders (clams, for example), and subsurface deposit feeders (polychaetes or worms, for example).

Functions of aquatic substrate include providing physical structure in which to live, feed, or reproduce. Many organisms located here are prey items for larger consumers and are part of the base of the local food web.

Stressors include activities that change the physical, chemical and biological characteristics of the substrate such as dredge or fill (that can alter elevation, slope, water circulation, or current patterns, smother immobile fauna and flora, and compress void spaces within the substrate altering biological and physical processes.

- **Banks and Bluffs**

Banks and bluffs are not within the CWA 404 jurisdictional area unless there are wetlands or streams within the bluff.

A bluff is described as a steep, high coastal slope cut into unconsolidated sediment with a broad face. While banks are not as tall as bluffs they share some of the same characteristics. Typically, both can be vegetated on top (in the study area, vegetation usually includes trees such as Douglas fir or Madrona) but if the front face is near-vertical it will be devoid of vegetation. Trees toppling down bluff faces are one of the main sources of woody debris to the beach below. Characteristics affecting bluffs and banks include aspect, underlying geology, topography, hydrology, and erosional forces (such as wind or rain).

Banks and bluffs are particularly vulnerable to sliding (Terich et al.1991). The geology of the site (primarily, any recently deposited glacial material) has a great effect on the stability of the slope. The weather in Puget Sound also plays a role with the long wet winters providing plenty of moisture and therefore additional weight on the face of the bluff. Depending on the type of material in the bluff, waves eroding the toe of the slope can also have an effect. When it is not interrupted, material that sloughs off the face of a bluff or bank functions as the primary source of sediment to the nearshore (Johannessen 2010).

Stressors include: impervious surface at the top of the bluff, fill and excavation including construction of impervious surfaces on the top of the bluff, de-vegetation on the top or face of the bluff, bulkheading at the toe of the bluff, and sea level rise. These actions can also cause changes to local hydrology that affect the function of the bluff or bank area that in turn affects the nearshore.

### *3.1.2. Investigation of Cumulative Effects Along the Shoreline of the Study Area.*

By definition, cumulative effects result from a combination of individual actions over time. The actions can be all of one type such as hardening the shoreline over a period of time. Or there could be variety of stressors that occur in the same location. In the study area, examples of actions include persistent impacts from a railroad along the shoreline (space-crowded disturbance)(Figure 3-2), incremental shoreline hardening (nibbling effect from each successive activity leading to the need for additional hardening), and a combination of activities such as shoreline hardening and addition of overwater structures that cause synergistic effects such that the total area affected is much larger than the sum of the areas affected by singular activities. Shipman (2010) commented on the effects of the railroad:

*"The Great Northern Railroad constructed the tracks along the beach at the toe of the bluffs in the late 1890s. Landslides have long been an issue for the railroad (now Burlington Northern Santa Fe), requiring frequent maintenance and cleanup following storms and resulting in the relocation of the grade waterward in several locations to minimize potential impacts from slides and debris flows."*


**Figure 3-2 Typical shoreline today in Subsection 5 – Edmonds with railroad track next to the beach. Photo is taken during low tide.** Source: WDOE 2006.

### *3.1.3. Nearshore Disturbances in the Study Area*

Major impacts or actions in the study area include dredging, addition of overwater structures (shading), shoreline hardening, and ferry system impacts.

**Dredging**

The two ongoing federal navigation projects that occur within the study area, are in the Lower Duwamish Waterway and in the Snohomish river near the Port of Everett. Dredging generally occurs every second year. In addition, there are several dredging projects not related to federal navigation channels that occur in Elliott Bay and the Port of Everett. Non-federal dredging is conducted either by port authorities or by private companies. Disposal of dredged material can occur at a variety of sites either in-water at designated Puget Sound Dredge Disposal Area (PSSDA) sites (this is only for "clean" material that undergoes rigorous testing) or at "upland" disposal sites used for material designated as unsuitable for in-water disposal. When possible, Federal navigation projects provide clean dredged material for beneficial uses such as a capping over contaminated sediments or to enhance or enlarge intertidal habitat as in the case of Jetty Island in Port Gardner.

**Historical Dredging**

The greatest impacts from dredging,within the study area, were historic. Loss of aquatic habitat due to dredging, including in losses in areas that once were wetlands areas that were filled with dredged material such as in the lower Duwamish and Everett areas, is documented in Historical Loss of Special Aquatic

Sites(3.2). While much of the dredging and filling occurred prior to passage of the CWA, the historic loss of special aquatic sites is still relevant from a cumulative effects standpoint.

Many of the major impacts occurred when dredging of an area was first initiated, but recurring maintenance dredging also has impacts. These include:

- Disturbance. The physical act of dredging and the time it takes is a source of disturbance every time it occurs. Most dredging occurs either in a channel or in the nearshore slips where boats are moored. Noise, lights, anchors being dragged, use of clam-shell buckets or hydraulic dredger heads, and propellers all are sources of disturbances for the aquatic organisms in the vicinity of the project. Many aquatic species are mobile and the assumption is they move away but sessile organisms are affected. Dredging projects can last for a few days or a few months. Timing restrictions are placed on in-water projects to minimize impacts to species that are considered sensitive but for species that are present year round there may be unrecorded impacts. Different types of sediment also require different lengths of time to re-establish sediment structure and this affects how quickly benthic communities recover. .
- Loss of benthos. Benthic community structure is affected by recurring disturbance. Some benthic species are important food sources for demersal fish and disruption of these communities can cause a local disruption of the food web. (Newell et al. 1998) While the speed of benthic re-colonization is debated, it is likely that recurring disturbances affect diversity, distribution, and abundance of organisms important to the local food web. This effect may be positive or negative depending upon the species being studied.
- Sedimentation and turbidity effects. Dredging usually results in the release of some sediment to the water column as the dredge bucket contacts the bottom, closes, and is raised through the water column. Dredging results in pulsed and localized increases in suspended solids to the water column.
- Changes in salinity patterns. One obvious effect of dredging is the increase in depth or change in elevation of the channel or river in which it occurs. In marine environments this has caused a major change to the distribution and depth to which salt water intrudes (as well as the gradient of salinity levels) into an estuary and subsequently affects both populations (if they have a narrow tolerance for varying salinity levels) and distribution of species. Over the years and especially now with more “post-Panamax” vessels, ships have gotten larger with deeper drafts. As a result, navigation channels and berths need to be excavated to greater depths resulting in salt-entrained waters moving further upstream than previously able. This has direct implications for juvenile salmon and other fish that undergo osmoregulation prior to their migration to the sea. The reduction of estuarine areas for osmoregulation puts additional stress on salmon in particular. A similar effect can occur in circulation patterns in estuaries as a result of increasing depth.

## Ferry Terminals and Other Overwater Structures.

There are a number of overwater structures along the study area shoreline including piers, marinas, wharves, and docks of various sizes. The study area shoreline includes several large marinas, fishing piers, piers that support housing, historic wharves, and berths and docks for private residences. There are four large ferry terminals within the study area at Fauntleroy, Seattle, Edmonds, and Mukilteo (Figure 3-3). These are long narrow piers where the ferry vessels can load and off-load. Typically the vessels leave their propellers running the entire time they are at the dock. Over 60% of the nearshore area of downtown Seattle (Subsection 3 – Elliott Bay) contains piers (Figure 3-4).

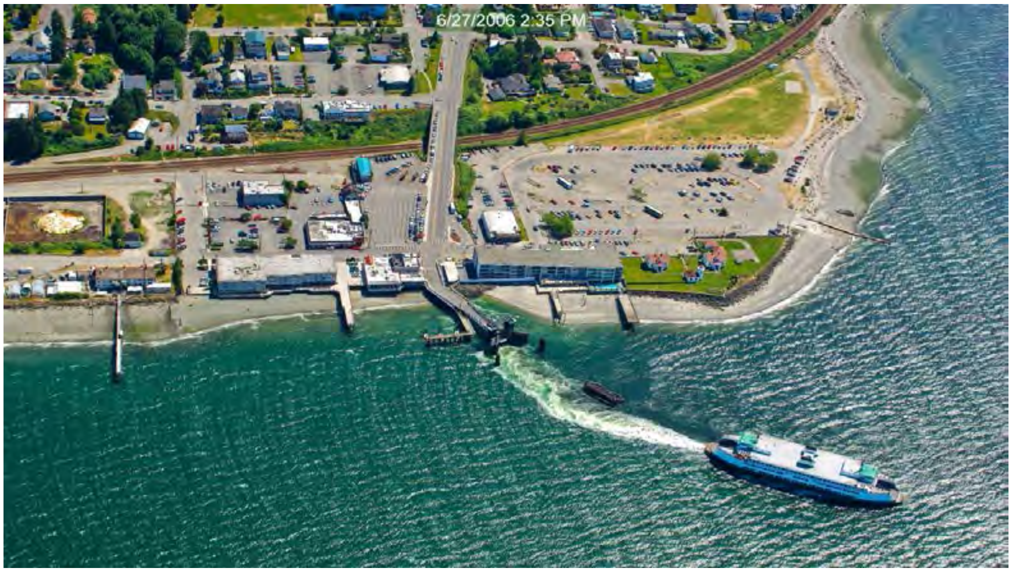



**Figure 3-3 View of the Ferry terminal at Mukilteo** Source: WDOE 2006.

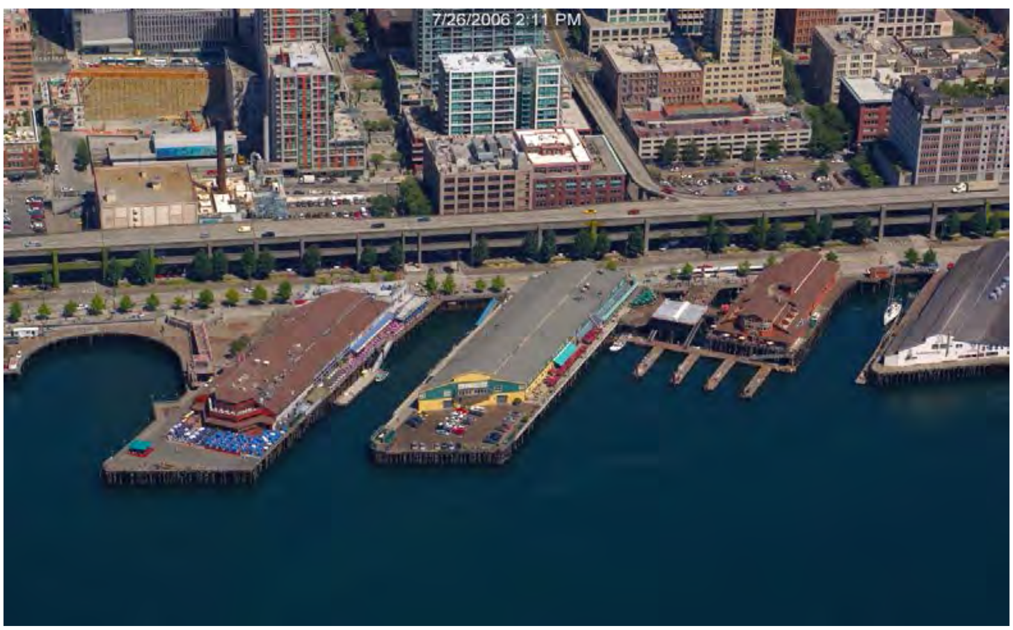



**Figure 3-4 View of downtown Seattle with overwater structures.** Source: WDOE 2006.

All of these structures shade the water and parts of the shoreline and many were built in nearshore habitats that were important for aquatic species requiring forage or refuge. The following impacts are associated with overwater structures:

- Over water structures block sunlight to nearby vegetation. When undisturbed, the nearshore area often includes a fringing band of vegetation; much of the Puget Sound shoreline includes vegetated shallows and algal beds. Physically blocking available sunlight limits the amount of shoreline vegetation. This has a cumulative effect when considering the sheer volume of overwater structures in the study area.

- Overwater structures cause a migratory behavior change as outgoing salmon become confused when encountering the shadow beneath the dock (Toft et al. 2007).

*"Juvenile salmon were most often observed away from the edge and toward open water. This supports the premise that juvenile salmon avoid overwater structures because they physically block normal movement patterns or decrease light levels."*

- Overwater structures may increase predation on juvenile fish as they alter their migration into deeper waters where large fish reside.
- When the cumulative number and size of overwater structures is considered, they may reduce the carrying capacity of juvenile salmon due to reduced foraging opportunities and decreased refuge (Ono et al. 2010).

## Shoreline Hardening

Recently, the widespread extent of shoreline hardening has been examined as significant issue in shoreline management in Puget Sound. Shipman et al. (2010) states, "The issue is complicated by the long-term and cumulative nature of the impacts…". Roughly one third of the Puget Sound overall linear shoreline is armored; however, in some areas (such as King County) as much as 68% of the shoreline is armored. In addition, in the 2005-2010 time period, the rate of new or replacement armoring far outweighed removal of hardened shoreline structures (Figure 3-5).

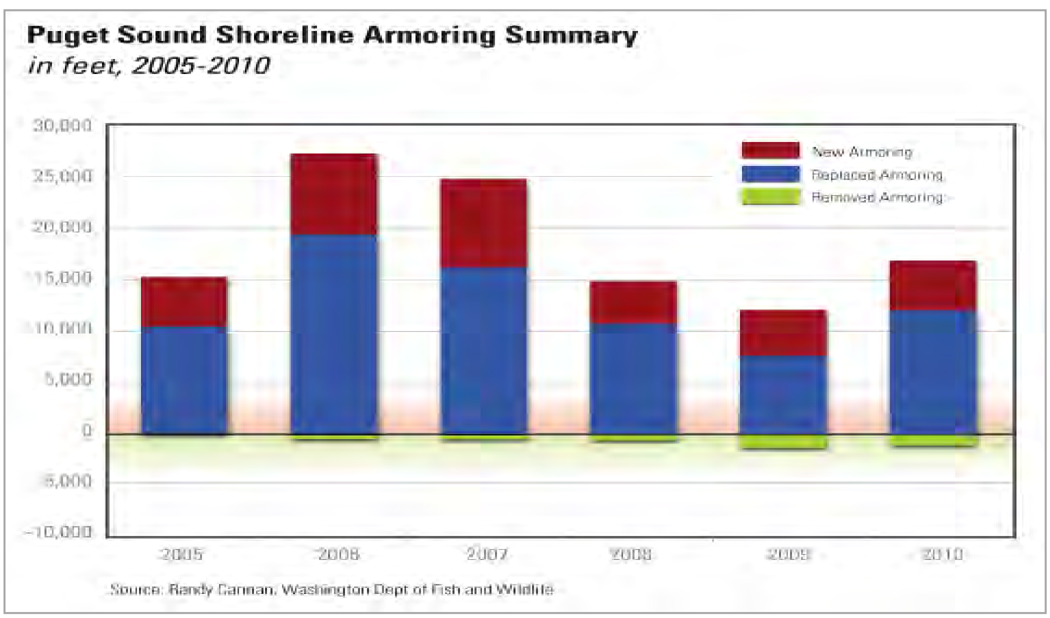



**Figure 3-5 Trend of bankline armoring for all of Puget Sound.** Source: Carman et al. 2011

No impact is more widely dispersed over the study area. On average, over 72% of the shoreline within the study area has some form of armoring, encompassing both time-crowding and nibbling effects (Figure 3-6).

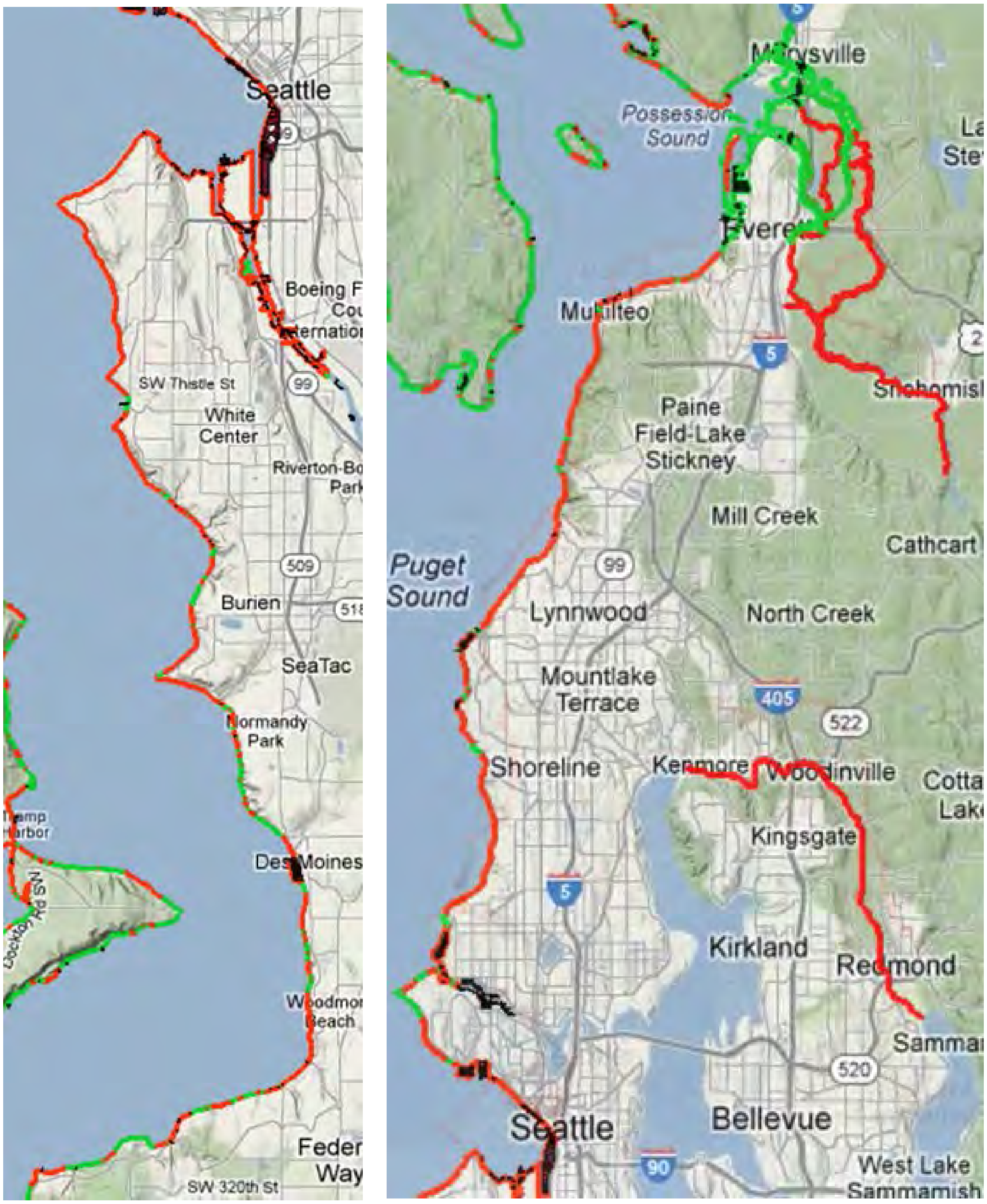



**Figure 3-6 Bankline armoring and levees in the study area.** Red areas indicate hardened areas, green areas indicate that hardening is absent and black areas indicate overwater structures such as piers, wharves, or marinas. Data Source: Puget Sound Nearshore Program via the Corps of Engineers Puget Sound Program (CPSP) web viewer (see Document Reading Tips for more information about this application.)

### *3.1.4. Physical Processes Affected by Shoreline Armoring*

**Loss of Upper Beach and Backshore**

Multiple physical processes occurring on the Puget Sound shoreline that affect shoreline structure and function are impacted by shoreline hardening. Shipman (2010) states, “Even when built high on the beach profile, seawalls typically eliminate a narrow zone of the high tide beach. On Puget Sound, this may result in the absence of accumulated drift logs and beach wrack and the loss of dry beach at high tides, which may in turn reduce the area available for forage fish spawning and for recreation." Beach and backshore loss can decrease the number of habitat types available, which can reduce diversity and abundance of macroinvertebrates. It can eliminate nesting habitats for fish and birds (Dugan and Hubbard 2010) and benthic production (Meyers 2010).

## Erosion/Impoundment

Passive erosion, which is naturally occurring, will continue after armoring is put into place. Over time, there will be a narrowing of the remaining beach, loss of upper beach, and increased interaction of the structure with waves (Shipman 2010). Also, local scour or flanking erosion at the ends of armoring structures can have an effect on existing structures and/or adjacent properties. However, this type of erosion is dependent on many factors including wave height, period, angle of wave approach, and configuration of armoring structure (O'Connell 2010).

In the Puget Sound area, feeder bluffs provide sediment to beaches and littoral cells. One study of historic feeder bluff mapping shows that there has been a 63.4% loss of feeder bluff length over the study area. Portions of the study area have lost up to 100% sediment input from the armoring of the shoreline. This trend likely has led to increased shoreline erosion and loss of beach and nearshore habitat area (Johannessen 2010).

## Sediment Size, Delivery, and Transport

An important physical shore processes such as sediment size, delivery, and transport can also be affected by armoring. Armoring can stop the natural erosion of bluffs which reduces the delivery of sediment to the littoral system (Shipman 2010). Without deposition of sediments from natural erosion, the beach profile can be altered (including coarsening of the sediment) which can decrease barrier/lagoon or saltmarsh stability and reduce forage fish spawning (Meyers 2010). Also, Sobocinski (2003) showed that armored sites have coarser sediment sizes than unaltered sections of the beaches where her studies in Puget Sound were conducted.

Changes to sediment and debris movement are one major impact that has caused the degradation of river deltas within Puget Sound. According to Walters, approximately 44 percent of the historic river delta extent in the Salish Sea has been lost thus far (Walters 2011). Armoring and other shoreline modifications "alter both the transport of sediments into river deltas and the distribution of sediments within the delta itself" (Walters 2011).

## Altered Wave Action/Turbulence

Wave action is an important process which contributes to shoreline structure and function and when altered can possibly increase erosion and scour and influence longshore sediment transport patterns (Shipman 2010). One study showed that marsh vegetation seaward of bulkheads had an increased mortality rate due to stress from increased turbulence and scour (Currin et al. 2010). Also, Spalding and Jackson (2001) note that "disturbance of the sediment matrix by waves, currents, or humans can alter sediment and drainage characteristics and result in lower meiofaunal densities compared to densities found at undisturbed sites. Increased energy due to wave reflection at the structure can increase sediment activation and transport at the base of the structure and alter sediment volume and grain size characteristics of beach habitat".

## Biological Alterations

Salmon are a keystone species in the Pacific Northwest. Not only are they an important commercial and cultural species but from a biological point of view they are an excellent bellwether of ecosystem health. Juvenile salmon use the nearshore area of Puget Sound in preparation for and during out-migration to deeper water. Along this migration route, it is important that they are offered the opportunity to feed and find refuge. Changes in processes, structure, and function of the nearshore affect the biological resources utilizing these areas. Studies have determined that in armored areas of Puget Sound biological species were lower in numbers than those in areas without armoring. "Paired sampling showed that ecologically important invertebrates, such as talitrids, insects, and collembolans are reduced significantly at sites where shoreline modifications are installed lower than MHHW (Mean Higher High Water). Additionally, the invertebrate assemblage changes to include more marine crustaceans when the land/sea interface is lowered by shoreline armoring," (Sobocinski 2003).

Juvenile and embryonic fish species are in decline as well due to adverse effects of shoreline armoring. Rice (2007) states, "Historical data from Puget Sound summer beach spawn surveys showed that beaches without terrestrial shoreline vegetation had significantly lower proportions of live smelt embryos." Two adjacent beaches, one armored with no overhanging terrestrial vegetation and the other not armored with extensive terrestrial vegetation, were used to study the proportion of eggs containing live surf smelt embryos (Rice 2007). Results showed that, "Both the proportion of eggs containing live embryos and total egg density at the altered beach were approximately half that of the natural beach," (Rice 2007). The reasons for these declines can be contributed to the fact that "…shoreline alteration can make shoreline environments in Puget Sound brighter, hotter, drier, and less suitable for surf smelt embryos," (Rice 2007).

## Modified Transitions between Terrestrial and Aquatic Ecosystems/Decreased Debris

The structure of the shoreline, when modified by armoring, can affect the transition between terrestrial and aquatic ecosystems (Figure 3-7). The movement of materials and organisms between systems is reduced, along with the quality of riparian functions, and it introduces discontinuities to the narrow ecological corridor (Shipman 2010). It can also reduce the amount of vegetation dropped into the shoreline that would have provided food for insects, therefore reducing the number of insect species which can then lead to a decline in the fish and birds that feed on them (Dethier 2010). The percentage of organic debris, such as large wood, wrack, and leaf litter is shown to be lower in areas of armoring (Sobocinski 2003). The decreased amount of debris on the shores is just one way that armoring results in loss of habitat for biological organisms.


**Figure 3-7 Typical shoreline today in Subsection 1 – Federal Way . Photo was taken during low tide. Source: WDOE 2006**

On the California coastline, along the sandy beaches of El Capitan and Refugio, a study by Dugan et al. (2008) showed macroinvertebrate species abundance, biomass, and mean individual size to be greater on unarmored segments of the beaches compared to the armored segments and overall mean abundance of birds to be greater The reasons for these observed declines can be contributed to the loss of beach, which eliminates the habitats for fish, birds, etc. (Dugan and Hubbard 2010).

Change in species abundance is not the only effect of nearshore armoring. Toft et al. (2007) identified differences in fish behavior and usage between armored and unarmored shorelines and noted that, "The scale of the direct effects of armoring is related to the tidal elevation to which the armoring footprint extends: (1) within terrestrial and supralittoral, (2) into intertidal, and (3) across the entire beach profile into subtidal waters. Impacts to shoreline biota can often be more extreme where shoreline armoring extends into deeper subtidal areas, severely truncating the nearshore and destroying the natural gradual slope of the intertidal zone."

### *3.1.5. Ecological Thresholds (Triggers)*

While researching the information for this study, an effort was made to determine whether ecological triggers are identified within the literature. When considering shoreline development, the question remains of whether there is a "tipping point," a certain amount of change, beyond which alterations affect the local biotic community. Bilkovic and Roggero (2008) describe the problem in this way:

*"Shoreline development can directly affect local water quality and aquatic communities through the loss of intertidal habitat, changes in hydrology, increases in nutrient inputs, loss of allocthanous material, increased recreational use and loss of natural erosion control. Shoreline hardening, (generally related to upland development) affects benthic or interstitial invertebrate communities, fish egg mortality, predator abundances and fish community integrity."*

Evaluation of the impacts of shoreline development in Chesapeake Bay included shoreline hardening on nearshore nekton communities. After extensive sampling of local development, aquatic habitat and associated fish communities Bilkovic and Roggero (2008) concluded that: "even in areas with low development, the presence of shoreline erosion control structures had a negative impact on local fish community integrity." Upland development impacts on fish communities were identified at larger spatial scales (200 and 1000 m) and >23% development provided measurable thresholds of biotic response. This is similar to other thresholds discussed in the paper such as compromised ecosystem functions with tributary development of 10-25%, marsh bird community integrity at disturbance thresholds of approximately 14%, and degradation of fish communities with as little as 10% watershed development within large estuaries and 10-20% urbanization within streams.

Given the amount of shoreline hardening in the study area and throughout Puget Sound, it is expected that large and small scale changes in function and species composition have occurred as identified by multiple authors (Toft et al. 2007, 2010; Shipman et al. 2010; Sobocinski 2003).

## 3.2. Historical Loss of Special Aquatic Sites

Wetlands are one type of special aquatic sites, as these sites are defined in the Clean Water Act (CWA). Mudflats and vegetated shallows are two other types. Three additional types are defined in the (CWA 40 CFR 230, Subpart E) but do not exist in the study area, so the special aquatic sites considered in this study are wetlands, mudflats, and vegetated shallows.

Special aquatic sites are defined in the [CWA] 404(b)(1) guidelines (Guidelines; 40 CFR 230) as "…geographic areas, large or small possessing special ecological characteristics of productivity, habitat, wildlife protection, or other important and easily disrupted ecological values." The description goes on to say, "These areas are generally recognized as significantly influencing or positively contributing to the general overall environmental health or vitality of the entire ecosystem of a region." (40 CFR 230.39 (q-1))

In the literature, historical wetlands and mudflats and their losses are commonly documented together. Here, they are described in separate subsections (3.2.1 and 3.2.2), and then their combined loss is discussed in section 3.2.3. Vegetated shallows and their losses are discussed in section 3.2.4. Data from published literature as well as data analysis completed as part of this study were used to derive the loss estimates.

### *3.2.1. Wetlands*

Wetlands are defined in the Guidelines as follows: "Wetlands consist of areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances to support, a prevalence of vegetation typically adapted for life in saturated soil conditions." (40 CFR 230.41) For the purposes of this cumulative effects study, wetlands typically are transitional areas that form the interface between uplands and the marine environment. Standard wetland functions include groundwater discharge and recharge, flood storage, sediment trapping, nutrient retention, shoreline protection, and dissipation of erosional effects. However, the value of wetland is a product of the functions that it provides. Not all wetlands provide the same functions and not all wetlands provide functions equally well: the location and size of a wetland determines what functions it may perform and factors such as climate conditions, quantity of water entering the wetland, and the type of surrounding area all affect the functions it performs. Many of the habitats and functions of wetlands are interdependent such as a riparian area and the adjoining wetland providing improved water quality or flood reduction function.

Wetlands provide critical life support habitat functions such as refuge, osmoregulation (changing from a fresh water physiology to saltwater) and highly productive feeding areas (increased growth rate improves chances for ocean survival) (Simenstad et al. 1982) for many juvenile fish. Several species of fish that depend on the Duwamish and Snohomish Rivers are Endangered Species Act (ESA)-listed species.

Wetlands are key sources for primary and secondary productivity, which, when coupled with detritus generation, are the main source of energy that drive the local aquatic food chain. Prior to human modification, this was particularly true in the Duwamish and Snohomish estuaries, which contained large swaths of both emergent and forested vascular plants. Algae and bacteria found in high abundance in wetland environments are primary drivers in biogeochemical cycling and as such are important sources of energy for higher organisms.

Connectivity, which in this case refers to the ability to facilitate movement between different habitat types, can be biological (such as the ability of organisms to move between habitats) or physical or chemical migration such as detritus washed to a mudflat by the tide.

### *3.2.2. Mudflats*

Mudflats are defined in the Guidelines as *"broad flat areas along the sea coasts and in coastal rivers to the head of tidal influence"* (Guidelines 40 CFR 230.42). They occur predominantly in estuaries and nearby coastal areas, in sheltered marine bays, and in semi-enclosed areas behind barrier islands including lagoons where energy is low and deposition can occur. Mudflats are comprised mainly of fine particles, mostly in the silt and clay fraction, often with a high organic content. Intertidal mudflats support communities characterized by polychaetes, bivalves, and oligochaetes. They are heavily influenced by biological, chemical, and physical processes such as wave and tidal action.

Mudflats provide multiple functions including habitat for many marine species including clams due to their typically fine-grained sediments. Mudflats provide important feeding and resting sites for populations of migrant and wintering waterfowl and shore birds at low tide, feeding and refuge sites for many marine fish species at high tide, and dispersal and recruitment of larval marine species particularly when connected to wetlands.

### *3.2.3. Stresses and Losses of Wetlands and Mudflats*

Within the study area, losses of wetlands and mudflats have been best documented in the two major estuaries: Snohomish, which empties into Port Gardner just north of Everett; and Duwamish, located just south of Elliott Bay in the City of Seattle. Ongoing stressors in both estuaries include: filling and excavation, levee construction and maintenance, ditching or other hydrologic alterations (such as pumping), conversion to agricultural uses, road construction, hazardous substance releases, poor water quality, and bank hardening. In addition, climate change and sea level rise are two global stressors that affect these estuaries and Puget Sound as a whole; these factors are briefly discussed separately in Section 10.

Historical and current estuarine extent and estimates of wetland loss for the Snohomish and Duwamish estuaries are relatively well understood and are described in Sections 0 and 0. Although wetland losses are not as well documented for the remainder of the study area, some trends are apparent and are discussed in section 0.

**<u>Snohomish Estuary</u>**

The Snohomish River watershed (Subsection 7 – Snohomish Estuary of the study area) is approximately 1,856 square miles with an annual average discharge of 9,500 cubic feet per second (cfs) and a total linear shoreline length of 20 miles. The study area incorporates the lower 7 miles of the Snohomish River, which originates at the confluence of the Skykomish and Snoqualmie rivers that drain a portion of the western side of the Cascade Mountains. Historically, the majority of land area in the Snohomish River valley " … was either channel or wetland. Vast floodplain wetlands and extensive estuarine marshes accounted for nearly two-thirds of the valley bottom. By the 19th century's end, much of this wetland had been diked, ditched, and drained; by the end of the 20th century, only small patches remained. Especially notable in the Snohomish basin were vast riverine-tidal wetlands, or freshwater wetlands influence by the tides" (Collins et al. 2003). Both the Snohomish and Duwamish estuaries were a mosaic of interconnected habitats (for example, mudflats abutted emergent marshes which were bisected by intertidal channels) that facilitated the movement of both energy and organisms through the system.

Wetland loss began when European settlement came into the area, with agriculture and logging driving major development. Diking[2] of tidal wetlands continued for the next hundred years; the current extent is shown in Figure 3-8. By 1884 there were approximately 100 acres of diked farmland near Spencer Island. Construction of the Great Northern railroad occurred shortly thereafter along the shoreline through Port Gardner and crossing the Snohomish River and its three distributary channels. Filling was required to support the bridge piers. The Monte Cristo railroad was constructed to the town of Lowell

[2] A levee is any artificial barrier that will divert or restrain the flow of a stream or lake for the purpose of protecting an area from inundation from flood waters. Historically, a dike is used to divert or restrain flood water from tidal bodies of water. In many cases, the words are interchangeable.

(the eastern terminus of the study area) and from there joined the Great Northern tracks with an additional track near Ebey Island.

In 1892, Snohomish County commissioners contracted for a dike circumnavigating Ebey Island and creating Diking District #1. By 1895 diking was being carried out in the marshland areas, followed by dikes around Smith, Spencer, Otter, and North Ebey Islands. Near the turn of the century a deepwater port was constructed near the confluence of the Snohomish River and Steamboat Slough. This included a riverside dock and a jetty to create a protected harbor. Snagging operations to remove large logjams were initiated at this time. It was not until federal maintenance dredging began in 1910 that the port facility was fully utilized.

River dredging, timber harvest, log storage on the mudflats, and the establishment of lumber mills along with diking and draining for agricultural purposes affected extensive areas of the estuary between the 1860s and the 1940s. In particular, diking and draining caused the conversion of estuarine wetlands to palustrine wetlands. Additionally, the railroad filled wetlands at Lowell and behind the Weyerhauser Mill in Everett to create new switching yards. From 1910 to 1940 the Port was expanded and new log rafting areas were established west of Smith and North Ebey Islands. Since the 1940s there has been a progressive loss of wetlands due to continued Port development, industrialization, and urbanization.

Most but not all of the impacts to the lower Snohomish estuary occurred prior to passage of the Clean Water Act in 1972.

There has been limited recovery of tidal wetlands in the last 40 years. A few agricultural areas have been abandoned due to the cost of maintaining the extensive diking system, and of tiling and pumping agricultural fields to facilitate drainage. However, the amount of area converted back to wetland is small relative to the total area impacted.


**Figure 3-8 Extensive levee system on lower Snohomish River. Existing levees shown in red.** Courtesy USACE.

Several authors reconstructed the historical condition of the Snohomish River valley to estimate wetland loss (Figure 3-9, Figure 3-10, Table 3-1, Table 3-2, and Table 3-3). Methodologies differed among the authors and their estimates of wetland loss in the Snohomish Estuary differ, ranging from 64% (Bortelson et al. 1980) to 93% (Collins and Sheikh 2005a). Boule et al. (1983) estimated total historical wetland area at 6.6 square miles ($mi^2$) while Simenstad et al. estimated 32.7 $mi^2$. Estimates of the amount of

Snohomish wetland remaining today ranges from a high of 7.3 mi² (Bortelson et al. 1980) to a low of 1.4 mi² (Boule et al. 1983).

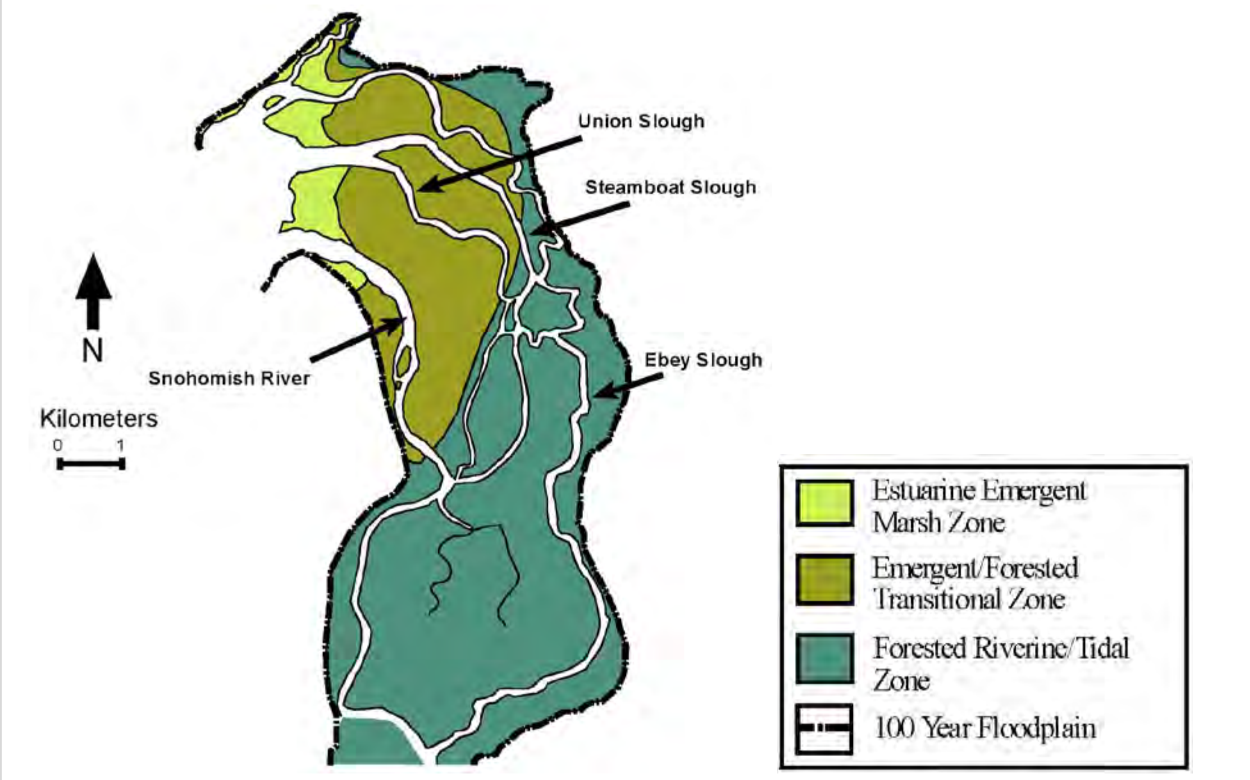



**Figure 3-9 Historic distribution of wetlands in the Snohomish estuary.** Haas and Collins (2001), based on an interpretation of the Government Land Office Survey (Surveyor General 1869-74).

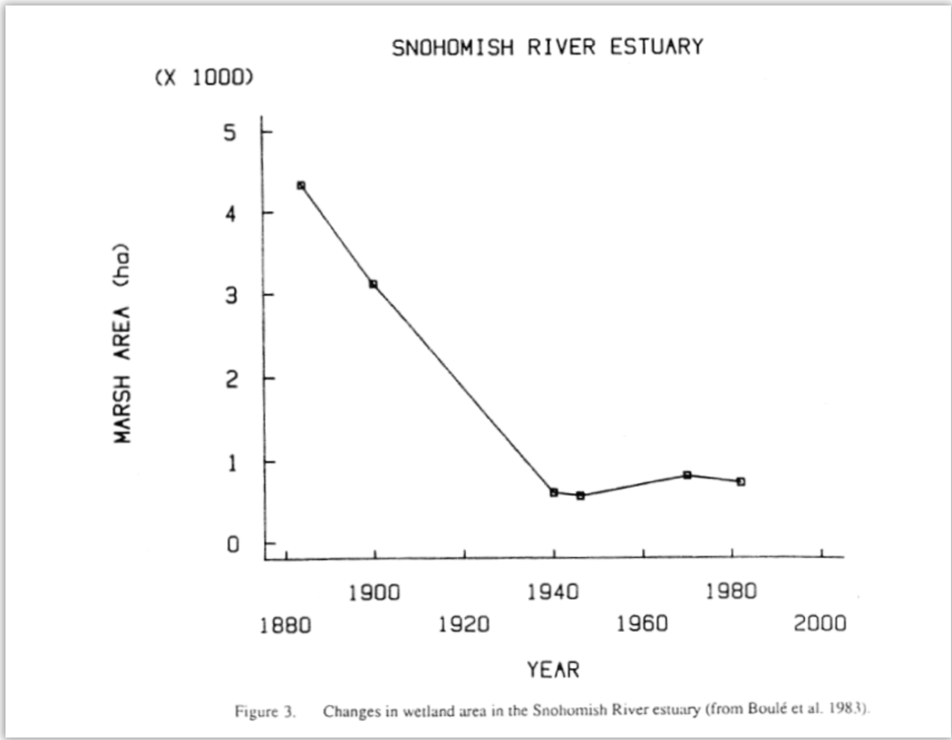



**Figure 3-10 Estimated loss of wetlands in the Snohomish estuary.** Boule et al. (1983).

**Table 3-1 One summary of wetland loss and conversion in the Snohomish estuary.** Data source: Haas and Collins (2001); "Tidal Marsh" section.

| Wetland type (Cowardin Classification [a]) | Historical Acreage | Current (1991) Acreage | Notes |
|---|---|---|---|
| Estuarine emergent (E2EM) | 635 | 254 | Estuarine wetland was converted to PEM [b] through diking. |
| Estuarine emergent transition (E2EM/E2FO) | 3038 | 1016 | Estuarine wetland was converted to PEM through diking. This portion of the estuary is the transition zone between tidal emergent and forested wetlands. |
| Estuarine forested (E2FO) | 6350 | 254 | Estuarine wetland was converted to PEM through diking. |
| Total | 10,023 (15.6 mi²) | 1,524 (2.4 mi²) | 83% loss of total wetlands. |

a. E2EM, E2FO, and E2EM/E2FO are classification codes for estuarine emergent, estuarine forested, and estuarine emergent transition, respectively, based on the classification scheme developed by Cowardin et al. (1979). These codes correspond with abbreviations in Haas and Collins (2001) as follows: E2EM = EEM; E2EM/E2FO = EFT; E2FO = FRT.

b. PEM – Palustrine Emergent Marsh

**Table 3-2 Direct comparison of two estimates of historical loss of wetlands in the Snohomish estuary.** Data sources: Bortelson et al. (1980); Collins and Sheikh (2005a)

| Data Source | Wetland type (acres) | Wetland type (acres) | Wetland type (acres) | Total[a] (acres) | Notes |
|---|---|---|---|---|---|
| **Bortelson et al. (1980)** | **Intertidal** | **Sub aerial[b]** | (no compa-rable type) | | Note 1 Bortelson's calculations are from 1980. |
| Historic amount | 3200 | 9664 | — | 12864 | Note 2: Collins and (Sheikh 2005a) think Bortleson et al. (1980) under- |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | estimated the amount. |
| Current amount | 2176 | 2496 | — | 4672 (64% loss) | |
| **Collins and Sheikh (2005a)** | **Estuarine** | **Riverine Tidal Transition** | **Palustrine** | | |
| Historic amount | 4096 | 11712 | 4096 | 19968 | |
| Current amount | 256 | 960 | 256 | 1472 (93%loss) | Much of this conversion was from estuarine to palustrine wetlands; a large portion of the palustrine wetlands are in agriculture. |

a. Bortelson et al. (1980) divided wetlands into only two types; which are summed here for total wetlands; Collins and Sheikh (2005a) divided wetlands into three types and all three are summed here for total wetlands.

b. Sub aerial wetlands are those wetlands landward of the general saltwater shoreline; i.e., non-tidal wetlands

**Table 3-3 Historical and current estimates of area for four wetland types in the Snohomish estuary**
Data source: Simenstad et al. (2011), Table 8.

| Euryhaline Un-vegetated (acres) | | | Estuarine Mixing (acres) | | | Oligohaline Transition (acres) | | | Tidal Freshwater (acres) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Historic | Current | Change | Historic | Current | Change | Historic | Current | Change | Historic | Current | Change |
| 2,212 | 2,520 | + 14% | 2,348 | 729 | - 69% | 3,245 | 0 | - 100% | 13,114 | 1,280 | - 90% |

*Note: Conversion factor of 247.10538 was used for $km^2$ to acre.

## Duwamish Estuary

Changes to the Green/Duwamish basin (Subsection 3 – Elliott Bay and Subsection 4 – Duwamish Estuary of the study area) began shortly after the turn of the century. In 1906 the White River, once a tributary to the Green, was diverted to the Puyallup River. Approximately 20 million cubic yards of soil and 2.5 million cubic yards of sand and trash were sluiced from hillsides along the river and used to fill in thousands of acres of estuary habitat to create the industrial corridor of South Seattle. The large mudflat in the area now occupied by Harbor Island was filled and a dredge was purchased. Around 1909 the Duwamish waterway was deepened and material was sidecast to above flood stage to provide for future industrial use. The east and west waterways were dredged to approximately a 50 foot depth and the fill at Harbor Island was completed. By 1911, the 14-mile meandering Duwamish River had been channelized to a shorter, straighter waterway. With the opening of USACE Chittenden locks in 1916 the water level of Lake Washington dropped 9 feet and as a result both the Cedar River and Lake Washington that formerly drained into the Green/Duwamish were diverted to Puget Sound. The Green/Duwamish watershed that historically drained an area of over 1,600 square miles was reduced to about 440 square miles. The historic average flow of 2,500 to 9,000 cubic feet per second was reduced to approximately 1,300 cubic feet per second (Blomberg et al., 1988). By the 1920s the vast majority of dredging and filling was finished. In addition to construction of the Lake Washington (Chittenden) locks and navigation channel, almost all of the shoreline was hardened with riprap and armor. What once was a meandering tidal channel with associated marshes, swamps, and blind channels of over 9.3 miles in length was reduced to a straight-line ditch of approximately 5.3 miles with very little associated wetland habitat. The salinity gradient as well as tidal inundation within the estuary was also significantly changed by the constriction and deepening of the waterway. The navigation channel constructed by the City of Seattle is now a federal navigation dredging project maintained by the Seattle District USACE.

The final large-scale alteration to the Green/Duwamish watershed occurred in 1963 with the completion of Howard Hanson Dam at Eagle Gorge. The dam was constructed for flood control purposes and restricts sediment deposition to the lower valley. As predicted, industry flocked to the "quick land" developed along the banks of the Duwamish. Historical or current commercial and industrial operations include cargo handling and storage; marine construction; boat manufacturing; marina operations; cement manufacturing; paper and metals fabrication; food processing; and airplane parts manufacturing. Contaminants may have entered the river via several transport mechanisms, including spillage during product shipping and handling, direct disposal or discharge, contaminated groundwater discharge, surface water runoff, storm water discharge, or contaminated soil erosion. Several City of Seattle or King County combined sewer overflow (CSO) outfalls exist in the lower Duwamish River. Seven of these outfalls together discharge 318 million gallons of raw untreated sewage annually to the lower Duwamish River. Toxics such as heavy metals, polychlorinated biphenyls (PCBs), and other toxics were discharged to the waterway by the industries that grew along the Duwamish. The Lower Duwamish Waterway was added to the EPA National Priorities List (i.e., was designated a Superfund site) in 2001. Several authors have estimated loss of wetlands and other habitat from the Duwamish estuary, similar to the Snohomish estuary as discussed in section 3.2 generally using a combination of historical data and interpretation of that data. The results of these efforts for the Duwamish estuary are shown in Table 3-4, Table 3-5, Table 3-6 and Table 3-7.

As in the Snohomish estuary analyses, estimation methodologies differ, but authors agree that there has been nearly 100% loss of wetlands in the Duwamish estuary, through conversion to industrial and other land uses. Much of the conversion had occurred by the end of the1930s but several remnant wetland sites persisted until the 1980s (Blomberg et al. 1988). Now only a few small wetlands exist (such as Kellogg Island) as well as a few wetland restoration projects as described in Study Area Existing Conditions.

Collins and Sheikh (2005b) noted that within the Puget Sound, the greatest loss of tidal wetlands has been in the Duwamish estuary and Elliott Bay:

*" … in the central sound sub-basin in which the Duwamish estuary and Elliott Bay are located, proportionately less of the historical tidal wetlands remain than in any other sub-basin of the Puget Sound region; it has the lowest percentage of remaining historical tidal wetlands by number of wetlands, and the lowest percentage of its historical wetland area … "*

As in the Snohomish estuary, much of the Duwamish wetland loss occurred prior to initiation of the Clean Water Act, however, small-scale losses continued into the 1980s – 1990s.

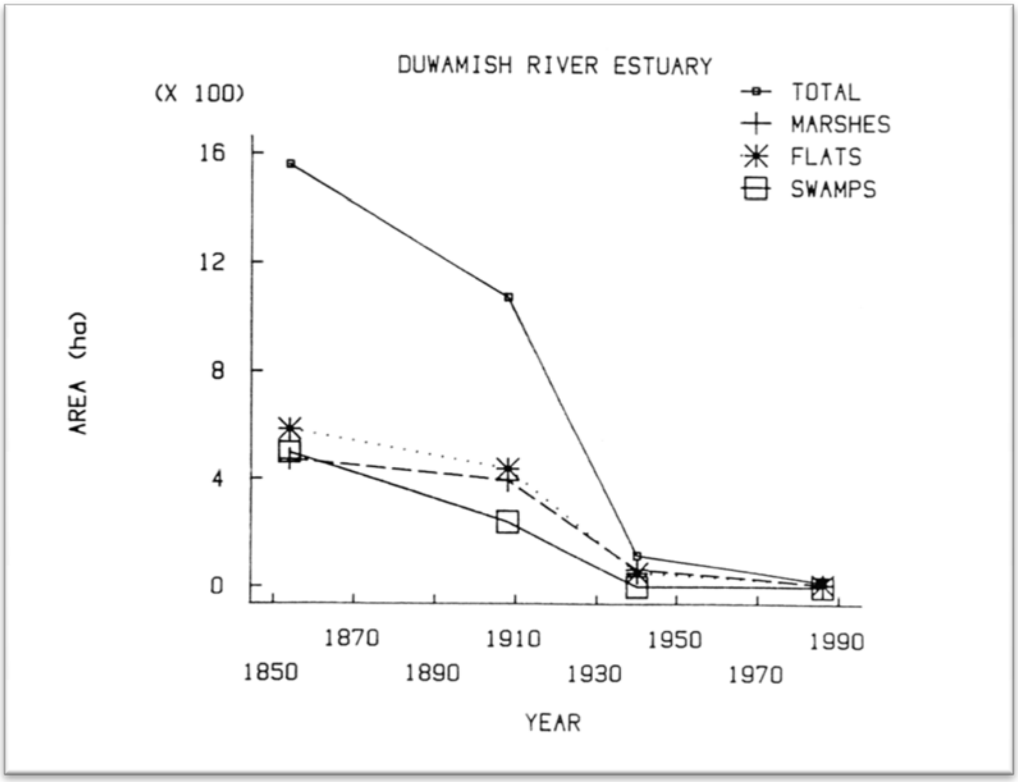



**Figure 3-11 Estimated loss of wetlands in the Duwamish estuary by year 1850 – 1990.** Boule et al. (1983).

**Table 3-4 One estimate of amount of habitat loss in Elliott Bay and the Duwamish estuary by habitat type.** Data source: Collins and Sheik (2005b).

| Habitat type | Location | Acres of loss |
|---|---|---|
| Estuarine distributary channel | Mouth of the Duwamish | 147 |
| Estuarine blind Channel | Duwamish | 36 |
| Estuarine blind channel | Elliott Bay | 10 |
| Tidal -freshwater channel | Duwamish | 551 |
| Palustrine wetlands | Duwamish | 493 |
| Riverine-tidal wetlands | Duwamish | 422 |
| Estuarine wetlands | Duwamish | 442 |
| Estuarine wetlands | Elliott Bay | 76 |

**Table 3-5 One estimate of historical loss of wetland habitat in the Duwamish.** Data source: Bortelson et al. (1980)[a].

| Wetland type | Historic (acres) | Present (1980) (acres) | Percent Change |
|---|---|---|---|
| Intertidal wetland (E2EM) | 2,100 | 0 | 100% loss |
| Sub aerial wetlands[b] (PEM, PSS, PFO) | 642 | 7 | 99% loss |

a. Note: Collins and Sheikh (2005b) consider estimates by Bortelson et al. (1980) to be overestimated by approximately 50%.

b. *Sub aerial wetlands are those wetlands landward of the general saltwater shoreline, i.e. non-tidal wetlands.

**Table 3-6 Historical and current estimates of area for four wetland types in the Duwamish estuary.** From Simenstad et al. (2011), Table 8.

| Euryhaline Unvegetated (acres[a]) | | | Estuarine mixing (acres[a]) | | | Oligohaline Transition (acres[a]) | | | Tidal Freshwater (acres[a]) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Historic | Current | Change | Historic | Current | Change | Historic | Current | Change | Historic | Current | Change |
| 2,204 | 37 | 98% loss | 581 | 5 | 99% loss | 0 | 0 | No change | 951 | 0 | 100% loss |

a. Note: Conversion factor of 247.10538 was used for km2 to acre.

**Table 3-7 Estimates of wetland loss in the Duwamish estuary by habitat type.** Data source: Blomberg et al. (1988).

| Habitat Type | Amount (Acres) in 1854 | Amount (Acres) in 1908 | Amount (Acres) in 1940 | Amount (Acres) in 1986 | Change (1854-1988) |
|---|---|---|---|---|---|
| Medium depth water | 440 | 410 | 390 | 360 | -18% |
| Shallows and flats | 1450 | 1080 | 130 | 25 | -98% |
| Tidal marshes | 1170 | 970 | 160 | 20 | -98% |
| Tidal swamps | 1230 | 590 | 0 | 0 | -100% |
| Developed shorelands and floodplain | 0 | 1210 | 3750 | 5220 | +430% |

Based on multiple estimates of historical wetland acreage (Table 3-4, Table 3-5, Table 3-6 and Table 3-7), it appears there were 1,500 to 2,500 acres in the Duwamish estuary. Estimates of current wetland area range from 10 to 20 acres with approximately half being recent habitat restoration projects. There are less than 40 acres of mudflat remaining in the Duwamish estuary, most as small fragmented slivers adjacent to hardened bankline. A large mudflat remains at the third turning basin and has the highest concentration of juvenile salmonids measured in the waterway.

These estimates reveal a precipitous decline in the type and extent of wetland loss in both the Duwamish and Snohomish estuaries. This study looks at what results this may have in terms of diminished function and impacts to the aquatic ecosystem (Section 3.2.1).

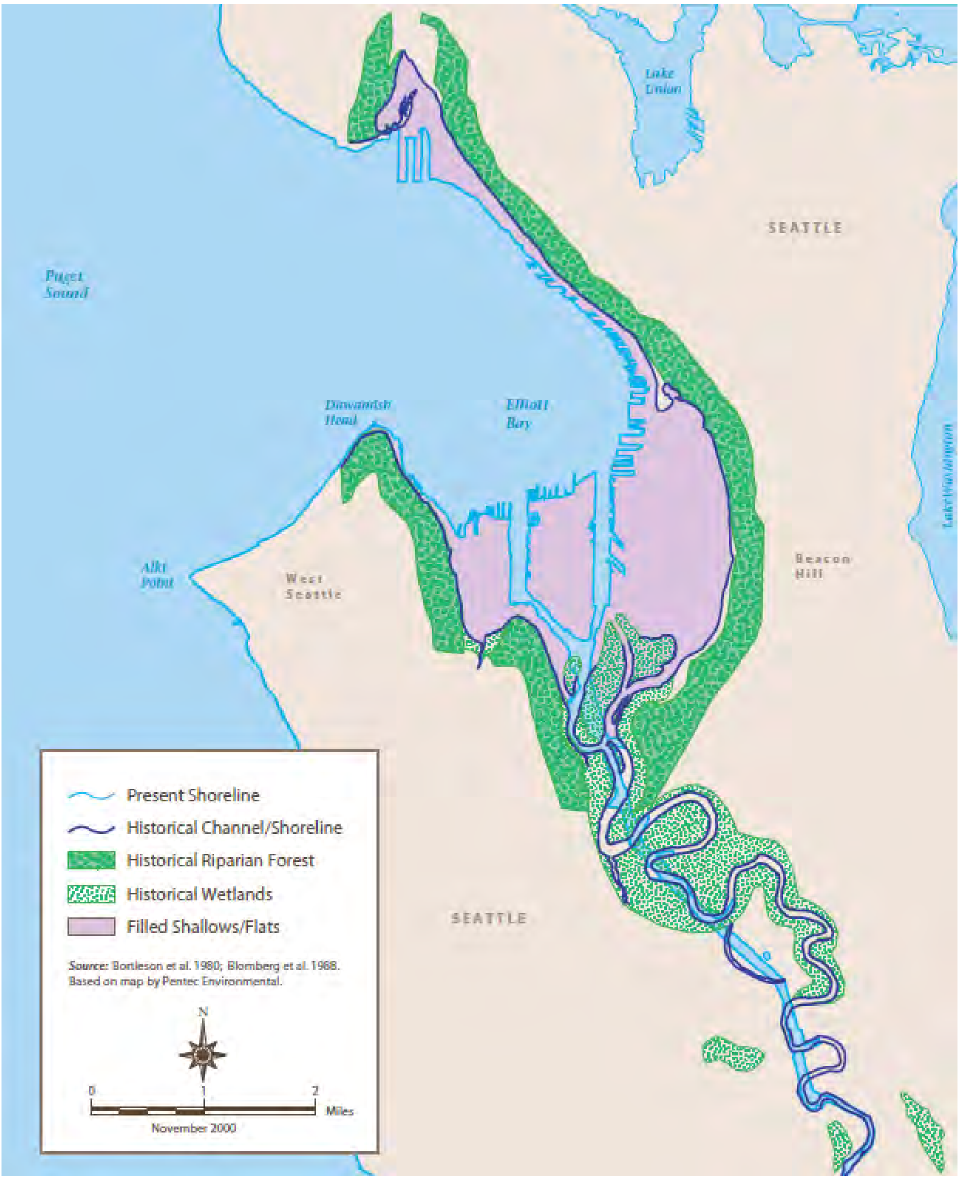



**Figure 3-12 Historic distribution of aquatic habitats in the Duwamish estuary and Elliott Bay.** Map developed by King County Department of Natural Resources.

## Trends in loss of special aquatic sites in the remainder of the study area

Loss of special aquatic sites have also occurred in other parts of the study area; however, there is considerably less documentation to support estimates of loss in these areas, with the exception of Elliott Bay.

Prior to European settlement, Elliott Bay contained considerable mudflats and a few wetland complexes. The earliest filled marsh complex in Elliott Bay occurred by 1875, and was approximately 6.5 acres in size. The area historically known as Smith Cove (commonly referred to as Interbay) had a rather large contiguous tidal marsh complex of approximately 48 acres with a fringing marsh of about 8 acres.  By 1909 the marsh complex was filled (Collins and Sheikh 2005b). It appears for Elliott Bay there were historically approximately 60 acres of wetlands. Currently there are about 2 acres remaining indicating a loss of about 97%. The loss of mudflats in Elliott Bay is not well documented but there are currently only a few, fragmented mudflats in existence.

Collins and Sheikh (2005b) digitized and rectified US Coast and Geodetic Survey topographic survey sheets (T-sheets) for Puget Sound to estimate the historic nearshore environment, while another data layer identifying wetlands was created from aerial photos (1998 to 2004) and wetlands mapped by National Wetlands Inventory (NWI). We compared the two data sets to estimate the amount of change over time in the remainder of the study area (not including the Snohomish and Duwamish estuaries [subsection 7 and subsections 3 and 4 of the study area, respectively). The results of the estimate are shown in Table 3-8.

**Table 3-8 Estimate of changes in nearshore wetlands within the study area[a].**

| Study Area Subsections | Subsection 1 – Federal Way | Subsection 2 – Burien/West Seattle | Subsection 5 – Edmonds | Subsection 6 – Everett[a] |
|---|---|---|---|---|
| Estimated historic amount of wetlands | 49 acres | 3 acres | 34 acres | 173 acres |
| Estimated current amount of wetlands | 8.3 acres | 0 acres | 5.5 acres | 26.7 acres |
| Percent Change | 83% loss | 100% loss | 84% loss | 85% loss |

a. Note: there are mudflats in this sub-section not included in the wetland estimate.

### 3.2.4. Losses of vegetated shallows (eelgrass) within the study area

Vegetated shallows are another type of special aquatic site regulated under section 404 of the CWA. Eelgrass is the predominant rooted vascular plant in the Pacific Northwest and is critical habitat that many species (including specied listed under the Endangered Species Act [ESA)]) depend upon for portions of their life history. Vegetated shallows are defined in the Guidelines as *"permanently inundated areas under normal circumstances that support communities of rooted aquatic vegetation, such as turtle grass and eelgrass in estuarine or marine systems as well as a number of freshwater species in rivers and lakes."* (40 CFR 230.43) This study focused on eelgrass in estuarine and marine systems.

The key eelgrass species found within the study area is Zostera marina, which occurs from the lower intertidal area (2 feet above mean higher high-water [+2 ft. MLLW]) to the edge of the photic zone (about -30 ft. MLLW) and is usually found on mud or mixed mud and sand substrate in sheltered areas (Philips 1984). Its upper elevation is limited by exposure during low tide, and lower elevation is limited by light penetration in the shallow subtidal zone. There is also an introduced eelgrass species, Zostera japonica, that can be found at a slightly higher tidal elevation than Z. marina, but it is not prevalent within the study area. Eelgrass is distributed through most of the central Puget Sound but within the study area it is usually either found as a continuous patch in some areas such as Dash Point or as irregular thin bands of eelgrass such as in West Seattle, or is noticeably absent such as in the inner harbor of Elliott Bay and Everett harbor.

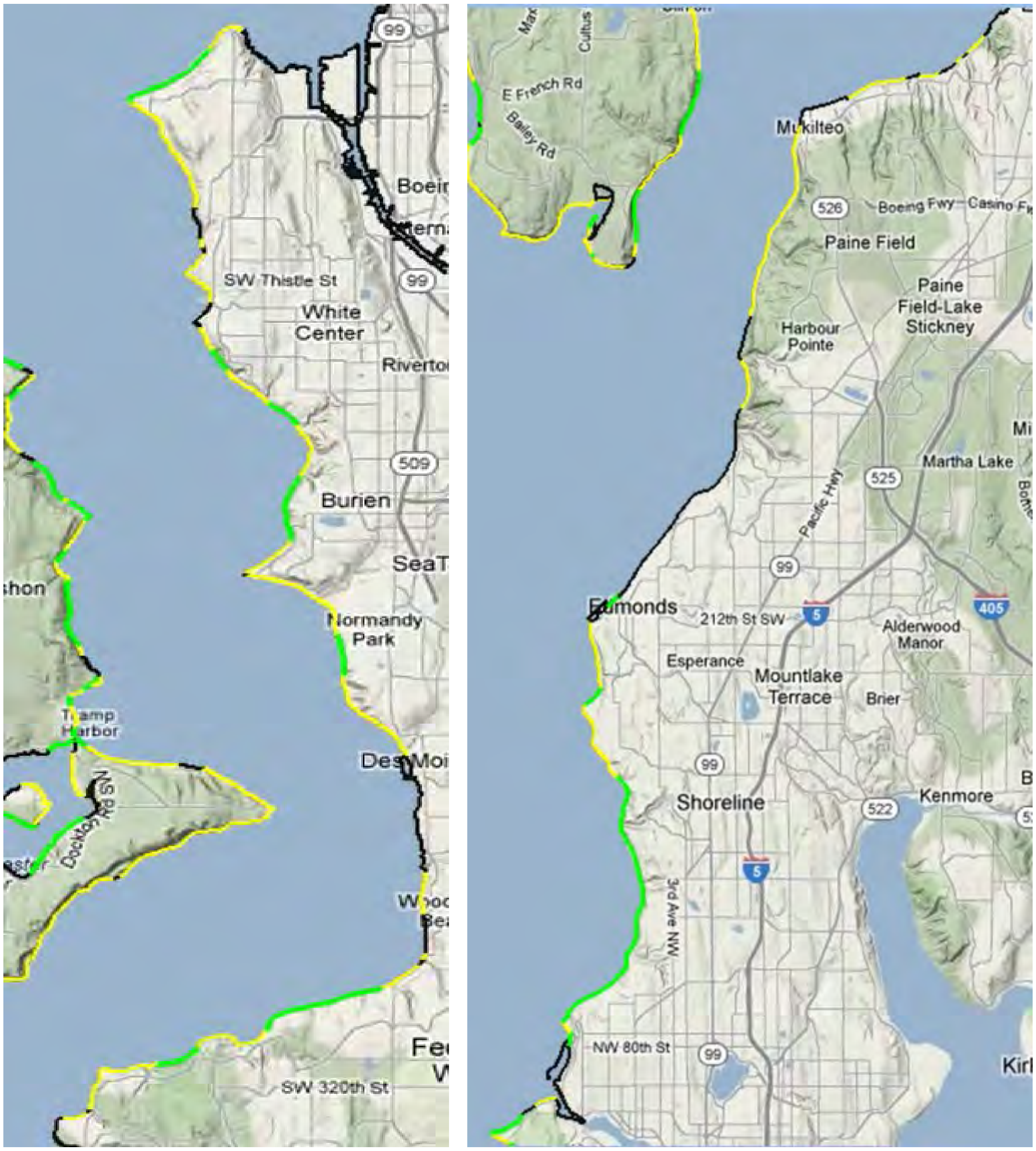
Eelgrass functions include: help stabilize sediments and limit erosion; provide direct and indirect food sources for food chain support either from grazing (black brant) or as a source of detritus; provide substrate for spawning and egg attachment (Pacific herring); provide shelter (physical structure) and refuge for small fish and epibenthic and nertic fauna, many of which are commercially important (crab, shrimp, herring,perch, sculpin and juvenile salmon); and provide tremendous primary productivity potential (up to 500 grams of carbon per meter $^2$ per year) (Phillips 1984). Nutrient cycle, plant uptake nutrients from the substrate through their roots and release these nutrients from their leaves into the water column. Eelgrass structure provides a location for attachment by a wide variety of epiphytes that support high diversity in the nearshore.

Eelgrass stressors include high levels of suspended solids that can occur from nearby dredging and filling activities, chemical contamination, elevated temperature and salinity, elevated water temperatures, sea level rise (limits the photic zone), ocean acidification, nutrient-driven algal blooms, and shading from overwater structures.

Washington State Department of Natural Resources has monitored eelgrass (Zostera marina) since 2000 in Puget Sound. Key findings from the 2009 Puget Sound Submerged Vegetation Monitoring Project (Gaeckle et al. 2011; executive summary) suggest that there is a pattern of Z. marina decline throughout Puget Sound supported by several findings including: (1) there are twice as many sites with long-term declining trends in Z. marina area than increasing trends since 2004, and (2) more year-to-year significant declines than increases in Z. marina area were evident in eight out of nine sampling intervals since 2000. The executive summary goes on to note;

*"Although there is a marginally significant increasing trend in Z. marina area, the pattern of site level decline throughout Puget Sound suggests losses are prevalent at a number of individual sites. There is consistently greater prevalence of year-to-year and long-term declines in Z. marina area and depth distribution throughout the study area. … The occurrence and soundwide distribution of sites with significant declines is of concern for habitat connectivity and ecological functions. The effect of Z. marina loss in areas that are considered critical nursery, forage, and migration habitat for ecologically and economically important species could affect ecosystem processes and the overall health of these areas and Puget Sound."*

There is also some anecdotal evidence of eelgrass loss in specific locations such as the loss of 157 acres near Preston Point in the Snohomish estuary prior to 1900 (Thom and Hallum 1990).




Explanation: Green = continuous eelgrass; Yellow = patchy eelgrass; Black = no eelgrass present.

**Figure 3-13 Eelgrass distribution in the study area.** Data Source: DNR, via the Corps Puget Sound Program (CPSP) web viewer (see Document Reading Tips for more information about this application.)

### *3.2.5. Evaluating Losses of Special Aquatic Sites*

This section identifies direct impacts to wetlands and other special aquatic sites throughout the study area. The impacts were large in scale and cumulative in nature. We can be fairly confident that, in general, the greater the acreage of wetland lost, the greater the probability of cumulative effects regardless of their cause. According to Bedford and Preston (1988) “In lieu of any mechanistic understanding, we propose using past losses of wetland acreage and current rates of loss as surrogates for estimating the potential for new actions to produce cumulative effects.

## 3.3. Changes in Riparian Habitat and Functions within the Study Area

Riparian areas are transitional, providing connections between and affecting both adjacent aquatic and terrestrial systems (Figure 3-14). There are a variety of riparian types, but for this study we will focus on riparian areas as they relate to the creeks or rivers within the study area that empty into the marine shores of Puget Sound, riparian areas along the marine shoreline, and riparian areas at the edge of wetlands.

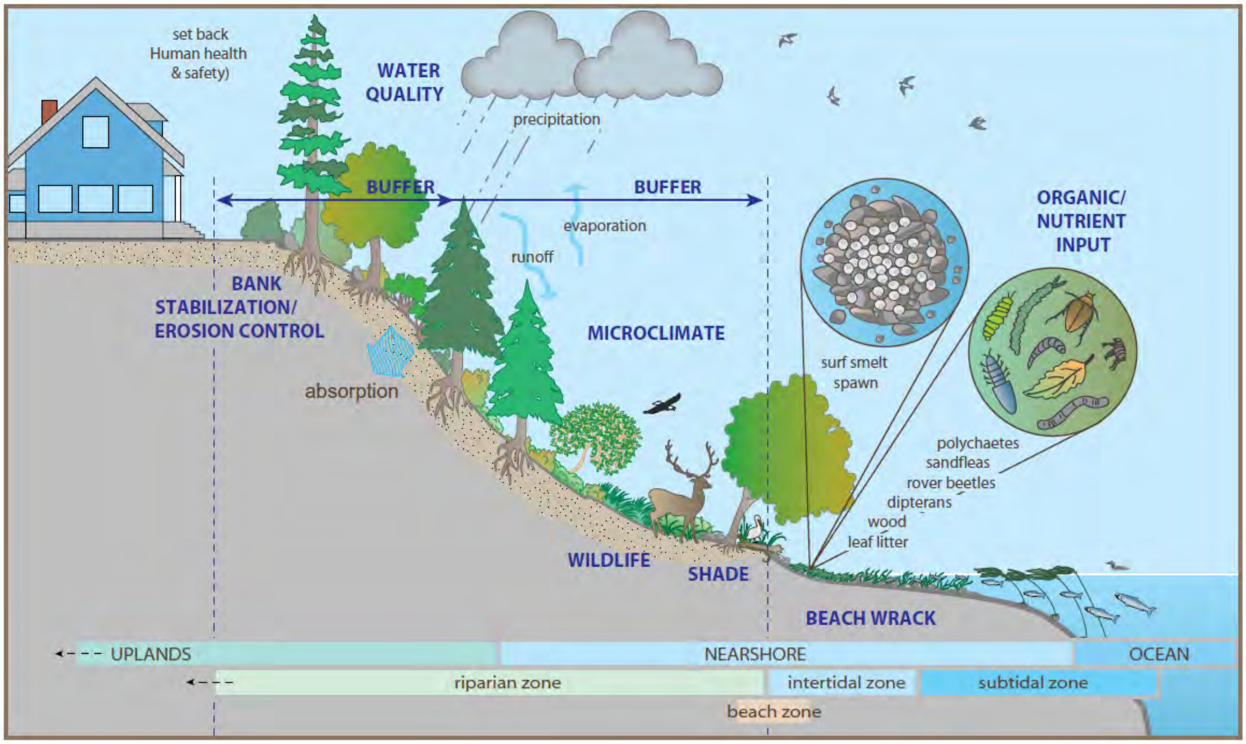



**Figure 3-14 Conceptual Model of Marine Riparian Functions.** Source: King County Department of Natural Resources (2001)

Marine riparian areas are typically vegetated and associated with long contiguous corridors at the water's edge between upland areas and nearshore areas. Historically, most riparian areas along the marine shoreline were comprised of mature conifers (such as western hemlock, Douglas fir, shore pine, and western red cedar) with occasional deciduous species such as maple, alder, or madrone depending on the types of soils, steepness of slopes, or amount of natural disturbance (such as wind throws). There are other types of specialized communities adjacent to shorelines of Puget Sound, including forest, prairies, sand dunes, and salt marshes. River and creek riparian areas usually include more deciduous trees such as alder and cottonwood because of channel migration that is favorable to them. And depending on the location of the wetland in the landscape a wide variety of vegetation could be expected. Riparian areas regulated under CWA 404 in Washington State are those below mean higher high water (MHHW) and the adjacent wetlands.

### *3.3.1. Importance of Riparian Areas*

This transition zone between land and water, when it is a well-functioning riparian area, provides the following specialized functions (Brennan et al. 2009):

1. **Water quality** benefits:
    - Facilitates infiltration and reduces surface water runoff.
    - Filters out nutrients, and some pollutants. Microorganisms within the soil metabolize nutrients and some pollutants.
    - Provides for some thermal support to adjacent waters (i.e., less heating of the water in summer and less cooling and freezing in winter) if there is adequate canopy height and riparian-area width.
2. **Sediment control** that benefits adjacent receiving waters:
    - Roots and litter help bind soil and capture soil particles as well as increasing shear strength of soil.
    - Soil that is porous and permeable, due to being vegetated, helps improve water absorption.
    - Riparian canopy absorbs some rainfall energy, thereby reducing soil compaction.
    - Transpiration within the riparian area helps moderate soil moisture levels.
3. **Large woody debris (LWD)** that is exported from riparian areas to neighboring habitats:
    - LWD provides structural complexity in both fish and wildlife habitat.
    - LWD in the aquatic environment helps to moderate local water temperature and soil moisture.
    - LWD traps sediments and helps with bankline stabilization.
    - LWD helps accumulate detritus which is also a food source for decomposition.
4. **Slope and soil stability**. Roots help bind the local soils, which can help prevent landslides. Landslides are a major concern within the study area and frequently happen in the winter when soils are saturated and rain is frequent. Landslides are more common in the northern section of the study area (Subsection 5 – Edmonds and Subsection 6 – Everett) especially along the railroad tracks that are adjacent to the shoreline. Sediment plumes from landslides often bury the intertidal zone where they smother sessile marine organisms. However, sediment input to the nearshore system can also have beneficial effects (Shipman et al 2010).
5. **Habitat diversity**. Well-functioning riparian areas provide nesting and perching opportunities , and food and refuge for multiple fauna Allan et al. (2003) notes the importance of terrestrial invertebrates as an important trophic link and described the dependence of juvenile coho on them during the growing season in southwestern Alaska streams. The importance of terrestrial food inputs to the marine nearshore in the study area is also described by Armbrust and others. When USACE and the city of Burien implemented a seawall removal and shoreline restoration project monitoring at the site identified terrestrial invertebrates as both major and minor salmonid prey items (Armbrust et al. 2009).
6. **Microclimate/temperature control**. Because of their unique settings between land and water, riparian areas can have their own microclimates, which are often more moderate than in other

areas. This is especially true along marine shorelines in both summer (less hot than surrounding areas) and winter (less cold). The ability to provide shade and temperature relief is especially important to marine organisms such as amphipods which are a food source to many marine creatures but even more significantly to forage fish such as surf smelt. Surf smelt are a ubiquitous nearshore marine species in Puget Sound where they are an important trophic link in the marine food web. They are a prey resource for the ESA-listed Chinook salmon and are also commercially harvested for human consumption. Researchers such as Penttila (2001) and Rice (2006) evaluated both beaches with intact riparian areas and beaches where the natural vegetation had been removed. Rice (2006) identified effects on microclimate and ecology as a result of shoreline alteration and concluded that the modifications identified have the "potential for cumulative ecological effects….at the landscape level."

These temperature- and climate-related functions affect spawning of forage fish. Penttila (2001) offers a states that shading in the marine riparian corridor has a positive effect critical species such as surf smelt. Forage fish spawning observed in the study area is shown in Figure 3-15.

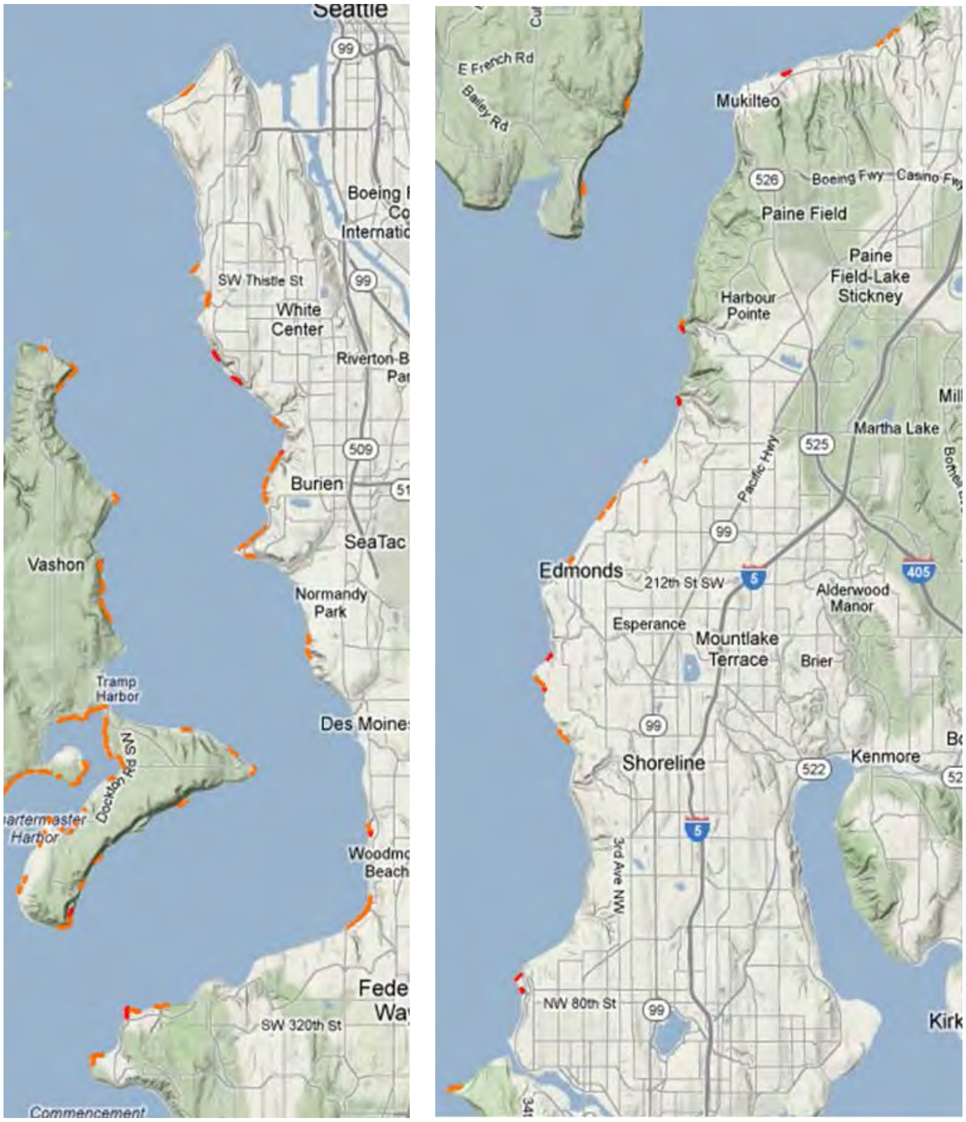



**Figure 3-15 Forage fish spawning within the study area.** Note the study area is only the eastern shoreline and does not include Vashon Island. The portions highlighted in orange are spawning locations for either sand lance or surf smelt. Data source: PSNERP.

While the riparian zone provides a number of important functions it is also susceptible to a host of disturbances. The most severe type of disturbance is modern development which often completely removes the native vegetation and replaces it with a different land cover such as grass, concrete or asphalt. Often the topsoil is removed in this process or is compacted and much of the organic component is lost. The scale at which this happens is also important. While small residential developments were constructed first along the coastline, these have generally been followed by increased adjacent development. Natural areas were replaced by roads and driveways creating impervious surfaces that no long filter the water that the former riparian areas did. Fine sediments are also no longer trapped and subsequently fill in the streams and shoreline areas smothering invertebrates and fish eggs. As noted above, when the mature tree canopy is removed it affects both amount of shade and local climate. Habitat is also degraded and the species dependent on riparian habitat are lost or forced to move to less desirable habitat. To compound this impact on habitat an important source of food is also lacking. Finally, the loss of the structural aspect of riparian areas that comes with riparian removal affects the physical stability of the area around it. Much of the study area along Puget Sound is comprised of bluff-backed beaches. These bluffs are often steep and when riparian vegetation is removed at the toe of the slope it facilitates landslides, commonly in the wet winter months.

### *3.3.2. Trends in Riparian Vegetation within the Study Area*

USACE analyzed riparian vegetation trends within the study area. Our analysis identified land classification trends within the study area to support identification of changes in patch size and density (Urbanization). Data from the following three sources were evaluated, with each further described below: a land cover classifications; USGS 7.5° quad sheets; historical aerial photos.

#### Land Cover Classifications

Our analysis used available land cover classifications including a 2001 national land cover dataset (NLCD), which is a standardized U.S. land classification system. The classification system incorporates three distinct land cover types for trees: deciduous trees, coniferous trees, and mixed trees.

#### USGS 7.5° Quad Sheets

We digitized and geo-referenced USGS 7.5° quad sheets prior to analyzing them. The existing NLCD land cover classes were used in evaluating the quad sheets.

#### Historical Aerial Photos

Historical aerial photos were visually interpreted. The existing NLCD land cover classes were used in interpreting the photos. While many of the historical aerial photo sets covered most of the study area, no one set covered the entire study area. To fill in some of the missing information, additional photos from different years were used. For example, the oldest air photos that covered most of the study area were from 1943, and to cover some of the missing data in this set, photos from different years (such as 1953) were included in the analysis. When this information is presented in this report, the entire date range of each photo set are provided. So for the earliest air photos in our trends analysis, the example just given, the date range is listed as 1943 to 1953. The next set spanned 1956 to 1968 with images predominantly from 1968. The last set was the 2001 NLCD data we already had.

#### Area Evaluated

For each of the seven study area subsections, the 600-foot strip landward of the shoreline was evaluated and classified. The deciduous, coniferous, and mixed categories were combined to determine the total percent cover as displayed in Figure 3-16 below.

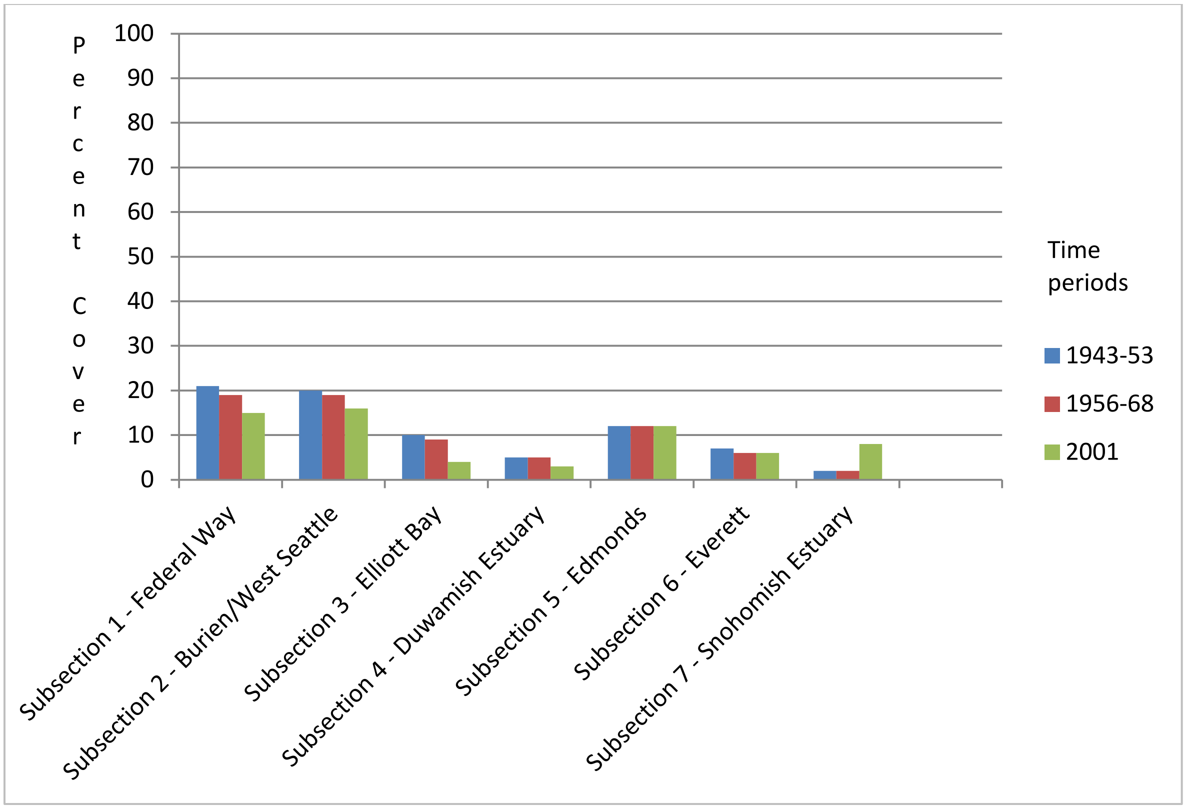



**Figure 3-16 Changes in riparian vegetation over time.** Source: Franklin and Dyrness (1973)

Based on historical accounts shoreline vegetation was significantly reduced by the mid-1900s when the first aerial photos that we evaluated were taken. Prior to settlement in the 1850s, the study area is thought to have contained a mature climax forest of western hemlock right to the water's edge (Kruckeberg 1991):

*"…Captain Vancouver, intrepid eighteenth century circumnavigator of Puget Sound, encountered on our shores an evergreen forest of majestic and awesome dimensions. Only the beach or the deck of a ship was a sanctuary of open space in those early times."*

By the time of WWII, what was once an area of 95 to 100% forest cover was reduced to approximately 5 to 20% cover based on our analysis of historical aerial photographs. During the time period of this analysis, there was a continued decrease in vegetative cover of approximately 2-5% in all but two of the study area subsections. Subsection 7 – Snohomish Estuary shows a recent increase in vegetative cover of approximately 5% that appears to be due to a large area in the southeast Snohomish floodplain that was planted with trees, possibly as a commercial venture. Subsection 1 – Federal Way and Subsection 2 – Burien/West Seattle appear to have retained the most vegetation (about 15%), which may be due to the predominance of steep bluffs behind the beach areas that restrict development. Subsection 4 – Duwamish Estuary show the lowest vegetative cover of approximately 2-5%. Subsection 5 – Edmonds appears the most stable over time with 11% vegetative cover consistent over the 70 year analysis period.

## 3.4. Urbanization

The effects of urbanization in the Seattle Metropolitan area are well documented. (Alberti 2005; Alberti et al. 2007; Booth and Jackson 1997; Booth et al. 2004; Robinson et al. 2004). "Across US metropolitan areas, land consumption has been outpacing population, with most urban areas expanding at about twice the rate of the population growth" (Alberti et al. 2007). As briefly described in the introduction most cities started as small developments along the shoreline of Puget Sound. Transportation in these small encampments was almost entirely water focused with few roads having been developed.

Initial expansion focused upon resource extraction such as logging, coal extraction and fishing. Saw mills and canneries were then developed as well as the marine facilities to export the materials. Once the logs were removed, the small communities developed outward building roads and infrastructure. Agriculture followed the removal of forests. Even before the turn of the 20th century, large scale land alterations accomplished by sluicing, diking, dredging and filling were occurring in the Everett and Seattle areas.

By 1900, population started to rise dramatically in the study area. The combined population of King County and Snohomish County, which includes the study area, increased from 1.4 million in 1970 to 2.5 million in 2005 (Figure 3-17) (Washington Office of Financial Management, 2007). Seattle area population doubled from 315,312 in 1920 to 608,660 in 2010 (Figure 3-18). The population has been continuously increasing in the Seattle area with the exception of the Great Depression in the 1930s and the Boeing downturn in the early 1970s. Other cities within the study area also showed increases in population (Figure 3-19). Expanded railroads and roadways facilitated the sprawl. Industrial development (ship and airplane building) to support the war effort during World War II attracted even more people to the newly built factories. By the end of the war, the small urban centers outside of Seattle were increasing in size along with an expanding transportation system. Shorelines along Puget Sound became prime real-estate as more people desired a view of the water. What were once separate coastal communities became a megalopolis from Everett to Tacoma. The effect of this around the nation are summarized in Beach (2002): "Because the coast hosts more than half of the U.S population on less than one-fifth the nation's land area, the impact of land conversion is greatly magnified."

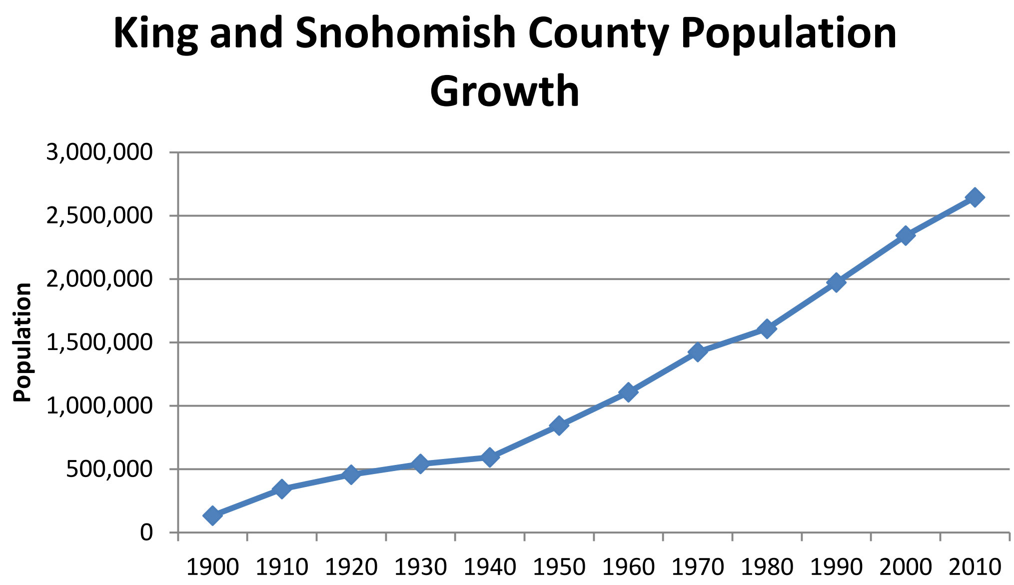



**Figure 3-17 King and Snohomish population for years 1900 to 2010. Data Source: Washington Office of Financial Management, 2007.**

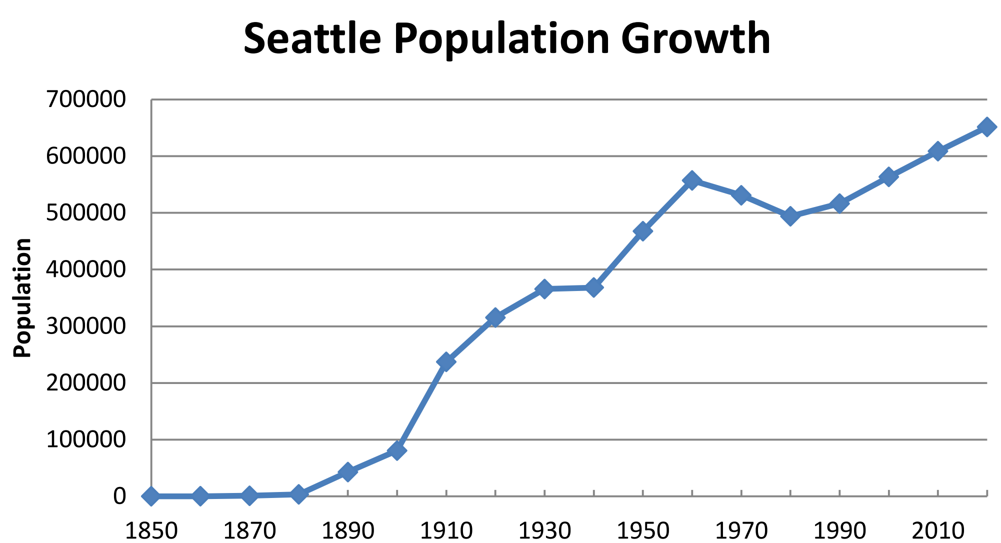



**Figure 3-18 Seattle area population between 1850-2010. Data Source: Washington Office of Financial Management, 2007.**

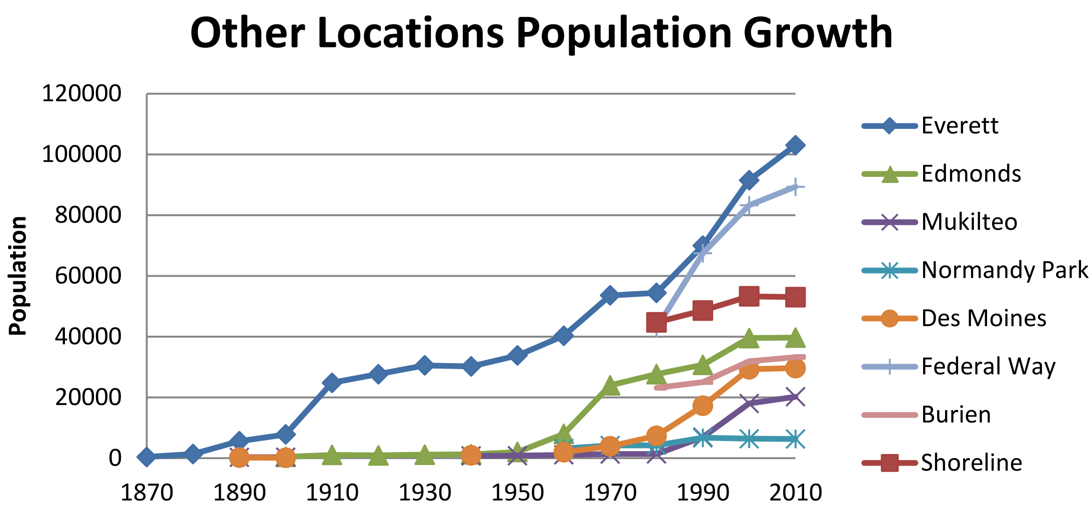



**Figure 3-19 Population growth in major population centers within the study areas. Data Source: Washington Office of Financial Management, 2007**

While the focus of this cumulative impact study was on regulatory actions within the study area and their potential effects, early research identified that the driver of many of the 404 actions were the result of urbanization and development. The question we attempt to answer is how urbanization is correlated with cumulative impacts and CWA Section 404. With regard to impacts to waters of the U.S., urbanization and development provide for direct effects (such as filling, excavation and bankline hardening) as well as secondary effects such as changes to hydrology, hydro-period, alteration of channel morphology, changes to water quality and effects to local wetland populations of flora and fauna (Reinfelt 1998). Urbanization causes a wide range of cumulative effects including; time crowded, space crowded, synergistic, nibbling and indirect effects. As a result, wetlands and shorelines have been filled and streams within the study area have deteriorated. Urban sprawl is responsible for over 51% of all wetland loss within the United States (FWS 2000).

While urbanization is a complex subject and has been well researched within the greater Seattle- Everett metropolitan area, for this cumulative impact study, three parameters of urbanization were chosen to represent some of the impacts on the landscape as a result of rapid growth and sprawl and their possible effects on the aquatic environment; road density, impervious surface coverage and landscape fragmentation.

### *3.4.1. Roads*

Roads seem to be just about everywhere in the urban landscape. While a dense road network may facilitate vehicular traffic through an urban setting, it restricts movement through the landscape by many of the creatures that have to live within the road system. Within the study area for this report, roads exist in many places right down to the shore line edge (Figure 3-20).


**Figure 3-20 Shoreline area near Redondo Beach, Federal Way Washington. That is Redondo Beach Dr. S running parallel to the shore. Source: WDOE 2006.**

The King and Pierce county area has an extensive road network. Within the study area there are highways, arterials and residential roads. There is also a bus system that is dependent on the road system. For the most part, those that commute between work and home travel as individuals in cars (65%), and only a small percentage use public transportation or carpool (Figure 3-21 and Figure 3-22).

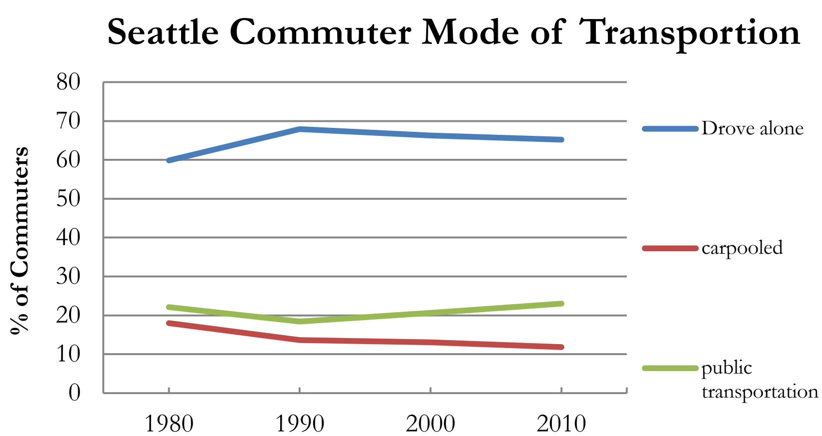



**Figure 3-21 Method of commuting in Seattle Area as a percentage of commuters.**

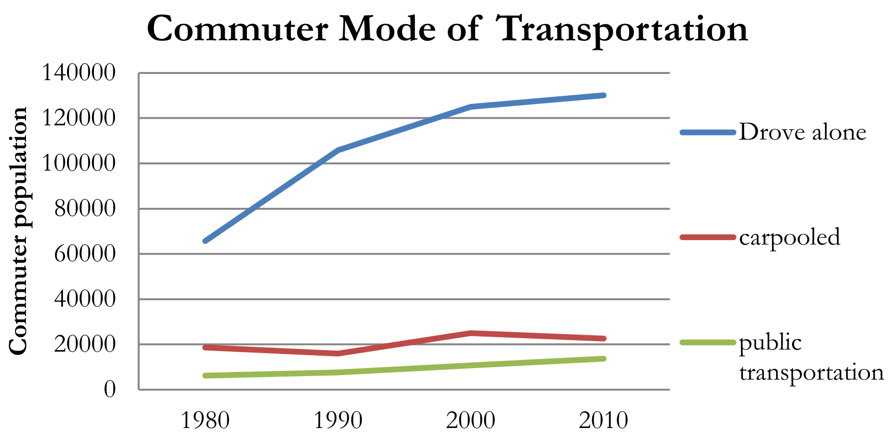



**Figure 3-22 Method of commuting in the study area by population.**

In the Northern portion of the study area railroads are also adjacent to the shoreline (Figure 3-23). The impacts from railroads are similar to roads. While society and our economy are dependent on the road system there is a downside to having so many roads. In 1998, the well known landscape ecologist Richard Forman (Forman and Alexander 1998) prepared a manuscript outlining many of impacts of our road system. Below is a summary from the report of the relevant issues as they apply to the study area for this report;

- Roads act as barriers and facilitate habitat fragmentation. All roads serve as barriers or filters to some animal movement. Species diversity decrease around roads and right of way areas accommodate more species associated with humans (crows, starlings, opossums etc.). Wetland species, including amphibians and turtles show a reduced tendency to cross roads. The barrier effect tends to create metapopulations where roads divide a large continuous population into smaller, partially isolated local populations. Roads also inhibit immigration into the area.
- Roads increase water runoff and sediment yield and are the key to the physical process whereby roads have an impact on streams and other aquatic system. Also, flood frequency is correlated with percentage road cover in a basin.
- Roads provide an avenue for chemical input into the aquatic system. Most chemical transport from roads occurs in stormwater runoff through or over soil. Many of the pollutants come from cars or atmospheric deposition. Toxics such as lead, Zinc, cadmium, copper, asbestos, fertilizers herbicides and nitrous oxide can have deleterious effects to aquatic organisms a including salmon. See the discussion in the water quality section on Pre-spawning mortality.
- Road density has been proposed as a useful, broad indicator of several ecological effects that roads have on the landscape. One California study (McGurk and Fong 1995) found detrimental effects on aquatic ecosystems, based upon macro-invertebrate diversity, were evident where roads covered 5% or more of the watershed. In another study conducted in Ontario, species richness of wetland plants, amphibians/reptiles, and birds each correlated negatively with road density within ½ to 1 mile of a wetland. (Finday and Houlahan 1997).

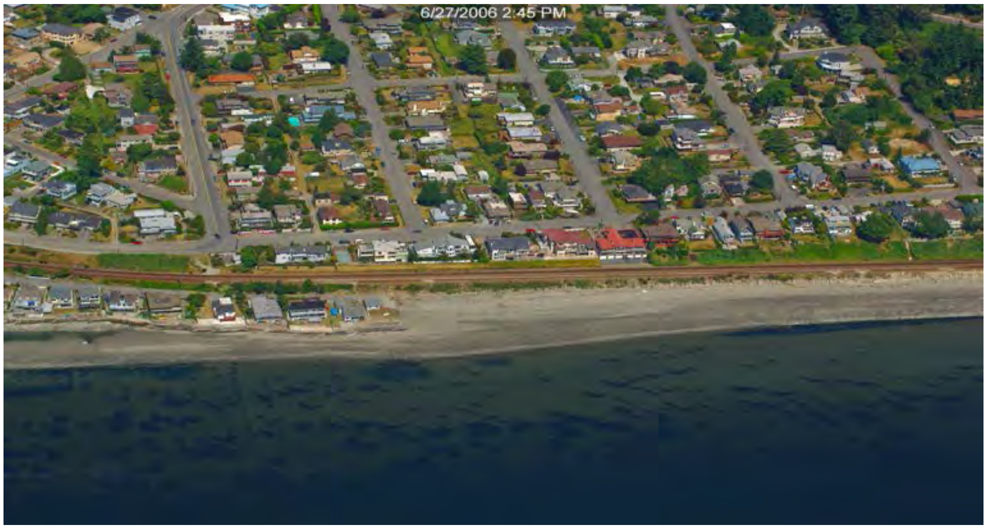



**Figure 3-23 BNSF railroad in the Shoreline area. Source: WDOE, 2006.**

## Trends in road density in the study area

Because road density is one indicator of development in the environment there was interest in evaluating it for this study to identify trends in road density over time. Below, there are two graphs for road density by subsection, one for the nearshore study area (the 630 foot strip along the shoreline and one for the process unit that is upslope and drains to the study area and again broken into subsections. Generally, the process unit has a greater road density than its counterpoint in the nearshore area by 2 to 4%. Road development was already well established by 1949 when the first photos were evaluated and in some subsections the density hasn't changed much in 60 years (such as Subsection 1 – Federal Way, 5 – Edmonds and 6 – Everett) (**Error! Reference source not found.** and Figure 3-25). In some subsections there does seem to be a trend of higher road density in the 1968 photos to a slightly less density in the 2006 photos. The differences are usually 1 to 2%, this may be a real trend but it could also be the margin of error in mapping the road network. This trend is more pronounced in the process unit than the nearshore area. Subsection 4 – Duwamish Estuary and its associated process unit has the highest road density (about 12%) than any other portion of the study area and Subsection 6 – Everett has the lowest (1% in the nearshore area). Subsections 1 – Federal Way, 2 – Burien/West Seattle, 3 – Elliott Bay and 4 – Duwamish Estuary exceed 5% of the area in roads for the nearshore area while five Subsections 1 – Federal Way, 2 – Burien/West Seattle, 3 – Elliott Bay, 4 – Duwamish Estuary and 5 – Edmonds exceed 5% in the process units of the study area. One thing to consider on road density in the nearshore portion of the study area is that it is a relatively narrow band along the shoreline and much of the area is dominated by steep bluff back beaches. The steepness and relatively unstable nature of the bluffs limit how much road can be constructed in these areas.

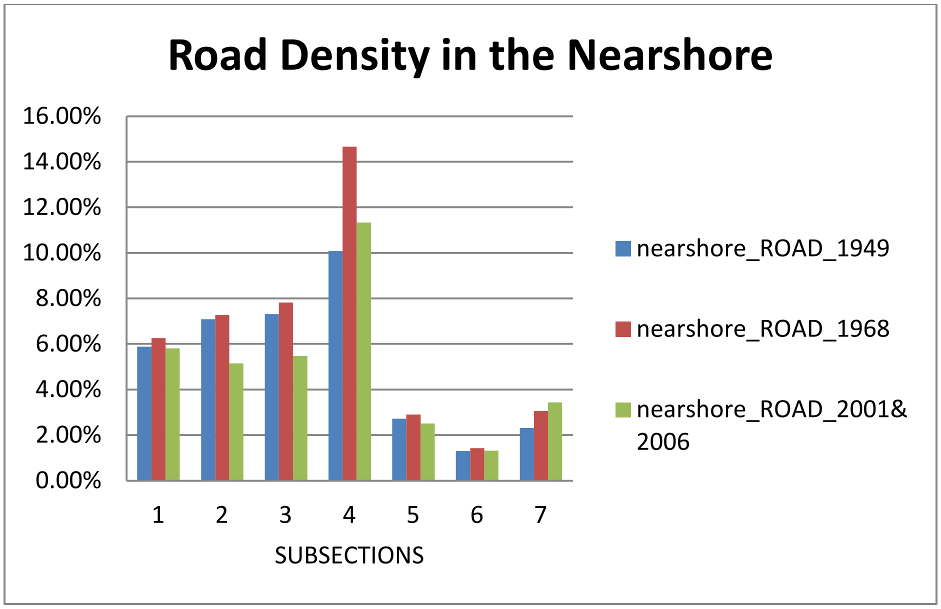



**Figure 3-24 Road density in the nearshore subsections. Subsection 1 – Federal Way, Subsection 2 – Burien/West Seattle, Subsection 3 – Elliott Bay, Subsection 4 – Duwamish Estuary, Subsection 5 – Edmonds, Subsection 6 – Everett, Subsection 7 – Snohomish.**

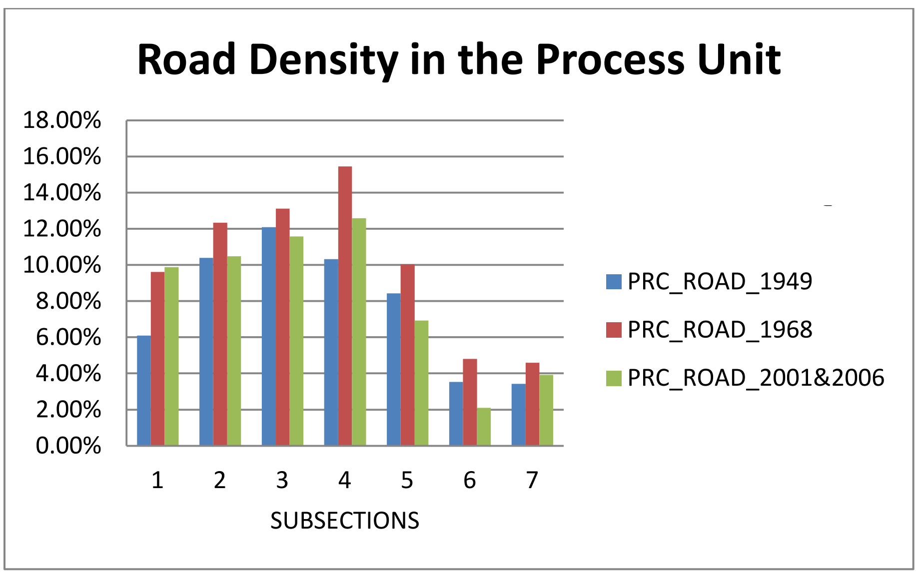



**Figure 3-25 Road Density by subsection in the process unit. Subsection 1 – Federal Way, Subsection 2 – Burien/West Seattle, Subsection 3 – Elliott Bay, Subsection 4 – Duwamish Estuary, Subsection 5 – Edmonds, Subsection 6 – Everett, Subsection 7 – Snohomish.**

## Methodology for Determining Road Density

Road density for both the 1949 and 1968 time periods was determined using USGS topographic maps and aerial photographs from the Department of Energy, WA State Department of Ecology, and the Department of Defense for each time series and were obtained as a means to find locations of historical roads and highways. These source files were heads-up digitized (GIS line shapefiles were created by tracing the road networks). The line shape files indicate where roads were during the time series of interest. A buffer distance was added for each road type as follows:

- Primary Highways = 16 meter buffer
- Secondary Highways = 16 meter buffer
- Light Duty Roads = 5 meter buffer
- Unimproved Roads = 5 meter buffer
- All Other Types = 5 meter buffer

In order to capture the relative footprint area of the roads for the study area, buffer distances varied according to the approximate width of a given road type. Road density was then calculated by dividing total roadway area over total land cover for each sub area.

There could be a small discrepancy between the two datasets (in house historic evaluation of 1949 and 1968 and the PSNERP 2001) due to mapping scale. The PSNERP data has 30 meter resolution and the earlier dataset that came from maps and air photos is about 2.5 meters. It is possible that the 2001 with 30 meter resolution under estimates small roads so in the resulting graphs, there appears to be more road area in some cases compared to 2001.

### 3.4.2. Impervious surface

Another common measure of urbanization is the amount of impervious surface within the landscape. Impervious surface is the portion of the study area that is covered over by built surfaces and compacted bare ground (such as unpaved roads). It includes not only roads and road shoulders but parking lots, roofs of buildings, driveways and other hard surfaces that restrict water infiltration. Types of land modification that support an increase in impervious surface include vegetation clearing, soil compaction, and ditching and draining. While these hardened surfaces restrict water infiltration to groundwater, they also concentrate and direct water to surface waters such as streams, ditches and occasionally to a water detention facility. Peak runoff of from impervious surface has the ability not only to affect the hydroperiod of nearby streams but also alters stream morphology due to increased scour and increased peak flows. Another harmful effect of impervious surfaces is they diminish water quality. Much of the study area experiences long dry summers (80 days of no measurable rain in 2012 for months July, August and September), during that time pollutants from cars, atmospheric deposition and other sources allows for a buildup of harmful chemicals on hardened surfaces. Once the Fall rains begin, runoff laden with potentially harmful chemicals is swept off the road surface and ends up in local water bodies. Water and Sediment Quality discusses one of the effects of this runoff as the causation of pre-spawning mortality in the streams located within the study area (Section 6). This study evaluated the change in impervious surface in the study area by subsection as described below.

### 3.4.3. Methodology for Determining Imperviousness

Surface imperviousness for the 1943-1953 and 1956-1968 time periods was determined for each NLCD based land classification that was delineated in the study area. This was based on land cover type utilizing USGS topographic maps, aerial photography, oblique photography, and current land cover. Land cover types within the study area included: open water, developed open space, developed low intensity, developed medium intensity, developed high intensity, barren land, deciduous forest, evergreen forest, mixed forest, dwarf scrub, shrub, grassland/herbaceous, sedge/herbaceous, pasture/hay, cultivated crops, woody wetlands, and emergent herbaceous wetland.

An impermeability value range of 0- 10% was assigned to all land cover types except the developed areas, which used the following values: low intensity 10-30%, medium intensity 30-50%, and high intensity 50-100%. The impermeability ranges from the PSNERP impervious feature class were used, and represent the 2001 time period. The PSNERP feature classes were derived from the Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Data (MRLC NLCD). The potential exists that a small discrepancy between the two datasets (in house historic evaluation of 1943-1953 and 1956-1968 compared to the PSNERP 2001) due to mapping scale.

**Trends in impervious surface**

Impervious surface area trends show that high intensity development occurred in every subsection between the years 1968-2001. This is the only specific trend obvious in every subsection.

Figure 3-26 shows changes in impervious surfaces for Subsection 1 – Federal Way between years 1943 and 2001. There was a slight decrease in the percentage of undeveloped area, but most of the fluctuation occurred within the three developed areas. In the 1943-1953 data sample, the amount of high intensity development area was only one percent, and by 2001 high intensity development area represented 10% of the study area.

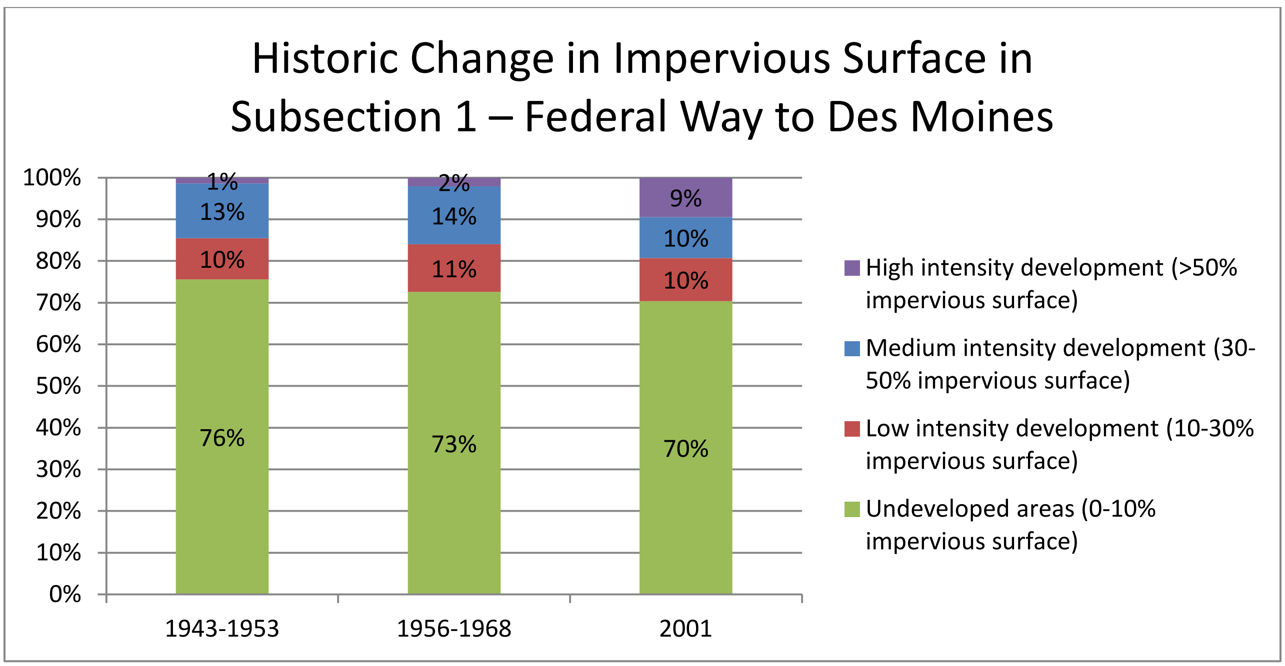



**Figure 3-26 Change in area of impervious surface over time in Subsection 1.**

Between the years 1943-2001, 75% of the total land in Subsection 2 – Burien/West Seattle was undeveloped (0-10% impervious) (Figure 3-27). The amount of medium intensity development remained at a steady 17% of the total land between the years 1943-1968 and in 2001 decreased to 7% while high intensity development increased to 10% of the total land. The amount of undeveloped area remained the same while the distribution of developed area shifted from medium intensity to high intensity.

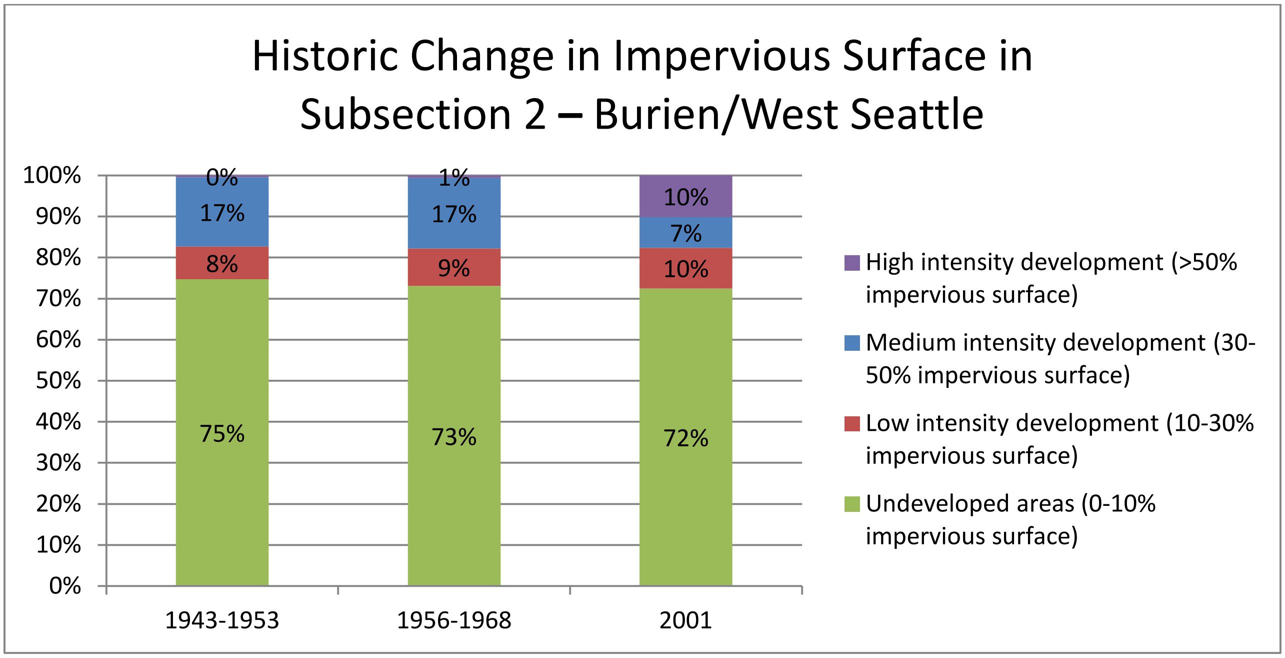



**Figure 3-27 Change in area of impervious surface over time in Subsection 2 – Burien/West Seattle.**

In the 1943-1953 sample 73% of Subsection 3 – Elliott Bay (Figure 3-28) was undeveloped area. By 2001, approximately 65% of the total area in Subsection 3 – Elliott Bay was undeveloped area (0 to 10% impervious). Much of the 10% change could be attributed to the 8% increase in high intensity development. Medium and low intensity development did not change in the 60 year time period.

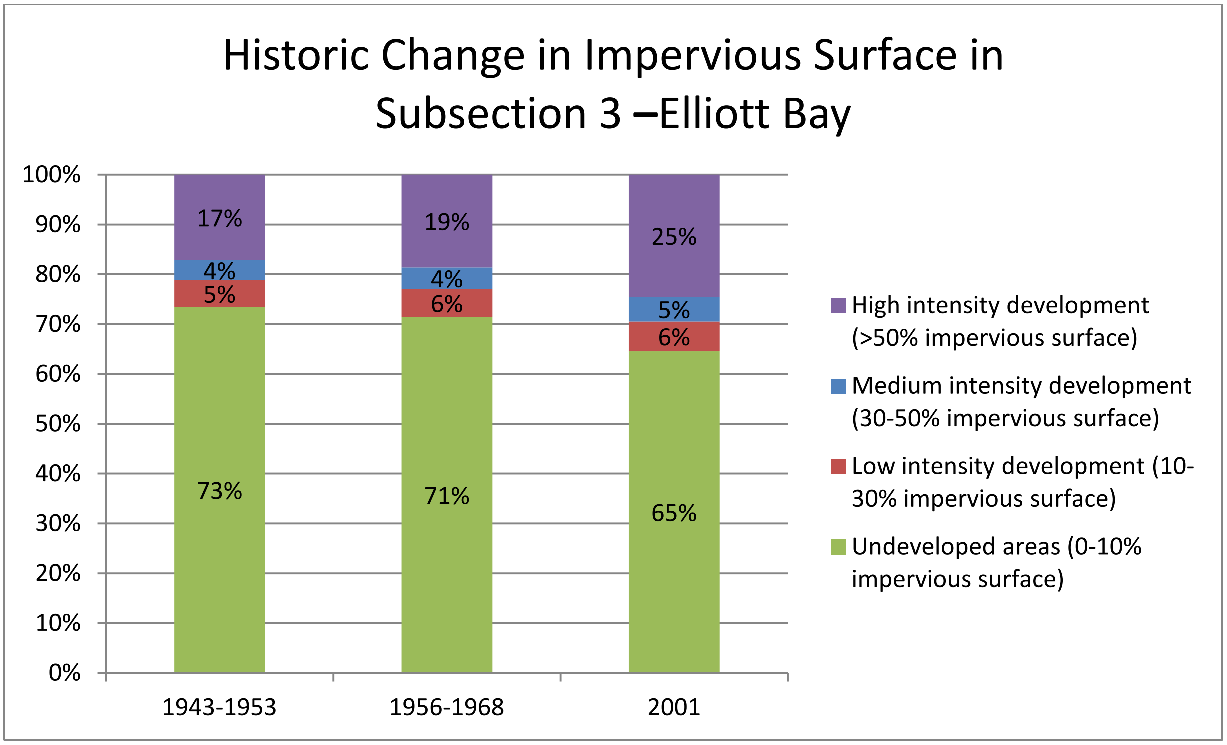



**Figure 3-28 Change in area of impervious surface over time in Subsection 3 – Elliott Bay**

Subsection 4 – Duwamish Estuary (Figure 3-29) has the highest percentage of high intensity development in comparison to the other six subsections. In the years 1943-1968 there was approximately 55% of the total land in Subsection 4 – Duwamish Estuary classified as high density development. This percentage increased to 80% of the total land by 2001. There was a concurrent decline in the percentage of total land in Subsection 4 – Duwamish Estuary undeveloped area (0 to 10% impervious).

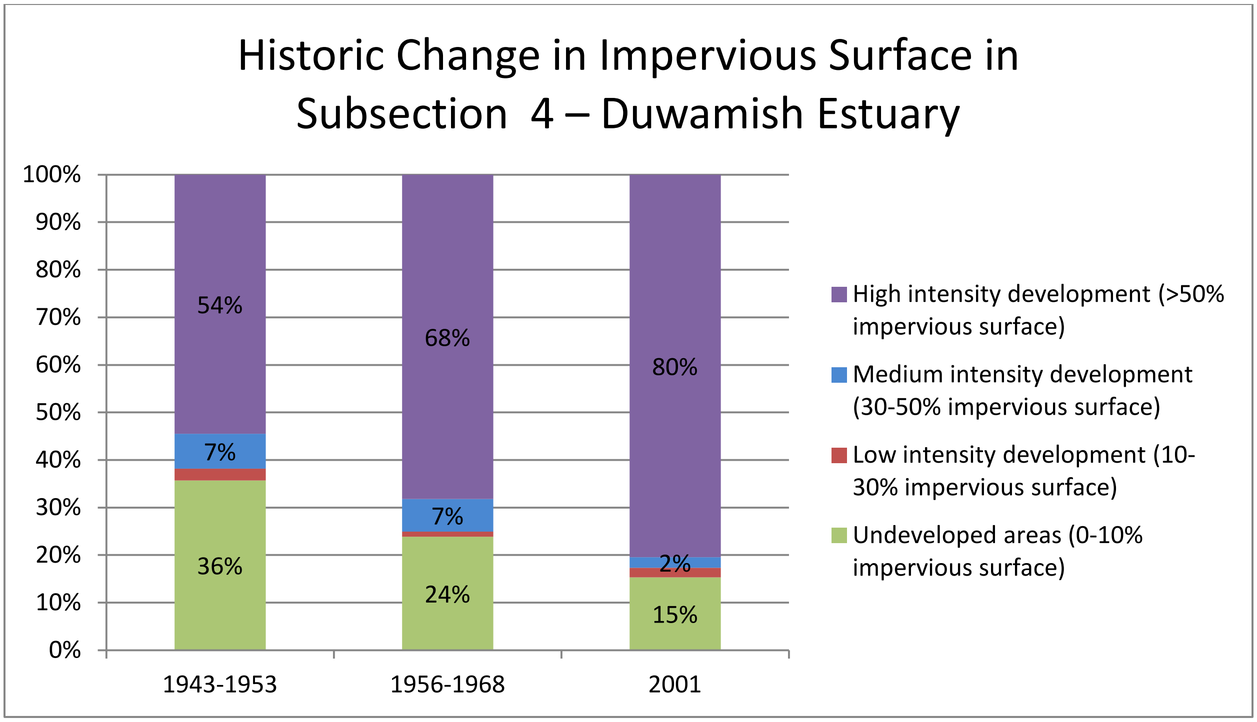



**Figure 3-29 Change in area of impervious surface over time in Subsection 4 – Duwamish Estuary**

The composition of Subsection 5 – Edmonds (Figure 3-30) showed little change in comparison to the other subsections. Each impervious surface category did not change by more than 5% for each of the time intervals. Approximately 80% of the total land was undeveloped area (0-10% impervious). Similarly, the high density development area remained approximately 10% for the years 1945-2001. This was the only subsection where the percentage of total land classified as high intensity development decreased between 1968 and 2001.

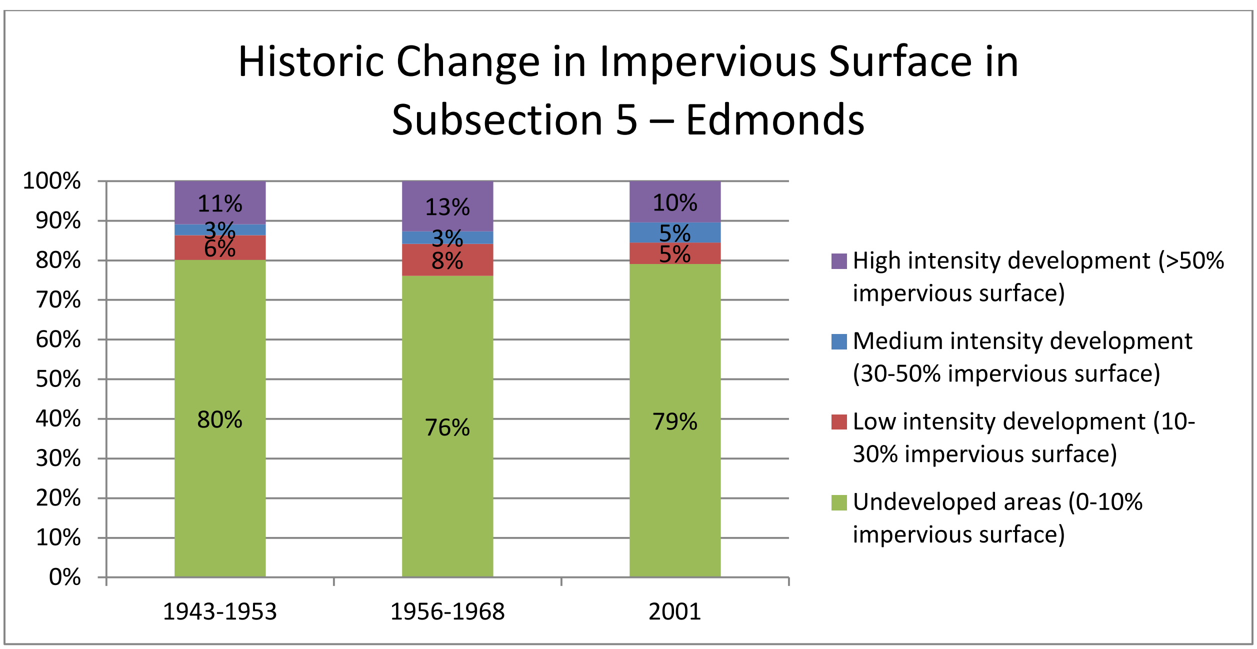



**Figure 3-30 Change in area of impervious surface over time in Subsection 5 – Edmonds**

Subsection 6 – Everett (Figure 3-31) is comprised mostly of undeveloped area that decreased in percentage of total land from 87% in 1943-1953 to 84% in 2001. Conversely, there was an increase of 2% for high intensity development area. The greatest change is in the two middle categories where there is a trend in increasing the 30 to 50% category. The majority of change occurred within the medium intensity development.

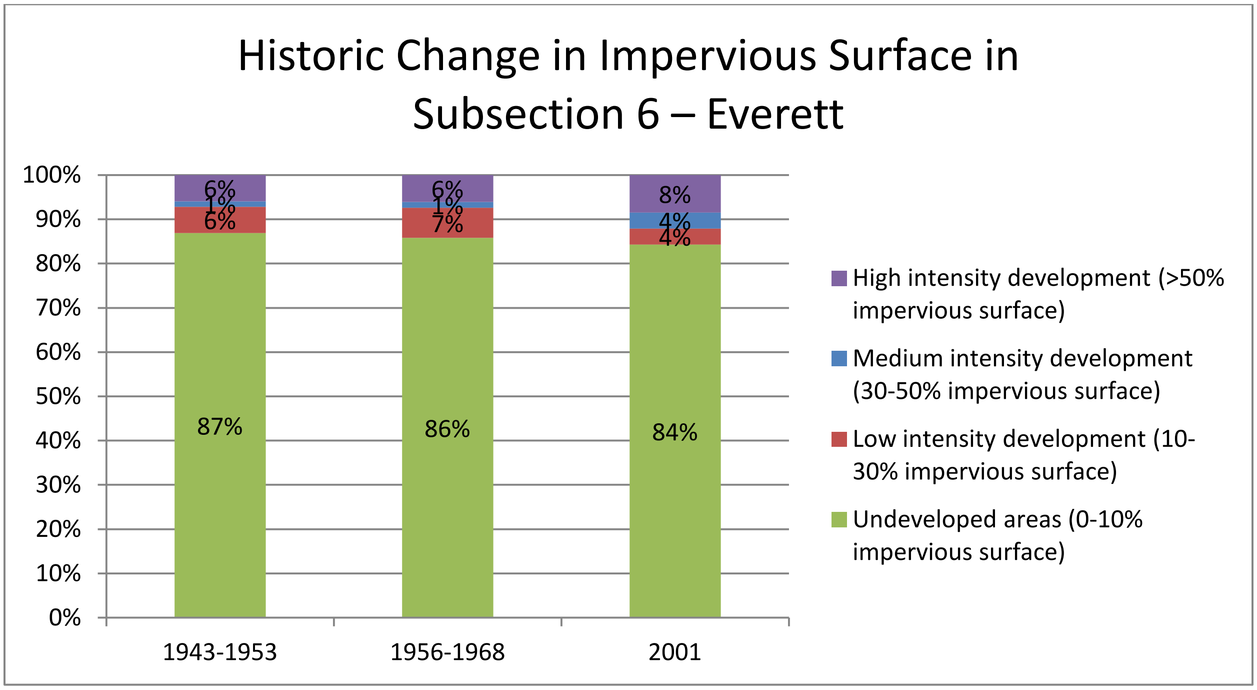



**Figure 3-31 Change in area of impervious surface over time in Subsection 6 – Everett**

Subsection 7 – Snohomish (Figure 3-32) includes the Snohomish River delta. This subsection had very little change in types of impervious surfaces. There was less than 3% difference between 1968 and 2001. Undeveloped areas and low intensity development both decreased and medium and high intensity development increased in area.

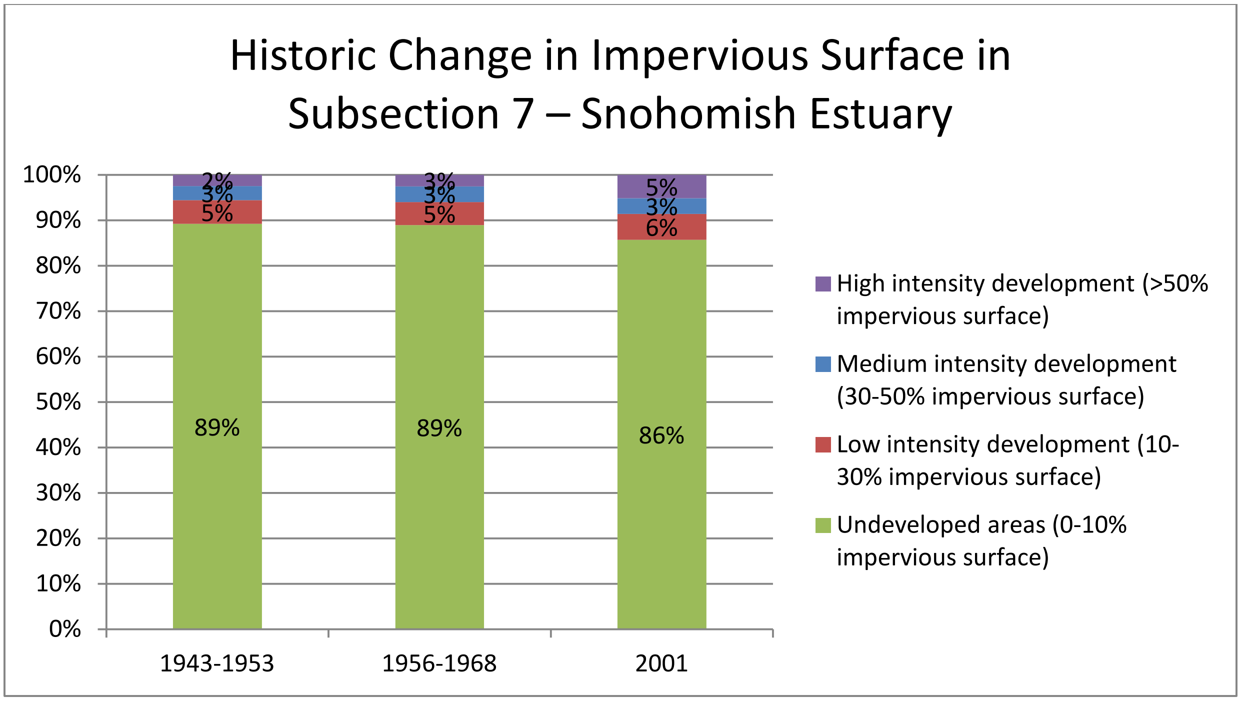



**Figure 3-32 Change in area of impervious surface over time in 7 – Snohomish**

The northern subsections showed less change in land type than the four southern subsections. In all subsections, a trend toward increased impervious surface over time is apparent. The trend is more pronounced in subsections such as 2 (Burien to West Seattle) and less pronounced in Subsection 4 (the Duwamish Waterway).

### *3.4.4. Results from other studies that include a portion of this study area*

In a study on impervious surfaces in Water Resource Inventory Area (WRIA) 7 (the Snohomish River basin) that covers portions of King and Snohomish Counties, Powell et al. (2008) analyzed Landsat data over a 34 year time period (Figure 3-33). They concluded; "…between 1972 and 2006, the area of impervious surface increased from 8,117 acres to 28,793 acres across the Study area (Snohomish and King Counties) representing an increase of 225%. During that same time period, population in the two counties increased from 1.4 million to 2.5 million, an increase of 79%. This differential growth rate between impervious surface and population is typical of urban sprawl" (Powell et al. 2008).

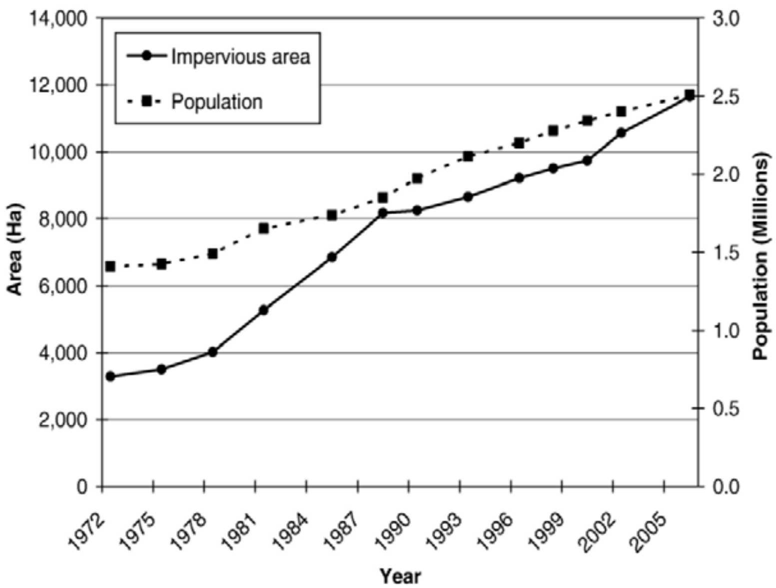



**Figure 3-33 Change in impervious area in the Snohomish WRIA 7 and change in population in Snohomish and King Counties between 1972 and 2006. Source: Powell 2008.**

More recently, the Northwest Indian Fisheries Commission (2012) concluded that impervious surface increased from 31% in 1986 to 38% in 2006 for the Green Duwamish valley (which includes a portion of Subsections 3 – Elliott Bay and 4 – Duwamish Estuary).

## A threshold of concern for impacts to the aquatic environment

Booth and Jackson (1997) state that “In western Washington, and likely in other humid regions as well, approximately 10% effective impervious area in a watershed typically yields demonstrable, and probably irreversible, loss of aquatic-system function.” Results of this study (as well as several other studies in King and Snohomish counties) conclude that there was a greater than 10% increase in impervious surface area in each of the seven study area subsections as far back in time as 1943.

## Fragmentation

“Habitat fragmentation, by definition, is an event that creates a greater number of habitat patches that are smaller in size than the original contiguous tract(s) of habitat,” (Bender et al. 1998).

The third method of evaluating the effects of urbanization within the study area involved the use of landscape ecology. Landscape ecology evaluates the spatial patterns of ecological processes such as heterogeneity (diverse or dissimilar types of land cover or different habitat types), scale, and temporal/spatial relations. The spatial configuration and composition of landscapes (i.e. patches, habitats) are integral to the ecological function and diversity. Landscape ecology deals with the relationship of landscape patterns and processes at different temporal or spatial scales. For this study, the landscape was evaluated at two different scales, the landscape scale (that is the entire subsection) and the class scale, or each land cover class.

"Landscape ecology emphasizes broad spatial scales and the ecological effects of the spatial patterning of ecosystems. Specifically, it considers (a) the development and dynamics of spatial heterogeneity, (b) interactions and exchanges across heterogeneous landscapes, (c) the influences of spatial heterogeneity on biotic and abiotic processes, and (d) the management of spatial heterogeneity." (Turner 1989)

"Landscape ecological studies focus on the effects that spatial patterning and changes in landscape structure (e.g. habitat fragmentation) have on the distribution, movement and persistence of species" …The size, shape and diversity of patches also influence patterns of species abundance."(Turner 1989).

A few key definitions are important for this discussion;

- Patch is a single discrete unit of habitat or a land cover type. For example, an isolated emergent 4 acre wetland surrounded by other, different landcover types (say a forest or housing development) would be a 4 acre patch. Both the habitat type (in this case an emergent wetland), its size as well as the composition of the surrounding patches can all influence the number, diversity and behavior of species that can utilize the patch. Patch size and its composition is probably the single best parameter to evaluate a landscape
- Edge is the term for the boundary between two different land classes or habitat types. For example of the emergent wetland that borders a deciduous forest, has an edge of a certain length and width between these two different patch types. In the past, it was viewed that the amount of edge within a landscape was a good thing but over the past few decades that idea has changed. In some cases to much edge allows for some edge species to outcompete some interior species. Brood parasitism by cowbirds is one example of too much edge as an impact. Now it seems edge effects should be evaluated though the lens of a species centered perspective.
- Interior species are various types of species that need a certain size of homogenous (similar) habitat to complete a portion of their life history. Chestnut backed chickadees, pine siskins or in the case of wetlands, American bittern, are all good examples of interior species.
- Edge species are those that can exploit the areas between two different habitat types. Examples of edge species would include the robin in your back yard that borders a woodland, or crows (Northwest and common) or the rufus humming bird. Juvenile salmon are sometimes referred to as an edge species as the hug the shallow shoreline for feeding and refuge as they outmigrate.
- Edge Density is total length of edge in the landscape or in this instance the total length of edge within the subsection. By recording edge density on a per unit basis it allows comparison between other landscapes or subsections.
- Patch Density is the total number of patches within a landscape per unit area. At the class level it is the total number of patches of a particular land cover type. This is another useful measurement to compare between different landscapes or subsections.

### 3.4.5. Methods for Landscape Analysis

To evaluate trends in the study area in regards to their landscape composition, a software program called FRAGSTATS (McGarigal and Cushman 2012) was used. Information on land cover comes from two sources. The most recent information (2001) comes from the PSNERP geo-database derived from the Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Data (MRLC NLCD). The interpretation of aerial photography and USGS topographic 7.5 minute quad maps from the time periods

1943 -1953 and 1956-1968 used the same NLCD land cover classifications system, resulting in the two earlier datasets being used for change analysis. The earlier air photos were in black and white (1943 to 1948), and subsequent air photos were color. The entire study area was mapped according to the land cover classes and divided into the seven subsections.

The aerial photograph frames were scanned and geo-referenced in GIS prior to classification. Land cover classes included; developed high intensity, developed medium intensity, developed low intensity, developed open space, emergent herbaceous wetlands, woody wetlands, herbaceous, evergreen forest, deciduous forest, mixed forest, scrub/shrub, open water, cultivated crops and barren land. A map, showing the example of the land classification can be found in Figure 3-52.

"From an ecological perspective, urban development affects patch structure by altering the size, shape, interconnectivity and composition of natural patches. It also produces a variety of unprecedented and intense disturbances through physical changes in the landscape…In landscape ecology, the patch is the fundamental element of the landscape. The size and shape of the patch and its edge are particularly important patch characteristics that can affect species habitat, resource availability, and competition. Native plant and animal species in isolated patches decline with patch size as a result of habitat loss and interspecific interactions" (Alberti 2005).

For brevity, we have used Subsection 1 – Federal Way and Subsection 3 – Elliott Bay to illustrate the landscape trends but the other subsections show similar trends although the scale varies among subsections. All of the FRAGSTATS graphs for all the subsections can be located in Appendix A.

## Landscape level metrics

Note that within Subsection 1 – Federal Way and Subsection 3 – Elliott Bay, (Figure 3-34 and Figure 3-35) the amount of patches remains stable for the years 1943 to 1968 and then triples to approximately 566 patches by 2001.

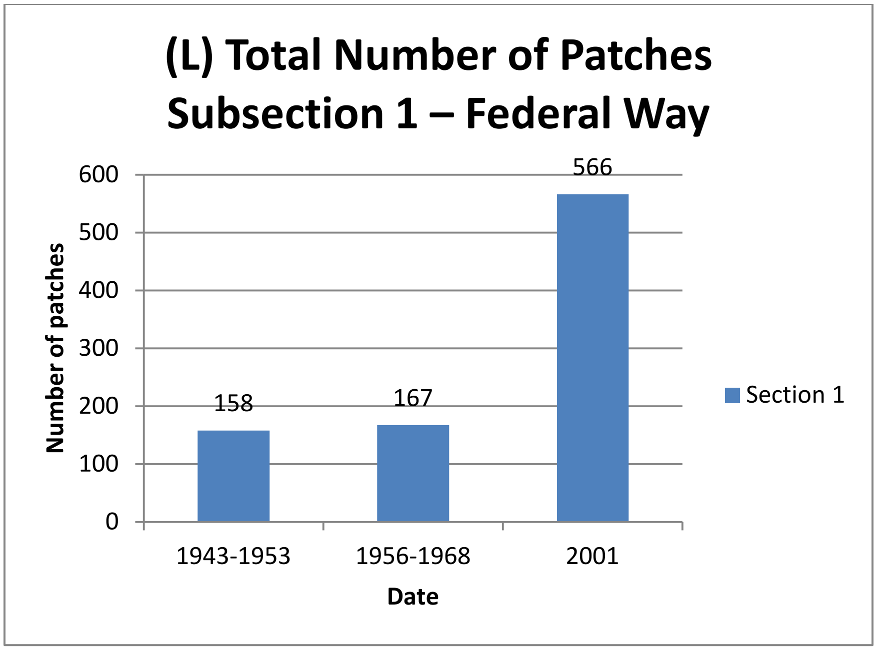



**Figure 3-34 The total number of patches in Subsection 1 – Federal Way at the Landscape level. This graph depicts the total number of patches and is inclusive of all land cover classes.**

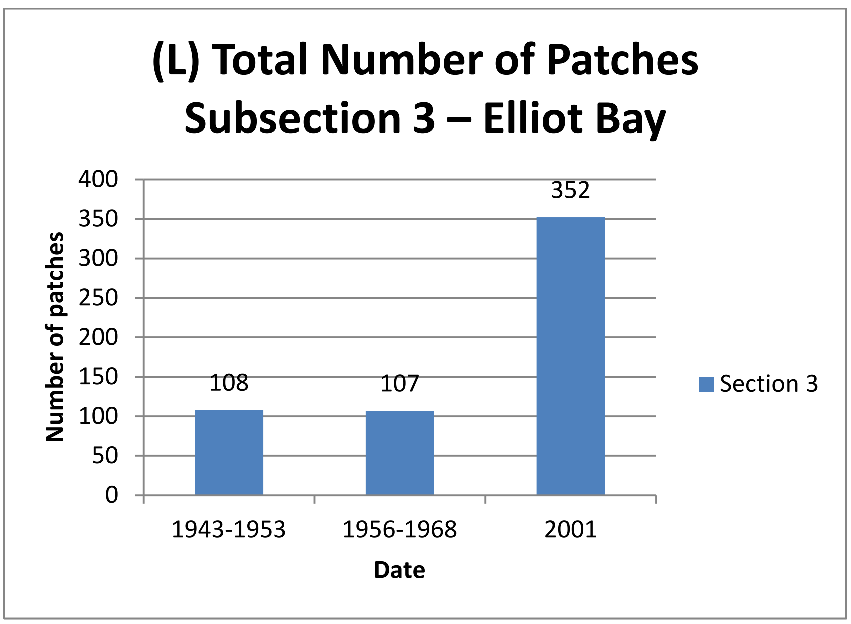



**Figure 3-35 The total number of patches in Subsection 3 – Elliott Bay at the Landscape level. This graph depicts the total number of patches and is inclusive of all land cover classes.**

There is a similar trend in both subsections (actually the trend in patch density is the same for all the subsections). While the number of patches per 100 acres changes between the subsections the trend is constant, that patch density increases over time (Figure 3-36 and Figure 3-37). The patch density in 2001 is more than three times as dense as in the 1956 to 1968 time period. Patch density in the time periods 1943 to 1953 is very close to patch density in 1956 to 1968.

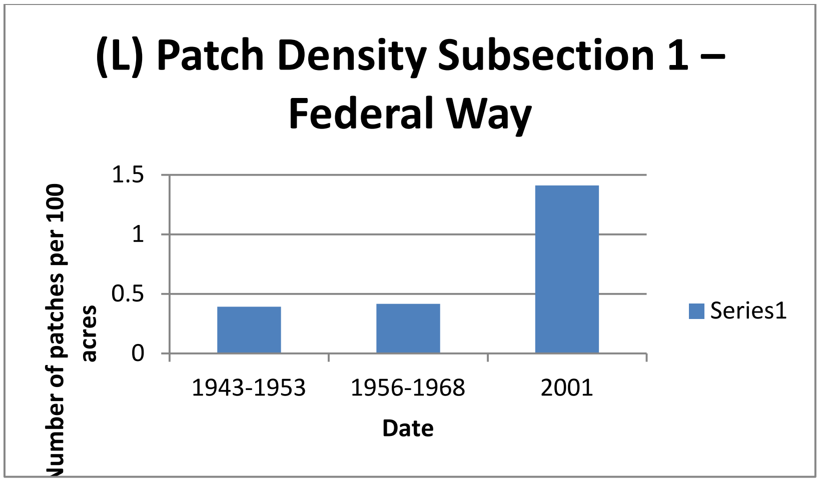



**Figure 3-36 Patch density in Subsection 1 – Federal Way**

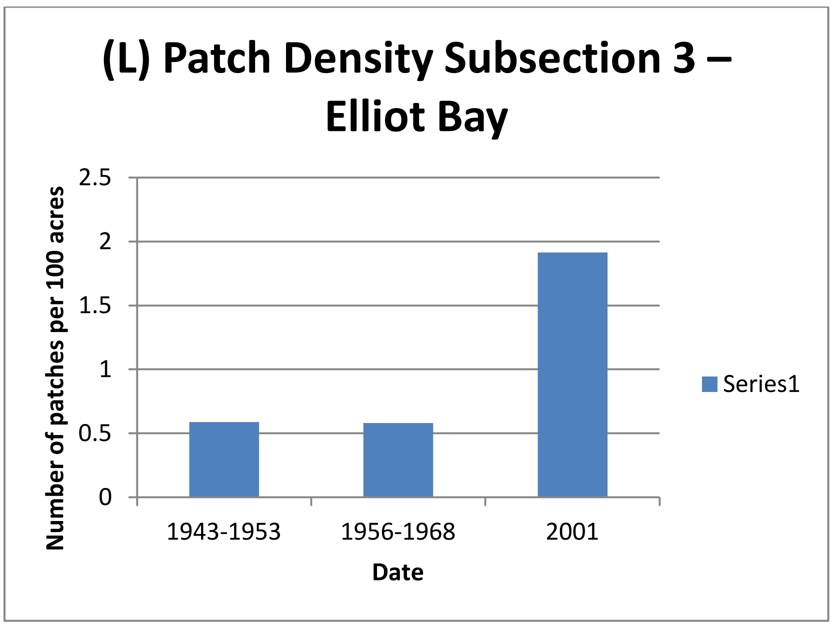



**Figure 3-37 Patch density in Subsection 3 – Elliott Bay**

In a study to evaluate the conditions that patch size effects are important determinants in regards to population density Bender et al. (1998) found that;

*"Although we could not partition out the source(s) of the strong patch size effects that were observed for edge and interior species the results is still interesting. It confirms that the patch size effects is a general and predictable effect that occurs for a broad set of edge and interior species living in patchy landscapes. Regardless of the mechanism(s), this result predicts that habitat loss and fragmentation will greatly affect the abundance of edge and interior species. In situations in which habitat loss and fragmentation create greater number of smaller patches from pieces of previously contiguous habitat, interior species should always suffer a decline in population, attributable to these patch size effects, that occurs in addition to the decline attributable to habitat loss."*

Figure 3-38 and Figure 3-39 are typical examples of the total amount of edge (edge density) at the landscape level. All of the subsections showed the same trend that is, a somewhat stable edge density between 1943 to 1968 then a doubling of edge density by 2001. If the amount of change in number of patches, patch density and edge density are considered there is a large increase in landscape fragmentation from 1968 to 2001.

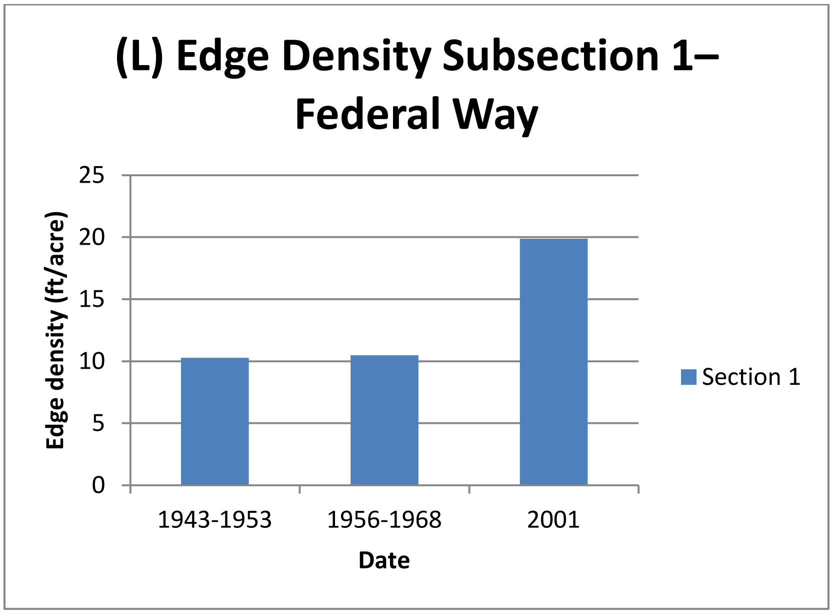



**Figure 3-38 Edge density in Subsection 1 – Federal Way**

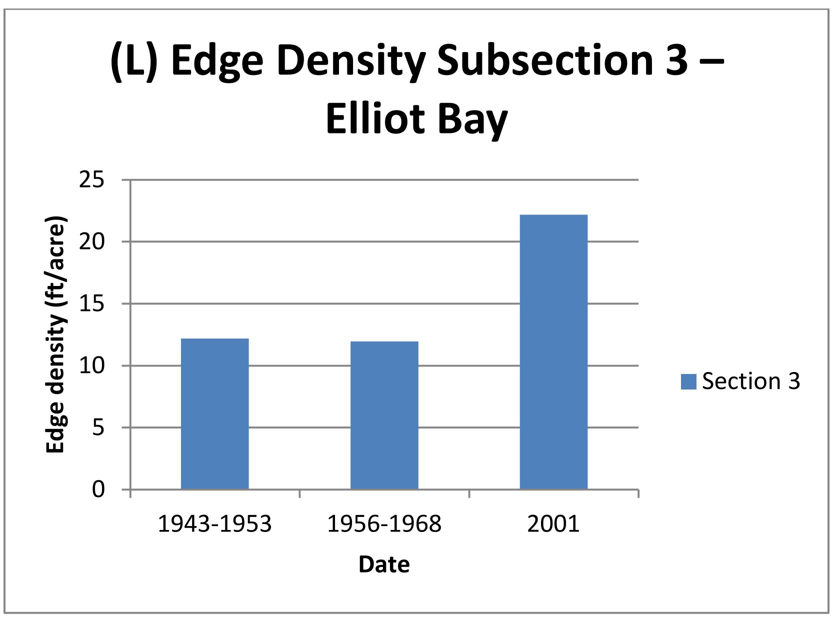



**Figure 3-39 Edge density in Subsection 3 – Elliott Bay**

**Class level metrics**

Class level metrics focus on the different changes in specific land cover classes like high intensity development or deciduous forest. In this section, developed high intensity is compared with changes in mixed forest.

The two land cover classes shown in Figure 3-40 and Figure 3-41 show opposing trends although the scale is different between the two classes. High intensity development areas increase over time while mixed forest areas decrease.

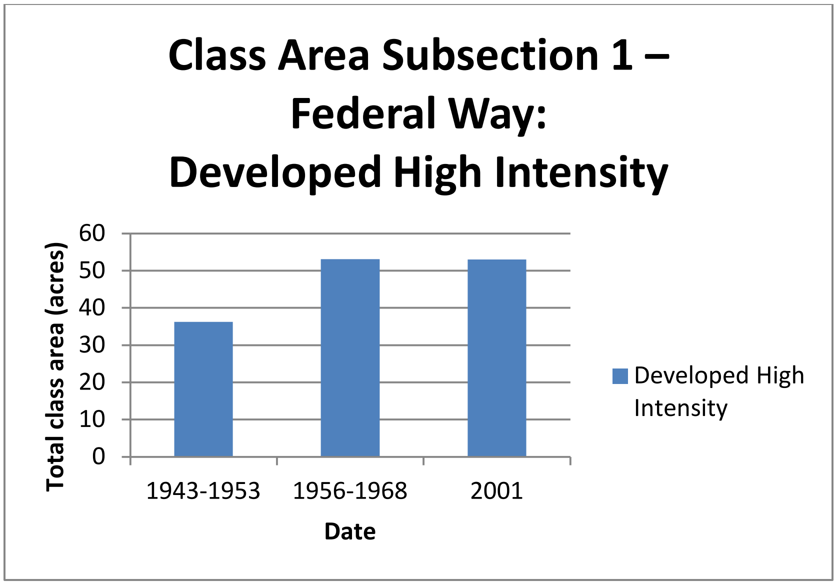



**Figure 3-40 Change in the area of high density development versus time in Subsection 1 – Federal Way.**

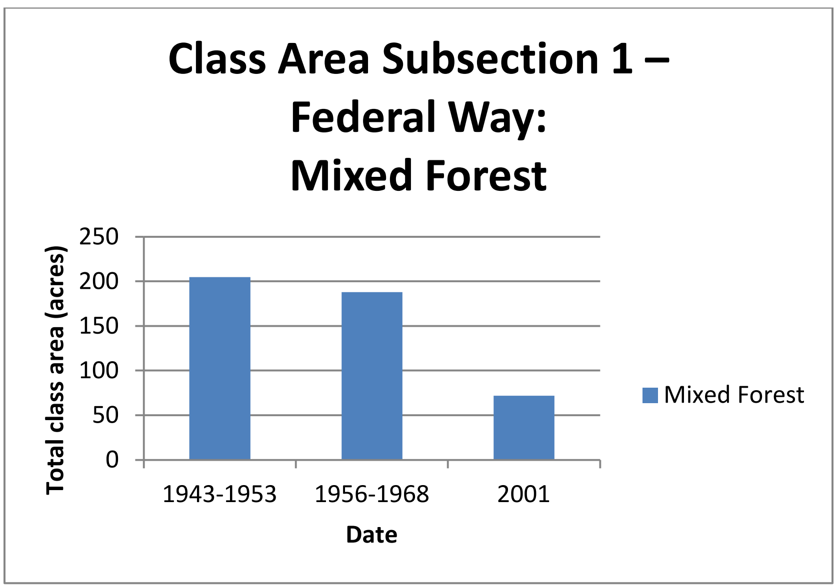



**Figure 3-41 Changes in the area of mixed forest versus time in Subsection 1 – Federal Way.**

There is a very similar trend in Subsection 3 – Elliott Bay (Figure 3-42 and Figure 3-43). This is the area of mixed forest loss in almost a mirror image in the increase in High Intensity development.

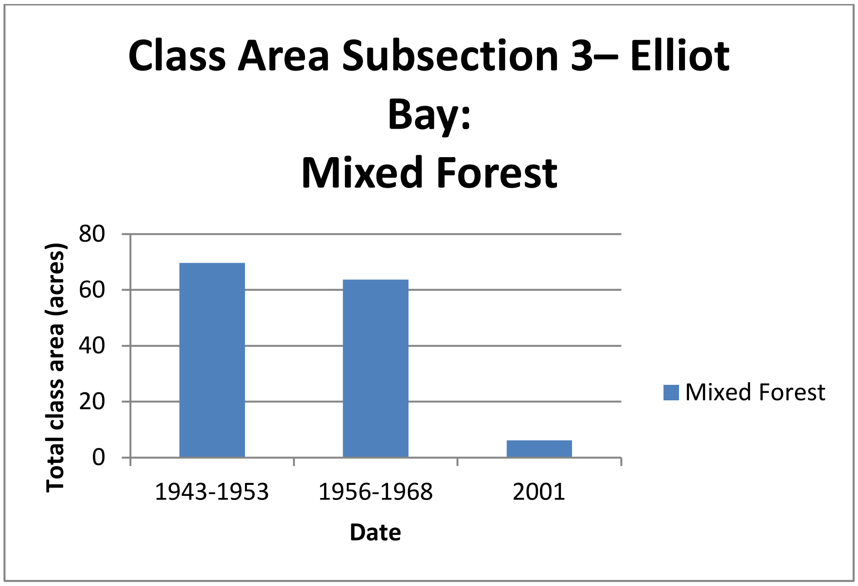



**Figure 3-42 Changes in area of mixed forest versus time in Subsection 3 – Elliott Bay.**

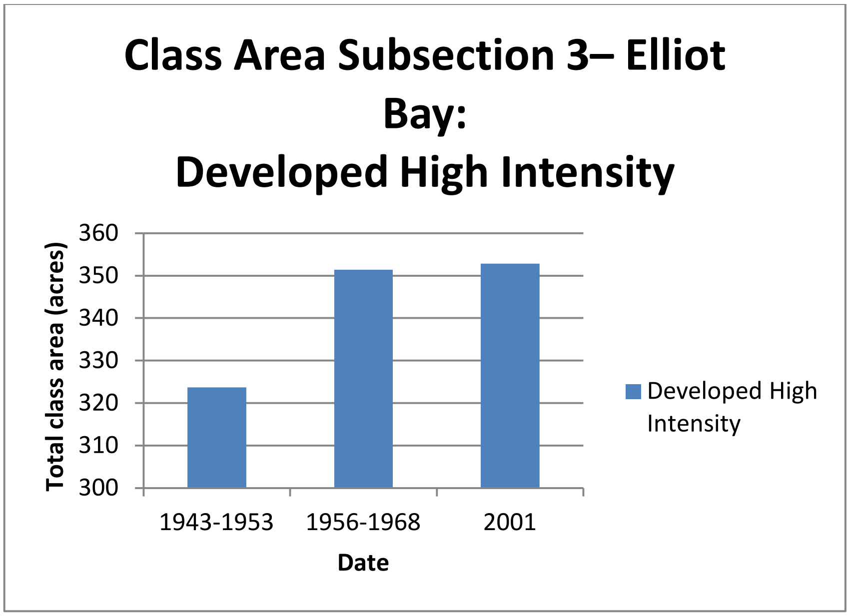



**Figure 3-43 Changes in area of high density development versus time in Subsection 3 – Elliott Bay.**

A consistent trend was seen in Subsection 1 – Federal Way for both land cover classes (Figure 3-44 and Figure 3-45). Patch density increases with time as patches become smaller.

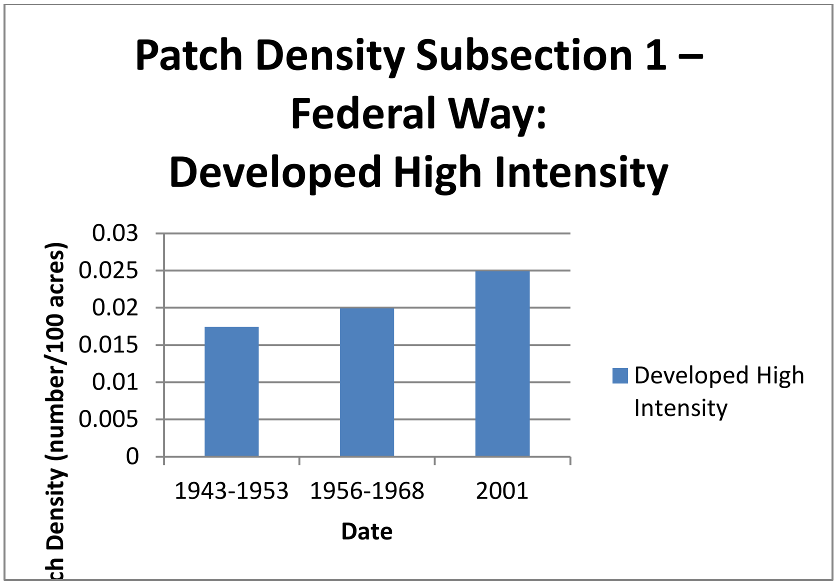



**Figure 3-44 Changes in patch density for Developed High Intensity at the class level for Subsection 1 – Federal Way**

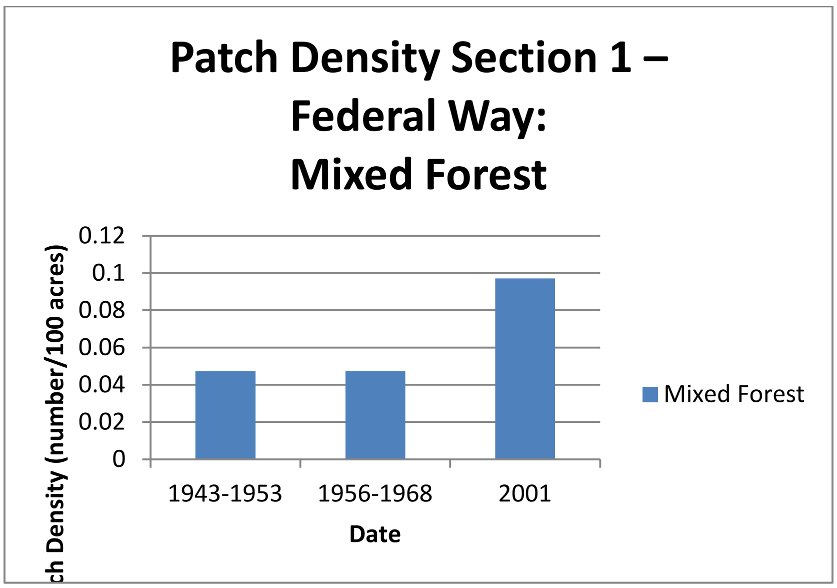



**Figure 3-45 Changes in patch density for Mixed Forest at the class level for Subsection 1 – Federal Way**

Figure 3-46 and Figure 3-47 show a contrasting trend in patch density. While high intensity development shows an increase over time, the mixed forest actually shows a decrease. Perhaps, some patches of mixed forest that were cut during earlier construction have matured and increased. The other possible explanation is a change from Evergreen Forest and Deciduous forest to mixed forest. In Subsection 3 – Elliott Bay, both Deciduous Forest and Evergreen Forest have much greater increased patch density in 2001 than the previous years.

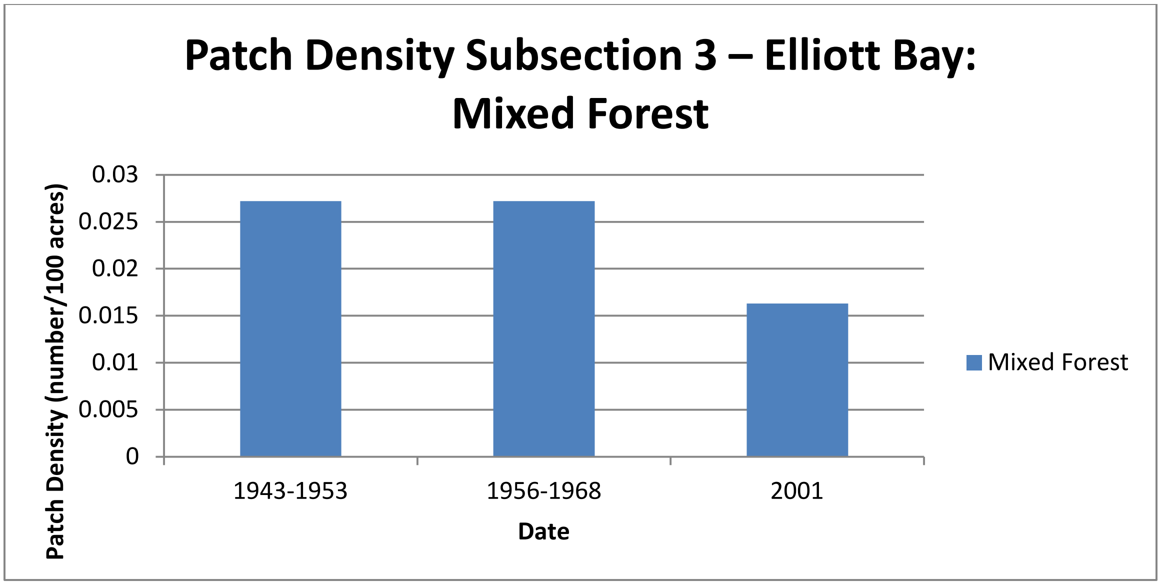



**Figure 3-46 Changes in patch density of mixed forest versus time in Subsection 3 – Elliott Bay.**

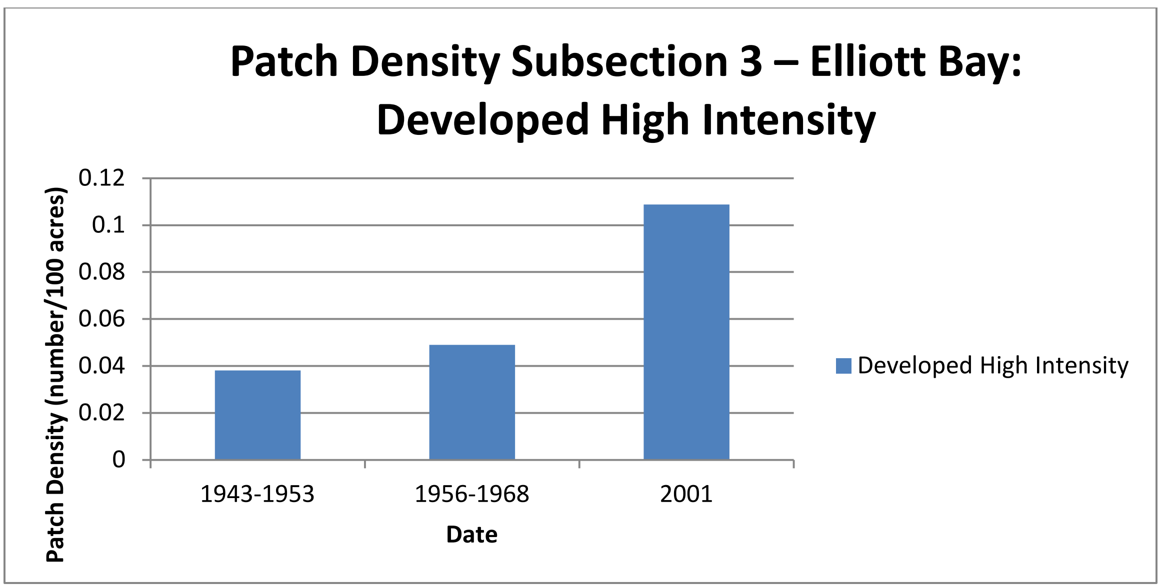



**Figure 3-47 Changes in patch density of developed high intensity versus time in Subsection 3 – Elliott Bay.**

Edge density is the total length of patch edge per unit area (in this case, feet per acre) within each subsection. There is a consistent increasing trend in edge density for Figure 3-48, Figure 3-49, Figure 3-50 and Figure 3-51. The trend is more pronounce in Subsection 3 – Elliott Bay than in Subsection 1 – Federal Way. With the increase in patch density the landscape becomes more fragmented.

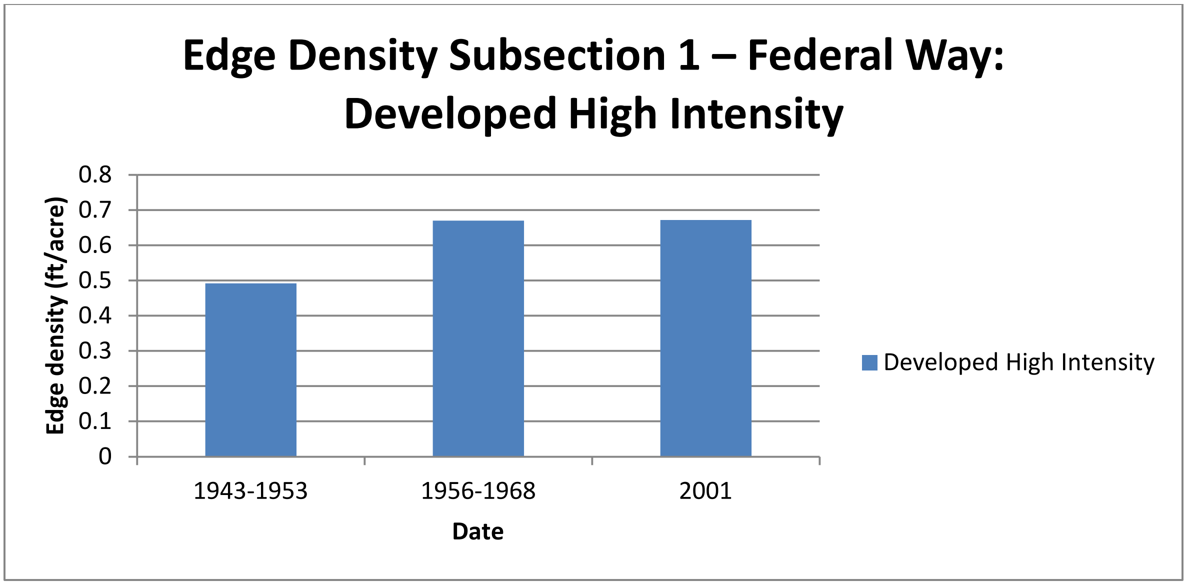



**Figure 3-48 Changes in edge density for High intensity development at the class level for Subsection 1 – Federal Way**

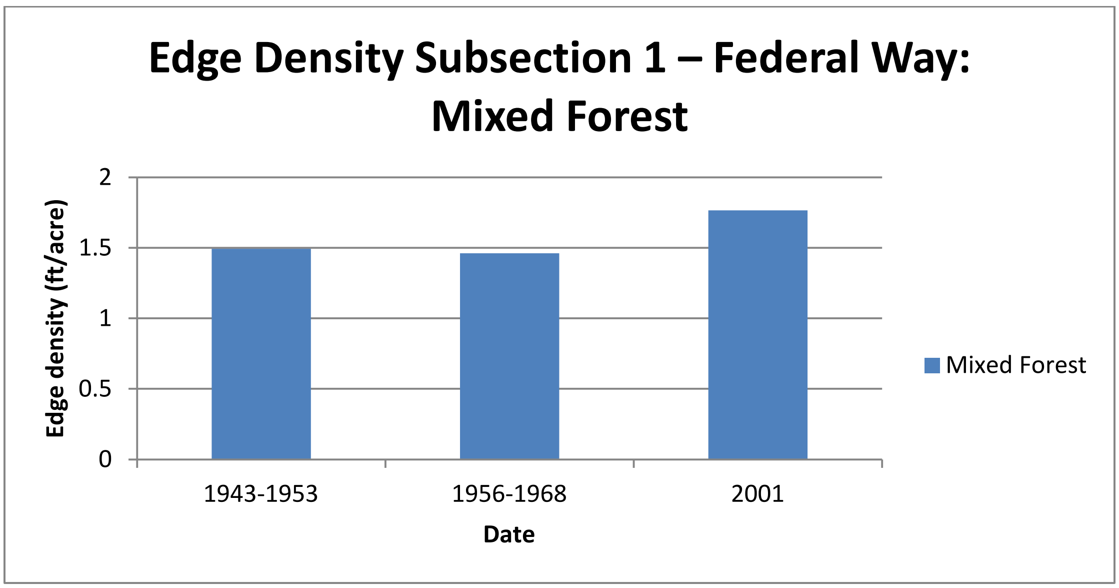



**Figure 3-49 Changes in edge density for Mixed Forest at the class level for Subsection 1 – Federal Way**

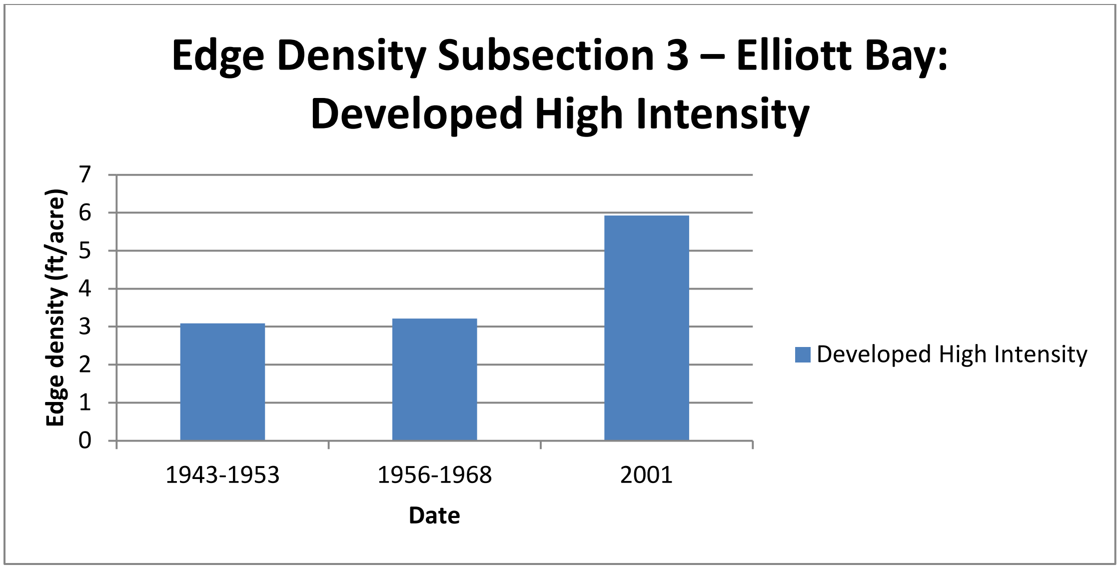



**Figure 3-50 Changes in edge density for high intensity development at the class level for Subsection 3 – Elliott Bay.**

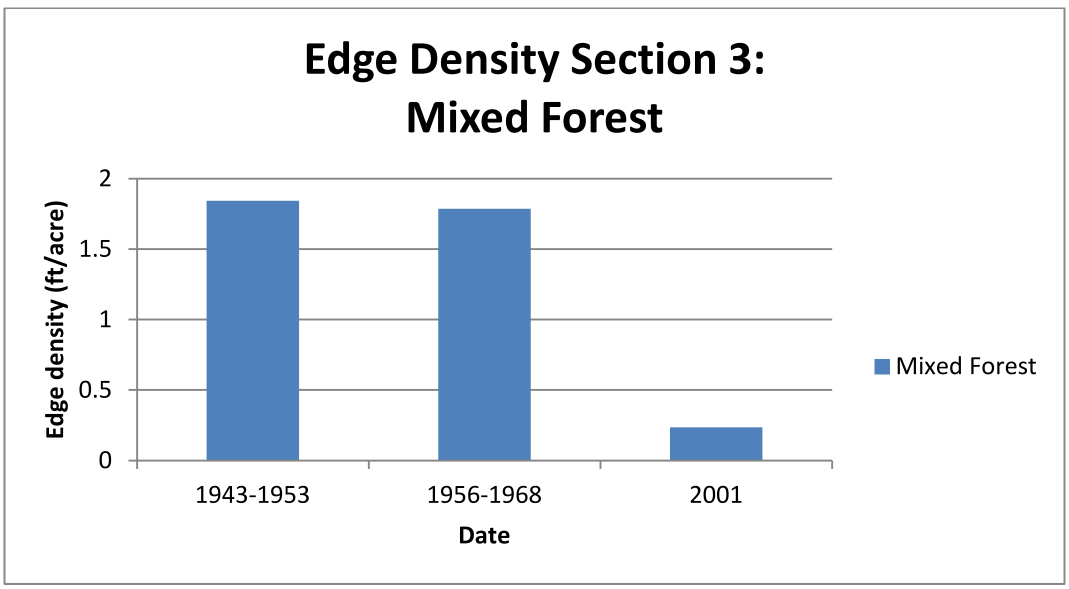



**Figure 3-51 Changes in edge density for Mixed Forest at the class level for Subsection 3 – Elliott Bay.**

*"A primary outcome of habitat fragmentation is an increase in habitat edge, which is effectively quantified with edge density. This measure is entirely dependent on the ratio of the patch area to patch edge, and landscapes with small patches or irregular shapes will have higher edge density values than landscapes with large patches or simple shapes at the same proportion of disturbance. It is intuitive that edge density will increase with increasing representation of a disturbance cover type…Edge density is an effective tool for evaluating the effects of patch shape and area on abundance of habitat edge." (Hargis et al. 1998)*

The insert in Figure 3-52 provides a good visual example what many of the graphs above are showing. The figure indicates the types of changes through time within Subsection 3 – Elliott Bay of the study area.

In the first insert, 1943 to 1953 time period, it shows the Smith cove/Southeast Magnolia bluff area. Using the NLCD land classification this first insert is dominated by the mixed forest trees toward the bottom of Magnolia bluff. The area also includes a large patch of emergent herbaceous wetland near the shore and the two large Port of Seattle piers 89/91 as high intensity development. By the 1956-1968 time period in the next insert, there is an increase in both high and medium level intensity development as it moves west of the piers, and some of the mixed forest is lost. In the 2001 insert, almost all of the wetland and mixed forest are lost to more high and medium intensity development. The large section of high intensity development just offshore (and to the west of pier 89) is the Elliott Bay Marina that was built in the mid 90s.

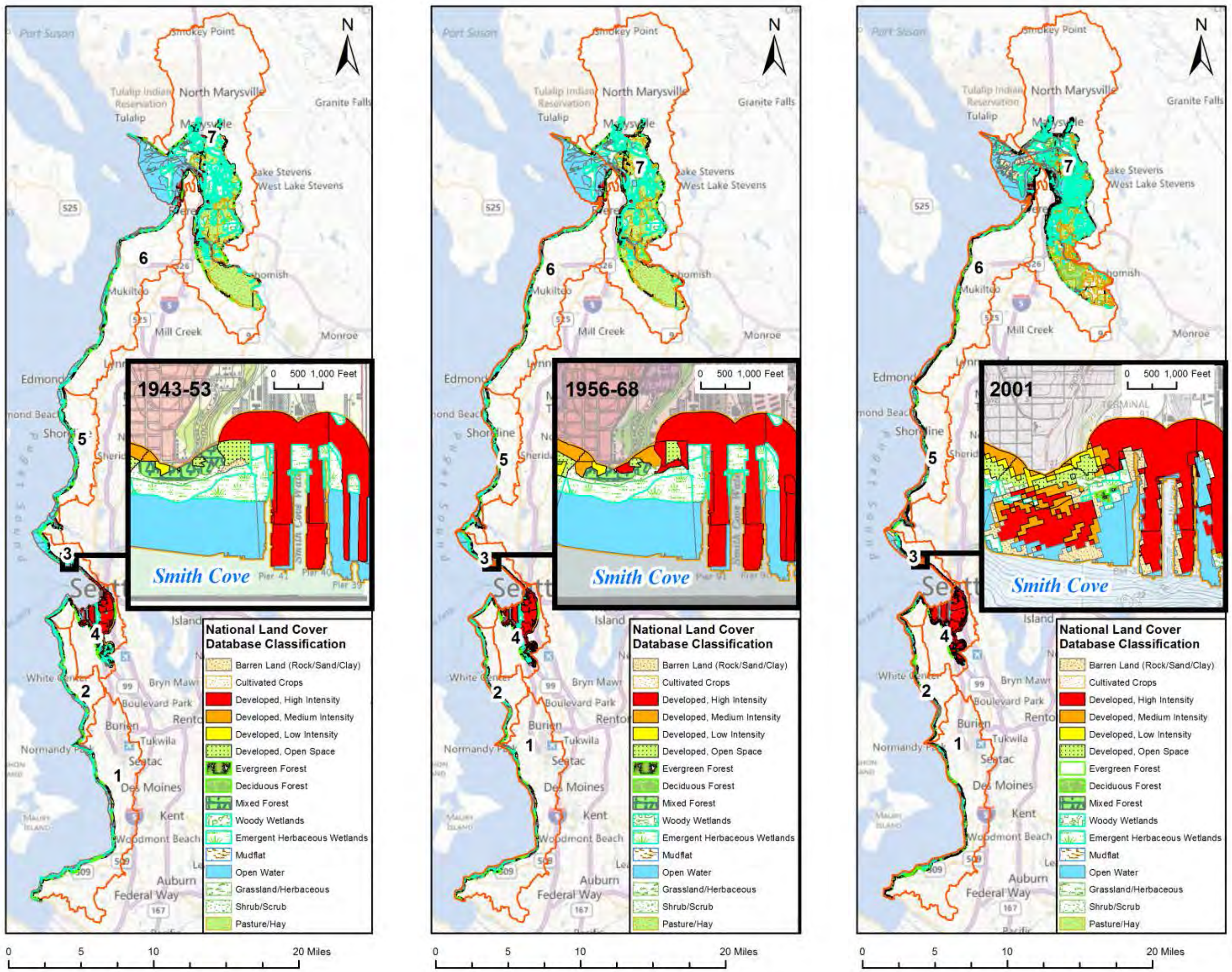



**Figure 3-52 Land classification for the project study area. The insert shows a time series of change in the Smith cove/Pier 89-91 area of Elliott Bay.**

In a study on the effects of urban growth boundaries conducted in the Seattle area (which includes much of the study area of this report), over a 25 year period Robinson et al. (2004) found that;

*"Single-family housing was a primary cause of land conversion. Expansion of single-family housing closely resembles the overall pattern of land conversion. There were significantly more patches of single family housing in suburban and exurban areas in 1998 than in 1974, while the number of patches of single-family housing in areas now classified as rural and wildland remained relatively constant. However, most single-family development since 1974 has taken place in former wildland areas that are now classified as exurban. Conversion to commercial development was more frequent in already settled areas."*

This study showed a similar result as the Robinson study mentioned above. Over a 58 year time period there was a consistent trend in reduced patch size within the study area, and for the most part both patch density and edged density increased displaying a deeply fragmented landscape. The area of High intensity and Medium intensity development increased as wetlands and forested areas decreased. This occurred at both the landscape and class scale. The implications of the fragmentation are that there is less abundance of the historic species that utilized the area and less diversity of species as well. It supports the contention in 4.3 Marine birds as indicators of cumulative effects that has demonstrated a reduction in avian abundance and the proliferation of human associated avian species (Rice 2007).

*"Many ecosystems are affected by cumulative impacts, which, although not individually catastrophic, collectively result in the loss and fragmentation of habitats and shifts in biodiversity, associated with the removal of habitat-specific or functionally important species" (Thrush et al. 2008).*

### 3.4.6. Results

Three standard parameters of urbanization were examined for this study, road density, impervious surface and landscape fragmentation. When road density was evaluated for the study it showed most of the subsections with about a 6% of area was in roads. Subsection 4 – Duwamish Estuary showed the highest road density at about 12% and the lowest was Subsection 6 – Everett at about 1%. When looking for a trend in road density there did seem to be a trend in increasing road density over the 55 years of evaluation which was slightly confusing due to the two different scales at which the data were developed at. The first two time periods (1949 and 1968) were mapped at 3 meter resolution while the 2001 time period was mapped at 30 meter resolution and likely missed some of the shorter, narrower roads.

In regards to impervious surfaces, there was an increasing trend in impervious surface within all of the subsections over the 55 year period. Some of the subsections displayed a strong trend such as Subsection 2 – Burien/West Seattle while a few subsections such as Subsection 5 – Edmond show only a slight trend. A threshold of concern of 10% impervious surface has been shown to have harmful effects to the aquatic environment has been established in studies (Booth and Jackson 1997) that include a portion of the study area. It appears the entire study area exceeds the 10% threshold of concern.

Lastly, we looked at the effects of landscape fragmentation in the study area. The assessment was done at two different scales (landscape and class) and also evaluated over a 55 year time period and the results were dramatic. Among all of the subsections of the study area at the landscape level, patch area decreased and patch density and edge density increased showing at the end of the 55 years of analysis a deeply fragmented landscape dominated by high and medium level development.  For the most part, single family housing was the dominant forcing mechanism. This is especially true in the nearshore of the study area where typically large, view houses and associated infrastructure (driveways, bulkheads, etc.) has resulted in hardening of over 72% of the shoreline.

# 4. Resources Affected

## 4.1. Impact of habitat loss and modification on salmon and trout

There are multiple lines of evidence suggesting that the cumulative loss of estuarine habitat has had an effect on the species that reside in them; typically, one of the effects is population decline. In addition to the loss of wetlands and other special aquatic sites, other factors in population decline include large-scale alterations to hydrology (river diversions, dams), increased sedimentation, ocean and weather conditions, predation, and harvest and hatchery impacts.

The previous section summarized the large-scale direct loss of special aquatic sites within the study area and the functions associated with the lost habitat. This section on fisheries examines the implications of loss of both function and habitat. In particular, it summarizes the impact of the loss of special aquatic sites on salmonids, a cornerstone species in the Northwest. Several species of salmon that occur throughout the study area are listed species under the Endangered Species Act (ESA): they include Chinook salmon, steelhead, and bulltrout. This is most succinctly described by Simenstad and Cordell (2000);

*"In the Pacific Northwest dramatically reduced and altered estuarine landscapes have been associated with declining salmonid populations …Estuaries constitute highly variable, large-scale ecotones through which anadromous salmonid stocks must pass as outmigrating juveniles and returning adults. In particular, passage and rearing of juveniles (particularly ocean-type Chinook and chum salmon) in estuarine habitats are often viewed as cornerstone phases of their life history when physiological adaptation, foraging, and refugia from predators or adverse physiochemical stressors are critical. The degree to which anadromous salmonids are actually "dependent" upon estuarine habitats is still debated and remains to be tested conclusively. However, patterns of juvenile salmon growth and survival in different estuarine habitats and conditions argue that occupation of estuarine habitats contributes to the survival and fitness of juvenile salmon throughout their life history. It is likely that the loss of more than 50% of the historical estuarine wetland area in this region has contributed to the decline of anadromous salmonids."*

The most profound impact to salmon populations would be extinction. There are a few runs of salmon that historically occurred in both the Snohomish and Duwamish system that no longer exist. The best documented cases of extinction are for specific runs of salmon. A spring run of Chinook on the Green/Duwamish River is now extinct. The Snohomish River no longer has a spring run of Chinook (Good et al 2005). One run of chum on the Green/Duwamish River and a run of steelhead on the Tolt River (a tributary within the Snohomish system) are currently threatened with extinction (Nehlsen et al 1991).

### *4.1.1. Loss of Function Associated with Loss of Special Aquatic Sites*

In the previous section we briefly discussed the functions of special aquatic sites that are typically associated with estuaries. We now expand on these functions to better explain the importance of wetlands and mudflats in their relationship to salmon, especially chum and Chinook that spend the most time in estuaries.

*" In estuarine and nearshore environments, the importance of a particular life phase's influence on population structure varies by species. In particular, juvenile chum and ocean-type Chinook salmon are recognized as being fundamentally dependent on estuarine ecosystems, which have been called the "life support system" for these species. The dependence of chum and ocean-type Chinook on estuarine ecosystems has been tested directly by measuring survival of juvenile salmon following estuarine residence and indirectly using surrogates of survival, such as growth and diet overlap with invertebrate assemblages. This estuarine dependence is of heightened significance given the Endangered Species Act- listed Puget Sound Chinook salmon occur throughout many of King County's estuarine and nearshore ecosystem" (Martin and Shreffler, 2004).*

Estuaries in the study area and their associated habitats (such as mudflats, tidal channels, and wetlands) provide four basic functions for migratory salmon;

- Estuaries are part of the <u>migration</u> route. After emergence from their spawning gravels juvenile salmon need to eventually migrate to sea. When salmon mature to adults, they must also return to their natal stream to reproduce. Estuaries are part of the long corridor that fish must travel through both to get to marine waters and to get back to their spawning grounds.
- Estuaries provide the primary location in which salmon go through smoltification (changing physiology) prior to moving into salt water. Changing salinity patterns (based on the physical configuration, amount of river flow, tides, and salinity of inflow) and food resources within the estuary provide juvenile outmigrants the optimal location for this change.
- Intertidal habitats within estuaries provide <u>refuge</u>. Fringing marshes and tidal mudflats provide the shallow protected waters that allow juvenile fish protection from predators.
- Estuarine habitat drives the <u>food web</u>. The vegetation associated with wetlands and mudflats provides organic carbon and detritus that drives the food chain. Juvenile salmon increase their chances of survival by spending time within the estuaries and increasing their size. Fish that are larger when migrating to the ocean have a better chance of survival and are less susceptible to predation.

These functions are best exemplified by Bottom et al (2005):

*"Ocean-type Chinook and other species and life history types (e.g., chum salmon) considered most estuarine dependent … rear in estuaries for up to several months. Studies in British Columbia and Washington estuaries have shown that subyearling salmon use shallow-water habitat and prey resources at least during their early stages of estuarine residency …. Studies in several Oregon estuaries further confirm that small, subyearling juvenile salmon typically occupy shallow habitats, including emergent marshes, forested wetlands, and peripheral floodplain channels and beaver ponds ….*

*Throughout their estuarine residency, juvenile salmon consume a wide variety of prey taxa and often are described as opportunistic feeders …. Yet within particular estuarine regions and habitats, salmon appear to feed more selectively. In oligohaline and brackish habitats, for example, juvenile salmon feed extensively on emergent insects (particularly larvae, pupae, emergent chironomid (Chironomidea), and other dipteran flies, and aphids (Apidae) …" [Editor's note; many of these prey species can be tied directly to wetland and riparian plants.] " … and epibenthic crustaceans (e.g., mysids (Mysidacea) and gammarid amphipods*

*(Grammaridea [sic]) … " [Editors note: these prey items are linked to dissolved organics and detritus.]. In more saline portions of the estuary, salmon often consume epibenthic crustaceans, including gammarid amphipods and harpacticoid copepods." [Editor's note: many of these prey species are linked to dissolved organic carbon and detritus derived from wetlands.]*

A number of studies document the dependence of juvenile salmon (predominantly but not limited to ocean-type Chinook and chum) on estuaries (Healy 1982, Simenstad et al. 1982). Estuarine habitats provide both the structure (tidal and blind channels as well as shallow intertidal areas) and food resources that these migratory fish depend upon. In the previous section it was demonstrated that 98% of estuarine habitats in the Duwamish estuary and 64-93% of those in the Snohomish estuary have been lost. The consequences of habitat loss at this scale have been affected migratory fish. Magnusson and Hilborn (2003) conducted research in Northwest estuaries and have demonstrated conclusively the implications this has on salmon survival, stating:

*"The magnitude of the impact of estuarine condition on salmon life history is considerable…that with zero habitat left pristine, the estimated average survival rate is 0.5%, while the estimated survival in total pristine estuaries is more than three times higher, 1.77%....*

*The data presented here show clearly that fall Chinook residing in severely altered estuaries in northern California, Oregon, and Washington have significantly lower survival rates than those residing in estuaries where habitat is more or less natural."*

In the Snohomish River basin, the spread of agriculture has coincided with the destruction and isolation of off-channel and wetland areas over the last 70 to 120 years. Removal of riparian and floodplain vegetation, in favor of agriculture, began in the 1860s and agriculture in the former wetland areas was well established in the basin by 1900.

There are also specific examples of indirect effects of habitat loss within the study area. Haas and Collins (2001), estimated that the historic loss of estuarine habitat reduced Chinook smolt production within the Snohomish system by approximately half (Figure 4-1).

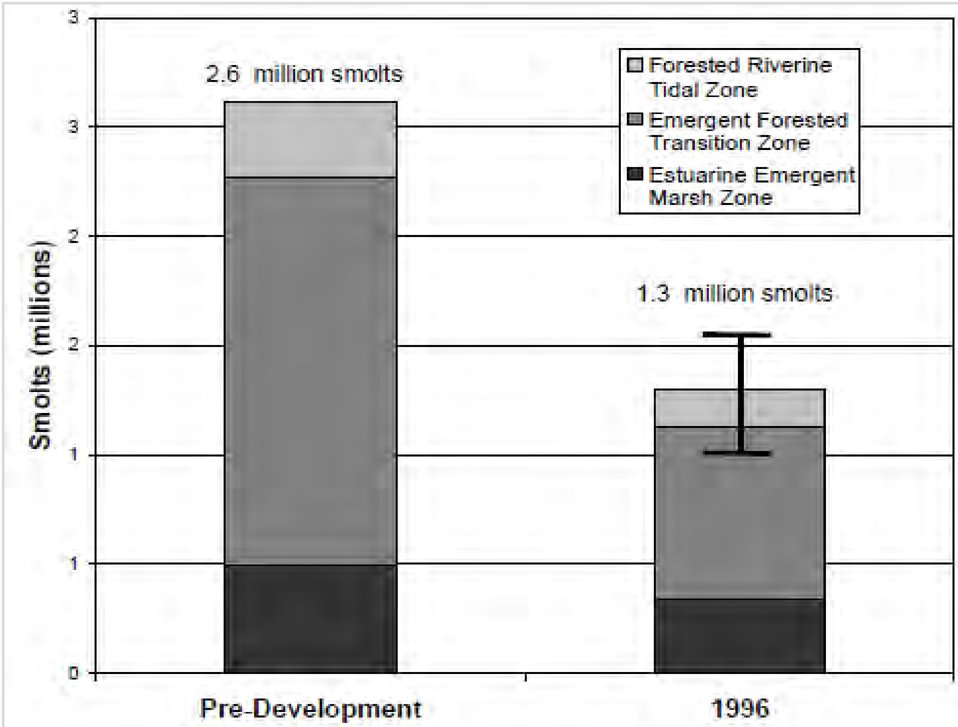



**Figure 4-1 Chinook smolt production capacity in the lower Snohomish estuary by habitat zone.** Source Haas and Collins (2001).

Similarly, Pess et al. (2003), estimated that Coho densities in the Snohomish were reduced by two to three times due to wetland loss and specifically loss of forested wetlands that were historically abundant in the system but are now rare, as they observed in detail:

*"Today, the Snohomish River floodplain and neighboring foothills along the channel are located predominantly in rural residential, agricultural, and urbanized areas. Throughout much of the lower portion of the Snohomish River basin, forested and agricultural areas are zoned to allow future development to rural residential, suburban, and urban land use. … Stream reaches in forests support 2.5 times more coho than rural, urban, or agricultural streams. Streams in agricultural areas support the fewest salmon, where average weighted fish-days were 4 times lower than the other land-use categories. Differences in relative salmon abundance are observed between hydrologically altered and unaltered wetlands …. Hydrologically altered wetlands included those ditched or separated from the stream channel by bank armoring or diking. Stream reaches with unaltered wetlands associated with the stream channel (i.e., wetlands present at the reach scale) had adult coho salmon densities 2 to 3 times greater than spawner survey reaches with altered wetlands. … If the relationships identified above are correct, then an increase in specific land-uses, such as urban or agricultural areas, or a decrease in specific reach-scale habitat characteristics, such as wetlands, can further alter coho abundance and future distribution."*

### *4.1.2. Declining Chinook salmon populations*

The final line of evidence in the discussion of secondary effects to salmon from wetland loss is salmon population trends. The assumption is that loss of habitat, primarily estuarine and marine special aquatic sites is a major contributor (but not the sole contributor) to declines in anadromous salmon populations within the study area.

## Chinook salmon populations in the Duwamish system

There are several published salmonid population trends for the Duwamish, summarized in the following paragraphs.

Figure 4-2 shows that there has been a precipitous decline in sub yearling migrant Chinook abundance from 2000-2011. Topping and Zimmerman (2011), stated that the "juvenile migrant Chinook in 2009 and 2010 were among the lowest observed in 11 years of study. Declines in sub yearling Chinook in these years are most likely due to low spawner abundances." WDFW concludes that much of the decline may be a result of increased competition from pink salmon within the system. In a separate evaluation in 2002, WDFW had listed Duwamish/Green river Chinook stock status as healthy because escapements had been high; however, they acknowledge that hatchery strays contribute heavily to fish counted as natural Chinook spawning within the system (WDFW 2002)

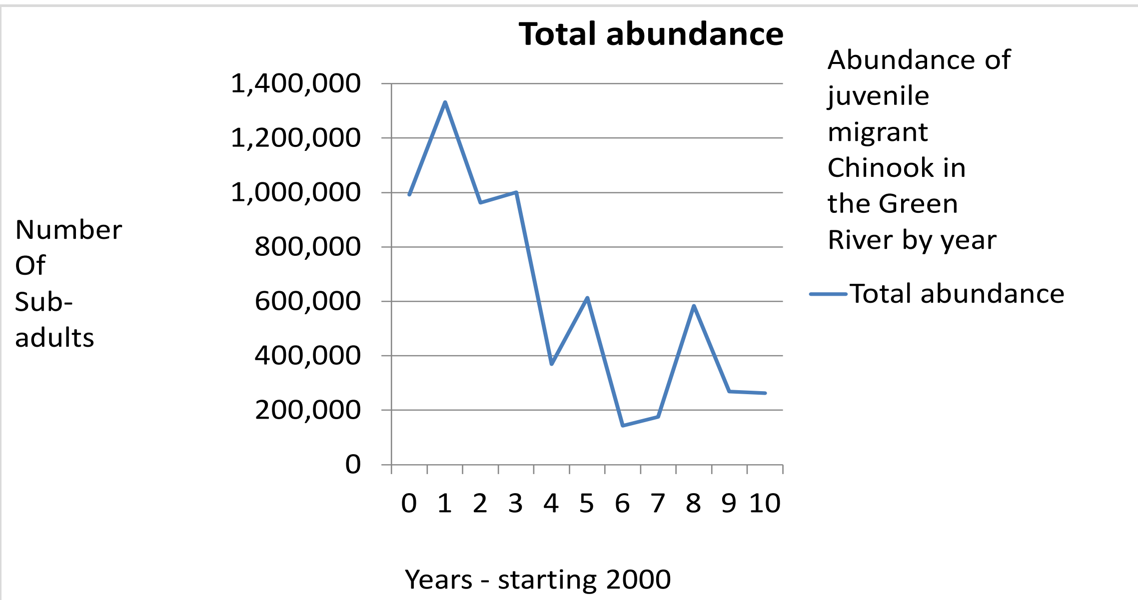



**Figure 4-2 Decline of abundance in Green River juvenile natural-origin Chinook, Trap Year 2000 – 2010.** Data Source Topping and Zimmerman (2012), Table 4.

National Marine Fisheries Service (NMFS; Ford 2011) evaluated natural and hatchery Chinook spawning within the Green/Duwamish River. They concluded that spawning numbers declined in the Duwamish between 1985 and 2009 regardless of whether natural and hatchery spawners or natural spawners alone were evaluated (Figure 4-3). However, there was a much more significant decline after 2000 when only natural spawners were evaluated (Figure 4-4).

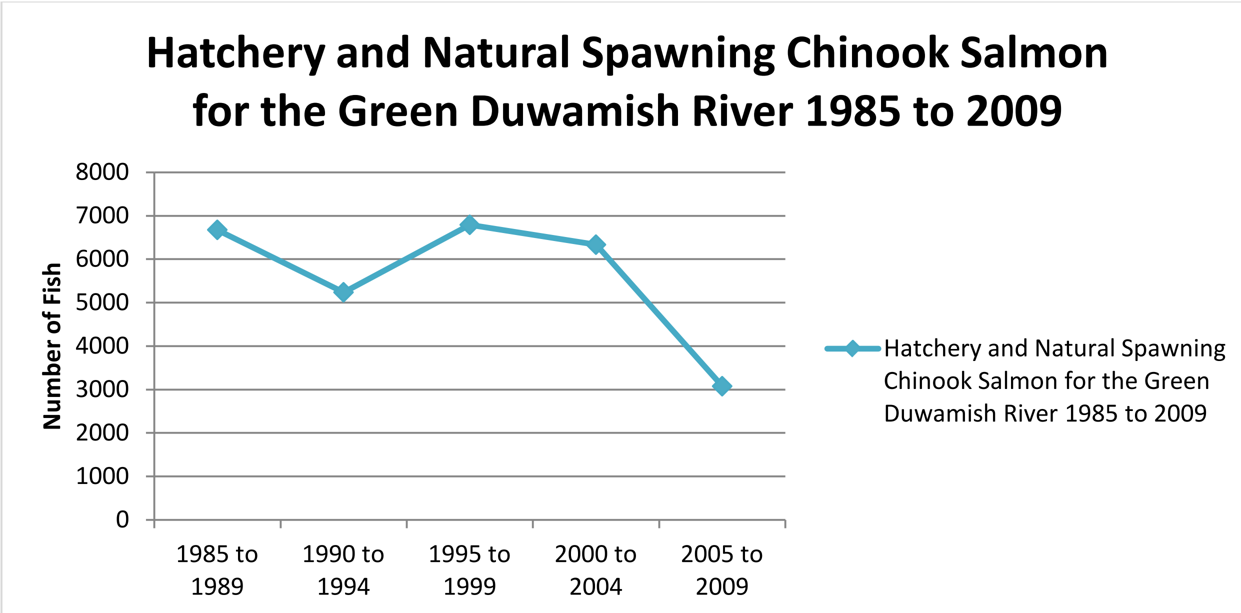



**Figure 4-3 Green/Duwamish River Chinook hatchery and natural combined spawning numbers for 1985-2009.** Data Source :Ford (2011), Table 50.

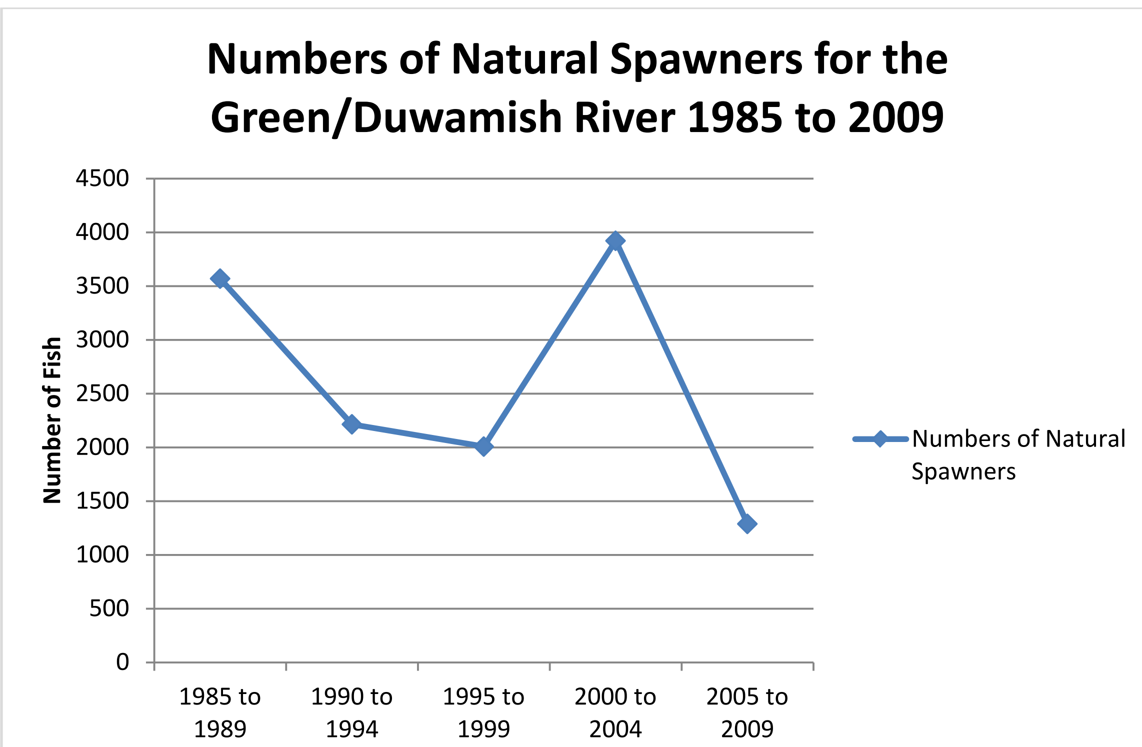



**Figure 4-4 Green/Duwamish River Chinook natural spawning numbers for 1985-2009. Data** Source: Ford (2011), Table 50.

## Chinook populations in the Snohomish system

Snohomish natural spawner data shows a peak in year 2000 with a less precipitous decline than in the Duwamish. However, the spawning numbers are still below the level of recruitment needed for a healthy population and are nearly the same level in 2009 as in 1985 when the census began (Figure 4-5).

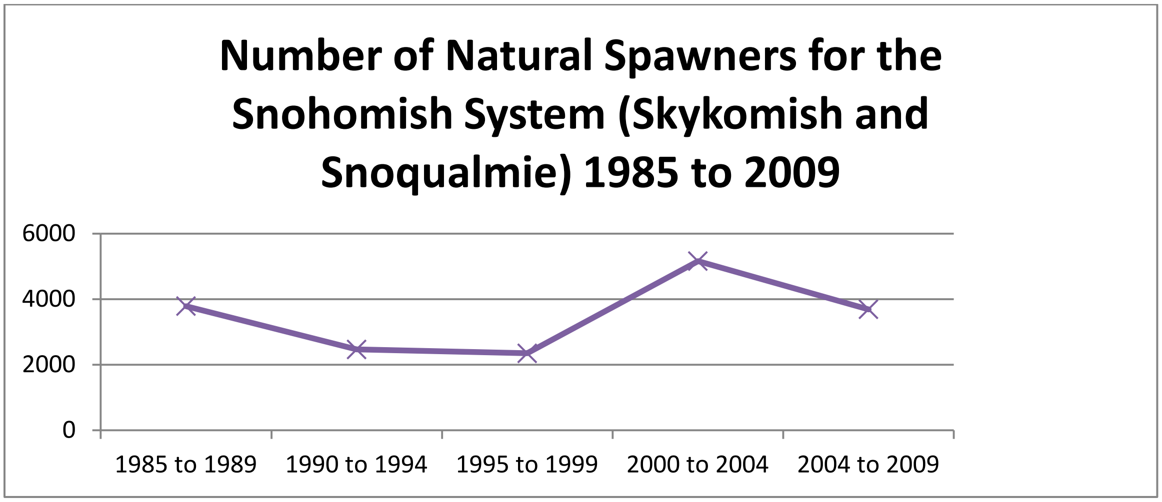



**Figure 4-5 Number of natural Chinook spawners in the Snoqualimie Sytem.** Data Source: Ford (2011), Table 50

## Summary of Chinook populations in Puget Sound

NMFS provides the following summary of Chinook populations in Puget Sound inclusive of the Snohomish and Duwamish systems (Ford 2011).

*"All Puget Sound Chinook salmon populations are well below the TRT [Technical Recovery Team] planning ranges for recovery escapement levels. Most populations are also consistently below the spawner-recruit levels identified by the TRT as consistent with recovery. Across the ESU [evolutionary significant unit], most populations have declined in abundance somewhat since the last status review in 2005, and trends since 1995 are mostly flat. Several of the risk factors identified by Good et al. (2005) are also still present, including high fractions of hatchery fish in many populations and widespread loss and degradation of habitat. Many of the habitat and hatchery actions identified in the Puget Sound Chinook Salmon Recovery Plan are expected to take years or decades to be implemented and to produce significant improvements in natural population attributes; population trends are consistent with these expectations. Overall, new information on abundance, productivity, spatial structure, and diversity since the 2005 review does not indicate a change in the biological risk category since the time of the last BRT [Biological Review Team] status review.*

### 4.1.3. Loss of Special Aquatic Sites Summary

The documented wetland losses range between 80% in the Snohomish estuary to 98% in the Duwamish estuary by area. While the rate of wetland loss has slowed in recent years through much of the study area, this is due to the fact that there is now less wetland area to be impacted since much of the area is already developed. It could be concluded that the threshold for cumulative effects to wetlands and other special aquatic sites these two areas have been exceeded. The majority of the impacts occurred prior to passage of the Clean Water Act. There continues to be nibbling of the few wetlands that remain. Implications of this loss will be discussed in subsequent sections.

## 4.2. Water and Sediment Quality

Impacts to water and sediment quality are being considered in association with loss of wetlands and other special aquatic sites. Wetland loss and negative impacts to water quality have been documented on a number of occasions (Nixon et al. 1988; Howard-Williams 1985; Johnston et al. 1990). Wetlands posses several functions that relate to water quality including removing nutrients, limiting biological and chemical oxygen demand, reducing chemical contaminants through plant uptake, settling, filtering, water storage, (Hemond and Beniot 1988). While not all negative impacts to water quality are solely attributed to the filling and elimination or degradation of wetlands, the presumption is that loss of wetlands, riparian areas, and undeveloped open spaces limits the functions of remaining habitat and is one of the major causes of poor water quality within the study area.

### 4.2.1. Water Quality Standards

Some water and sediment quality trends and issues are relevant to this study. As described in Section 2, water quality problems are pervasive throughout the study area. Several shoreline locations and many of the creeks from Brown's Point to the Snohomish River are listed as impaired on the EPA-required 303(d) list. The most common type of water quality problem is elevated levels of fecal coliform (Table 4-1). As a result, the Washington State Department of Health advises against any shellfish harvest on any beach on the eastern shores of Puget Sound between Everett and Tacoma due to public health concerns related to biotoxins (red tide blooms) (Table 4-1 and Table 4-2). Figure 4-6 below highlights in red the areas of both sediment and water quality found on the State's 303(d) list (2008).

**Table 4-1 Creeks in the study area with measured water quality exceedances.** Data sources are in the last column.

| Creek Name | Location | Water quality exceedance (Category 5)[a] | Data Sources |
|---|---|---|---|
| Joes Creek[b] | Federal Way | Fecal Coliform | Federal Way Shoreline inventory 2007 |
| Des Moines Creek[c] | Des Moines | Fecal Coliform, Zinc, Copper and Dissolved Oxygen | Department of Ecology 2008 Water Quality 303(d)- 5 List for WRIA 9 |
| Redondo Creek | Des Moines | Fecal Coliform | City of Des Moines Shoreline Inventory Public Review Draft 2004 |

| Creek Name | Location | Water quality exceedance (Category 5)[a] | Data Sources |
|---|---|---|---|
| Miller/Walker Creeks | Normandy Park | Fecal Coliform | City of Normandy Park Draft Shoreline Inventory and Characterization Report (2010). |
| Fauntleroy Creek | West Seattle | Fecal Coliform | City of Seattle.  State of the Waters 2007 |
| Longfellow Creek | West Seattle | Fecal Coliform and D.O. | Department of Ecology 2008 Water Quality 303(d)- 5 List for WRIA 9 |
| Pipers Creek | North Seattle | Fecal Coliform (Category 5) Total Nitrogen and total phosphorus (EPA standards) | City of Seattle.  State of the Waters 2007 |
| Japanese Gulch Creek | Mukilteo | Fecal coliform and nutrients (sampled in the 1990s era) | City of Mukilteo Inventory and Shoreline Characterization Draft 2011 |
| Ebey Slough (Snohomish) | Marysville | Fecal Coliform | Department of Ecology 2008 Water Quality 303(d)- 5 List for WRIA 7 |

Category 5 waters are those that have exceeded water quality standards but do not have a Total Maximum Daily Load (TMDL) plan established.

**Table 4-2 Marine areas in the study area with measured water and/or sediment quality exceedances.** Data sources are in the last column.

| Location – Reference Figure 4-6 for more specific locations | Water quality exceedance (303(d) list Category 5 except as noted)[a] | Data sources |
|---|---|---|
| Central Puget Sound | Dioxin, Furans, Polychlorinated Biphenyls (PCBs), and Fecal Coliform | Department of Ecology 2008 Water Quality 303(d)- 5 List for WRIA 9 |
| Des Moines Shoreline | Fecal coliform, Ammonia, pH, 2,4 Dimethylphenol, 2 Methylphenol and Benzyl Alchohol | City of Des Moines Shoreline Inventory and Characterization, Public Review Draft 2004 |
| Burien | Fecal Coliform and Fish habitat; 303(d) list Category 4c[b] for algal blooms. | City of Burien Shoreline Master Program Update Shoreline Inventory 2008 |
| Elliott Bay | Fecal Coliform | Department of Ecology 2008 Water Quality 303(d)- 5 List for WRIA 9 |
| Duwamish | PAH, Dissolved Oxygen, Pentacholorophenol, Diclorobenzene, and a host of others —Superfund site | Department of Ecology 2008 Water Quality 303(d)- 5 List for WRIA 9 |
| Port Gardner and inner Everett Harbor | Sediment Bioassay | Department of Ecology 2008 Water Quality 303(d)- 5 List for WRIA 7 |

a. Category 5 waters are those that have exceed water quality standards but do not have a Total Maximum Daily Load (TMDL) plan established.

b. Category 4c waters are impaired by a non-pollutant source that can't be addressed by a TMDL.

It should be noted that streams and marine areas are not evaluated for all potential deleterious substances. For instance, no state water quality criteria have been established for nutrients. Municipalities within the study area do not always monitor harmful substances such as elevated levels of nutrients (nitrogen, phosphate, and ammonia, for example) even though nutrient loading may present a significant problem. Paul and Meyer (2001) noted that urbanization generally leads to higher phosphorus concentrations in urban streams where fertilizers from lawns are a major source. Additionally, not all streams have been sampled in the study area. While the list presented here is incomplete, many of the streams and the two rivers within the study area that empty into Puget Sound demonstrate degraded water quality (Figure 4-1).This is also manifested in some of the shoreline areas (Figure 4-6 and Table 4-2).

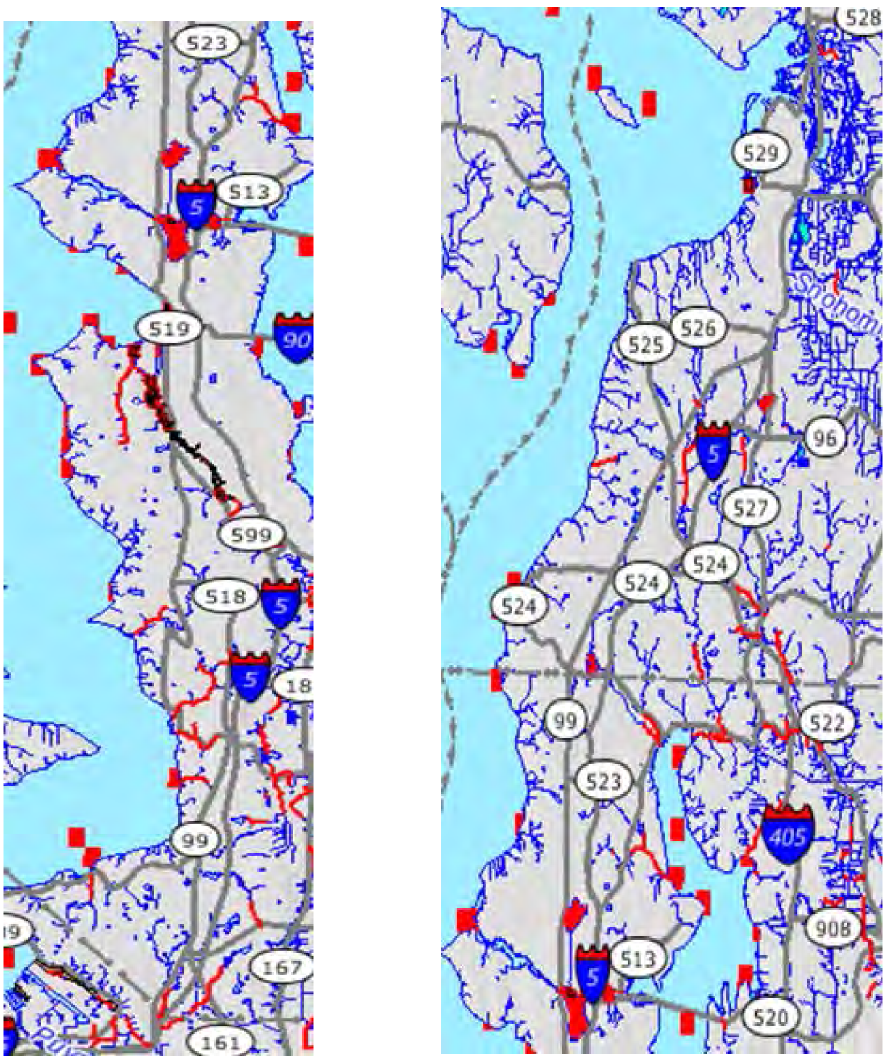



**Figure 4-6 Water quality exceedances of Washington State standards** The left map is from Brown's Point to approximately WestPoint. The right map is approximately WestPoint to Snohomish River. Areas colored red have water quality exceedances. Source: Washington Department of Ecology 2008.

According to the Washington State Department of Ecology, findings from the 2008-09 sediment quality assessment stated that sediment quality in Central Puget Sound declined over the previous ten year period. Results included increased severity and spatial extent of sediment toxicity and an increase in adversely affected benthic invertebrate communities even though they recorded a decrease in some contaminants such as lead, mercury, silver, tin and some polyaromatic hydrocarbons.

In addition, the potential for eutrophication has migrated into the deeper marine waters in central Puget Sound. This is not a recent occurrence but has been a trend for the past 10 years. Krembs (2012) describes nutrient increases in Puget Sound noting that measured water quality trends suggest that increased population in urbanized areas is a significant factor.

### *4.2.2. Pre Spawning Mortality*

One of the most troubling trends to occur in relation to water quality and aquatic species is known as "pre-spawn mortality" (PSM) of coho salmon. Starting in the late 1990's monitoring of local streams within the study area identified that coho returning to their natal streams in late fall showed strange swimming behavior (surface swimming, gaping, spasms, and disorientation) and sometimes rapid mortality (Figure 4-7). Coho often died within a short timeframe after displaying symptoms. When fish carcasses were examined it was noted that many of the female coho had retained their eggs instead of spawning. In some streams, the percentage of PSM found was significant.

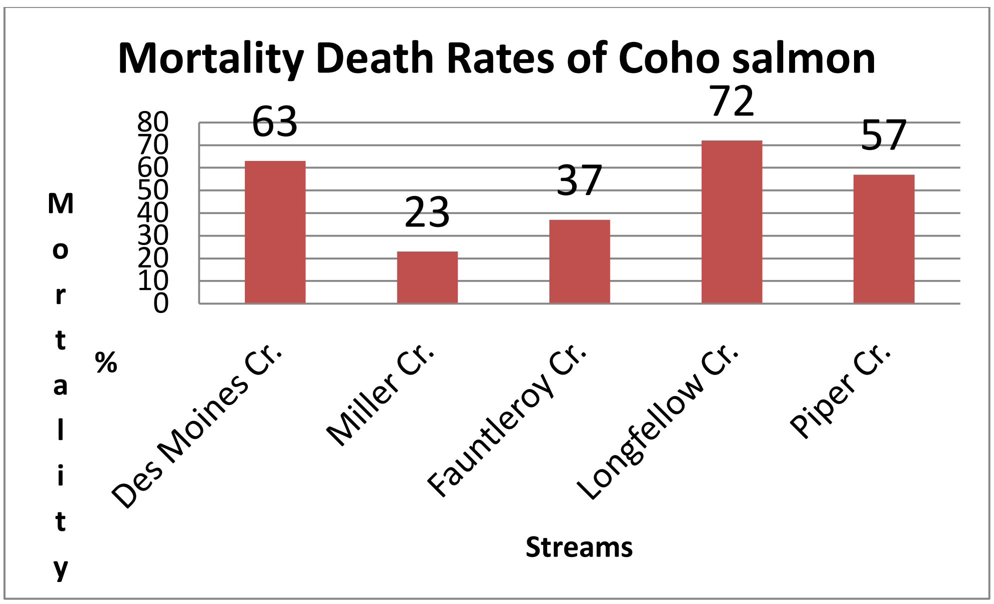



**Figure 4-7 Mortality death rates or "pre-spawn mortality" (PSM) percentages of coho salmon at various creeks in the study area.** Data source for Des Moines, Fauntleroy, Longfellow, and Piper Creek (Average for 2000-2009): Feist et al. 2011 (Table 1). Data Source for Miller Creek:

When PSM was first observed several possible causes were postulated. Early on a relationship was drawn between die offs and precipitation. Preliminary information showed higher rates of die-off in years that had little rainfall and only occasional storms (McCarthy et al. 2008). However McCarthy et al. (2008) noted:

*Instead, the weight of evidence suggests that adult coho are acutely sensitive to nonpoint source stormwater runoff from urban landscapes. Whether salmon are dying from exposure to single* *contaminant or a mixture is not yet known. On the one hand, most pollutants are present in urban surface waters at concentrations below those that will typically cause fish kills. On the other hand, coho spawners undergo important physical changes as they transition from saltwater to freshwater. These changes may render them vulnerable to toxic chemicals, alone or in combination with other environmental stressors. Research to identify the precise cause of coho PSM is ongoing.*

*The "urban stream syndrome" comprises of a suite of common characteristics that include flashy flow regimes during storm events, increased sedimentation, higher levels of contaminants, and low abundance and survival of sensitive species."*

PSM has been identified in many of the streams within the study area and there is some overlap with the streams that have degraded water quality (Figure 4-8). Correlation between streams with water quality excedences such as fecal coliform and PSM have not been systematically evaluated, but it appears that elevated levels of fecal coliform and nutrients may be symptomatic of what was referred to as "urban stream syndrome. Other studies on PSM have demonstrated that it occurs only in highly urbanized settings. When more rural or forested streams are evaluated there is little to no PSM found. In addition, when typical parameters associated with salmon stress such as low dissolved oxygen or high temperatures are examined there is no correlation with PSM. (Scholtz et al. 2011)

*"The weight of evidence therefore suggests that adult coho salmon are unusually vulnerable to the toxic effects of one or more chemical contaminants, most likely delivered to urban spawning habitats via stormwater runoff. The rapid progression of the syndrome and the specific nature of the symptoms are consistent with acute cardiorespiratory toxicity".*

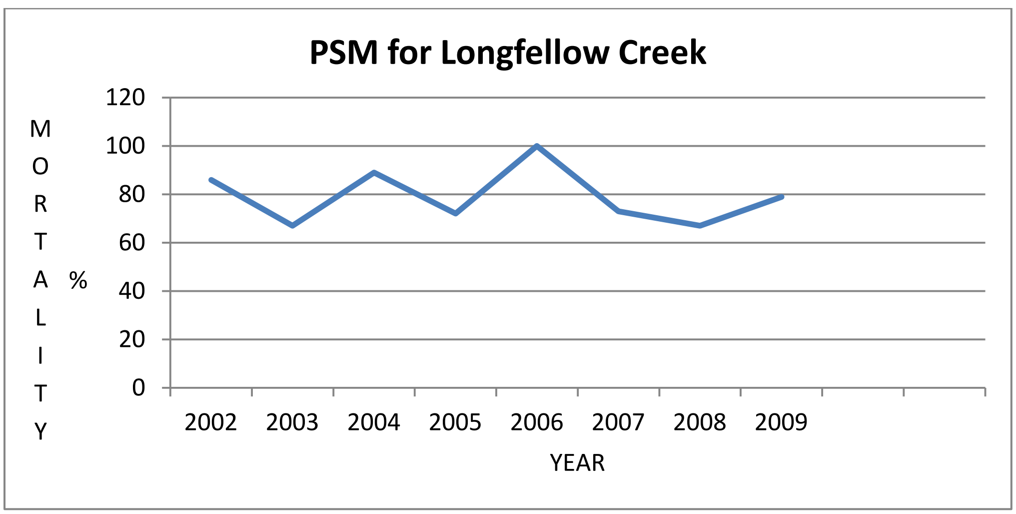



**Figure 4-8 Mortality of coho salmon in Longfellow Creek 2002 to 2009.** Data source: Feist et al. 2011.

Feist et al. (2011) evaluated PSM and concluded that toxic contaminants entering spawning areas from surface runoff are likely to affect sensitive species such as coho salmon.

### *4.2.3. Algal Blooms*

When discussing water quality within the context of the cumulative impact study it is important to briefly mention the importance of algal blooms. There are a few different types of blooms that occur in the waters within the study area. “Green sides” or algal blooms are usually associated with large scale production of Ulva related algae (either Enteromorpha, Ulva, or Ulvaria) (Nelson et al. 2003). These large blooms of what is commonly called “sea lettuce” can form dense mats that can negatively impact eelgrass beds, affect the local marine fauna, and induce local areas with anoxia. Nelson et al. (2003) described that “… dense patches of ulvoidalgae are probably capable of reducing eelgrass density even though mean ulvoid biomass is not particularly high …” As noted earlier in the Introduction, one focus of this report is special aquatic sites, of which vegetated shallows (in this case, eelgrass) is one type. There is not sufficient data on the frequency and locations of green tides to identify trends within the study area but Nelson (2003) states that “The strong positive correlation between ulvoid algal biomass and Dissolved Inorganic Nitrogen (DIN) suggests that additional anthropogenic nitrogen would increase algal biomass and thus cause greater harm to seagrass meadows.” Early on in this section the presence of increased nutrient loading into the study area was discussed.

The other type of algal bloom frequently encountered in the study area, as well as the rest of Puget Sound, is commonly called “red tide.” This is a more serious problem because several mortalities have been associated with paralytic shellfish poisoning (PSP) which is the same as red tide. This harmful dinoflagellate algae is usually of the genus Alexandrium or Pseudo-nitzschia (Anderson et al. 2008). PSP was relatively unknown in Puget Sound until the late 1950s. “A study of decadal patterns of shellfish toxicity indicated that the frequency, magnitude and geographic scope of paralytic shellfish toxicities in Puget Sound have increased since the 1950s” (Moore et al. 2009). This would also include the study area for this report. The cause of the increase of PSP is open to debate. Some authors identify the increase in nitrogen as the cause (Anderson et al. 2008) while others such as Moore et al. (2009) look at changes in weather patterns and water circulation. Regardless of the cause, the outcome is the same; that is, a greater risk to people who harvest shellfish, and additional beach closures. Jerry Borchert (Washington Department of Public Health, personal communication 2-11-2013) noted that last year (2012) was a particularly bad year for all shellfish species with regard to PSP. Borchert went on to say that PSP is difficult to predict; they have noted a trend that when PSP does occur they are seeing higher level of toxicity within the shellfish and that the occurrences of PSP are moving into southern Puget Sound. The two maps below (Figure 4-9 and Figure 4-10) depict shellfish harvesting closures of beaches within the enitre study area for butter and varnish clams.

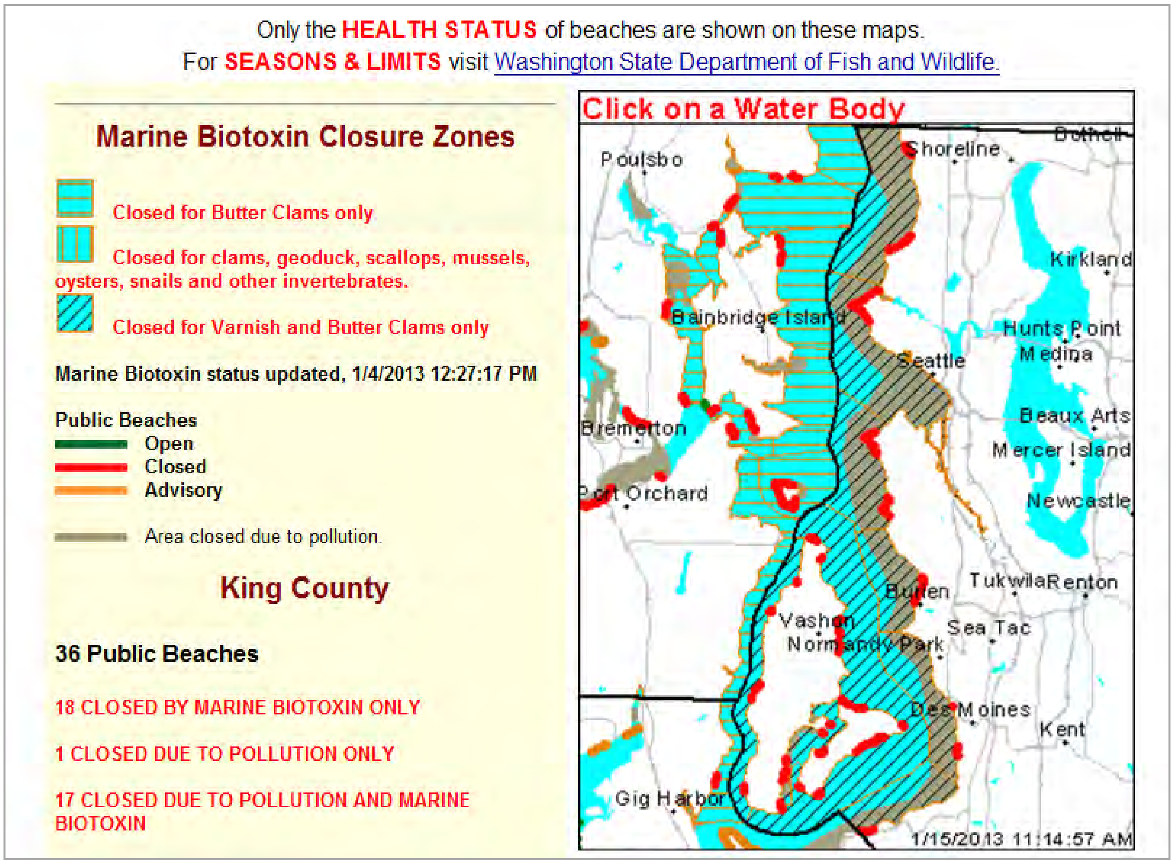



**Figure 4-9 Coastal areas in Puget Sound that have closed due to pollution are indicated in grey. Public beaches that have been closed are indicated in red.** Source: WDOH 2013.

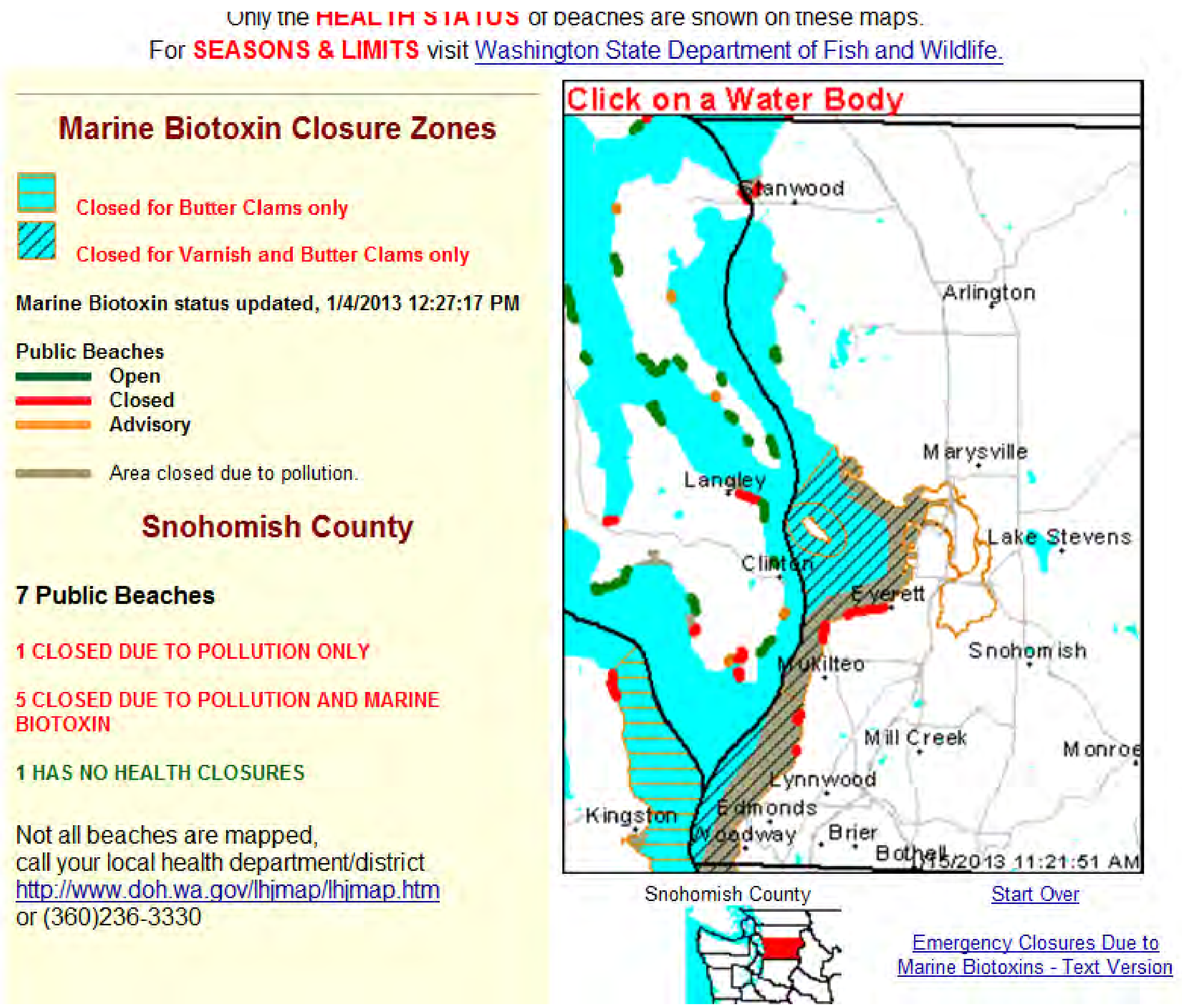



**Figure 4-10 Coastal areas in Northern Puget Sound that have closed due to pollution are indicated in grey. Public beaches that have been closed are indicated in red.** Source: WDOH 2013.

## 4.3. Marine birds as indicators of cumulative effects

In the Puget Sound, a few species of marine birds actually breed within the area but the majority of marine birds and waterfowl are migratory with most species using the Sound as a wintering area (Angell and Balcomb 1982). Changes in the amount of wintering habitat and the quality of habitat relative to food production have been cited as factors affecting the abundance of wintering waterfowl in Puget Sound (Anderson et al. 2009; Bower 2009).

One of the few baseline studies of marine birds in the Straits of Juan De Fuca and Northern Puget Sound was the Marine Ecosystem Analysis (MESA) conducted by NOAA in 1978 and 1979. A similar study was completed in 2003 and 2005 by Western Washington University (Bower 2009). Based on the WWU survey findings, the 2007 Puget Sound Update (PSAT 2007) reported that "the total number of marine birds in Puget Sound has declined by 27 to 47 percent overall since the MESA surveys … Of the 30 most common species in the 1970s, 19 declined by 20 percent or more." The 2007 Puget Sound Update also found a few species of marine birds in severe decline, particularly all three species of scoters with reductions of 64% in surf scooters, 33% in white-winged scoters, and 3% in black scoters. In 2009, based on comparison of the WWU data with the MESA data, Bower reported that "of the 37 most common overwintering Salish Sea species, 14 showed significant decreases, including decreases of more than 50% for 11 species … and six species showed significant increases." Increases in abundance of some species were consistently noted in various reports, suggesting that the drivers of abundance declines may have different effects on different species.

Marine bird populations have also been monitored since 1992 (among other marine indicators) by the Puget Sound Ambient Monitoring Program (PSAMP). Comparison of the MESA historic surveys with PSAMP monitoring results have shown marine bird declines similar to those found in the WWU studies. Feeding guilds that contain multiple species also showed declines in at least some species within each guild, however, limited assessment of the causes of changing species abundance found that reasons differed and were tied to both survey location and type of data collected (Bower 2009). Overall, survey results demonstrate widespread changes in the abundance of marine birds and suggest that restoration of degraded habitat and protection of existing habitat are important.

### *4.3.1. Findings of an Interannual Marine Bird Trend Analysis from Historical Marine Bird Aerial Census*

USACE commissioned assessment of two marine bird aerial surveys spanning 49 years to assess temporal trends in species that occurred within the study areas: a 1958-1985 historical marine bird aerial census (HMBAC) (identified through personal communication with Don Krage of Washington Department of Fisheries and Wildlife), and a 1994-2010 PSAMP survey data. The completed report including methods used for assessing interannual trends in HMBAC and PSAMP aerial survey data are described in detail in Appendix C. Of the 21 species groups encountered by HMBAC surveys, 19 were found within the Tulalip Point to Brown's Point study area; two others were not observed. Of those, sample sizes were sufficient for analysis of only twelve species. Therefore, PSAMP data used was restricted to only these groups, all of which are within the Anatidae family as follows:

- two Aythya species (lesser and greater scaups: A. marila and A. affinis, respectively);
- three Bucephala species (Barrow's and common goldeneyes: B. islandica and B. clangula, respectively; and buffleheads, B. albeola);
- three Melanitta species (black, surf, and white-winged scoters: M. nigra, M. fusca and M. perspicillata, respectively);
- hooded mergansers (Lophodytes cucullatus);
- three Anas species (American wigeons, mallards, and northern pintails,: A. americana, A. platyrhynchos, and A. acuta, respectively).

In general, results from this data evaluation, suggest that all marine bird species except buffleheads declined in the study area over the 49 years of aerial survey data reviewed, but the pattern of decline differs among species over time. Combined and transformed time series data from both studies are shown in Figure 4-11.

The evaluation also found that some species such as scoters did not display a long-term decline similar to that found in other studies. Since potential sources of uncertainty between data sources such as differences in spatial coverage, survey methodology, sample sizes, and relative spatial scale were identified and accounted for, trend differences within and among species are suggestive of differences in forcing factors over the time period of data collection.

For example, hooded mergansers rose from near zero in the 1960s to a maximum in the 1970s and 1980s, then, returned to the limits of detection again from the 1990s onward. While it may be that early observers were not targeting this species, it is also possible that there was a depressive factor in the early years of observation with a second, perhaps different, depressive factor in the later years. This suggestion is supported by the fact that other species such as mallards, American widgeons, and northern pintails were found in abundance during the same timeframe. Additionally, it is possible that the chance of finding larger rafts of Anas species has declined from the 1970s-80s to the present. Goldeneye and scoter trends also suggest that a forcing factor not previously in play may be depressing abundance of these species in the study area after the 1990s. Both of these species displayed an early period of low stable abundance, with a maximum value in the early PSAMP years, followed by a steady decline to or below early period averages. While once prevalent in the study area, scaups appear to have declined in number essentially to zero (or at least the limits of detectability) at the present time. As noted in the report, previous studies reported significant decreases in scaup densities in Puget Sound (Nysewander et al. 2005; Anderson et al. 2009), and similar long-term trends were also reported for scaup surveyed in their northern breeding range within western Canada (Afton and Anderson 2001).

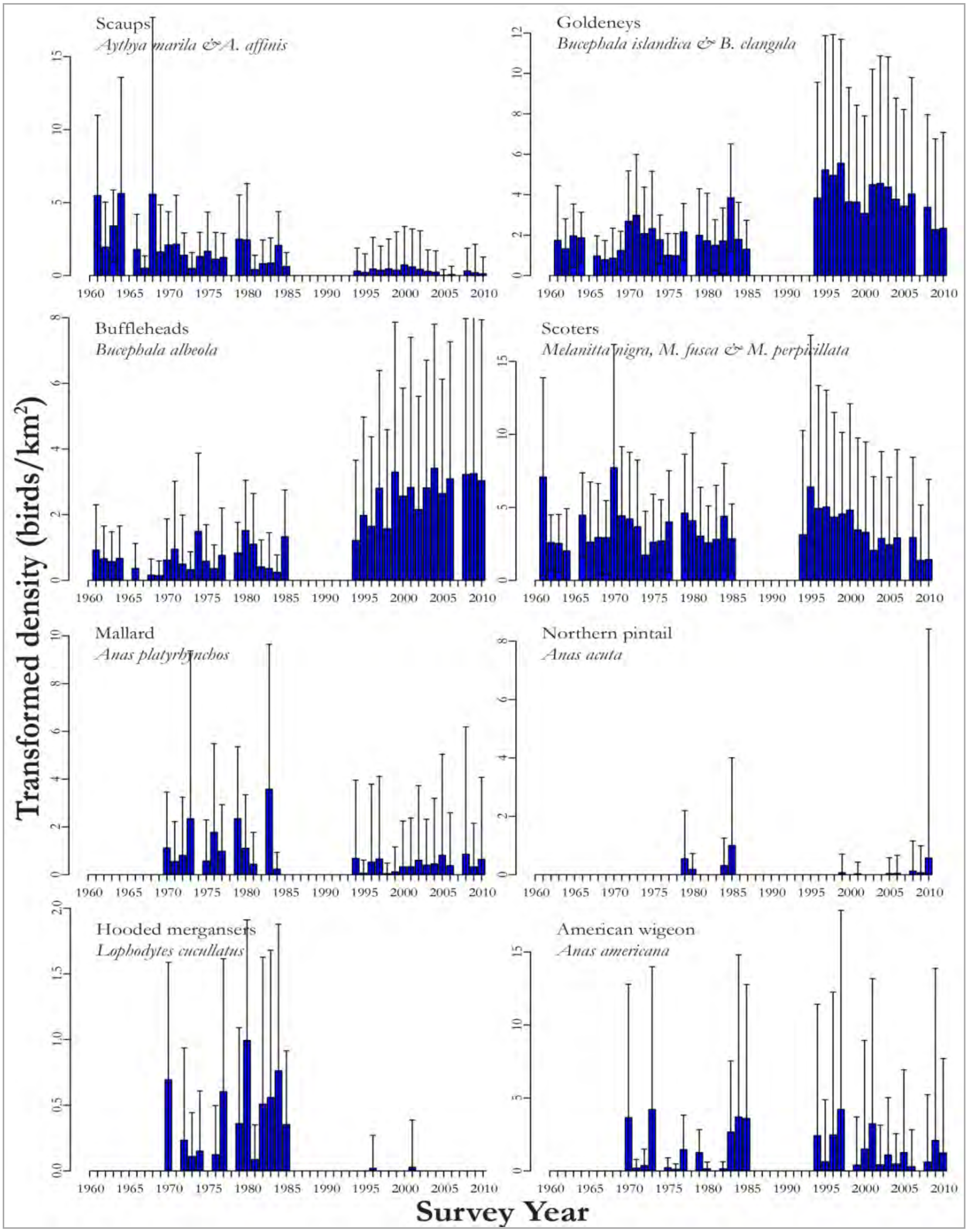



**Figure 4-11 Square-root-transformed yearly average densities for the eight bird species groups included in the trend analyses. Error bars represent standard errors of the mean.**

In summary, over the half-century encompassed by the HMBAC-PSAMP combined time series of select marine waterfowl nearshore abundance in the Tulalip Point to Brown's Point study area, almost all species have shown declines from historical numbers; the exception being buffleheads. The pattern of decline differs, however. Scaups declined first, entirely within the HMBAC survey period. Goldeneyes and scoters displayed no trend within the early years, peaked at the beginning of the PSAMP surveys and declined thereafter. Hooded mergansers and the Anas species were variably absent in the beginning of the HMBAC survey period, showed variable irruptive patterns in the latter portion of this survey period, and are less present in the study area during the PSAMP survey period.

With the rapid increase in post-WWII population within the study area it is easy to speculate that both habitat loss and disturbance should be considered factors in these declines. According to a WDFW unpublished "Status and Trends of Marine Birds in Washington's Southern Puget Sound" there are several reasons for the decline in marine avian species in Washington State;

- Declines in key herring spawning stocks
- Change in local food webs or quality of habitats
- Relationship to human factors (harvest, disturbance, contaminant loads, mortality events)
- Low survival of juveniles and or adults
- Disruption of age/sex ratios of species population
- Change in reproductive success for Washington oriented component of individual species
- Shifting distributions in flyway
- Effects related to acute or chronic contamination
- Global or climatic oscillations

Other studies have also indicated declines in marine bird and waterfowl populations likely due to human influence. Using the same PSAMP data that was included in USACE evaluation Rice (2007), concluded that human activity did affect marine bird and waterfowl taxonomic composition in Puget Sound in both summer and winter by identifying distinct assemblage composition between urban and non-urban areas (Table 4-3).

**Table 4-3 Percent taxon contribution (based on relative frequency of occurrence) to within-group assemblage similarity during summer and winter in urban (Duwamish, Puyallup and Snohomish), and non-urban (Skagit, Stillaguamish, Skokomish and Nisqually) estuaries (SIMPER test; 1993-1996).** Source: Rice (2007) Table 5.7.

| Summer | | | | | |
|---|---|---|---|---|---|
| Urban<br>Average similarity across years: 82 | | | Non-urban<br>Average similarity across years: 88 | | |
| Taxon | Contrib. % | Cumul. % | Taxon | Contrib. % | Cumul. % |
| Large Gulls | 69 | 69 | Large Gulls | 43 | 43 |
| Terns | 9 | 78 | Herons | 15 | 58 |
| Geese | 8 | 86 | Terns | 11 | 70 |
| Crows | 6 | 92 | Diving Ducks | 7 | 77 |
| | | | Small Gulls | 5 | 82 |
| | | | Crows | 4 | 85 |
| | | | Dabbling Ducks | 4 | 89 |
| | | | Raptors | 3 | 92 |

| Winter | | | | | |
|---|---|---|---|---|---|
| Urban<br>Average similarity across years: 76 | | | Non-urban<br>Average similarity across years: 76 | | |
| Taxon | Contrib. % | Cumul. % | Taxon | Contrib. % | Cumul. % |
| Large Gulls | 32 | 32 | Diving Ducks | 29 | 29 |
| Diving Ducks | 23 | 54 | Large Gulls | 21 | 50 |
| Grebes | 20 | 74 | Dabbling Ducks | 15 | 65 |
| Cormorants | 16 | 90 | Grebes | 7 | 72 |
| | | | Loons | 6 | 78 |
| | | | Cormorants | 5 | 83 |
| | | | Herons | 4 | 88 |
| | | | Shorebirds | 4 | 91 |

The methods used in Rice (2007) included the aerial bird surveys from PSAMP as well as maps of physical shoreline structure and land cover to explore changes in marine bird and waterfowl assemblage composition across years. As shown in Table 4-3, in the urban environment only four taxon are represented in 90% of the population in both winter and summer while in the more diverse non-urban areas eight taxon are represented in the same population level. Several of the urban taxon are species typically associated with humans or human disturbance such as crows, gulls, and some geese (such as Canadian geese). The Urban areas used in the Rice (2007) evaluation consisted of much of the shoreline included in the cumulative impact study area as well as the Puyallup estuary.

DeLuca et al. 2004 also identified disturbance, habitat degradation, and the effects of urbanization as common themes with regard to alterations of marine bird assemblages within the study area. Starting in September of 1996 and continuing until May of 2000 four sites within the Duwamish estuary were evaluated for bird usage. The four sites consisted of two habitat restoration areas that included mudflats, wetlands, associated shoreline and riparian areas, and two reference sites that included similar habitats. One restoration project (T-105) and one reference site (Kellogg Island) are located about 1 mile south of the mouth of the Duwamish Waterway. One restoration site (Turning Basin) and one reference (turning Basin reference site) site are located about 6 miles south of the mouth of the Duwamish Waterway. All sites were tidally influenced. It should be noted that environmental mitigation and restoration sites comprise the majority of special aquatic sites in the Duwamish since less than 2% of historic mudflats and tidal marshes remain (3.2). The four individual sites were evaluated for species presence, abundance, and avian behavior. Observations were made on a quarterly basis and bird species were grouped into guilds for analysis.

Two significant trends were identified as a result of the monitoring. The first trend was the heavy influence of introduced or native/human associated bird species. The second trend is the role of disturbance on avian species in the study area. Cordell et al. (2001) noted that:

*"People were more frequently seen at all sites in 1999-2000 than in previous sampling years. An increased level of human activity appeared to have a negative impact on both bird abundance and diversity. Construction west of Kellogg Island (one of the reference sites) might be correlated with lower abundance, but there was no apparent change in diversity. At T-105,( the closest restoration site to the mouth of the Duwamish) increased levels of recreational use and the construction of a rendering plant probably correlated with lower diversity."*

In the previous report Cordell et al. (2001) describes site specific disturbance in more detail;

*"At T-105 a decline in abundance began in the later part of the summer 1997 season and this trend continued through the next four seasons of data collection. The timing of the downward trend in abundance at T-105 was closely tied to the construction and operation of the rendering plant to the west of T-105. For example, during the initial construction, a vacant lot was cleared of trees and brush where 15-20 white-crowned sparrows had previously been observed foraging and exhibiting territorial behavior. Since then, no more than 1 male white-crowned sparrow has been seen at T-105."*

Both species abundance and richness declined over the length of the study at T-105. Additionally, species abundance declined at the reference site (Kellog Island) which was also susceptible to disturbance from increased human activity. Mean richness for all nine of the monitoring seasons declined by 40-57% when calculated without the 14 introduced and human associated species (brown-headed cowbirds, crows, starlings, English sparrows and glaucous–winged gull).

De Luca et al. (2008) provides insight into what is occurring with regard to loss of abundance and diversity of marine birds in Chesapeake Bay and which appears applicable to the Puget Sound. Many of the impacts described are similar to the cumulative effects described in this report:

*"…It is clear that waterbird communities are sensitive to anthropogenic disturbance in particular. We detected a nonlinear, threshold response in waterbird community integrity at low levels in urban development (<5%) at local scales."*

Regardless of a lack of knowledge regarding specific stressor responses in marine birds and waterfowl suggested by Durrant et al. (2009), the data evaluation and literature review described here strongly suggests that marine birds in general are affected by human activities such that their individual and collective abundance and diversity are affected. Additionally, the level of disturbance described in the study area in previous sections likely exceeds a threshold at which marine bird species will continue to be affected.

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# 5. Permit Evaluation

## 5.1. Regulatory Background

Much of this document has focused on disturbance to the aquatic environment within the study area and the causes for those disturbances. Many of the habitats discussed fall under the jurisdiction of Section 404 of the CWA. USACE regulates activities under the following laws: Section 10 of the Rivers and Harbors Act, Section 404 of the CWA, and Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972. USACE can issue a Department of the Army (DA) permit for work impacting navigable waters of the U.S. (Section 10), for discharges of dredged or fill material into waters of the U.S., including special aquatic sites such as wetlands (Section 404) and/or for the transportation and discharge of dredged material into ocean waters (Section 103). Figure 5-1 below shows USACE regulatory jurisdiction under these laws. Approximately 700 USACE CWA 404 permit files were located within the study area from 1998-2011. Of those, 400 USACE CWA 404 permit files from 2002-2011 (Appendix D) were reviewed and evaluated to identify the number and type of permits per year, type and location of the permitted action, and whether the permitted activity included fill, excavation, dredging, mitigation and/or shoreline hardening. The goal was to assess the type and location of permits over a ten year period to identify patterns in permit use and physical location, respectively. This is similar to the permit evaluation methodology conducted for the 1993 Cumulative Impact Study completed for Commencement Bay (USACE 1993). In addition, findings from other studies of USACE permitted actions are summarized.

There are four types of DA permits issued by USACE: Standard Individual Permits (IP), Letter of Permission (LOP), Nationwide Permits (NWP), and Regional General Permits (RGP). There were no RGPs in the study area, therefore, these are not defined and will not be discussed further.

Individual Permits (IP) are projects are generally the larger and/or more controversial projects, e.g., those projects not meeting the terms and conditions of a NWP or RGP. IPs require a more robust analysis and thus have a lengthier review process. The IP review process includes a public notice (PN) for an opportunity for public comment, an alternatives analysis, a public interest review, determination of compliance with the 404(b)(1) Guidelines, etc. Compensatory mitigation is often required to offset the proposed impacts. A permit will be granted if the proposed project is not contrary to the public interest, complies with other federal laws, is consistent with Tribal Treaty Rights and meets other legal requirements, such as the 404(b)(1) Guidelines.

A letter of permission (LOP) is a type of individual permit issued through a streamlined processing procedure compared to an individual permit. The Seattle District issues LOPs under Section 10 only; LOPs are not available for work subject to Section 404 of the Clean Water Act. An LOP may be issued in cases where proposed work would not have significant individual or cumulative impacts on environmental values, and should encounter no appreciable opposition. The types of projects often authorized by LOPs are minor dredging and construction, maintenance, or replacement of piers, ramps or floats. Compliance reviews under Section 7 of the Endangered Species Act and Section 106 of the

National Historic Preservation Act still apply. In addition, notification of the project is sent to the National Marine Fisheries Service, U.S. Fish and Wildlife Service, Washington State Department of Ecology, and various Tribes with notification agreements for comments in lieu of a public notice.

Nationwide permits (NWPs) are a type of general permit issued by USACE on a nationwide basis for activities similar in nature and having minimal individual or cumulative impacts. NWPs are designed to provide timely Department of the Army authorization for certain activities in waters of the United States while also protecting the Nation's aquatic resources. Activities authorized by NWPs must be similar in nature, cause only minimal adverse environmental effects when performed separately, and cause only minimal cumulative adverse effect on the aquatic environment. NWPs can authorize activities pursuant to Section 404 of the Clean Water Act and/or Section 10 of the Rivers and Harbors Act of 1899. The NWPs are proposed, issued, modified, reissued (extended), or revoked every 5 years, after the opportunity for public notice and comment. Last issued on March 19, 2012, there are currently 50 Nationwide Permits. All of these Nationwide Permits expire five years after issuance on March 18, 2017.

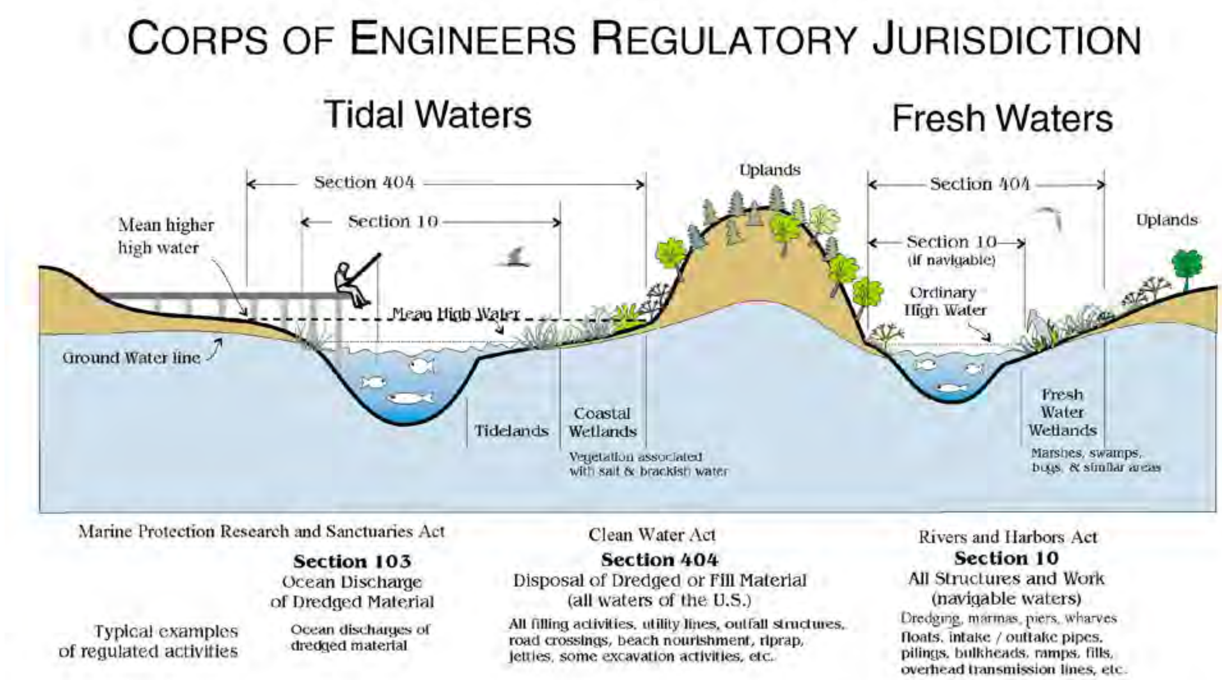


**Figure 5-1 USACE Regulatory Jurisdiction. Source: US Army Corps of Engineers (2013)**

In 1992, Kentula et al. evaluated 404 permit decisions for altered wetlands that occurred in Washington and Oregon from 1977-1986. This subset of permits represented about 3% of the permit record in both states at that time. They attempted to document the location, type, size and number of wetlands impacted or created (in the case of mitigation) and trends over time were characterized resulting in the following summary:

- Most of the permitted activity (96%) was located on the West side of the Cascade Mountains.
- Eighty-seven percent of the impacted and created wetlands were associated with the coast, or an estuary or waterway primarily in Puget Sound.

- Sixty- six percent occurred within about three miles of an urban area with a population greater than 5000. The majority were in the vicinity of the Seattle/Tacoma metropolitan area.
- Construction of marinas, boat basins and docks, and channel maintenance activities were responsible for the majority of permits requiring mitigation.

In a different study, focused on 404 wetland permitting in Texas and Florida, Brody et al. conducted spatial analysis to evaluate cumulative effects in over 85 watersheds. In the introduction of the report Brody summarized work by other researchers and noted:

- Stein and Ambrose (1998) evaluated riparian conditions in the Santa Margarita watershed in Southern California and concluded that while the Section 404 program reduced overall project impacts, it had not minimized cumulative impacts. Nationwide permits accounted for proportionally more cumulative impacts despite the fact that they affect less total area across the watershed. They noted a high degree of correlation between population growth and cumulative permit actions.
- Kelly (2001) in North Carolina, found net loss of wetlands under the section 404 permitting program in addition to habitat fragmentation in 80% of areas adjacent to permit sites. Literature suggests that permitting activity is a direct result of urban growth and expansion.
- Brody et al. (2008) concluded their evaluation by stating "our results suggest that sprawling development primarily from residential projects is escalating in coastal areas."

## 5.2. Methods used in permit evaluation

The permits evaluated in this study were selected based on location of the permitted activity within the study area. Of a total of 700 permit records initiated in the study area from 1998-2011, approximately 400 permit files were retrieved and evaluated for actions initiated during years 2002-2011. These included nationwide permits (NWP), Individual Permits (IP), letters of permission (LOP), nationwide permits whose type was not able to be identified, no permit required (NPR), and unauthorized action (UNAUTHACT). Three types of permit files were not included in our impact evaluation, NPR, UNAUTHACT, and nationwide permits whose type could not be identified from the database. There were 19 different NWP, that applied to the study area, which, included NWP 1 Aids to Navigation, NWP 3 Maintenance, NWP 4 Fish and Wildlife Harvesting, Enhancement, and Attraction Devices and Activities, NWP 5 Scientific Measurement Devices, NWP 6 Survey Activities, NWP 7 Outfall Structures and Associated Intake Structures, NWP 10 Mooring Buoys, NWP 11 Temporary Recreation Structures, NWP 12 Utility Line Activities, NWP 13 Bank Stabilization, NWP 14 Linear Transportation Projects, NWP 18 Minor Discharges, NWP 23 Approved Categorical Exclusions, NWP 26 Structural Discharges, NWP 27 Aquatic Habitat Restoration, Establishment, and Enhancement Activities, NWP 28 Modification of Existing Marinas, NWP 29 Residential Developments, NWP 33 Temporary Construction, Access and Dewatering, NWP 38 Cleanup of Hazardous and Toxic Waste, and NWP 39 Commercial and Institutional Development.

Each permit file was reviewed for amount of fill, excavation, dredging, mitigation and shoreline hardening and the location was quality checked with a master database. The type of documentation was inconsistent among permits, where applicable, acreage or volume of fill or linear feet of shoreline activity was recorded. Maintenance permits that allow fill to be placed in the footprint of an existing project and utility work that replaces excavated soil were not included in the fill quantities.

Lastly, a summary list of all permits completed from 2007-2011 for Washington State and for the Puget Sound was compiled for comparison to those in the study area (Appendix D). The extent of the database allowed for only a 5 year period of comparison to Washington State and Puget Sound.

## 5.3. Permit Evaluation

During the 14 years that were evaluated, the most active year for permitting in the study area was 2004 with 65 permits authorized, and the lowest year was 2007 with 31 permits authorized. The number of permits authorized each year shows a decreasing trend for years 1998-2011 (Figure 5-2). The number of permits in 2011 is limited to Jan-July; therefore, 2011 is not directly comparable to other years. Figure 5-3 shows the spatial distribution of all NWP issued between 1998 and 2011.

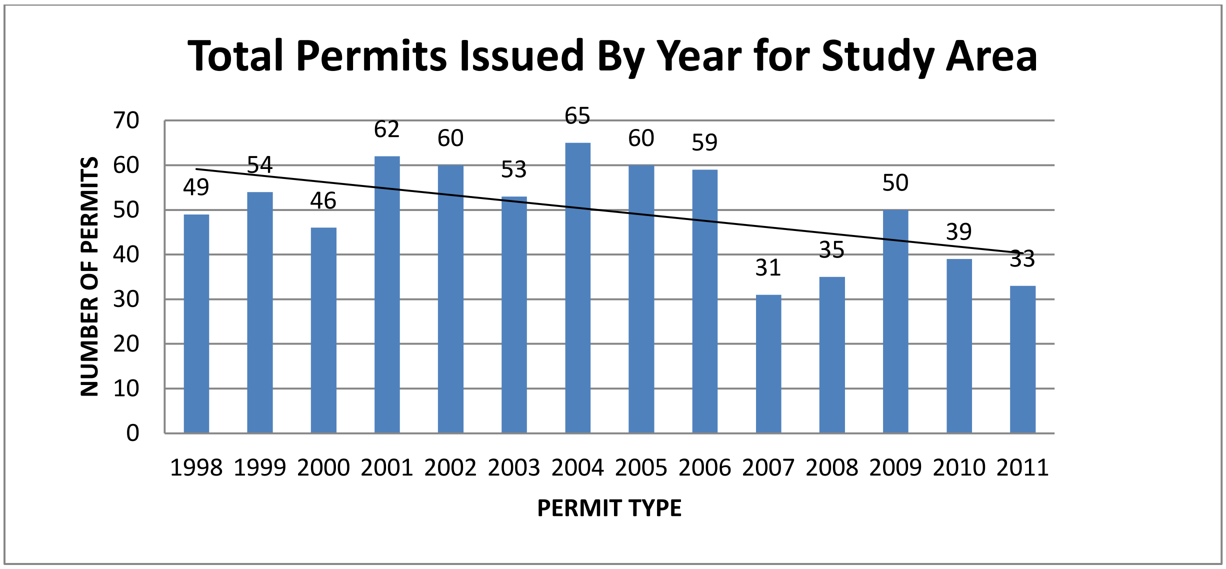


**Figure 5-2 Total permits by year within the study area. The regression line is used to show that since 1998 there has been a decreasing trend in total number of permits issued.**

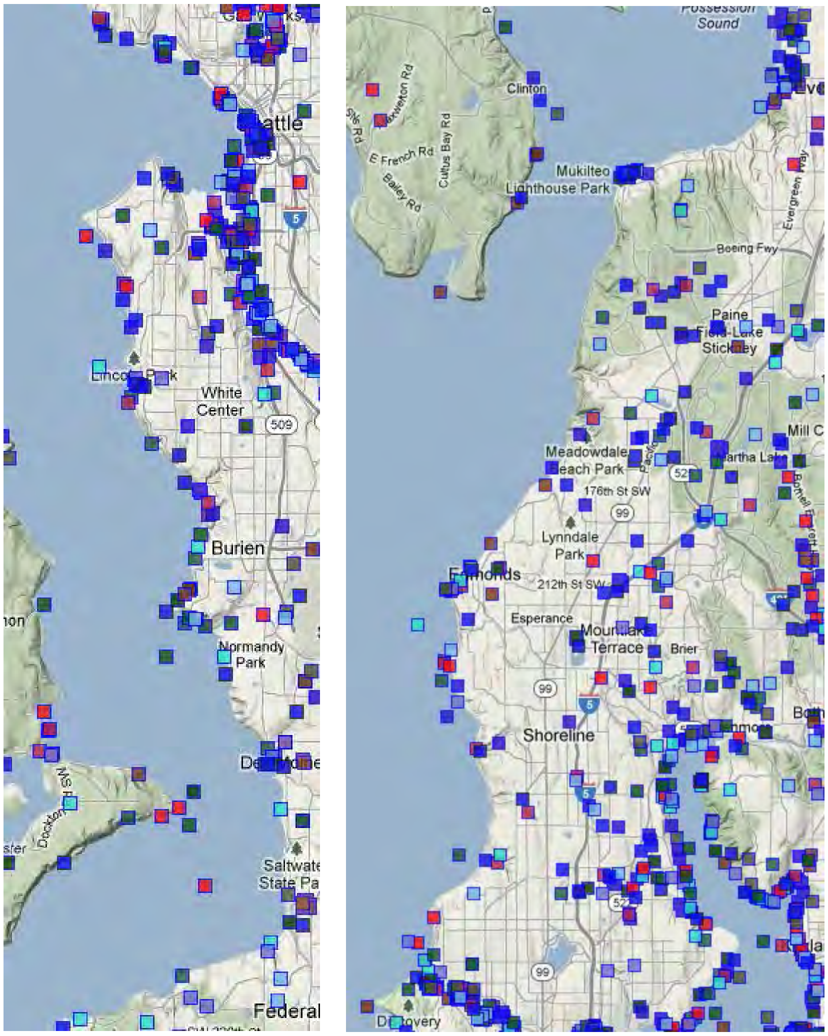


**Figure 5-3 Locations of all nationwide permits in the study area over 14 years (1998-2011). Colored rectangles are specific locations of authorized nationwide permits in the study area. Note; the size of the rectangle is not the size of the project area.**

Of the 700 permits issued from 1998-2011, 69% were nationwide permits, 14% were IP, 10% were unidentified NWP, 8% were unauthorized actions, 5% were LOP, and 5% were "no permit required". NWP 3 (maintenance) were the most frequently issued, followed by IP, NWP 6 (survey activities), LOP, NWP 12 (utility line activities), NWP 27 (aquatic habitat restoration, establishment, and enhancement activities), NWP18 (minor discharges), and NWP 13(bank stabilization) (Figure 5-4).

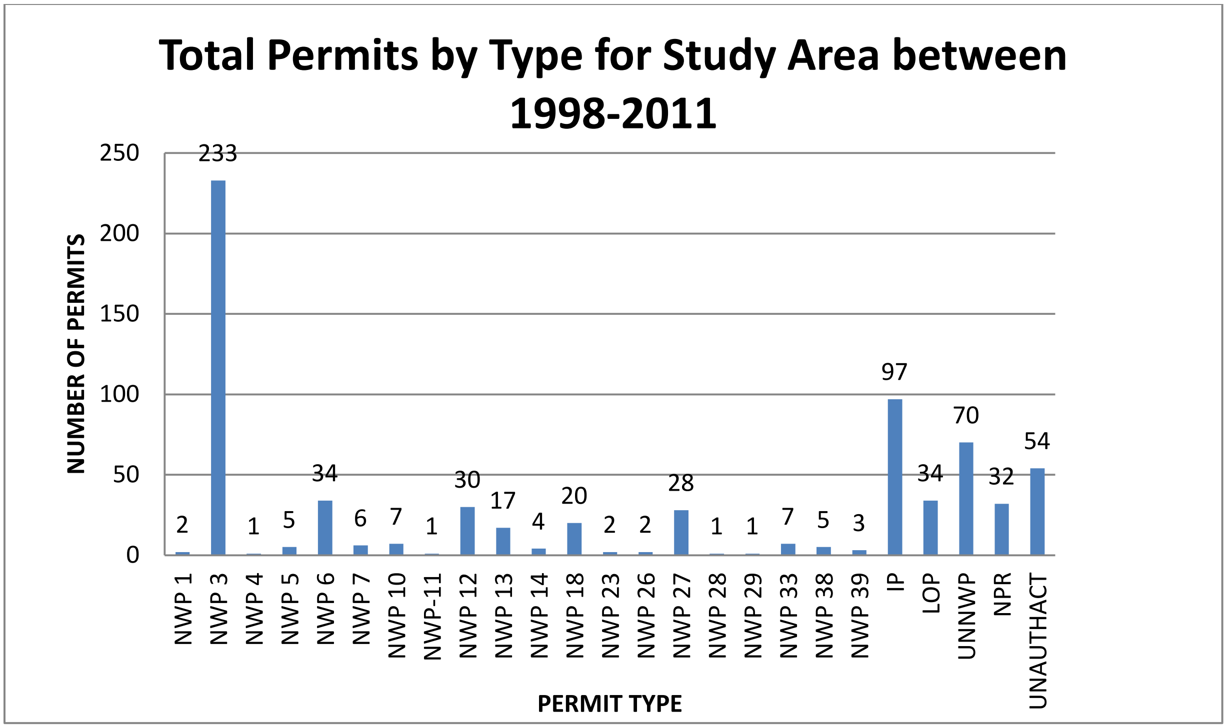


**Figure 5-4 Distribution of permits by type in the study area.**

### *5.3.1. Bank Stabilization*

As noted previously the extent and rate of bankline hardening in Puget Sound is of concern based on the disruption of natural physical processes such as sediment transport. Based on PSNERP, over 72% of the shoreline in the study area is hardened, the highest percentage in Puget Sound. Seventeen NWP 13 (bank stabilization) permits occurred in the study area between the years1998 and 2011. From the data evaluated from the years 2002-2011, shoreline activity permitted under CWA 404 was largely maintenance of existing structures which was not included in the fill quantities described below. There are three potential explanations for the discrepancy between the evaluation results and the relatively high percentage of shoreline hardening in the study area:

1. Much of the identified shoreline hardening is above MHHW and not under USACE jurisdiction.
2. Much of the shoreline hardening was accomplished under some kind of permit but prior to the CWA.
3. The shoreline hardening was accomplished without obtaining a permit.

While this study could not differentiate between these possibilities, we do know that there were approximately 1,100 Hydraulic Project Approvals (HPA) for shoreline armoring projects issued by the State of Washington between 2005 and 2011 (

Table 5-1). In addition, from 2005-2010, the length of armoring replaced under HPA's far exceeded new or removed structures and new armoring substantially outpaced removal in the years evaluated.

**Table 5-1 Number of Armoring Projects in Puget Sound based on WDFW HPA. (For 2011 approximately 127 projects were authorized. This number is still preliminary, but is not likely to change by more than 3).**

| County | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total |
|---|---|---|---|---|---|---|---|
| Clallam | 2 | 2 | 2 | 2 | 6 | 1 | 15 |
| Island | 23 | 78 | 47 | 39 | 21 | 22 | 230 |
| Jefferson | 2 | 10 | 5 | 6 | 2 | 2 | 27 |
| King | 3 | 9 | 12 | 14 | 6 | 6 | 50 |
| Kitsap | 15 | 46 | 36 | 28 | 26 | 20 | 171 |
| Mason | 16 | 38 | 24 | 21 | 9 | 30 | 138 |
| Pierce | 46 | 36 | 41 | 18 | 18 | 12 | 171 |
| San Juan | 2 | 13 | 7 | 4 | 10 | 5 | 41 |
| Skagit | 4 | 3 | 11 | 8 | 7 | 6 | 39 |
| Snohomish | 5 | 11 | 9 | 9 | 3 | 3 | 40 |
| Thurston | 12 | 7 | 10 | 5 | 8 | 7 | 49 |
| Whatcom | | 2 | 2 | 2 | 2 | 2 | 10 |
| Total | 130 | 255 | 206 | 156 | 118 | 116 | **981** |

In addition, new armoring and armoring removal were evaluated by HPA applicant type (Figure 5-5). Single family residences make up the bulk (76%) of new armoring applicants, while government entities make up the bulk (63%) of armor removal applicants.

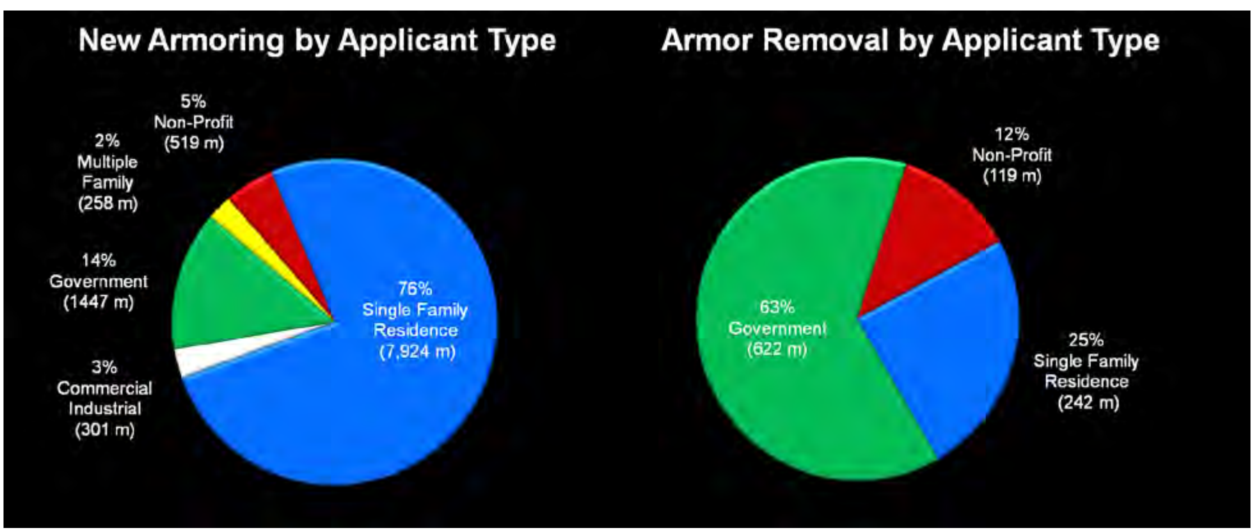


**Figure 5-5 Percentage of new armoring and armor removal by applicant type . Source: Carman et al. (2011)**

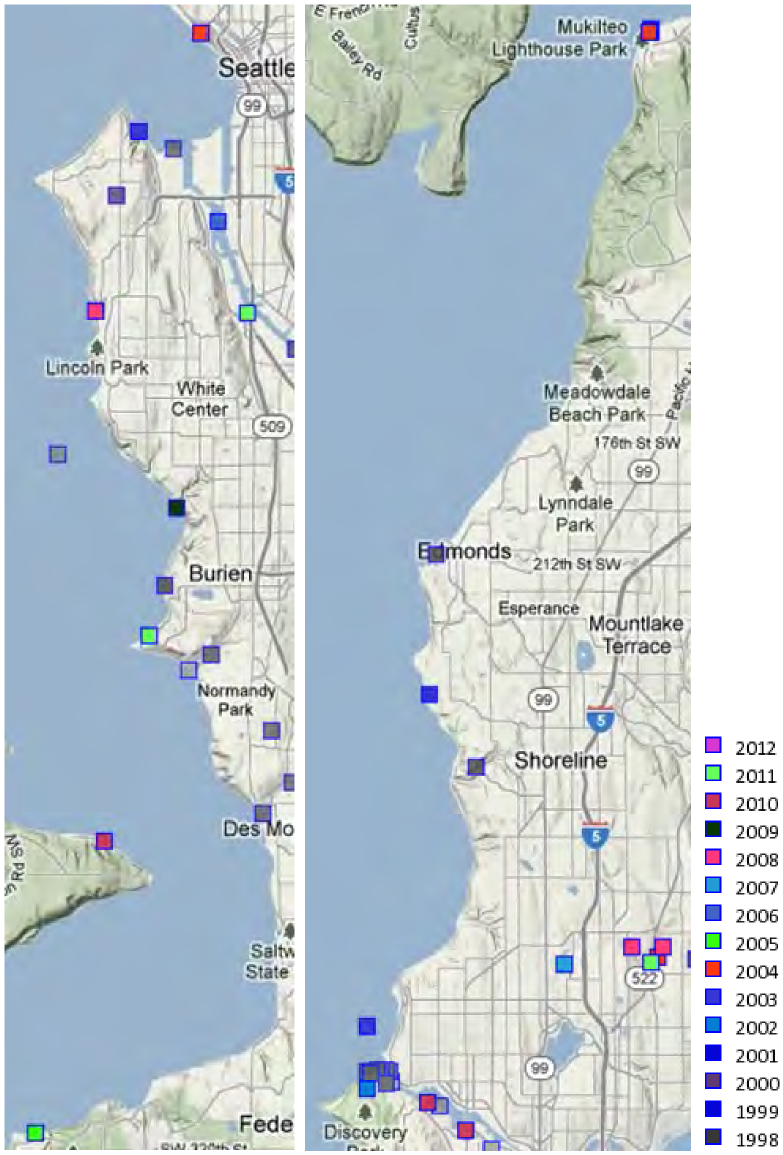


**Figure 5-6 Distribution of Nationwide Permit #13 (Bankline Protection) within the study area for years 1998-2012. The colored rectangles are locations where a nationwide permit was authorized and do not represent the size of the project area. Data Source: USACE ORM database.**

### *5.3.2. Maintenance*

Nationwide permit (NWP) 3 was most frequently issued permit between 1998-2011 (Figure 5-4). NWP 3 (Maintenance) is defined as the repair, rehabilitation, or replacement of any previously authorized, currently serviceable, structure, or fill, or of any currently serviceable structure or fill authorized by 33 CFR 330.3, provided that the structure or fill is not to be put to uses differing from those uses specified or contemplated for it in the original permit or the most recently authorized modification. This NWP authorizes the removal of accumulated sediments and debris in the vicinity of and within existing structures and the placement of new or additional material to protect structures. It also authorizes temporary structures, fill, and work necessary to conduct maintenance on existing structures. Within the study area, 233 NWP 3 were authorized between 1998 and 2011 based on the permit files provided in the database (Figure 5-7). In general, the activities in the study area included, repairing bulkheads, replacing creosote treated piling with steel piling, repairing seawalls, excavation of riverine sediment, removal of accumulated sediment, and sewer line maintenance. Fill or excavation was not included in our analysis if done for maintenance completed within the footprint of the original project. Approximately 20% of the NWP 3 permits reviewed for 2002-2011 were for the repair of bulkheads, which included adding or replacing riprap. Some activities under NWP#3 are beneficial such as replacing creosote treated or deteriorating pilings with new steel pilings.

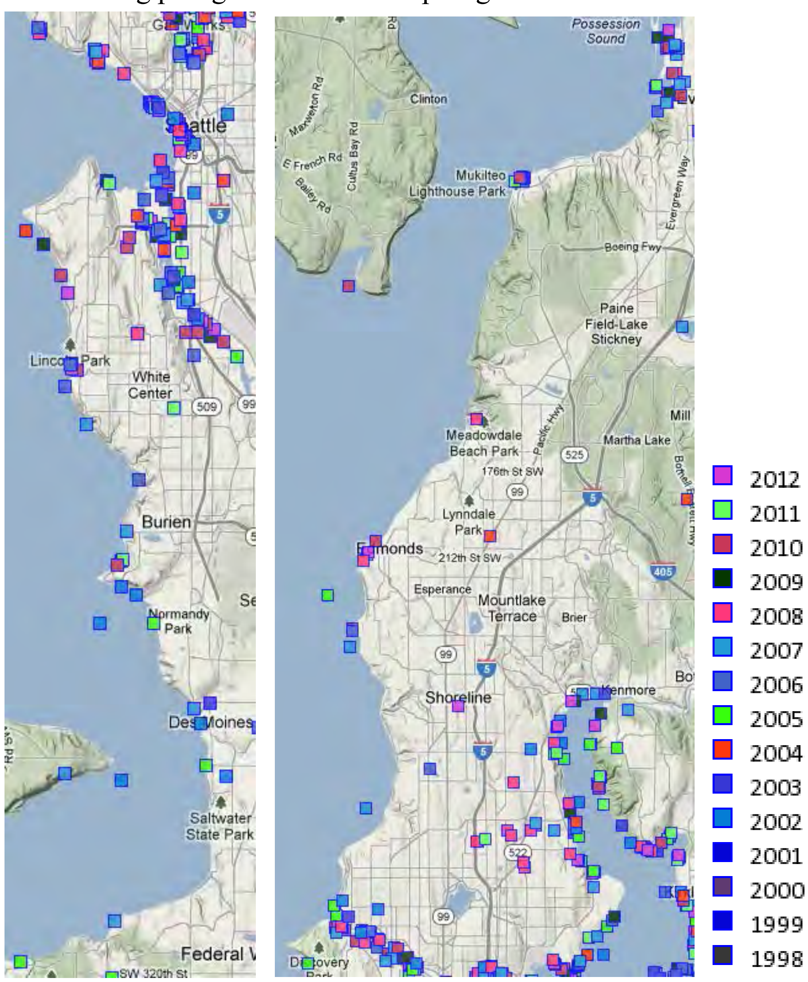


**Figure 5-7 Distribution of NWP #3 (Repair and Maintenance) within the study area from 1998-2012. The colored rectangles are locations where a nationwide permit was authorized and do not represent the size of the project area. Data Source: USACE ORM database.**

### *5.3.3. Individual Permit*

As identified above (Figure 5-4), 13% of the permits authorized were individual permits. Figure 5-8 and Figure 5-9 show the distribution of individual permits within the study area. The zoomed cut-out for Figure 5-8 is of the Port of Seattle (Elliott Bay and the Duwamish Waterway) and for Figure 5-9 is the Port of Everett (Port Gardner). Both ports are the most active areas for IPs. Individual permits in the ports can be for dredging, pier or marina construction and shoreline protection related work.

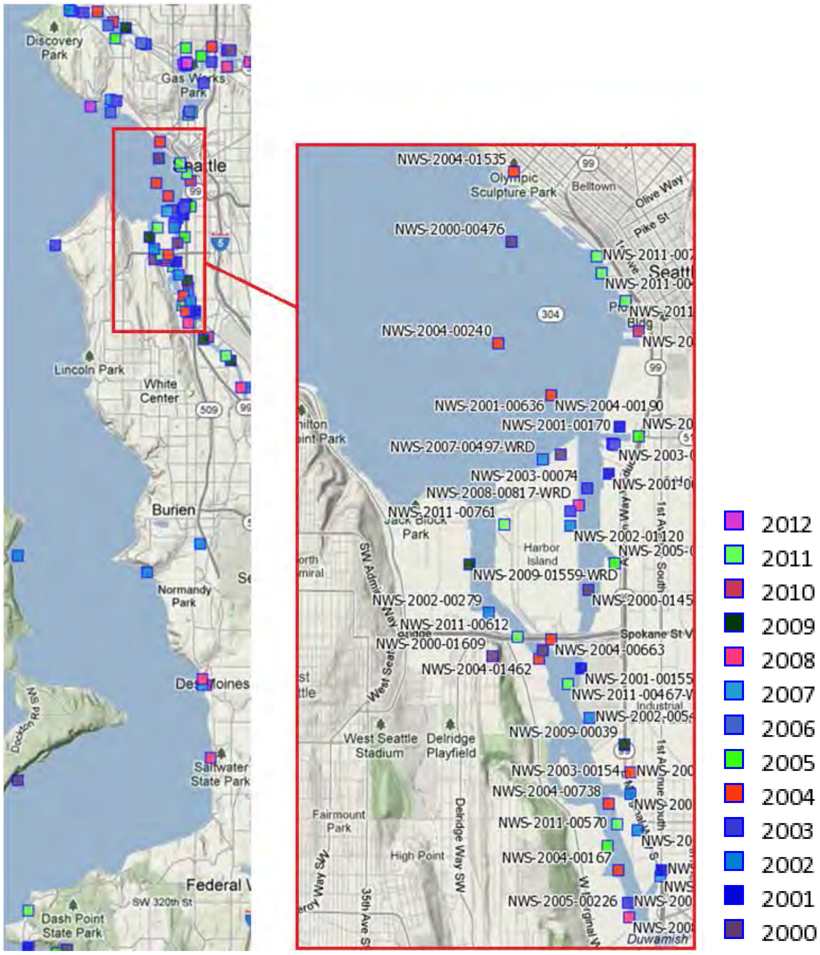


**Figure 5-8 Individual permits issued within the south portion of the study area during the last 13 years (2000 to 2012). The focus of this study is on the shoreline and within the two estuaries, therefore only permits within the study area were evaluated. Data Source: USACE ORM database. Each colored square is a permit issued at a specific location and does not represent the size of the project area. Note: Some squares may not be in the exact location of the project.**

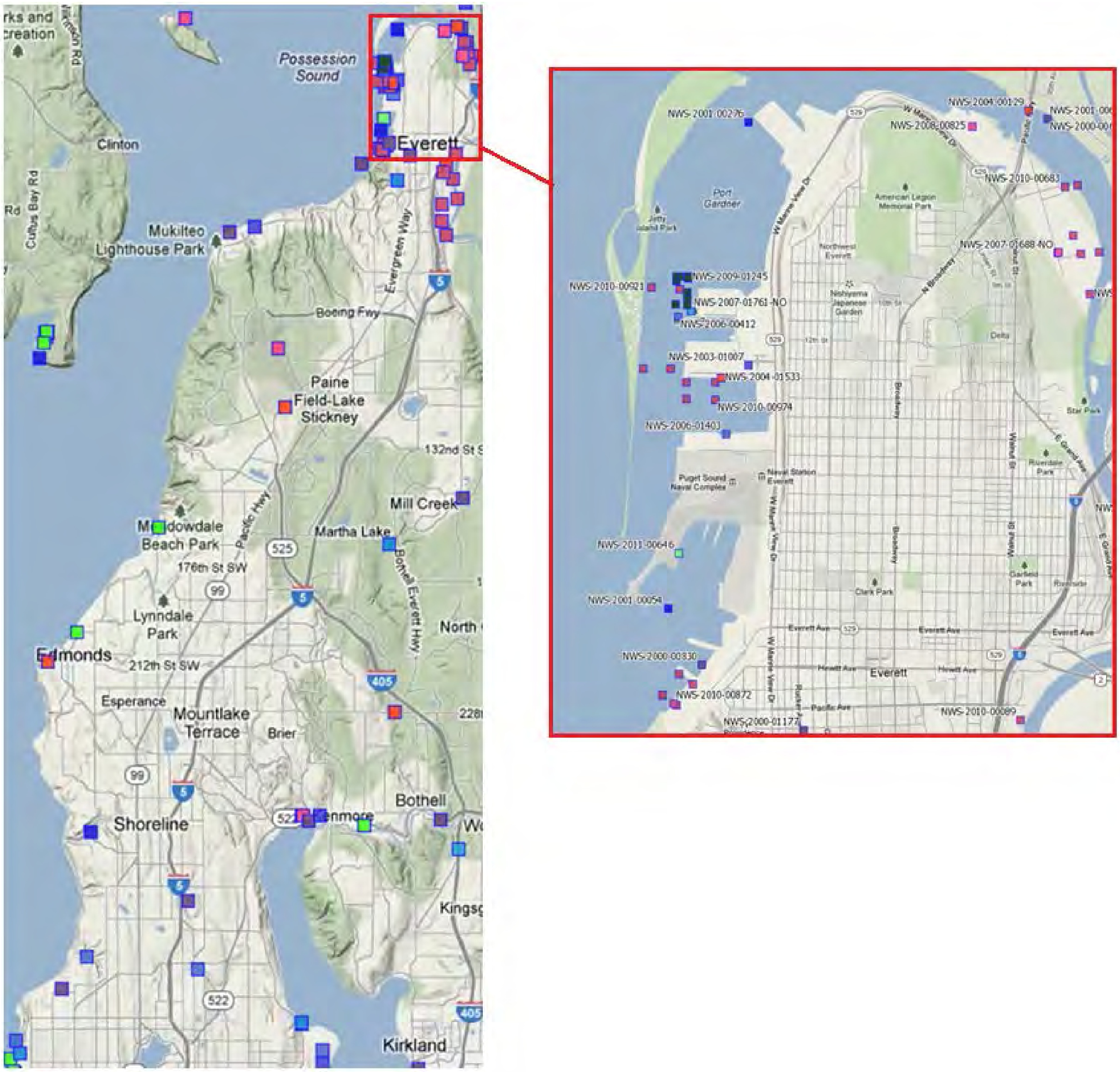


**Figure 5-9 Individual permits issued within the north portion of the study area during the last 13 years (2000 to 2012). The focus of this study is on the shoreline and within the two estuaries, therefore only permits within the study area were evaluated. Data Source: USACE ORM database. Each colored square is a permit issued at a specific location and does not represent the size of the project area. Note: Some squares may not be in the exact location of the project.**

## 5.4. Habitat Restoration

When preparing cumulative impact studies one of the most frequently asked questions is “How much habitat restoration is going on in the study area?” The implied question is this: “Is habitat restoration keeping pace with impacts to the aquatic system?” For this study we evaluated habitat restoration by identifying known restoration sites within the study area (Study Area Existing Conditions) and identifying the quantity and locations of NWP 27 from 1997-2011 (Figure 5-10). In the study area, a total of 28 NWP 27 were identified between 1998-2011. Ten of these occurred in the last 5 years. Many of these were small projects with the exception of several in the Snohomish estuary such as Spencer Island, Union slough and Qwuloot. This suggests that the total area of restoration (especially when considering historic loss) is substantially less than total loss of aquatic habitat.

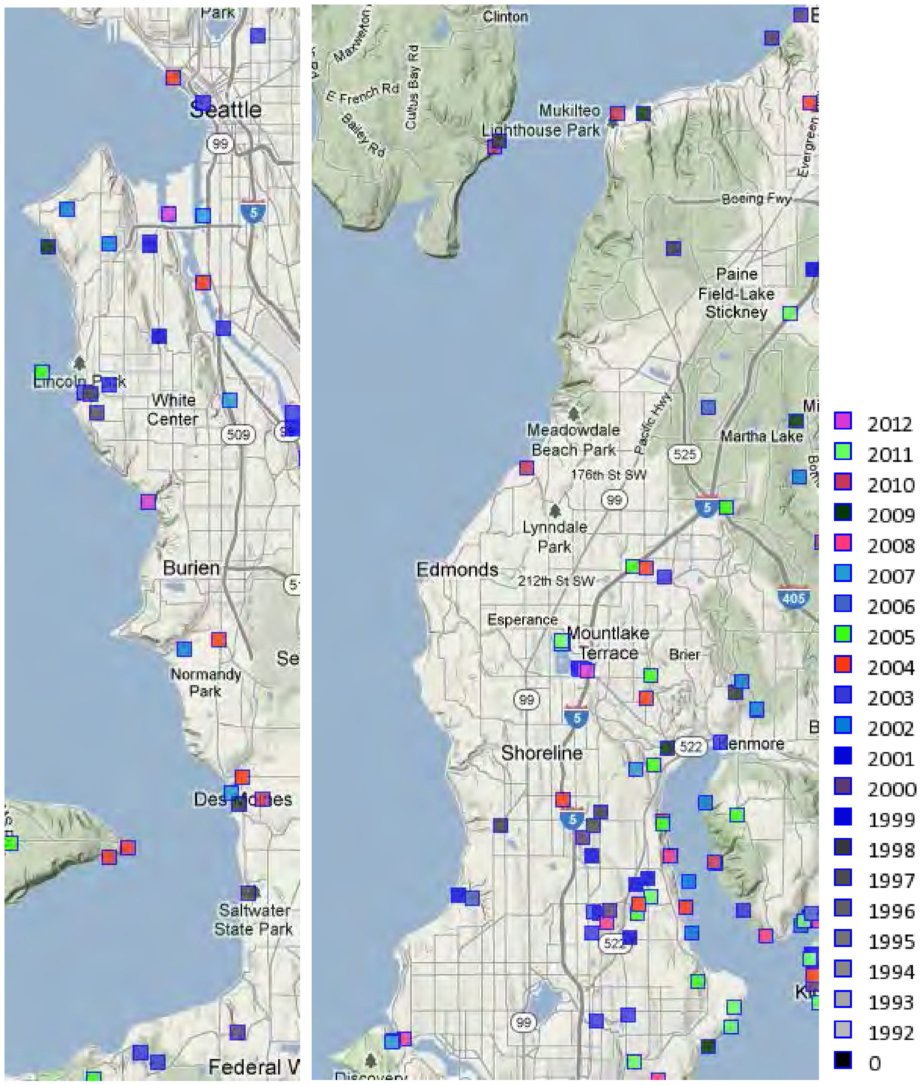


**Figure 5-10 Distribution of Nationwide Permit 27 (Aquatic Habitat Restoration) within the study area for the last 15 years (1997 to 2012). Note; the size of the rectangle does not relate to the area of restoration identified in the permit, they are just location markers. Data Source: USACE ORM database.**

## 5.5. Mitigation

Mitigation actions between 2002-2011 were assessed to determine the compensatory mitigation rate during that time. However, the context for compensatory mitigation changed in 2008 when USACE and EPA issued 40 CFR Part 230, Compensatory Mitigation for Losses of Aquatic Resources (Mitigation Rule). This rule codified the requirements for compensatory mitigation emphasizing a watershed approach and preference for mitigation banking and in-leiu programs over individual site mitigation. It established standards and criteria for mitigation requirements to improve the quality and success of compensatory mitigation projects for activities authorized by Department of Army permits. Neither the 2008 ruling nor the evolution of mitigation science and policy since then are fully reflected in the assessment because the permit review dates occur before and after 2008.

A total of 47 IP were recorded from 2002-2011 and ten were removed from this evaluation because they were for maintenance dredging which does not require compensatory mitigation. Of the remaining thirty-seven individual permits identified, five included compensatory mitigation actions. Two of these occurred in 2002 and 2003 and three occurred in 2008 and 2009. The only permit with impacts to tidal wetlands occurred in 2009. This is a 13.4% compensatory mitigation rate or about 1 in 4 individual permits resulting in one compensatory mitigation action.

Excluding permits that do not require mitigation(NWP 3, NWP 4, NWP 27, NWP 28, and IPs that involve maintenance dredging), the ratio of compensatory mitigation for all permit types is approximately 6%. The remaining actions, presumably, had implemented minimization and avoidance measures to reduce impacts.

## 5.6. Impacts from permitting within the study area

Another objective of the permit review was to identify impacts from the issued permits. Most impacts were characterized as either fill into "waters of the U.S" or excavation. For completeness, impacts were recorded here in the manner that shows up in the permit file (by volume or area) and the columns are not redundant. There are no trends evident regarding the amount of fill, excavation, dredging, or mitigation within or between years. The values shown in Table 5-2 show net impact over 10 years and supported identification of large projects in specific years within the study area that may have had a large impact. For example, in 2003, two projects contribute to fill and dredge amounts. In 2004 two dredging projects contribute to the amount of square feet of dredged. In 2005, the 15,000 cubic yards of fill was for a restoration project under NWP 27. In 2009, four projects (NWP #29, NWP#12, IP, and LOP) contributed to the amount of mitigation performed. In addition, three projects contributed to the 43,000 cubic yards of fill placed in non-tidal wetlands. Only one project contributed to the dredging amount in 2009.

**Table 5-2 Net impacts by year in the study area. One acre equals 43,650 square feet. Records assumed 1 cy or less of fill per linear foot of shoreline hardening.**

| | Amount of fill (c/y) | Amount of Fill (sq. ft) | Amount of excavation (c/y) | Amount of excavation (sq.ft.) | Dredgin g | Dredging sq. ft | Linear Ft. of Shore hardening ft. | Mitigation sq.ft |
|---|---|---|---|---|---|---|---|---|
| 2011 | 0 | 0 | 45 | 10,850 | 0 | 0 | 0 | 0 |
| 2010 | 0 | 0 | 95 | 2,028 | 10,192 | 69,200 | 85 | 400 |
| 2009 | 42,851 | 14,018 | 1,000 | 0 | 55,250 | 138,600 | 0 | 128,673 |
| 2008 | 4,658 | 0 | 1,450 | 0 | 36,780 | 27,443 | 725 | 2,894 |
| 2007 | 32 | 0 | 0 | 115 | 20,000 | 52,272 | 0 | 0 |
| 2006 | 933 | 19,733 | 430 | 8,973 | 5,000 | 0 | 0 | 0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2005 | 1,861 | 9,500 | 15,000 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 3,107 | 18,731 | 3,269 | 14,810 | 31,400 | 284,011 | 0 | 16,988 |
| 2003 | 244,318 | 80,375 | 0 | 0 | 361,930 | 396,396 | 0 | 191,664 |
| 2002 | 99,273 | 52,882 | 3 | 0 | 89,620 | 10,019 | 0 | 58,370 |

## 5.7. Dredging

Dredging is a common activity within the study area and is covered under RHA Section 10. In-water disposal of dredged material is covered under both RHA Section 10 and CWA Section 404. Both Elliott Bay and Port Gardner have large facilities to support marine commerce. There are also Federal navigation channels to aid marine transportation. Periodically, slips, berths and channels need to be dredged to facilitate commerce. Prior to any dredging activity, dredge material is screened to assure chemical and physical suitability for open water disposal. Table 5-3 shows dredge volumes, locations, and disposal sites for Federal dredging projects between 2007 and 2011. Approximately 1 million cubic yards of material were dredged in total, with approximately 350,000 cy disposed of in Elliott Bay and 650,000 cy disposed of at sites north of Elliott Bay.

**Table 5-3 Federal Dredge Volumes and Disposal Locations for Everett and Elliott/Duwamish subsections 2007-2011**

| Year | Location | Volume dredged/disposed (cy) |
|---|---|---|
| 2007 | Elliott/ Duwamish | 136,000 |
| 2009 | Elliott/ Duwamish | 60,000 |
| 2011 | Elliott/ Duwamish | 152,349 |
| 2007 | Everett | 75,000 |
| 2008 | Everett | 87,835 |
| 2009 | Everett | 52,302 |
| 2009 | Everett | 27,690 |
| 2010 | Everett | 329,594 |
| 2011 | Everett | 111,569 |

To accommodate private marine operations, non-federal entities such as ports, cities and private concerns also dredge. Table 5-5 shows dredge volumes and locations for Non-Federal dredging projects between 2007 and 2011. Approximately 224,000 cy of total material was dredged in total with ~105,000 cy from Subsection 3 – Elliott Bay and ~118,000 cy from Subsection 6 – Everett. Lastly, Table 5-5 shows 15 non-federal dredging projects with approximately 80,000 cy of material dredged from Subsection 3 – Elliott Bay and disposed of upland from 2007 to 2011.

**Table 5-4 Non- Federal Dredge Volumes and Disposal Locations for Subsection 3 – Elliott Bay and Subsection 4 – Duwamish Estuary and Subsection 6 – Everett for 2007-2011**

| Date | Project | Volume Dredged/ Disposed (cy) |
|---|---|---|

| | | |
|---|---|---|
| **Subsection 3 – Elliott Bay and Subsection 4 – Duwamish Estuary** | | |
| Jan. 2008 | Delta Marine | 6,924 |
| Feb. 2008 | Port of Seattle – Terminal 30 | 19,222 |
| Jan-Feb. 2008 | Port of Seattle – Terminal 91 | 10,768 |
| Dec. 2008-Feb 2009 | Port of Seattle – Terminal 30 | 20,133 |
| Jul. 2009-Feb. 2010 | City of Mercer Island Lake Line Replacement | 31,242 |
| Jan. 2009-Feb. 2010 | Delta Marine | 4,869 |
| Feb. 2011 | Boyer Towing Company | 2,076 |
| Aug. 2010 | City of Mercer Island Lake Line Replacement | 1,712 |
| Jan. 2011-Feb. 2011 | MJB Properties, Anacortes | 7,698 |
| Jan. 2011 | USACE Duwamish O&M "speedbump" | ~1,000 |
| **Subsection 6 – Everett** | | |
| Jan. 2007 | Port of Everett, 12th Street Marina | 4,400 |
| Nov. 2007- Feb. 2008 | Driftwood Key Club | 17,393 |
| Dec. 2008- Jan. 2009 | Port of Everett – South Marina Dock | 3,300 |
| Jun- Sept. 2008 | King County Wastewater Treatment Division Brightwater Outfall | 7,150 |
| Sept- Nov. 2009 | Port of Anacortes, Former Scott Mill Site | 19,671 |
| Jan- Feb 2010 | Port of Everett – 10th Street Boat Launch | 22,232 |
| Dec 2010-Feb. 2011 | City of Oak Harbor Marina | 44,196 |

**Table 5-5 Non-Federal Dredging with Upland Disposal 2007 to 2011**

| Year | Project | Volume Dredged/ Disposed (c/y) |
|---|---|---|
| 2004 | Lehigh NW – Duwamish | 3,000 |
| 2005 | Port of Seattle Fishermen's Terminal | 8,559 |
| 2005 | Port of Seattle Terminal 46 | 13,692 |
| 2006 | Port of Seattle T18 Stage 1A | 150 |
| 2007 | Port of Seattle T30 | 20,600 |
| 2007 | Shilshole Bay Marina | 430 |
| 2008 | Ashgrove Cement – Duwamish | 600 |
| 2009 | Tukwila Public Works | 40 |
| 2009 | Port of Seattle T115 | 3,000 |
| 2010 | Broadmoor Golf Club | <1,000 |
| 2010 | Fairweather Bay | <10,000 |
| 2010 | South Lake Union Park | ? |
| 2010 | Port of Seattle T5 | 6,390 |
| 2011 | Phillips Private Pier  Mercer Island | 520 |
| 2011 | South Park Bridge | 12,910 |

## 5.8. Comparison of Washington, Puget Sound and Study Area

Permit data for 2007-2011 in the study area, Puget Sound, and WA State were evaluated to identify the total number of permits completed in each area. A comparison of the total number of permits in the study area to those in both Puget Sound and Washington State was completed for 2007-2011 to identify if the study area had a disproportionate number of permits issued and whether the percentage of each permit type varied (Figure 5-11 and Figure 5-12). The study area represented an average about 6% of the total permits in Puget Sound, and less than 4% of all of Washington State permits for all years combined.

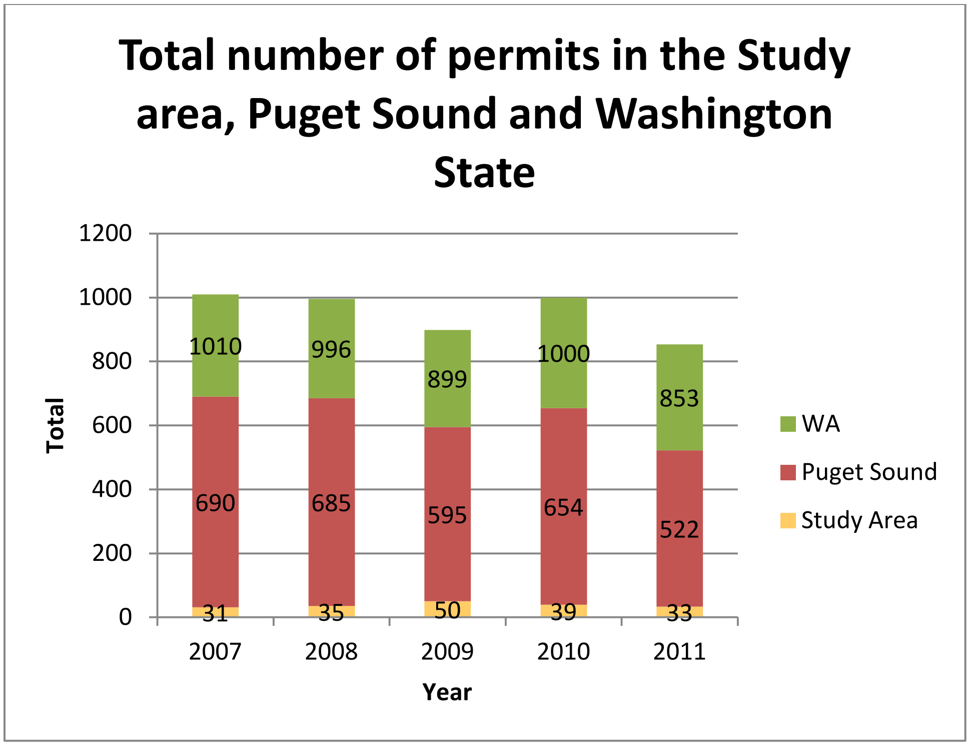


**Figure 5-11 The total number of permits awarded per year for the study area compared to the total number for Washington State and the Puget Sound permits.**

We then compared relative percentages of those permit types that made up the majority of the permits issued: IP, LOP, NWP3, NWP12, NWP13, NWP18, NWP27 (Figure 5-12).

- When summing permits by permit type for 2007-2011, 50-82% of all permits in WA were issued in Puget Sound. Approximately 1.5-7% of all permits in WA were issued in the study area.
- Puget Sound accounted for more than 50% of all NWP, IP and LOP issued in WA except for NWP 27 and NWP 13.
- LOP issued in the Puget Sound made up 82% of all LOPs issued in Washington State.
- Between 2007 and 2011 there were approximately half as many IPs issued as there was LOP issued in Puget Sound and Washington. However, in the study area this ratio was opposite; with approximately twice as many IPs issued than LOPs.
- NWP 3 (Maintenance) was the most frequently issued nationwide permit within all of Washington State and Puget Sound as well as within the study area. Approximately 7% of the total IPs in PS, were issued in the study area. It also appears that nationwide permit 27 (aquatic habitat restoration) has a low percentage of use (2%) in the study area compared to the rest of Puget Sound and Washington.

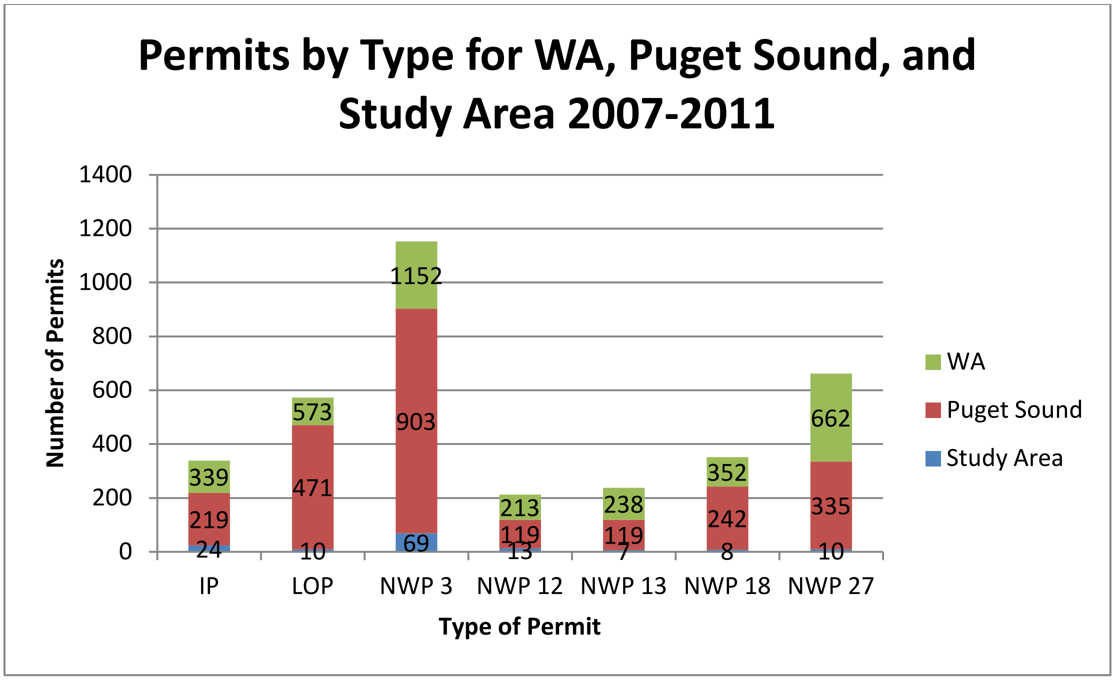


**Figure 5-12 Comparison of the more frequently issued permits by area. The number contained within the bag graph is the number of permits issued over a five year period.**

To determine relative differences among both number of permits issued and permit type, permit data was evaluated by county for 2007-2011. (Figure 5-13)

King County:

- Total number of permits issued in King County= 1003
- NWP 3 and LOP contribute most to the total number of permits
- NWP 3 equals 42% of permits issued
- LOP equals 22% of permits issued
- NWP 27 equals 11% of total permits issued

Pierce County:

- Total number of permits issued in Pierce County= 278
- NWP 3 and LOP contribute most to the total number of permits
- NWP 3 equals 32% of permits issued
- LOP equals 28% of permits issued
- NWP 27 equals 11% of total permits issued

Snohomish:

- Total number of permits issued in Snohomish County= 203
- NWP 3 and NWP 27 contribute the most to the total amount of permits

- NWP 3 equals 32% of permits issued
- LOP equals 3% of permits issued
- NWP 27 equals 25% of total permits issued
- 

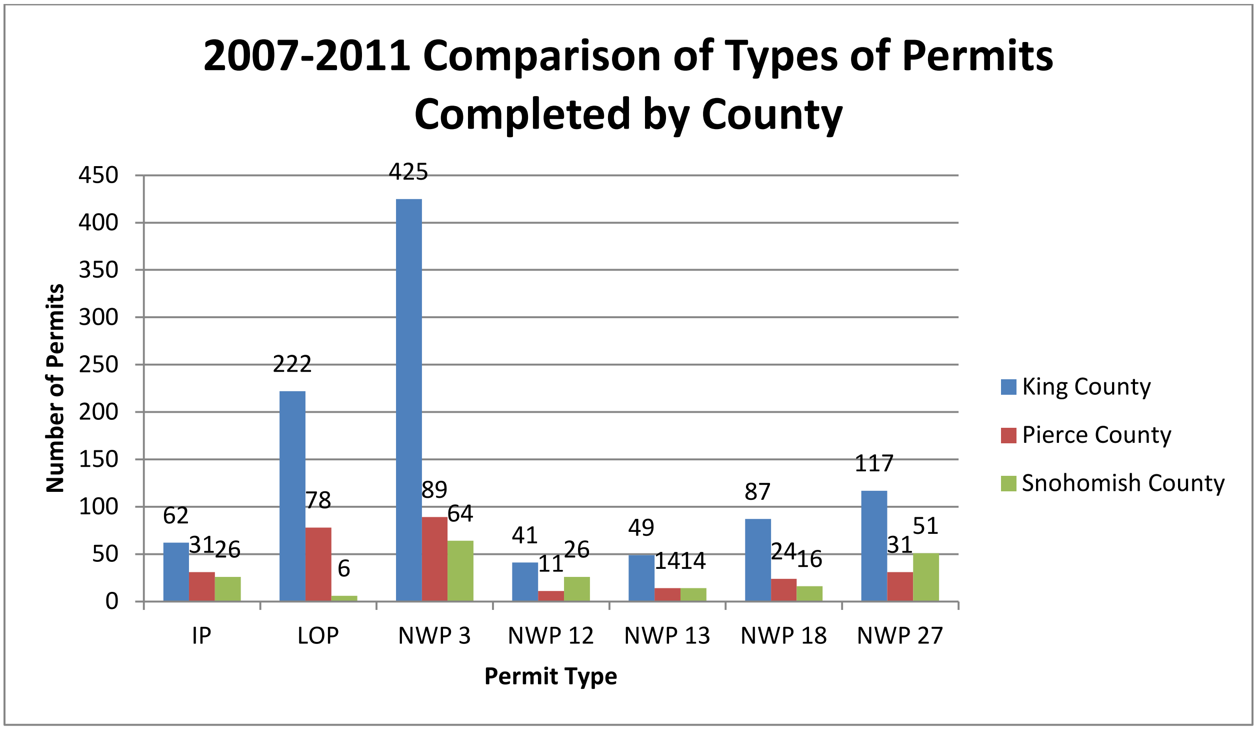


**Figure 5-13 Comparison of total number of permits and permit type by county for 2007-2011.**

## 5.9. Results Summary

Permits issued between 2002-2011 within the study area were evaluated to determine total number and type of permits issued. In addition, total number of permits in the study area were compared to the number and type issued in Puget Sound and Washington State. In all three areas, nationwide permit issuance exceeded that of individual permits.

When evaluating the number of NWP compared to IP/LOP used by state, PS, and study area, it was found that approximately 4 times as many NWP were issued as IP/LOP together.

In WA, the number of NWP (4292) completed between 2007 and 2011 was over 4 times the use of IP and LOP (1037). In PS, the number of NWP (2710) issued was 4 times the use of IP and LOP (690). In the study area, the number of NWP (129) issued was 4 times the use of IP and LOP (34).

The most frequently issued NWP by year or area was the NWP #3 (repair and rehabilitation). The other most frequently use NWP types were NWP 6, 12, 18, 27.

There were seventeen NWP13 (bank stabilization) issued in the study area during the 14 years of database results and nine within the 10 years (2002-2011) that were evaluated.

Individual permits in support of marine commerce and especially dredging are used most frequently in the two Port areas (Seattle and Everett).

While approximately 72% of the study's shoreline is armored there were relatively few NWP 13 (bank stabilization) issued during the 10 years of evaluation. This study was not able to discern whether bank stabilization work was above MHHW and not under USACE jurisdiction, was accomplished under an unknown permit in years prior to CWA implementation, or was accomplished without obtaining a permit. The high percentage of existing bank stabilization but few NWP 13 permits identified is most likely a result of a combination of these three.

Of the total number of permits evaluated, the Port of Seattle received 10% and the Port of Everett received 4%, with the Washington State Ferries and Burlington Northern Santa Fe Railroad each receiving 2% of the total permits evaluated.

# 6. Summary

Multiple authors have described the role of disturbance in species resilience and persistence in various ecosystems and the role of large-scale disturbance on total ecosystem resilience (Ruckelshaus and McClure, 2007; Bernhardt and Leslie, 2013; Westman, 1978). The observed loss of physical areas such as wetlands and subsequent diminished functions such as flood control, water quality, and habitat coupled with declining or changing species trends demonstrates a potential loss of ability within the study area and the Puget Sound ecosystem to recover from additional or ongoing impact even when those impacts are considered to be local. Ecosystem resilience is based upon ecological diversity, connectivity, and adaptive capacity, all of which we have shown to be affected by the land use changes described. For example, a lack of connected shoreline habitat limits the ability of species and populations of aquatic resources to recover from disturbance by affecting physical attributes such as sediment movement, nutrient load, water temperature, and food sources; a low diversity of species and habitats limits the variety of responses available to overcome disturbances and; fewer species and habitats affects the ability for adaptive capacity such as shifting species ranges. This study attempted to determine if there are cumulative impacts to the aquatic environment in the study area based on a 'weight of evidence approach'. Multiple primary and secondary lines of evidence described in detail in earlier sections of the report identified trends that can be used to make general statements about cumulative impacts to valued resources in the study area.

The body of literature reviewed and analyses undertaken for this study describes large-scale loss of estuarine and marine aquatic sites and riparian areas, degraded water quality, increasing road density and impervious surface, and land fragmentation. Few long term datasets are available to assess effects on biological resources over the timeframe used for the land use changes, but those that were available along with more recent research suggests significant effects have occurred on aquatic resources in the study area.

Estuarine and marine special aquatic sites play a pivotal role in maintaining the health and diversity of the aquatic ecosystem in the Pacific Northwest. Estimates of wetland and special aquatic site losses and alteration described herein, resulted from time-crowded disturbance, space-crowded disturbance, synergistic effects, nibbling, and indirect effects. Functions associated with the disturbed habitats were also lost, changed, or diminished. Continued loss of the remaining wetlands and special aquatic sites and diminished functions, habitats, and species associated with them is expected based on the predictions of population increase and associated land conversion. The ESA listing of multiple species of salmon and trout, including those strongly associated with wetlands (i.e., chum and ocean type Chinook) and other special aquatic sites, suggests that large-scale loss of these types of habitat is a significant factor in limiting the diversity, abundance, and distribution of marine species that are dependent upon them. Table 6-1 shows the dates of ESA listings of species located in or near the study area and that share the same aquatic resources. For example, Southern resident killer whales feed primarily on Chinook salmon and marbled murrelets are predominantly fish eaters.

**Table 6-1 ESA listed species in or near the study area**

| Endangered species | Status | Year listed |
|---|---|---|
| Marbled murrelet | Threatened | 1992 |
| Puget Sound Bulltrout | Threatened | 1999 |
| Puget Sound Chinook | Threatened | 1999 |
| Southern resident killer whale | Endangered | 2005 |
| Puget Sound steelhead | Threatened | 2007 |
| Yelloweye rockfish | Threatened | 2010 |
| Bocaccio | Threatened | 2010 |
| Canary rockfish | Threatened | 2010 |

While wetland and other special aquatic site loss is not the sole reason for diminished fisheries in the study area many authors agree it plays a significant role in the abundance and diversity of fish strongly associated with wetlands (Tanner et al. 2002; Pess et al. 2002; May and Horner 2000). The significant loss of Duwamish and Snohomish estuarine habitat show that these areas no longer sustain many species at previously documented levels. In the Snohomish estuary Pess et al. (2002), demonstrated that stream reaches with unaltered wetlands had adult coho salmon densities that were 2 to 3 times greater than reaches with altered wetlands. There are few un-altered stream reaches in the lower Snohomish estuary. Additionally, with little to no pristine habitat remaining, the estimated average survival rate (for juvenile Chinook-) is 0.5%, while the estimated survival in total pristine estuaries is more than three times higher, 1.77% (Magnusson and Hilborn 2003). Certainly a case could be made for the Duwamish Estuary having little if any pristine habitat remaining, putting it close to the 0.5% juvenile survivor rate which is approximately 1/3rd of the survival rate estimated for conditions that occurred prior to 1870.

Historically, areas such as the Duwamish and Snohomish that included extensive wetlands also had extensive forested riparian areas that have been gone for many years. Evidence of primary and secondary impacts which result in cumulative effects occur along the ecotone between the upland and the tidally influenced nearshore. A decrease or loss of vegetation in the riparian zone results in multiple effects such as mortality to surf smelt eggs in the marine intertidal zone from loss of thermal refuge and a decrease or loss of food web support to the marine environment due to removal of terrestrial insects that can provide 50% of the food used by salmon and possibly other species as well. Secondary effects include increased probability of landslides due to decreased slope stability from lack of vegetation, and loss of nearshore habitat from reduced large woody debris input. Riparian area loss is an example of a "nibbling" or small, incremental change that occurs over time and results in impacts to the aquatic environment. The extent of effect at a regional scale is indicated by the average of 91% loss of historic riparian habitat in the study area.

Water quality is generally a good indicator of ecosystem health and within the study area there is evidence of direct and secondary impacts to water quality in the area. Water quality degradation is pervasive throughout the study area both along the marine shoreline and in streams as evidenced by 303(d) listings. For example, beaches within the study area are often restricted for swimming and shellfish harvesting. Based on the State Department of Ecology 303(d) listings, water quality appears the most degraded in the Elliott Bay and Duwamish subsections as well as the southern portion of the study area. There is also a large-scale, increasing nutrient trend over the last ten years as evidenced by the Marine Water Condition Index (WA Department of Ecology May 2012) consistent with other large estuaries in the United States. Another indicator of poor water quality can be found in the persistent toxic algal bloom found along the shoreline of the study area.

As roads and impervious surface increased in the study area, historical habitats (wetlands, forests, riparian areas) decreased in size and their associated functions diminished. Urbanization is the cause most frequently cited for most of the impacts and what little remains of the historical natural landscape is no longer able to provide functions such as buffering runoff. Stream hydrology and the loss of infiltration of groundwater has also altered the amount and timing of water delivered to the stream network. It appears that all of these changes have had a serious impact on aquatic species dependent on these streams. Coho salmon in several of the streams in the study area are dying at a rapid rate. It appears these indirect effects are synergistic in nature. The cause appears to be large scale conversion from historic habitats such as forests and wetlands to urban land use that may no longer provide the resiliency needed to maintain valued resources.

Birds are also sensitive to landscape fragmentation, landscape composition and change in habitat structure and DeLuca et al. (2004) found that a level of between 10 to 20% of disturbance affected ecological integrity in Chesapeake Bay. The authors concluded that urban effects had a pronounced negative effect at the local scale on wetland bird assemblages. De Luca also noted that disturbances in close proximity to wetlands provides habitat for an abundance of generalist birds such as gulls, crows, starlings, house sparrows which are capable of invading the marsh and increasing interspecific competition with native marsh birds for available resources. Data from a 1979 Marine Ecosystem Analysis was evaluated and compared to 1990 to 2008 aerial surveys conducted under the Puget Sound Ambient Monitoring Program. The comparison demonstrated that 19 of the 30 most common bird species observed in the MESA study had declined by 20% or more in the PSAMP study, and 11 species had population densities increase by 20% or more. Rice (2007) used the same PSAMP data to demonstrate that ”diversity in marine birds and waterfowl assemblages generally declined throughout Puget Sound between 1993 and 1996 in the summer and between 1993 and 2003 in the winter”. He went on to show that differences in assemblage composition were apparent along urban shoreline gradients throughout Puget Sound including the study area. Rice illustrated that four urban marine species (mainly gulls, cormorants, crows, and geese) comprised 90% of the population while in less urban areas, 8 different assemblages of birds (shorebirds, divers, dabblers, loons ect) comprised 90% of the population. In the urban setting, birds in the marine environment were typically species associated with humans or introduced species. This same theme was again demonstrated on the Duwamish where a four year study of restored habitats demonstrated impacts that showed a similar effect between disturbance and the increase in generalist or human associated species (Cordell et al. 2001). Lastly, analysis of a 50 year dataset of completed during this study concluded that 9 of the 13 species of marine birds evaluated declined from historical numbers (Appendix C).

Similar to the declining fishery trends previously discussed, not all of the reduction in diversity and abundance of birds can be tied solely to loss of habitat. However, habitat loss and land use conversion does significantly affect bird density and abundance. Richter and Azous (2001) noted that wetlands are critical habitat for birds in the Puget Sound Basin and that 82% of the species identified in western Washington State are found in wetlands.

Consequences of habitat loss and landscape fragmentation on biodiversity have been identified in the literature and Harris (1988) identified four categories of impacts to biodiversity:

- Loss of wide ranging species, especially top carnivores. Aquatic migratory forms (such as fish) which are vulnerable to obstacles to migration, are particularly sensitive.
- Loss of area-sensitive or interior species that only reproduce in the interior of large tracts of wetland and are therefore vulnerable to reduction in size of the individual component wetlands as well as reduction in total wetland acreage. Bitterns and rails may be good examples of these species.
- Loss of genetic integrity from within species or populations that inhabit areas too small for a viable population of individuals.
- Increase in abundance of generalist species characteristic of disturbed habitats.

Urbanization displays many of the standard forms of cumulative impacts such as time-crowded disturbances, nibbling, and synergistic.

Table 6-2 assigns a scale, intensity, and permanence rating to the major study area changes described in earlier sections to better understand the implications of those changes. As shown, the initial impact scale of a single action is often considered to be local at the time of occurrence; however, these impacts can become regional or cumulative over time and space (the total effect of an action on a resource when considered in conjunction with effects of other human activities). Additionally, the magnitude, extent, and frequency of an activity on a resource can affect the scale of impact and permanence. For example, the documented large-scale loss of wetlands in the study area over the last 100 years is likely an irreversible impact because it is unlikely that sufficient acreage can be found to restore the same amount of wetlands. Similarly, loss of a specific run of salmon may be considered a local impact, but when multiple local runs are lost, the scale can become regional and potentially long-term or irreversible. In particular, several authors describe changes in physical shoreline conditions as a primary influence on local habitats and species (Rice 2007, Shipman et al. 2010) and understanding the cumulative nature of the impacts being considered for an individual action may support management measures that reduce the scale of impact.

The scale of impacts are rated as follows for the initial action (construction) and long-term impacts measured post-construction: (L) impacts measured at project level (i.e., dike installation); (R) impacts measured at a regional level (study area or Puget Sound) (i.e., reduction of nearshore sediment input due to shoreline hardening); (G) impacts measured at a global level that are likely to be persistent (i.e., ocean acidification); (C) spatial or temporal cumulative impacts (i.e., loss of forested riparian areas such that valued species such as surf smelt are reduced affecting salmonid populations.)

The intensity of impacts is defined as the magnitude, geographic extent, and frequency of effect as follows: (H) high (shoreline hardening requiring regular maintenance in an area with degraded salmonid habitat); (M) medium (activities that result in regular disturbance of a valued habitat such as forested riparian areas); (L) low (single, small-scale, short-term action that does not result in impacts to functions, habitat, or species except during construction. For example, replacement of decking on a pier or road installation where impervious surface previously existed.) Permanence of an impact is rated as a follows: (T) temporary or short duration (changed stream location due to construction activities followed by replacement to original location); (L) long-term duration denotes effects that may diminish over time or for which mitigation may occur (increased sedimentation due to altered hydrology); (I) impacts that are permanent (loss of sediment input to nearshore areas due to railroad or road installation that affect multiple resources over time).

**Table 6-2 Scale, intensity, and permanence of identified effects in the study area**

| Resource affected | Scale of initial impact | Current scale of impact | Intensity | Permanence | Disturbance mechanism |
|---|---|---|---|---|---|
| Alteration of sediment distribution in the nearshore. Loss of sediment input from feeder bluffs. Lack of accretion in nearshore limits habitat size and availability. | L | R, C | M | L | Water diversion, dams or structures such as marinas that cause physical alterations in the nearshore. Many of the major sources of disturbance have been in place for more than 50 years. |
| Change in abundance of fish (primarily Chinook and chum). ESA listing of fish and mammals | L | R, C | H | L | A variety of mechanism for this including habitat loss (filling and excavation), blockages, water diversion or withdrawal, etc. Loss of estuarine wetlands resulting in reduced feeding and rearing opportunities. |
| Change in abundance of marine birds | L | R | M | L | Filling or isolation of intertidal habitat, loss or reduction of food resources, increased disturbance. |
| Loss or reduction of fish prey resources | L | L, R, C | H | L | Hardening of the bankline affects prey resources for fish. Loss of fringing vegetation and thermal refuge. |
| Reduced water quality. | L | R,C | H | T, L | Change in hydrology, alteration of ground water or surface water, increase in impervious surface. Filling or excavation of wetlands and vegetated buffers, increase in sedimentation, road density and impervious surface, ocean acidification. |

| Resource affected | Scale of initial impact | Current scale of impact | Intensity | Permanence | Disturbance mechanism |
|---|---|---|---|---|---|
| Loss of forested riparian areas | L | R,G, C | H | I | Harvesting of trees and other resources and replacement with industrial, agricultural or residential development. Impacts to surf smelt spawning. Average loss of over 90% forest cover in the study area. |
| Wetland loss | R | R,C | H | I | Filling, excavation, diking. |
| Shoreline armoring | L | R, C | H | L | Shoreline hardening at multiple elevations mainly for protection of property. |
| Change in land use/urbanization | L | G, C | H | I | Relatively rapid change from timber and agriculture prior to WWII and then increasingly Urban impacts after the War. |

The habitats regulated under CWA Section 404 and Section 10 of the Rivers and Harbors Act are directly linked to the resource impacts discussed above. Detailed review of ten years of USACE permit applications revealed the number and type of applications and identified some trends within the study area, Puget Sound, and the state of Washington. For example, nationwide permits are used about four times as much as individual permits, the most frequently issued permit was nationwide permit #3 for repair and rehabilitation of existing structures, approximately 14% of the permits were issued to the Ports of Seattle or Everett, and nine NWP13 for bank stabilization were issued in the study area during the 10 years of permit data reviewed. Lastly, the urban nature of the study area consequently leads to frequent use of nationwide #12 (utility work) to maintain existing structures. Stein and Ambrose (1998) summarized reviews of USACE permitting effects on wetlands in a variety of states including Washington and concluded that wetlands are typically lost or modified as a result of CWA 404 permitting and that the landscape replaced by mitigation does not always provide similar capacity for flood control, habitat, or other functions that may be lost. A similar review of USACE permit database for the study area revealed that of 188 permit actions between 2007-2011, 11 identified impacts associated with tidal and non-tidal wetlands and water resource types (seven of these occurred in 2009). Five permits required compensatory mitigation and three of the permits impacting wetlands did not based on scale or type of impact. No permits with wetland impacts were identified in 2011 (through July). As noted previously, these results likely reflect the 2008 mitigation ruling and subsequent evolution of compensatory mitigation science. Restoration of 688 acres of wetland and 1360 linear feet of wetland buffer occurred under NWP 27 (Aquatic Habitat Restoration, Establishment and Enhancement Activities) issued in the study area. Permitted actions between 2007-2011 impacted approximately 1.21 acres of wetland and 3070 linear feet of wetland buffer, and compensatory mitigation for these actions restored or rehabilitated approximately 3.57 acres.

## 6.1. Conclusions

To date, the ability to clearly identify cumulative impacts at a scale at which management measures can be assigned has been elusive. Therivel and Ross (2007) suggest that cumulative effects assessment must occur on a scale that will allow identification of the management opportunities available to deal with the impact identified. However, the availability of management actions or the limitations of the program completing the effects assessment and the ultimate outcome on valued resources also drive the scale at which impacts will be assessed.

Nearly all of the evidence reviewed herein show that the study area has been impacted such that the ability to rebound is limited, especially for some impacts such as wetland loss. The multiple lines of evidence reviewed or assessed provide the following results that describe the degree to which they support this conclusion:

- Wetlands and Special Aquatic Sites: Approximately 80% loss of Snohomish and 98% loss of Duwamish estuarine habitat has occurred.
- Impervious Surface: An increasing trend in impervious surface occurred within all of the subsections over the 55 year period of analysis. The entire study area exceeds the documented 10% threshold of concern stated in Booth and Jackson (1997).
- Landscape Fragmentation: In all subsections of the study area at the landscape level, patch area decreased and patch density and edge density increased over the 55 year period of analysis. There remains a deeply fragmented landscape dominated by high and medium level development with hardening of over 72% of the shoreline.
- Salmon and Trout: All Puget Sound Chinook salmon populations are below planning ranges for recovery escapement levels. Most populations are below the spawner-recruit levels consistent with recovery. Most populations have declined in abundance since the 2005 status review, and trends since 1995 are mostly flat. Overall, new information on abundance, productivity, spatial structure, and diversity since the 2005 review does not indicate a change in the biological risk category. This includes PSM identified in multiple streams and shoreline areas within the study area.
- Water and Sediment Quality: Multiple creeks and marine shoreline areas in the study area display degraded water and sediment quality. There is restricted shellfish harvest on any beach on the eastern shores of Puget Sound between Everett and Tacoma. Sediment quality results included increased severity and spatial extent of sediment toxicity and an increase in adversely affected benthic invertebrate communities.
- Marine Birds: Three studies identified declining densities or assemblage changes in marine bird populations through Puget Sound as follows;
- Of the 30 most common bird species observed in the MESA study, 19 had declined by 20% or more in the PSAMP study, and 11 species had population densities increase by 20% or more.

- Marine bird diversity and waterfowl assemblages declined throughout Puget Sound between 1993 and 1996 in the summer and between 1993 and 2003 in the winter.
- Differences in assemblage composition were apparent along urban shoreline gradients throughout Puget Sound including the study area.
- Four urban marine species (mainly gulls, cormorants, crows, and geese) comprised 90% of the population while in less urban areas, 8 different assemblages of birds (shorebirds, divers, dabblers, loons etc.) comprised 90% of the population.
- On the Duwamish River, an increase in generalist or human associated bird species were correlated with increased disturbance (Cordell et al. 2001).
- Nine of the 13 species of marine birds evaluated declined from historical numbers based on analysis of a 50 year dataset.
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