CHAPTER 1

The Columbia River Estuary and Plume

Purpose of the Estuary Recovery Plan Module

This estuary recovery plan module is intended to complement other recovery plans in the region. With few exceptions, the module's focus is limited to habitat conditions and processes in the Columbia River estuary and plume, rather than hatchery or harvest practices, hydroelectricity production, or tributary habitats in the Columbia River basin. The purpose of this estuary recovery plan module is to identify and prioritize habitat-related management actions that, if implemented, would reduce threats to salmon and steelhead in the Columbia River estuary and plume. This was accomplished by reviewing and synthesizing current literature and gaining input and guidance from area experts, including staff at NOAA/NMFS's Northwest Fisheries Science Center.

The estuary recovery plan module identifies and prioritizes habitat-related salmon and steelhead limiting factors (see Chapter 3) and links them to the underlying environmental and human threats that have contributed to declines in abundance in the estuary (see Chapter 4). Threats are prioritized based on the priority of the limiting factors they contribute to and their relative contribution to those limiting factors. Management actions that have potential to reduce threats are identified in Chapter 5 and evaluated in terms of their implementation constraints, potential benefits, and costs. In Chapter 7, these factors are integrated to help characterize a scenario for improving the survival of salmonids as they rear in and migrate through the estuary, plume, and nearshore.

This estuary recovery plan module has important relationships to other planning processes and documents. In the context of Columbia River basin recovery planning, the estuary module provides information on how conditions in the estuary and plume affect the 13 listed Columbia Basin evolutionarily significant units (ESUs). It has been distributed in draft form to recovery planning forums around the Columbia River basin, and presentations on the module have been made to Oregon's Mid-Columbia Sounding Board, the Upper Willamette Recovery Planning Stakeholder Team, and the Oregon Lower Columbia River Recovery Planning Stakeholder Team.

In the context of lower Columbia River management plans, the estuary recovery plan module is consistent with information in the Northwest Power and Conservation Council's "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan" (in *Columbia River Basin Fish and Wildlife Program*, Northwest Power and Conservation Council 2004), the Lower Columbia River Estuary Partnership's *Comprehensive Conservation and Management Plan*, and the Columbia River Estuary Study Taskforce's Columbia River Estuary Data Development Program. In addition, other ongoing planning processes are using information from the estuary module to varying degrees; these include the Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) remand collaborative process and activities of the Lower Columbia Fish Recovery Board and Lower Columbia Stakeholders Group.

The process of identifying and prioritizing management actions in the estuary module has inherent difficulties. Although scientific knowledge about the estuary is advancing, it is still incomplete. In addition, effective management solutions must acknowledge irreversible changes in estuary conditions over time, reflect the social and political will of the region, and focus on the biological and physical needs of the fish. In the final analysis, it is likely that science will never fully explain how every action affects the viability of fish. It will be up to current and future residents of the basin to determine how much they are willing to pay or do without in order to return salmon and steelhead to viable levels.

Formation and Current Characteristics of the Estuary

The geographic scope of the estuary recovery module encompasses areas from Bonneville Dam (River Mile [RM] 146) to the mouth of the Columbia River, including the Columbia River plume and littoral cell. Tributaries entering the estuary are referred to for context only, as they are treated in other planning efforts, such as the Lower Columbia Fish Recovery Board's *Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan* (2004) and Oregon's Lower Columbia River recovery planning process.

The Columbia River estuary is a former river valley that, during the last ice age, was carved to 110 meters below current sea level. As sea levels subsequently rose, the floor of the valley was submerged and began to fill with sediments—initially from eastern drainages and then from the Cascade Range. The Missoula Floods, which occurred roughly 15,000 to 13,000 years ago, filled the valley with sand. This was followed by rapid sea level rise, which increased the size of the estuary and allowed further accumulation of mud and sand. By about 9,500 years ago, the rate of sea level rise had declined, the former river valley had filled with sediments, and most suspended sediment and bed load sand arriving from the Columbia River were being transported through the estuary to marine areas via the action of ebb tides and spring freshets, with some suspended sediment being deposited in floodplains and peripheral bays. This pattern continued to the historical period (Petersen et al. 2003).

The historical (circa 1880) total surface area of the Columbia River estuary has been estimated at up to 186 square miles (Thomas 1983, Simenstad et al. 1984 as cited in Northwest Power and Conservation Council 2004). The current estuary surface area is approximately 159 square miles (Northwest Power and Conservation Council 2004). The Willamette River is the largest tributary to the lower Columbia River. Other major tributaries originating in the Cascade Mountains include the Sandy River in Oregon and the Washougal, Lewis, Kalama, and Cowlitz rivers in Washington. Coastal range tributaries include the Elochoman and Grays rivers in Washington and the Lewis and Clark, Youngs, and Clatskanie rivers in Oregon. The general geography of the estuary is shown in Figure 1-1.

Tidal impacts in water levels are observed as far upstream as Bonneville Dam at RM 146. During low flows, reversal of river flow has been measured as far upstream as Oak Point at RM 53. The intrusion of saltwater is generally limited to Harrington Point at RM 23; however, at lower daily flows saltwater intrusion can extend past Pillar Rock at RM 28.

Today, the lowest river flows occur during September and October, when rainfall and snowmelt are lowest (Northwest Power and Conservation Council 2004). The highest flows occur from April to June and result from snowmelt runoff. High flows also occur between

November and March and are caused by heavy winter precipitation. Discharge at the mouth of the river currently ranges from 100,000 to 500,000 cubic feet per second (cfs). Historically, unregulated flows were both lower and higher—79,000 and 1 million cfs, respectively (Neal 1972 and Lower Columbia River Estuary Partnership 2002 as cited in Northwest Power and Conservation Council 2004).

Estuary Reaches

For the purposes of this estuary recovery plan module, the estuary is broadly defined to include the entire continuum where tidal forces and river flows interact, regardless of the extent of saltwater intrusion (Fresh et al. 2005, Northwest Power and Conservation Council 2004). For planning purposes, the upstream boundary is Bonneville Dam and the downstream boundary includes the Columbia River plume. These two divisions—the estuary and plume—have been used extensively in this estuary recovery plan module as distinct zones. Further delineation of the estuary has occurred, including efforts by Thomas (1983), Johnson et al. (2003), and—more recently—the Lower Columbia River Estuary Partnership (2005).

FIGURE 1-1
The Columbia River Estuary and Its Major Tributaries
(Reprinted from Bottom et al. 2005.)

In this estuary recovery plan module, limiting factors, threats, and management actions are identified at the finest reach level possible. In some cases, this may be as general as making a distinction between the estuary and plume. In other cases, additional definition is available at the reach scale. The Lower Columbia River Estuary Partnership, in conjunction with the University of Washington and U.S. Geological Survey, has developed and is continuing to refine several estuary landscape classifications. Of these overlaying classifications, the estuary recovery module uses the Level 3 Stratum, which organizes the estuary between the mouth and Bonneville Dam into eight lettered reaches (Lower Columbia River Estuary Partnership 2005).

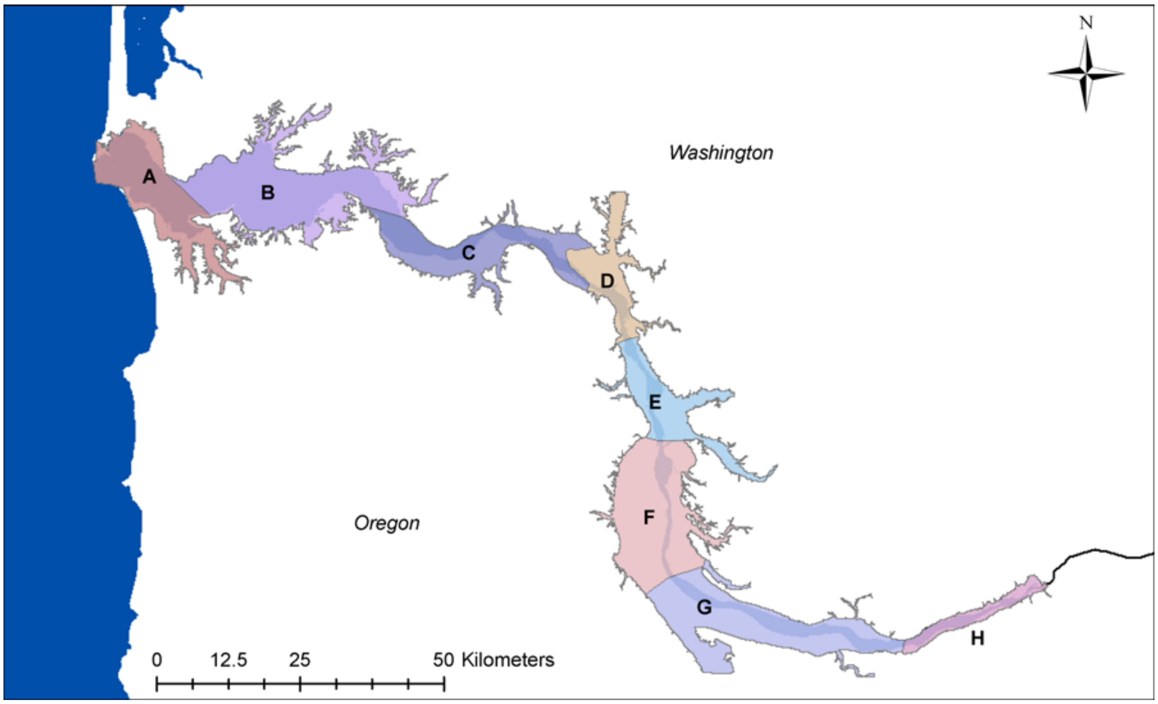

FIGURE 1-2
Lower Columbia River Estuary Reaches
(Reprinted from Northwest Power and Conservation Council 2004.)

Figure 1-2 shows these eight reaches, which can be described briefly as follows:

- **Reach A**. This area includes the estuary entrance (Clatsop Spit and Trestle Bay), Bakers Bay, and Youngs Bay. The entrance is dominated by subtidal habitat and has the highest salinity in the estuary. Historically, the estuary entrance was a high-energy area of natural fluvial land forms with a complex of channels, shallow water, and sand bars. Reach A supports the Columbia River plume, which creates a unique low-salinity, high-productivity environment that extends well into the ocean. The dynamic nature of the entrance area has changed as a result of dredging and the construction of jetties. These activities have limited wave action and the marine supply of sediment.

  Historically, ocean currents and wave action made Bakers Bay a high-energy area, but both currents and wave action have been altered by dredging and jetty construction. The migration of mid-channel islands toward the interior of Baker Bay also has sheltered the area from wave action. As a result, tidal marsh habitat has recently started to develop in some areas, although much of the historical tidal marsh and tidal swamp habitat has been lost because of dike construction in the floodplain. Given its proximity to the river mouth, Baker Bay consists primarily of brackish water.

Youngs Bay is characterized by a broad floodplain and historically was abundant in tidal marsh and swamp habitat. Diking and flood control structures have been used to convert floodplain habitat in the area to pasture. The remaining fragmented tidal marsh and tidal swamp habitats in Youngs Bay are thought to be different in structure and vegetative community than historical conditions of these habitats.

- **Reach B**. This area includes what has been referred to as the mixing zone (Northwest Power and Conservation Council 2004), Grays Bay, and Cathlamet Bay. The mixing zone is an area characterized by a network of mid-channel shoals and flats, such as Desdemona and Taylor Sands. It also has the highest variation in salinity within the estuary because of the interactions between tide cycles and river flows. The estuarine turbidity maximum (see p. 3-8), which is created through these interactions, is often located within this area of Reach B.

  Grays Bay is found on the Washington side of the river in Reach B. Historically, water circulation in this area was a result of interactions between river flow and tidal intrusion. Pile dike fields constructed adjacent to the main Columbia River navigation channel have decreased circulation in Grays Bay. This circulation change is suspected of causing flooding problems in the Grays and Deep River valley bottoms and may have promoted the beneficial development of tidal marsh habitat in the accreting bay. Dike construction, primarily for pasture conversion, has isolated the main channel from its historical floodplain and eliminated much of the historical tidal swamp habitat.

  Cathlamet Bay is located on the Oregon side of the river in Reach B. This area is characterized by some of the most intact and productive tidal marsh and swamp habitat remaining in the estuary, and a large portion of Cathlamet Bay is protected by the Lewis and Clark National Wildlife Refuge. The western edge of Cathlamet Bay contains part of the brackish oligohaline zone, which is thought to be important during the transition of juvenile anadromous fish from freshwater to saltwater. Portions of Cathlamet Bay have lost substantial acreage of tidal swamp habitat as a result of dike construction. Conversely, tidal marsh habitat has formed along the fringe of dredge disposal locations.

- **Reach C**. This area, which includes deep channels and steep shorelines on both sides of the river, ends just downstream of the city of Longview. The narrow channel structure produces an area dominated more by tidal swamp habitat than by edge habitat (tidal marsh). Dike construction and clearing of vegetation have resulted in a substantial loss of tidal marsh habitat on Puget Island and within the Skamokawa and Elochoman floodplains. Wallace Island and Crims Island also are located within Reach C.

- **Reach D**. This area begins just downstream of Longview and ends near the city of Kalama. Reach D is distinct from the downstream reaches in its geology, vegetation, and climate. It includes flows from the Cowlitz and Kalama rivers. Extensive diking and filling around Longview and the mouth of the Kalama River have significantly reduced access to the floodplain, and islands created through the disposal of dredged material are prevalent. High levels of polychlorinated biphenyls (PCBs) have been detected in the Longview and Kalama industrial area.

- **Reach E**. This area includes the river upstream of the city of Kalama to Woodland. The Lewis River system, including the North Fork and East Fork, flows into the Columbia River in Reach E. Sandy, Goat, Deer, Martin, and Burke islands are included in Reach E. Extensive diking has occurred on Deer Island and around the city of Woodland.
- **Reach F**. This area includes the river upstream of the confluence with the Lewis River up to and including Salmon Creek. Islands included in this reach are Bachelor and Sauvie. Sloughs include the Lake River system and Multnomah Channel. Scappoose Bay is relatively undiked; however, Sauvie Island and Bachelor Island have been extensively diked.
- **Reach G**. This area includes the river upstream of its confluence with Salmon Creek and extends upstream of Reed Island. This reach is dominated by flows from the Willamette, Washougal, and Sandy rivers. The cities of Portland and Vancouver straddle the Columbia River in this reach. Islands included in this reach are Hayden Island, Government Island, Lady Island, and Reed Island. Extensive diking has reduced the floodplain from the confluence of the Willamette River upstream to the mouth of the Sandy River. High readings of PCBs and polycyclic aromatic hydrocarbons (PAHs) are found along the lower Willamette River and the channelized banks of the Columbia River in this reach. Significant numbers of industrial piers and over-water structures line the Willamette and Columbia rivers in this reach.
- **Reach H**. This area includes the river upstream from Reed Island to Bonneville Dam. This reach receives flow from many small tributaries, including Gibbons, Duncan, Hamilton, Hardy, and Multnomah creeks. Notable islands in this reach include Ackerman and Skamania islands. Reach H includes the entrance to the Columbia River Gorge, which is characterized by steep slopes. Little diking has occurred in this area, primarily because of the lack of floodplain.

The Lower Columbia River Estuary Partnership, in conjunction with Pacific Northwest National Laboratory, has further delineated the estuary into discrete management areas at approximately the 6^{th} field hydrologic unit code (HUC). These management areas are geospatially referenced to a variety of data sets that can be used to generate statistics and geographic information system (GIS) maps. Statistics relating to floodplain changes, diking coverage, tide gates, contaminants, structures, and dredge fill locations are included where appropriate. GIS maps showing some of these features are presented in Appendix A. For additional information, see the *Columbia River Estuary Habitat Monitoring Plan* (Lower Columbia River Estuary Partnership 2004).

Columbia River Plume

The Columbia River plume is generally defined by a reduced-salinity contour near the ocean surface of approximately 31 parts per thousand (Fresh et al. 2005). In high flows, the plume front is easily recognized by the sharp contrast between the sediment-laden river water and the clearer ocean (see Figure 1-3). The plume's location varies seasonally with discharge, prevailing near-shore winds, and ocean currents. In summer, the plume extends far to the south and offshore along the Oregon coast. During the winter, it shifts northward and inshore along the Washington coast. Strong density gradients between ocean and plume waters create stable habitat features where organic matter and organisms are concentrated (Fresh et al. 2005). The Columbia River plume can extend beyond Cape

Mendocino, California, and influences salinity in marine waters as far away as San Francisco (Northwest Power and Conservation Council 2000). For the purposes of this estuary recovery plan module, the plume is considered to be off the immediate coasts of both Oregon and Washington and to extend outward to the continental shelf.

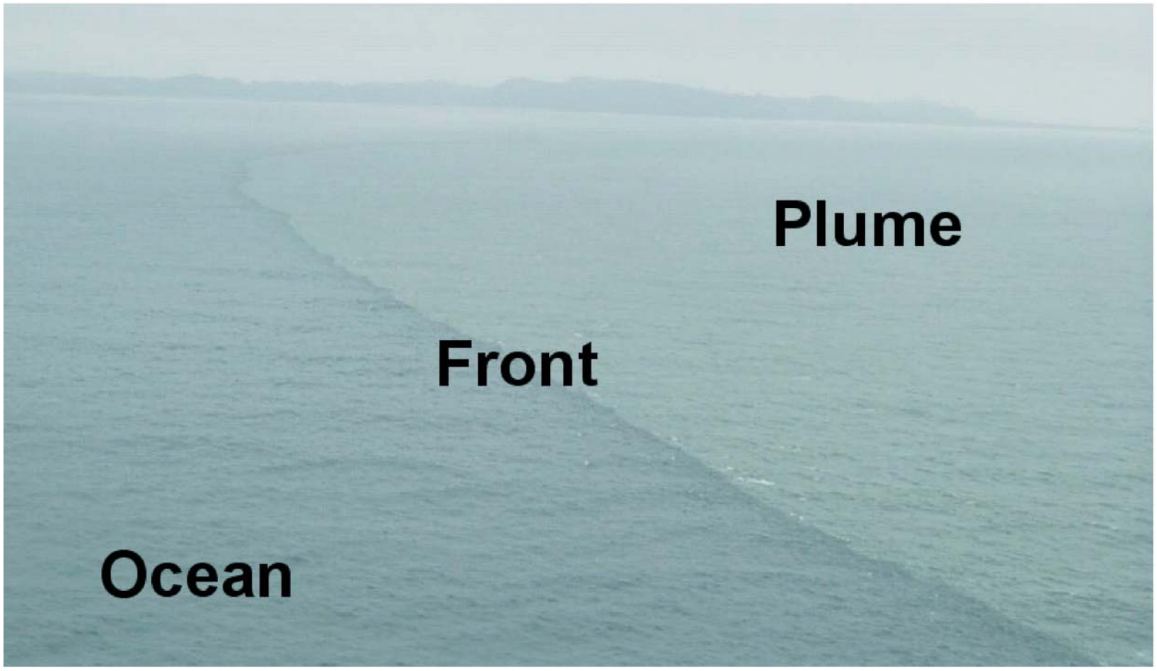

FIGURE 1-3
Plume Front
(Photo courtesy of NOAA Fisheries.)

Major Land Uses

A variety of land uses are found adjacent to the Columbia River estuary. The area contains multiple cities and political jurisdictions, including Portland, which is Oregon's largest city, and Vancouver, the fourth largest Washington city. Smaller cities include Astoria, Cathlamet, Longview, Kalama, Woodland, and Camas. Approximately 2.5 million people live in the vicinity of the estuary, and more are coming. Five deep-water ports in the area support a shipping industry that transports 30 million tons of goods annually (Lower Columbia Fish Recovery Board 2004), worth $13 billion each year (Columbia River Channel Improvement Reconsultation Project). Timber harvest occurs throughout the basin—six major pulp mills contribute to the region's economy. Until recently, aluminum plants along the river produced 43 percent of the country's aluminum. Agriculture is widespread throughout the floodplain and includes fruit and vegetable crops along with beef and dairy cattle. Commercial and recreational fishing activity plays an important role in local economies, bringing in millions of dollars of revenue each year. Primary outdoor recreational activities include fishing, wildlife observation, hunting, boating, hiking, and windsurfing.

Two Centuries of Change

Before Euro-American settlement of the Pacific Northwest, the Columbia River estuary and plume served as a physical and biological engine for salmon. Juveniles from hundreds of populations of steelhead, chum, chinook, and coho entered the estuary and plume every month of the year, with their timing honed over evolutionary history to make use of habitats rich with food. A beach seine survey during any month of the year would likely have yielded salmon of all species and many populations, with individuals of many sizes. This genetic variation in behavior was an important trait that allowed salmon and steelhead to occupy many habitat niches in time and space. It also guarded populations against catastrophic events such as volcanic eruptions (Bottom et al. 2005).

Today the Columbia River estuary and plume are much different. Notably, the North and South jetties at the mouth of the river restrict the marine flow of nutrients into the estuary. Dikes and levees lining the Washington and Oregon shores prevent access to areas that once were wetlands. New islands have been formed by dredged materials, and pile dike fields reach across the river, redirecting flows. Less visible but arguably equally important are changes in the size, timing, and magnitude of flows that, 200 years ago, regularly allowed the river to top its banks and provide salmon and steelhead with important access to habitats and food sources. Flow factors, along with ocean tides, are key determinants of habitat opportunity and capacity in the estuary and plume.

Salmon thrived in the Columbia River for 4,000 years. In the last 100 years, the entire Columbia River has undergone tremendous change as a direct result of people living and working in the basin. While the threats to salmon persistence are very diverse, at some level it is the increase in human population in the Northwest that underlies every human threat. There are an estimated 5 million people in the Columbia River basin today, and somewhere between 40 million and 100 million people are predicted to be living in the basin by the end of the twenty-first century (National Research Council 2004). If we want healthy salmon runs at the same time that our population is multiplying, our interactions with land and water must pose fewer threats to salmonids than they have in the last 100 years. Before identifying management actions that could do just that, this document discusses which salmonids currently use the Columbia River basin, and how.