1. Skagit Basin Overview

Abstract

Since the 1850s, the Skagit River basin has been altered by human activities such as logging, diking, and the construction of dams, roads, levees, and tide gates. Logging and construction of levees and dikes converted coniferous forest and wetlands to farmland, industrial, and urban/suburban residential development. Dams constructed in the Skagit River not only generate hydropower but also provide flood control, recreation opportunities, and diverse ecosystem services. Major highways constructed through Skagit County promoted both economic and population growth in Skagit County. These human developments have dramatically impacted the hydrology and geomorphology of the basin and have impacted or reduced habitat for a wide range of species, including multiple species of native anadromous fish historically reliant on Skagit River Basin tributaries. Low-lying farms, urban development, and other lands in the floodplain are currently vulnerable to river flooding and sea level rise. The economy of the Skagit River basin in the 19th and early 20th centuries was focused primarily on logging, mining, and agriculture, but has diversified through the second half of the 20th century. Rapid increases in population in the 21st century are projected for Skagit Co., which, under the Growth Management Act and the Skagit County Comprehensive Plan, will direct future growth primarily in urban areas.

1.1 Overview of the Skagit River Basin

The Skagit River basin is located in southwestern British Columbia in Canada and northwestern Washington in the United States (Figure 1.1) and drains an area of 3,115 square miles (Pacific International Engineering, 2008). Major tributaries in the basin are the Baker River, Cascade River, and Sauk River. The Skagit River basin is approximately 110 miles long and 90 miles wide (Pacific International Engineering, 2008). Downstream of the town of Mount Vernon, the river splits into the North Fork and the South Fork before entering Skagit Bay in Puget Sound (Figure 1.1). Under low to moderate flow conditions, about 60 % and 40 % of the Skagit River

flows are carried out by the North and South Forks, respectively, while at higher flows, this ratio is closer to a 50-50 split (Curran et al., in review; Pacific International Engineering, 2008). Although not considered in detail in this report, other local rivers such as the Samish and Stillaquamish also materially affect the local economy and natural resources of Skagit Co, and the ecology of the Puget Sound lowlands and Skagit Bay.

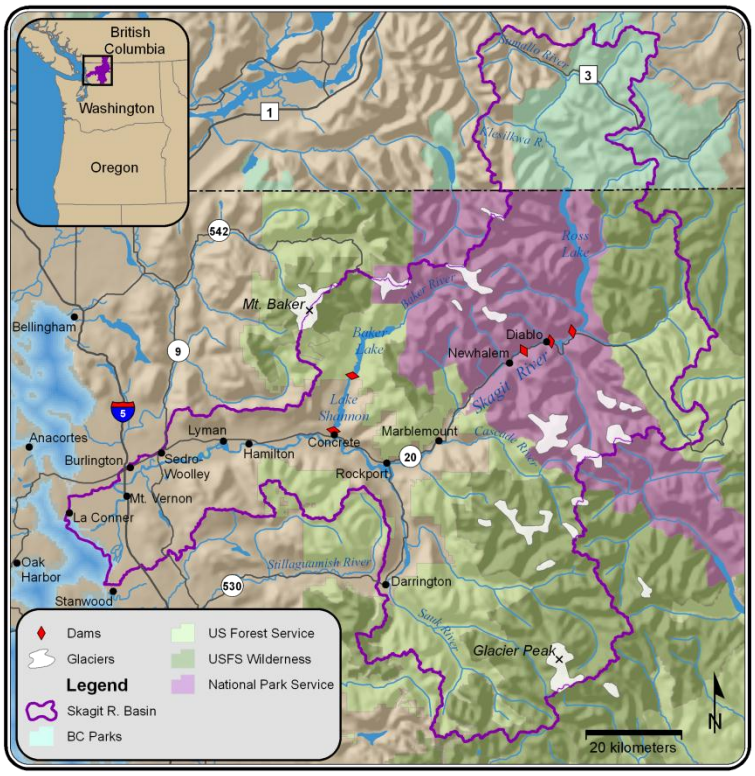

Figure 1.1 Key Geographic features of the Skagit River basin. Note that only the largest glaciers are shown on the figure (see Chapter 4 for details).

1.2 Geology and Land Cover

1.2.1 Geology

The eastern mountainous region of the basin consists of ancient metamorphic rocks, together with granitic rocks and volcanic deposits associated with Mount Baker and Glacier Peak (Pacific International Engineering, 2008). The two highest points in the basin are Mount Baker on the northern side of the basin at an elevation of 10,778 ft and Glacier Peak in the southern portion of

the basin at an elevation of 10,568 ft (Pacific International Engineering, 2008). Most of the eastern portion of the basin is above an elevation of 6,000 feet (Pacific International Engineering, 2008), where nearly all winter precipitation currently falls as snow. From Rockport to Sedro Woolley, the Skagit River flows in a 1-mile to 3-mile-wide valley that was largely formed by Alpine glaciers (Waitte, 1977; Pacific International Engineering, 2008). The valley walls are moderately steep, timbered hillsides with few developments (Pacific International Engineering, 2008). Below Sedro Woolley, the valley falls to nearly sea level and widens to a flat, fertile floodplain formed by continual river sediment transport and also by historic lahars from Glacier Peak - most notably an event about 5,900 years ago, which is estimated to have deposited between 0.5 and 0.7 cubic miles of sediment extending to the present location of Samish Bay to the northeast and La Conner and Stanwood to the southeast (Pacific International Engineering, 2008). Another study also identified a large lahar event approximately 1800 years ago that deposited large amounts of material to an overlapping area (Dragovich et al., 2000).

Prior to the late 19th century diking, floodwaters from the Skagit and Samish River basins and their associated suspended sediment commonly flowed across this entire geomorphic delta comprised of the modern Samish, Padilla and Skagit floodplains (Collins, 1998). Because of their different geological origins, the lower substrate of most deep valleys in the headwaters and middle basin consists of glacial deposits and/or moraines, while that of the floodplain in the lower basin is composed of volcanic sands and laharic deposits such as muddy, gravelly volcanic rock debris. The fertile upper layers of soil in the floodplain are composed primarily of finer sediments deposited by the river such as sands, silts, and clays (Collins, 1998; Pringle and Scott, 2001; Pacific International Engineering, 2008; Haugerud and Tabor, 2009).

Under current conditions the Skagit River has been estimated to transport between 1.7 million and 4.5 million tons of sediment annually (Collins, 1998, Curran and others, in review; Pacific International Engineering, 2008). In water year 1991, which included two major floods (Pacific International Engineering, 2008), the river transported 4.4 million tons of sediment (Collins, 1998). Recent studies present evidence that sediment delivery has increased dramatically since 1850 due to a combination of land use change (e.g. logging and road building), clearing and

dredging in the lower river, and channelization of flow, which reduced connectivity between river and floodplain (Grossman et al., in press) (See also chapter 6).

Largely as a consequence of these changes the Skagit River delta is currently prograding (increasing in area) (Beamer et al., 2005a). Extensive diking of the lower river has also dramatically changed where sediment is deposited, concentrating it at the mouths of the South and North Forks and on the outer face of the delta (Hood, 2004; Collins, 1998; Grossman et al., in press). Fine sediments, however, primarily bypass the delta, shoreline and tidal flats and are transported offshore (Grossman and others, 2007) (See Chapter 6 for more details).

Recent studies provide evidence that the entire Skagit tidal flats have been converted from a mud-rich system to a sand-dominated system since about 1850, which has led to habitat impacts and lost marine resources. For example, the Swinomish Tribe used to harvest soft shell clam in the delta, but this species is no longer viable in areas now dominated by sand deposition. Similarly the Swinomish Tribe used to harvest oysters in the area north of the current Jetty, but oysters are no longer viable in this area because of extensive mud accumulation since the 1940s when the jetty was emplaced (Grossman et al., in press and review; Grossman et al. 2007).

1.2.2 Land Cover

Since settlement by non-Native Americans began in the 1850s, the land cover of the Skagit River Valley (and adjoining areas in the Puget Sound Lowlands in the Samish and Stillaquamish River basins) has been changed from mostly coniferous forest and wetlands to farmland and urban or rural residential areas (Beechie et al., 2001; Cuo et al., 2009). Outside of national park and wilderness areas, forested foothills and mountains have been converted from old growth to commercial tree farms or second growth forest (Skagit County, 2007). Based on 2007 satellite images, land cover in Skagit County is 65.5% forest, 15.5% grassland or scrub/shrub (including recently cut forest), 7.3% agriculture, 3,5% developed, and 5.2% ice and rock (J. Greenberg, personal communication; see Figure 1.2). Based on current Skagit Co. zoning designations land use are classified as 48% public, 29% industrial forest, 12% secondary forest or rural, 8% agriculture, and 4% urban, including the cities of Mount Vernon, Burlington, and Sedro Woolley and the towns of Concrete, Hamilton, Lyman, and La Conner (J. Greenberg, personal

communication; see Figure 1.3). The basin also includes the reservations of the Sauk-Suiattle Indian Tribe and the Upper Skagit Indian Tribe. The City of Anacortes and the Swinomish Indian Tribal Community are on Fidalgo Island, just outside of the Skagit River basin boundary (Figure 1.1). The federally recognized Samish Indian Nation is currently headquartered in Anacortes, but does not have a reservation of its own. Although the reservation is outside the basin boundary, the Swinomish Tribe maintains significant treaty interests in the Skagit River and Skagit River delta, as does the Samish Tribe.

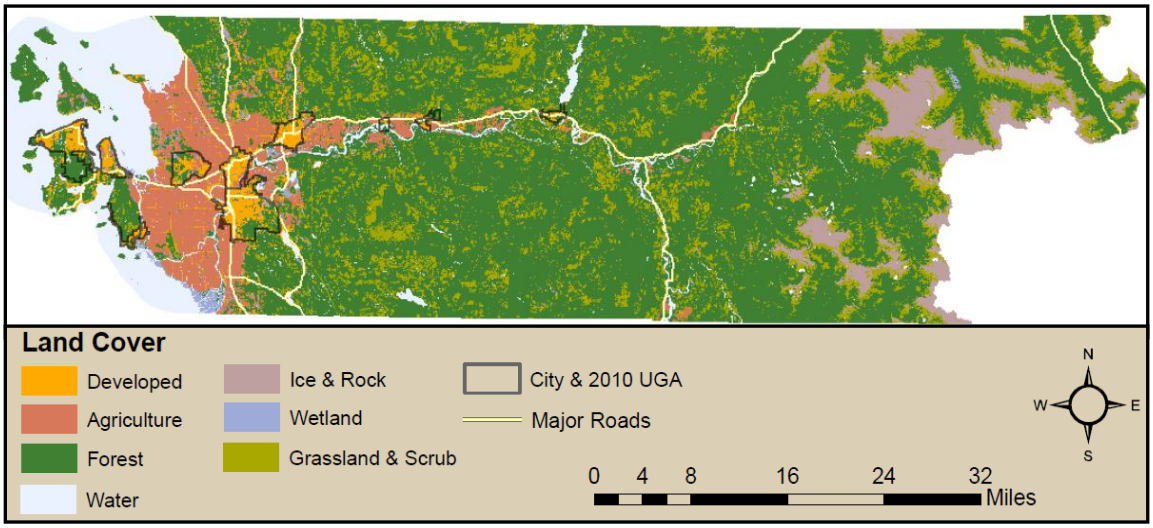

Figure 1.2 Land cover of Skagit County.

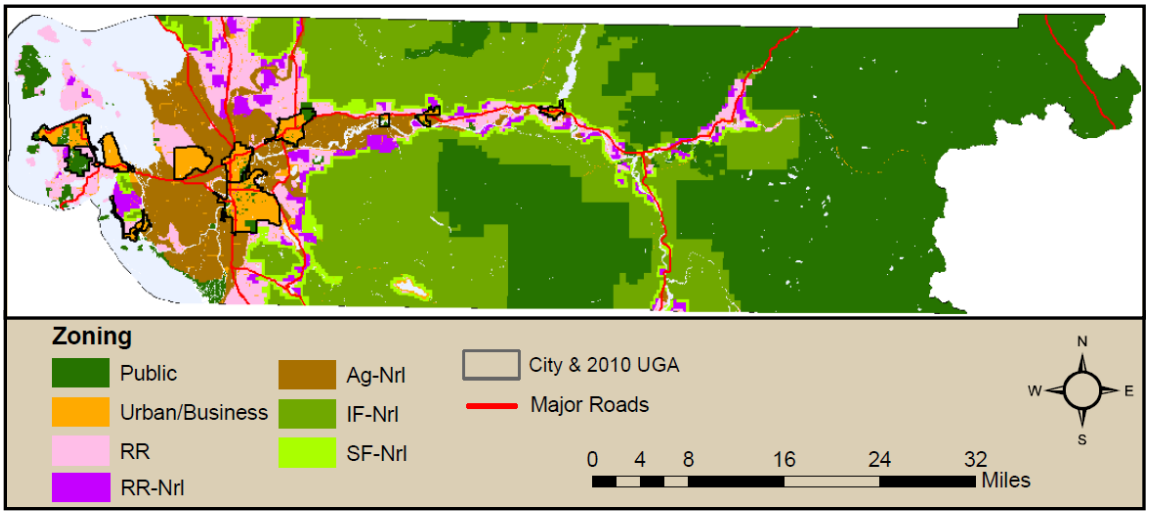

Figure 1.3 Major land use zones based on Skagit County designations. “IF-Nrl” is Industrial Forest, and “SF-Nrl” is Secondary Forest, “RR” is Rural Reserve, “RR-Nrl” is Rural Resource and “Ag-Nrl” is Agriculture. (Map produced by Skagit County GIS 2011.)

Prior to non-native settlement, at least one half of what is now the Skagit River delta was composed of perennial wetlands, including tidal marsh, freshwater marsh, or open channels (Collins, 1998). Historically, the lower Skagit River likely moved across the entire Skagit Flats, including the current Samish River Valley out to Samish Bay (Collins, 1998). A former channel of the river that led to Padilla Bay was clearly detectable in a U.S. Army Corps of Engineers analysis in 1881, for example (Kunzler, 2005).

1.3 Human Settlement of the Skagit Basin

Native Americans occupied lands within the Skagit River Basin for uncounted centuries prior to non-native settlement. Within a few years following the Oregon Treaty of 1846, which established American sovereignty below the 49th parallel, European-Americans and other ethnic groups began moving to the Puget Sound area. The first continuous non-native settlement in Skagit County was on the prairies of March Point in 1853 (Easton, 1976). The cession of tribal lands through the Point Elliott Treaty of 1855 provided the basis for granting land titles and encouraged more extensive settlement (Skagit County, 2007). The first dikes along the Skagit River are believed to have been constructed in 1863 (Breslow, 2011). La Conner was the first town established in the county. It began as a trading post in the early 1860s, benefitting from its location on a protected waterway (Easton, 1976). As was the case throughout western North America in the 18th and 19th century, ships, canoes, and other watercraft were the primary means of early transportation until clearing of upland forests made overland travel more feasible. Thus early settlement was typically near major water bodies such as the Skagit River and Puget Sound. Early agriculture in the delta focused on oats and barley, which did well in salty soils (Econorthwest, 2010). As early as 1873, the temperate microclimate of the Skagit Valley was found to be well-suited for growing cabbage and brassica seeds, which grew to be an economically important industry in the 20th century (Breslow, 2011; Econorthwest, 2010).

Before the early 1880s, two huge log jams blocked passage of steamer ships at Mount Vernon (Breslow, 2011). Until the jams were removed, they caused spring snow melt to flood across the valley downstream (Kunzler, 2005). Removal of the jams allowed Mount Vernon to grow; it

became the county seat in 1884 (Easton, 1976). Logging on the delta and along the river was the county's first major industry (Kunzler, 2005). Logging advanced upriver, along with early mining operations, after the U.S. Army Corps of Engineers completed removal of the log jams at Mount Vernon and cleared additional snags and jams further upriver to improve navigation (Breslow, 2011). Railroad connections cemented Mount Vernon's role as the leading city in the county in the late 19th century. Spur lines led to the growth of Anacortes and upriver towns. Most of these towns were established in association with nearby mines (Breslow, 2011). By the early 20th century, upriver floodplains had been extensively converted to agricultural use and the riparian forest had been logged from as far upstream as the Sauk River (Beechie et al., 2001). After timber near the river was cut, railroads supported logging operations as they moved up the hillsides (Kunzler, 2005; Easton, 1976).

In the 1950s, the county economy diversified its industrial base from its historic dependence on the agricultural and forestry industries, adding two petroleum refineries on Fidalgo Island near Anacortes and establishing a pleasure boat building industry (Hovee and Company, 2003). In the 1970s and 1980s, downturns in the lumber, wood, and food processing industries led to higher unemployment in Skagit County than elsewhere in Washington. The county has broadened its employment base since then. Today, services and retail are the county's two largest economic sectors (Hovee and Company, 2003).

1.3.1 Drainage Infrastructure

By the late 19th century, an extensive system of dikes had transformed the delta into some of the richest farmland in the state (Kunzler, 2005). The growing cities of Skagit County depended on agriculture as the basis for the local economy. However, the delta remained subject to catastrophic flooding, which was exacerbated by logging, the channelization of streams and rivers, and the dike and drainage system itself, which increased the severity of downstream flooding by channeling the river's force and removing the absorptive capacity of trees and wetlands (Breslow, 2011). Much of the land surface in the delta protected by dikes is currently below the mean higher high tide (J. Greenberg, personal communication; see Figure 1.4, making

it vulnerable to projected sea level rise, especially in combination with increased river flooding projected for a warmer future climate (see Chapters 5 and 8).

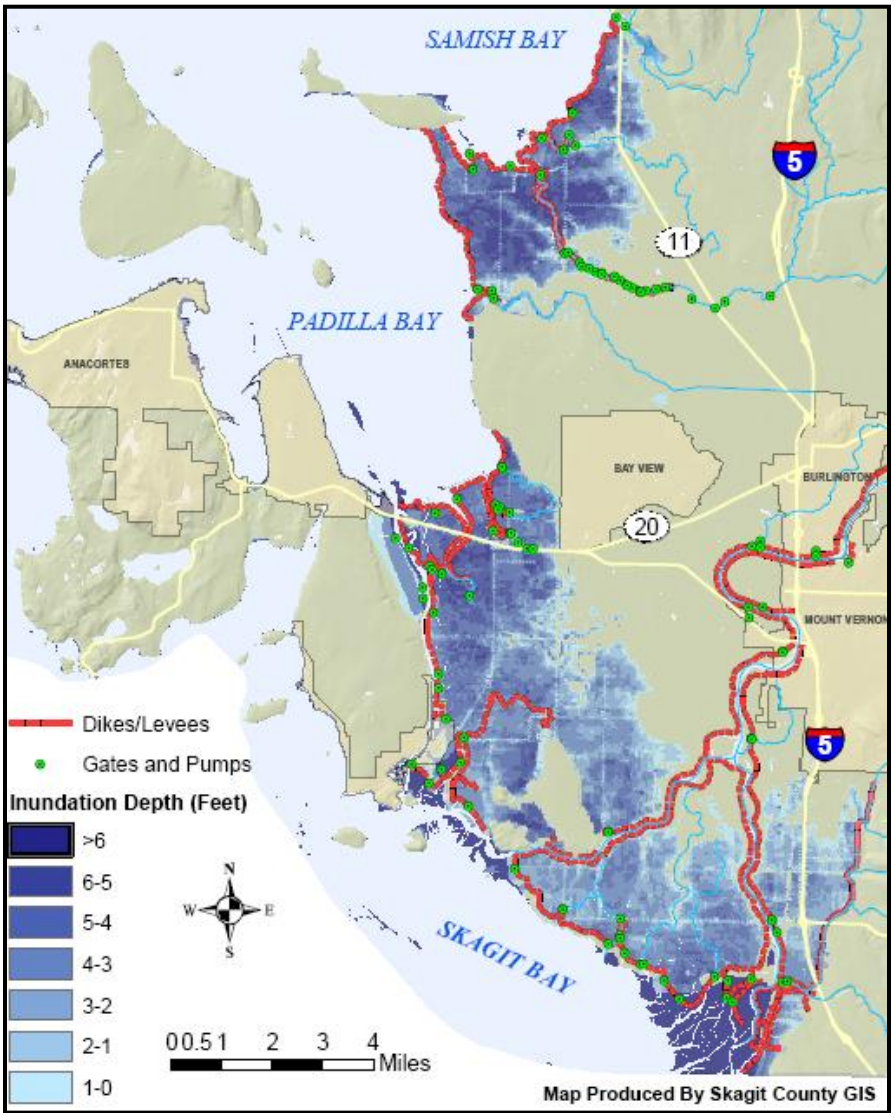

Figure 1.4 Predicted inundation extent at higher high tide in the Skagit Flats if tide gates were removed from existing dikes (J. Greenberg, personal communication). (Map produced by Skagit County GIS 2011.)

Tide gates and flood gates have been installed in low-lying land in the Skagit delta to protect against flooding and to provide adequate drainage for farming (Mitchell et al., 2005; WWAA et al., 2007). Tide gates are essentially one-way valves that allow drainage water to flow to marine waters during a low tide cycle. At high tide, tide gates close to keep saltwater out of the drainage

system (WWAA et al., 2007). Flood gates also prevent water in the Skagit River from back-flowing into a drainage system when the river is at flood stage (WWAA et al., 2007). These two types of drainage infrastructure are essential for the long-term sustainability of agriculture in the Skagit delta. They have also caused declines in salmonid productivity by blocking fish passage, and have reduced sediment transport to the Skagit delta. The performance of tide gates and flood gates is likely to be influenced by sea level rise, especially in combination with increased river flooding (Chapter 8).

1.3.2 Dams

Five major hydroelectric dams were constructed in the basin between 1924 and 1959: Gorge Dam (completed as a wooden structure in 1924, then replaced with a concrete dam in 1950), Diablo Dam (completed in 1931), and Ross Dam (first completed in 1940, then raised in 1949) on the upper Skagit River and, on the Baker River, Lower Baker Dam (completed in 1925) and Upper Baker Dam (completed in 1959). The three Seattle City Light dams on the upper Skagit River produce 805 megawatts (MW) of power: 460-MW Ross, 168-MW Diablo, and 177-MW Gorge. The two Puget Sound Energy dams on the Baker River generate 170 MW of hydropower: 91-MW Upper Baker and 79-MW Lower Baker (URLs 1 & 2).

The three storage dams (Ross, Upper Baker, and Lower Baker) significantly reduced natural spring river flows originating as snowmelt and also augment summer low flows (Pacific International Engineering, 2008). Since 1954, Ross Dam has provided 120,000 acre-feet of flood control storage. Since 1980, Upper Baker Dam has provided 74,000 acre-feet of additional storage (Pacific International Engineering, 2008). During a flood event when forecasted natural flow at Concrete is above 90,000 cfs, the U.S. Army Corps of Engineers operates Ross Dam in coordination with Upper Baker Dam to reduce flood peaks in the lower Skagit River valley (Puget Sound Energy, 2006). Collectively, Ross and Upper Baker Dams control runoff from about 39 percent of the drainage area of the Skagit River basin upstream of the Skagit River near Mount Vernon (Puget Sound Energy, 2006). Nevertheless, the five dams in the basin were not built primarily for flood control and provide only limited relief from the worst river flooding,

which generally occurs in late fall when warm storm systems bring heavy rainfall, which can also melt early snowpack (Kunzler, 2005).

1.3.3 Highways

Interstate 5 (I-5) was constructed through Skagit County in the 1960s. The final portion of I-5, between Everett and Marysville, opened in May 1969, connecting the county to the Seattle area and points south. This was a turning point for the local agricultural industry, cutting several hours from the time needed to move inputs, products, and labor between farms and markets, and also attracting new suppliers, processors, and resellers to the valley (Breslow, 2011). It also made commuting between Skagit County and the fast-growing central Puget Sound area much more feasible, leading to a significant and sustained increase in Skagit County's population growth rate, as discussed further in the section 1.5.

In summer 1972, the North Cascades Highway was completed, connecting the Skagit Valley to the Methow Valley east of the mountains. Combined with the creation of North Cascades National Park in 1968, this transformed Skagit County into a gateway to popular recreational areas in the mountains. The county was already a gateway to the San Juan Islands through a spur of State Routes (SR) 20 to the ferry terminal at Anacortes. Other major highways in the basin include SR 9, 538 and 536. Highways lying in the floodplain such as SR 20, 9, and 536 are susceptible to flooding and are closed during extreme high flows.

1.4 Ecological Change

The transformation of the Skagit River and its basin over the final decades of the 19th century and early decades of the 20th century involved dramatic changes to the basin's ecosystems. Figure 1.5 identifies changes just in estuarine habitat zones between the 1860s and 1991. Most of these changes had already taken place by the early 20th century (Collins, 1998). Snag removal and logging in the floodplain not only removed complex habitats used extensively by salmon and other species, they eliminated dynamic processes through which the river created and maintained habitats over time (Collins, 1998). Diking isolated more than 90% of the delta from riverine and

tidal influence (Hood, 2004), leading to dramatic losses in freshwater wetlands and estuarine habitats (see Figure 1.6). Beamer et al. (2005b) calculated a net loss of 98% of freshwater wetlands and floodplain forest in the non-tidal delta to Sedro Woolley (see Figure 1.7).

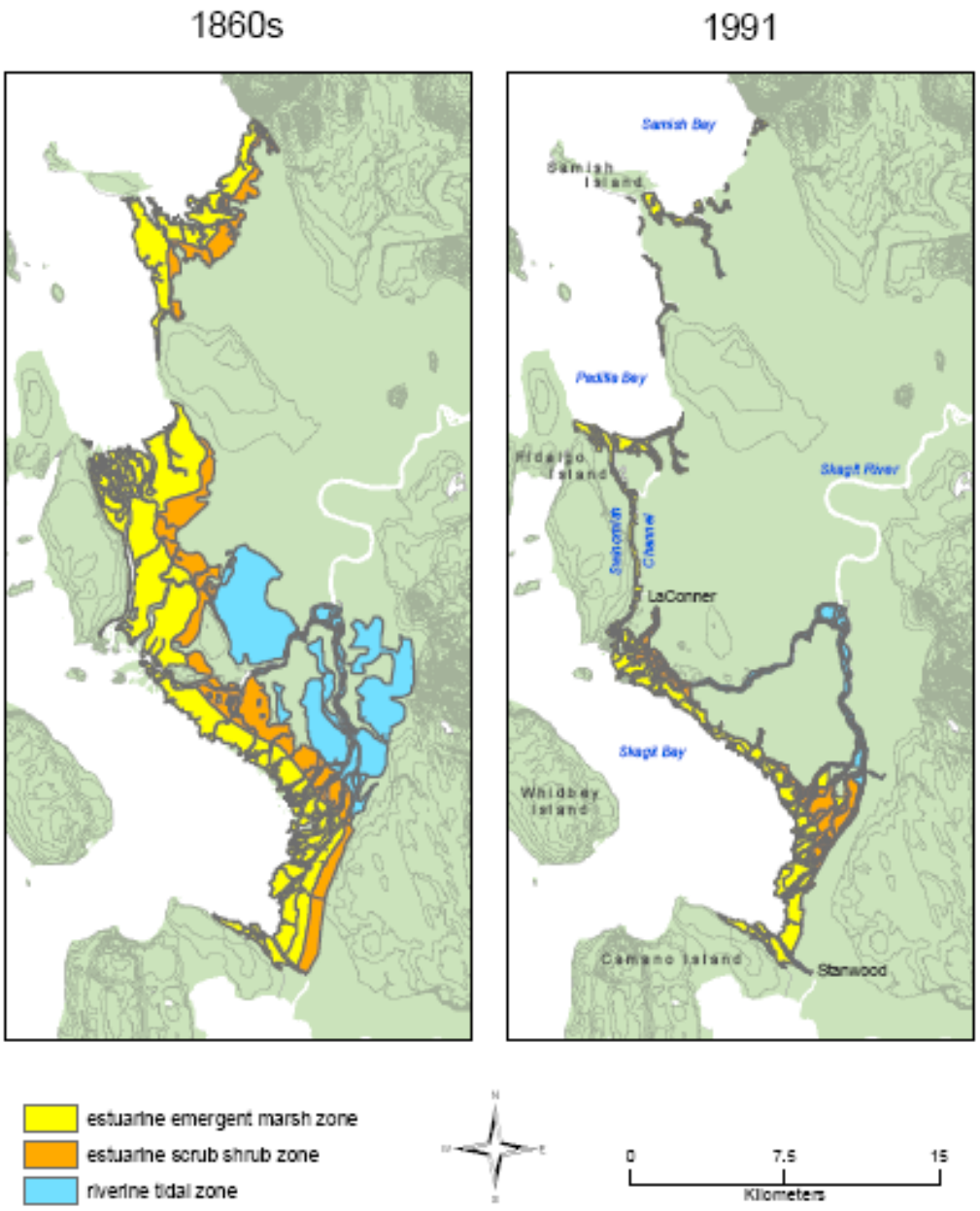

Figure 1.5 Changes to the estuarine habitat zones within the Skagit delta (Source: Beamer et al., 2005a).

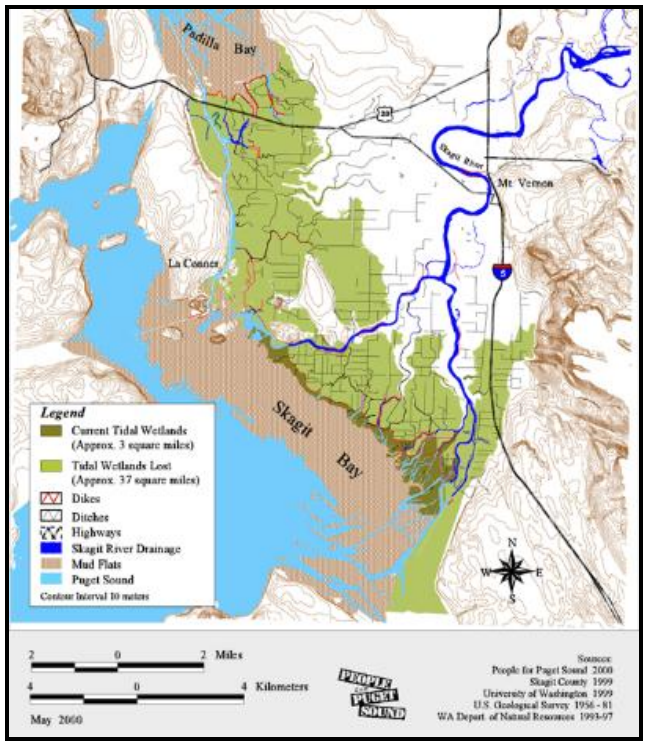

Figure 1.6 Historical and current vegetated tidal wetlands in the Skagit Estuary, Washington (Source: Dean et al., 2000)

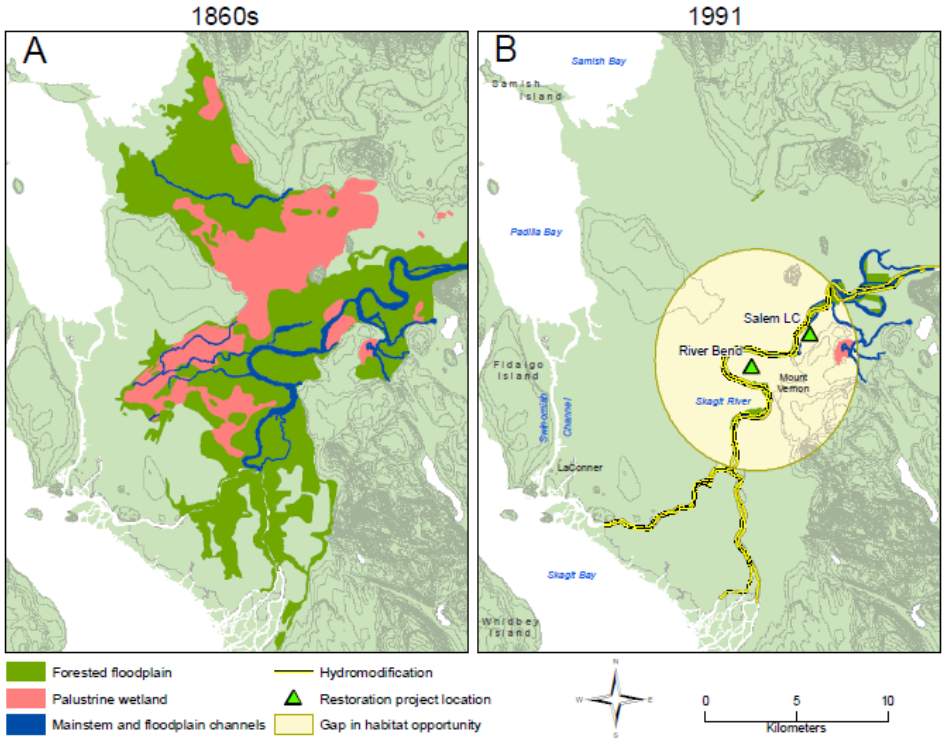

Figure 1.7 Floodplain areas for the non-tidal delta portion of the Skagit River. The map shows changes to floodplain and mainstream habitats (Source: Skagit River System Cooperative and Washington Department of Fish and Wildlife, 2005).

Diking also dramatically changed the processes that created and maintained remaining habitats. Blind tidal channels, which receive freshwater flow during floods but which regularly receive inflows from marine waters during high tides, were reduced in area by 94.6% between southern Padilla Bay and Camano Island (Beamer et al., 2005a). Distributary channels, which delivered water and sediment crucial to estuarine habitats, were cut off from the area between the North and South Forks of the river on lower Fir Island. Including other diked areas to the North, Beamer et al. (2005a) calculated a net loss of 74.6% of tidal estuarine area across the entire geomorphic Skagit delta, from Camano Island to Samish Bay. In addition to losses in total area, estuarine habitats also were disconnected from one another, becoming concentrated at the mouths of the North and South Forks of the river. These changes affected a wide range of species, including Chinook salmon, which particularly rely on estuarine habitats and which are currently listed as threatened under the Endangered Species Act. Beamer et al. (2005a) calculated that the area preferred by delta-rearing Chinook salmon has been reduced 87.9% compared to historic conditions. Upriver, dikes and roads have also dramatically reduced floodplain habitats and limited the processes that create and maintain them. Floodplains provide complex and dynamic habitats important to a wide range of species, including fish, birds, mammals, and amphibians. Between Sedro Woolley and Rockport, Beamer et al. (2005b) found that 31% of the floodplain had been isolated from hydrologic processes by dikes and roads. They found a similar amount of the floodplain was "shadowed" from river hydrology through bank hardening or roads, although these areas were not completely disconnected from the river. As discussed above, these same processes have also dramatically altered the sediment transport processes that create and maintain habitat in the delta (Chapter 6).

1.5 Population Growth and Future Projections

Skagit County's population grew rapidly during the first half of the twentieth century, from 14,292 in 1900 to 43,273 in 1950. This approximately tripling of the population was, however, slower than average for the Puget Sound area, where the human population more than quintupled over that time (Office of Financial Management, 2007). The pace of Skagit County's growth slowed significantly between 1950 and 1975, with population increasing less than 25% to 54,100

in 1975. With the completion of Interstate 5, the county's population increased much faster, nearly doubling to 102,979 by 2000 (Office of Financial Management, 2007). The pace of growth has slowed somewhat since then. The Envision Skagit 2060 project estimates that the county's 2010 population was probably slightly below 120,000 (K. Johnson, personal communication). The Envision Skagit 2060 project is considering low, high, and "most likely" projections for the county's population in 2060 of 192,412, 237,352 and 217,578, respectively. The high projection used by the project is an extension of the "medium" projection for the county in 2025 developed by the state Office of Financial Management. City and County planners working with Envision Skagit believed that extending the state's "high" projection for 2025 would be unrealistic over a 50-year time period. The "most likely" projection extends the 2025 planning target being used by the Skagit Council of Governments. These projections are also reasonably well aligned with currently observed growth rates. (K. Johnson, personal communication).

Under the Growth Management Act and the Skagit County Comprehensive Plan, the large majority of growth in the county's population is being directed to urban areas. While the county as a whole is projected to grow 44.8% between 2000 and 2025, the City of Mount Vernon is projected to grow 69.1%, from 28,332 to 47,900. Some urban areas are growing even faster, such as the Bayview urban growth area near the Skagit County Airport, which is projected to more than triple its population over the same period, from 1,700 in 2000 to 5,600 in 2025.

1.6 Summary and Conclusions

The Skagit River basin, which is located in northwestern Washington in the United States, drains an area of 3,115 square miles. Since European-American settlement around the 1850s, the Skagit River basin has been extensively developed. Key findings include the following:

- The formation of valleys, mountains and floodplains of the Skagit River basin has been influenced by both glaciers and volcanic activity. Therefore, geology of different areas of the Skagit River basin varies with its geological origin; the headwaters and middle basin

consist of glacial deposits and/or moraines while lowlands of the Skagit River are composed of volcanic sands and laharic deposits.

- The Skagit River basin has been extensively transformed since early European-American settlement in the 19th century by logging, agriculture, urbanization and the construction of dams, dikes, levees, tide gates, channels, roads, and railroads. These human developments have dramatically affected the hydrology, geomorphology, and ecosystems of the basin (discussed in more detail in Chapters 5, 6,7).
- Levees and dikes constrain river flows, facilitating agricultural development and urban and suburban development. This infrastructure reduces flood risk, but does not eliminate the threat of catastrophic floods (discussed in more detail in Chapter 8). Levees and dikes also constrain and redirect the river's transport of sediment, which now concentrates at the mouths of the North and South Forks of the river. Most of the sediment, however, actually bypasses the delta, shore and tidal flats. Sands accumulate mostly on the delta front, while fine sediments that once accumulated in the delta as mud are now exported to distant parts of Skagit Bay and outside Deception Pass. This represents a lost resource to the delta.
- Five dams were built in the Skagit River basin primarily for hydropower generation: Ross, Diablo, and Gorge Dams on the upper Skagit River and Upper and Lower Baker Dams on the Baker River. These dams provide also flood control, recreation opportunities, and diverse ecosystem services.
- Major highways such as I-5 and SR 20 were constructed through Skagit County during the 1960s and the early 1970s and promoted economic and population growth in Skagit County.
- The location of cities in the floodplain increases their vulnerability to projected increases in river flooding due to climate change. Agricultural land and associated drainage infrastructure are vulnerable to sea level rise, especially in combination with projected increases in river flooding (discussed in more detail in Chapter 8).
- Euro-American settlement has dramatically reduced habitat for a wide range of species. As discussed in more detail in Chapter 7, these species are vulnerable to additional stresses imposed by the effects of climate change and population growth.

URL 1: http://www.hydroworld.com/index/display/article-display/350726/articles/hydro-review/volume-26/issue-1/technical-articles/predicting-effects-of-climate-changes-a-study-of-the-skagit-river-hydro-project.html
URL 2: http://www.pse.com/SiteCollectionDocuments/mediaKit/045_Baker_Hydro.pdf

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