Conclusions

The Nooksack River estuary has seen dramatic changes in salmon habitat quantity and distribution throughout time. This habitat assessment tracks these changes through the lens of habitat-forming processes, seeking implications for salmon recovery. Within this context, this report provides estuarine habitat restoration and preservation options for feasibility review and prioritization.

Maps drawn prior to 1860 show the Nooksack River discharging the bulk of its flow to the Lummi Bay delta, with secondary distributaries contributing flow to the Bellingham Bay delta around either side of the Lummi Peninsula, then an island. Around 1860, the majority of its flow was shifted to the undeveloped Bellingham Bay delta. Surveys completed in the 1880s described the Lummi Delta and its floodplain with well-developed salt marsh habitat and extensive tidal and distributary channels still intact, maintained by reduced Nooksack River discharge and the tides. On the Bellingham Bay delta, the Nooksack River discharged directly to a small sand flat with salt marsh and scrub-shrub habitat not yet present. Complex estuarine habitat had not formed on the Bellingham Bay delta in the twenty years since the majority of flow was directed here. The river's connection to its distributary that fed the Lummi Delta was further curtailed by a log jam plug. Fresh water input to the Lummi Delta was provided through two small floodplain tributaries and by larger flood events that forced water down the Lummi River channel. This change in hydrology on both deltas eventually shifted active estuarine habitat forming processes from the Lummi Delta to the Nooksack Delta on Bellingham Bay.

Development of the floodplain and the main channel on the Bellingham Bay delta followed quickly on the heels of the isolation of the Lummi Delta from the Nooksack River. The portion of the mainstem below the modern Kwina Slough was shortened for better navigation in 1908, and nearly 50 years of habitat formation on the Bellingham Bay delta was again disturbed. The first aerial photos were made in 1933, revealing newly constructed levees lining the Nooksack River between Ferndale and Marine Drive, with nearly 80% of the estuarine floodplain converted to agriculture. Built by the Army Corps of Engineers, these levees also extended down the lower Lummi River and across its mouth. In these early aerial photos, results of the 1908 diversion were still apparent as the delta began to rebuild into Bellingham Bay. The main channel was braided across the exposed sand flat, with limited salt marsh and scrub-shrub habitat present. The upstream connection of the Lummi River distributary channel to the Nooksack River was isolated by an earthen dike, and an armored seawall had been constructed across the Lummi Delta on either side of the distributary channel, facilitating the reclamation of virtually all of the delta. These installations blocked fish passage into nearly all of the tidal channels and wetlands present on the Lummi Delta. This period reflects very low habitat abundance and diversity in the estuary, and likely represented limiting conditions for transitioning juvenile anadromous salmon.

Aerial photos from 1933 to the present show that the delta has continued to expand into Bellingham Bay and create habitat unimpacted by human management. Habitat abundance and diversity on this side of the estuary has increased dramatically, as the

main channel has formed and abandoned channels across the delta, creating a diverse network of distributaries and blind channels. These photos reveal that habitat quality on the Lummi Bay delta has not improved since the 1930s; it has been heavily impacted by land use, primarily agricultural development. A limited freshwater connection between the Nooksack River and its Lummi River distributary was established when a culvert was installed into the dike in 1951.

For the last 70 years the delta has been allowed to grow almost unmanaged into Bellingham Bay and now represents one of the most pristine major estuaries in the Puget Sound, and likely some of the highest quality rearing habitat that anadromous juvenile salmon encounter as they move down the Nooksack River. Abundant logjams, created from both upstream sources and local recruitment, affect habitat formation and provide complex cover in the edge habitat used by rearing juvenile salmon. Riparian zones in the estuary are maturing and conifers are present in the undergrowth of deciduous stands, indicating that wood recruitment is recovering in the estuary.

The habitat-forming processes that continue to create and maintain estuarine habitat on the Bellingham Bay delta are dominated by sediment, wood and water quality attributes. These attributes have had a direct impact on the quantity and quality of habitat in the estuarine environment. From historical analysis, we can project that the trends in channel development and closure in this delta since the 1930s will continue. The Bellingham Bay delta will continue to grow, due to the high sediment load produced by the Nooksack basin. While the delta progrades into Bellingham Bay, more distributary channels will continue to form, increasing the estuary's abundance and diversity of habitat available to salmon. The increased number of channels may also lead to a decrease in the ability of the channels to transport sediment, given the fixed amount of flow to maintain the channels and ultimately to a narrowing and shallowing of some of the major distributary channels. The amount of delta front that is not actively maintained by distributary channels will increase as it builds and connects Lummi Shore with the shoreline north of Bellingham, likely leading to increased blind tidal channel development. With a greater proportion of delta subject to marine forces, it is expected that the salt marsh and shrub-scrub zones will widen as the gradient of the delta lessens.

Coupled with the changes in sedimentation, the ecological and geomorphic value of wood in the delta has changed considerably through time, from the pre-development conditions in the mid-1800s described by an influx of wood from milling operations, to wood removal for channel "cleaning" shortly after the turn of the century. Since the 1930s, it appears that the wood functions that shape habitat are increasing in the estuary, as local sources for recruitment expand and logjams are allowed to develop and persist in the channel. In the rapidly growing delta, it is expected that wood will play a greater role in habitat development and maintenance. Improving riparian conditions in the watershed, along with attempts to preserve adequate migration areas for the channel, will improve long-term recruitment of wood to the estuary and likely provide important habitat benefits.

Habitat in the estuary is defined by both landscape and channel characteristics. Given the changes in wood and sediment delivery to the estuary, and the human development of the floodplain, the distribution and abundance of habitat classes has changed as well. The most dramatic change between conditions in the 1888 and 2004 was the increase in agriculture, which eclipsed 6000 acres of the estuarine floodplain by 1933. This change was accompanied by a decrease in salt marsh, scrub-shrub and forested habitat types. Agriculture now represents 77% of the habitat on the Lummi Bay delta and 63% of the habitat on the Bellingham Bay side of the estuary. Floodplain habitat types on the Lummi Bay delta have not changed much since 1933, but the rapid, unrestrained growth of the Bellingham Bay delta has led to a notable increase in diverse forested wetland, shrub-scrub, salt marsh, and tide flat habitat to the estuary overall.

These changes in floodplain landscape over time also affect the habitat quality of the channels that pass through these broad zones. The salmonid habitat attributes of protective cover; food resources; wood recruitment and function; and water quality are all impacted by changes in the landscape types. The conversion of much of the floodplain to agriculture and the active progradation of the delta into Bellingham Bay have led to a marked change in channel habitat characteristics since the 1880s. The Lummi Bay delta changed from the dominant outlet of the Nooksack River in the 1860s to an intermittent distributary by the 1880s. Following the isolation of the Lummi Delta from the Nooksack River and reduced tidal influence in the 1930s, all but one of the tidal channels on this side of the estuary was lost. The floodplain channel network is now dominated by drainage ditches, most of which are blocked by levees from their connection to natural freshwater channels. Freshwater sources to the delta were reduced to the two perennial tributaries: Jordan and Schell Creeks. While the Lummi Bay delta has seen a loss in channel habitat diversity, active prograding of the Bellingham Bay delta has led to a rapid increase in distributary channel length since the 1930s. Accompanying the increase in distributary channel length has been an increase in blind channel habitat as the delta front widens and a greater proportion is subjected to tidal influences. Blind channels on the Nooksack Delta provide important food resources and undercut bank refuge; however, the water quality usually found in these habitats is of higher salt content, preferred by juveniles more advanced in their smoltification.

Water quality, particularly temperature and salinity, is another important estuarine habitat factor in fish use. Water temperatures in the Nooksack estuary during the juvenile salmonid migration period vary temporally and spatially following seasonal patterns, and the extent of saltwater and mainstem influence. The ideal conditions for salmon to effectively rest, feed and grow occur in winter and spring juvenile outmigration periods. Coincidentally, many of the salmon species that use the Nooksack River estuary during smoltification, such as chinook, chum and pink fry migrants, do so between December and May. The bulk of Nooksack River juvenile salmon migrants enter the estuary between early May and early June, while water temperatures are ideal throughout the estuary. By mid-June, water temperatures rise above ideal levels in habitat types not directly influenced by the mainstem Nooksack or saltwater. Virtually all of the floodplain tributaries and blind channels reach lethal temperatures during the day, due to low flow and exposure to the sun. Channels crossing the exposed flats of the estuary

fluctuate wildly as the channel is cooled by the saltwater when the tide rises, and warms as the sun heats the water on the falling tide. The variability of water temperature through the delta means that opportunities for refuge from the influence of high water temperatures are present in different areas of the delta at different times of the year. Channels that are strongly influenced by the Nooksack River or incoming saltwater maintained lower temperatures into the summer months. These moderating influences may be beneficial to migrating, rearing, and transitional juvenile salmon.

Periods of lethally high temperatures in various habitats render them seasonably unsuitable for juvenile salmon. During the warmest months of the migratory period, only the mainstem of the Nooksack River, its main distributaries, and nearshore environments maintain temperatures below lethal limits. To ensure survival through summer months (June, July, and August), migrating salmon must reside in one of these three habitats. The extent of these habitats may effectively limit juvenile residency time in otherwise productive habitats. Fish that migrate rapidly from the estuary and into the nearshore environment find a marine environment that is consistently lower in temperature than river and tidal channel habitat during warm weather.

Salinity is another aspect of water quality that defines habitat in the estuary. Saltwater intrusion into estuarine channels is critical for providing diverse transitional habitat for juvenile salmon. The further upstream saltwater can penetrate estuarine channels, the greater the number of habitat types fish will be able to use for transitioning to saltwater. In the case of the Nooksack River estuary, the maximum extent of the freshwater-saltwater interface includes side channel, distributary, and main channel habitat types through the sand flat, salt marsh, scrub-shrub, and forested wetland habitat types. Through much of the delta, the salt wedge does not penetrate far. This limits refuge areas for transitioning juveniles to smaller, low-flow distributaries that maintain adequate water temperature, and a variety of landscape types in the transition zone. Currently, the greatest saltwater penetration occurs on the Lummi Bay delta, where reduced freshwater flow results in over 3 miles of tidally influenced transitional area in the Lummi River. However, this area is isolated from mainstem connectivity, has poor in-stream habitat quality, and water temperatures quickly approach lethal limits in the summer. The best example of high quality transition habitat occurs in Kwina Slough, where saltwater penetrates well into a forested channel in the estuary.

The patchwork of refuge areas distributed throughout the estuary provides unique habitat attributes for several species with temporal variability in their use of it. The Nooksack estuary provides migration, rearing and transitional habitat for outmigrating juvenile salmon, as well as spawning habitat for marine species such as longfin smelt. Among the salmonid species in the Nooksack are bull trout and two stocks of chinook salmon, listed as Threatened under the Endangered Species Act.

The first stage of juvenile migration through the Nooksack River estuary is tidally-influenced fresh water rearing. Securing adequate cover and food within cool temperature water are important goals of young salmon during this initial stage.

The second stage of juvenile outmigration through the estuary requires a change in habitat salinity, as young fish begin processing salt water. The salt wedge does not extensively penetrate channels that offer cover in the form of wood and shade. Moderately low water temperatures are important, as well as access to adequate cover. Food resources are of critical importance while the fish increase in size for marine survival. Low flow channels with wood accumulation provide shelter and food resources to fish in the second stage of outmigration.

The third stage of estuary utilization by juvenile salmonids requires saline water quality characteristics, but the primary requirements of food and shelter, remain as important as before. Juveniles in the third stage of estuarine migration are usually found in the nearshore and intertidal habitats. Benthic food resources are relatively abundant in higher salinity habitat, but the transition across the tide flat between fresh and highly saline water tends to be warmer than optimal in late spring and summer months. In the delta, blind channels provide important habitat characteristics, particularly undercut banks and abundant benthic invertebrates, and are heavily utilized by fish in this stage.

The diverse timing of Nooksack salmon stocks into the estuary presents both advantages and disadvantages to each stock. Early migrants, mainly fry migrant chinook, chum, and pink salmon, are met with abundant brackish and marine benthic invertebrate populations. Food may not be limiting during the early phase of outmigration. Flows are usually high during the early phase, creating maximum channel habitat in the estuary. Winter high tides, coupled with spring runoff, fill estuarine channels and provide juvenile salmon with maximum rearing habitat. Salinities are lower during spring freshets, allowing for a gradual transition of salmon from freshwater habitat to the marine environment. Water temperatures during winter/early spring are not limiting to salmon production. They remain consistently below the sub-lethal limit of 18° C.

Later spring arrivals to the estuary find somewhat fewer benthic food resources. Shelter opportunities begin to increase as bank and overhanging vegetation begins to fill interstitial spaces between branches. High discharge provides maximum channel habitat to outmigrants. Lower high tides during this time may warrant less salt wedge intrusion into delta habitats, thus reducing osmoregulatory transitional area for juveniles. Water temperatures remain cool throughout this phase. Late spring arrivals to the estuary enjoy all of the benefits the early spring arrivals do, with the addition of increased vegetation along streambanks.

Summer arrivals to the estuary are met with lower channel habitat volumes resulting from decreased discharge from the river. Decreased discharge results in higher salt concentrations as the salt wedge penetrates further into the freshwater channels. The saline transition zone in the delta becomes larger. Terrestrial insect populations are greater during the summer than in the winter, and benthic macroinvertebrates remain a significant source of food. The greatest disadvantage to summer arrivals to the estuary is potentially lethal water temperature. Increased temperatures during the summer may stimulate early migration to cooler nearshore habitats and into saline water quality.

Gaps in data that describe the current fish use of Nooksack River estuarine habitats prevent us from determining to what extent these habitats may be limiting salmonid productivity. More inclusive and systematic methods to monitor fish use of the estuary will help to gain a greater understanding of how and when estuarine habitats are used by fish. This knowledge will help drive an informed feasibility review of potential projects.

The Nooksack River estuary maintains diverse habitat that is important to several life stages of salmonid stocks, including ESA-listed chinook salmon and bull trout. While the lower Bellingham Bay delta of the Nooksack River remains largely undisturbed, opportunities exist to restore the historic connectivity of floodplain channels and sloughs that have been isolated in some areas by levees, tidegates, culverts, and ditches. Improving these areas can enhance important juvenile rearing habitat in the freshwater portions of the estuary. Other opportunities to restore habitat-forming processes throughout the watershed will also have a benefit to the estuary. Actions that preserve the quality of the Nooksack Delta habitat as it continues to develop into the future should be a priority for the area.

The Lummi Bay delta also offers opportunities to restore tidal processes and reconnect historic channels across much of the delta and floodplain. These actions will require considerable changes in land use on the floodplain and will likely require extensive stakeholder involvement to develop projects that benefit salmon without negatively impacting floodplain residents.

While estuarine habitat conditions have rapidly improved on the Bellingham Bay delta since the 1930s, salmon stocks, particularly chinook populations, have declined. Considering the estuarine habitat requirements of chinook juvenile salmon, habitat conservation and restoration projects should emphasize channel habitat that maintains diversity and complexity throughout the tidal cycle. Literature describes juvenile chinook preferences include deep tidal channels with pools and wood cover, only available in the Bellingham Bay side of the estuary during high tide events. They also prefer moderate salinities during estuarine residence, found in channels that have direct connection to the sea, but are well mixed with fresh water discharge (Allen and Hassler 1986). Unrestricted passage between various habitats is essential to successful utilization of estuarine habitats. The current capacity of the Nooksack estuary to provide rearing juvenile salmon habitat with these attributes is limited to seven short distributary channels and one larger side channel. The potential to increase rearing habitat through the reconnection of relict channels in other parts of the estuary is considerable.

Given the changes in the Nooksack estuary through time, and the recent decline of chinook salmon, restoration in the estuary study area holds promise for improving stock abundance, productivity, and diversity for ESA-listed species. While the initial study indicates that the relatively young Nooksack Delta estuary habitat is some of the best that anadromous Nooksack River fish stocks encounter as they migrate out of the river, the opportunities to provide improved access to isolated habitat and to restore habitat-forming processes are numerous, and should be fully explored. Several projects addressing these opportunities are outlined below.

Restoration Project Options

The recommendations in this section follow two general pathways: early action projects to better connect existing habitats, and the restoration of self-sustaining processes that create and maintain high quality habitat. For each project proposed, the degree to which it addresses a potentially limiting factor will be described, along with any additional analysis that may be needed and an assessment of near-term feasibility of the project. Over the long term, it will be important to restore the processes that maintain habitat to ensure that the early action projects can continue to function into the future. Project options will address the following habitat attributes, where applicable:

- Floodplain Function
- Water Quality
- Water Quantity
- Riparian Restoration
- In-stream Habitat Diversity
- Key Habitat Abundance

Floodplain Function

Land use activities throughout the Nooksack River watershed have impacted floodplain function and changed the delivery of wood, water, and sediment to the estuary. The most pronounced changes have occurred through diking, land clearing, wood removal, and channel straightening. By restoring some of the floodplain functions upstream, it will allow the estuary to return to more historic rates of habitat development and change.

Water Quality

Marked factors that may currently limit production are high estuarine water temperatures in tributaries and sloughs later in the migratory period, low dissolved oxygen, and limited freshwater-saline transitional habitat. Water quality recommendations focus on reducing sources of impairment and improving channel connectivity to encourage better water quality in important habitat areas and refuge areas. These two restoration tracks address the long-term solution of reducing water quality impairment and the near-term solution of providing a diverse array of refuge areas for rearing and transitioning anadromous salmon.

Water Quantity

Water quantity projects focus on improving the connectivity of channels and wetlands in the estuarine floodplain. Historic channels that are no longer available to migrating fish are reconnected to the estuarine channel complex, providing additional rearing habitat for outmigrating juvenile salmon and aquatic macroinvertebrates.

Habitat Diversity

Projects that increase habitat diversity will focus on removing invasive plants that compete with native species and simplify channels, adding wood to rearing areas for cover, and restoring riparian areas for longer-term habitat diversity.

Key Habitat Abundance
Fish access to the best estuarine habitat is not always possible. Immediate improvements to the estuary may be made by removing fish passage barriers and reconnecting high quality habitat not currently available for use by juvenile salmon to commonly used channels.

Restoration Options by Geographic Area

1. General Floodplain Projects

a) Slow transport of wood through mainstem and the estuary by:
   - Construction of in-stream structures (log racks) downstream of Everson to mimic the historic function of logjams in the main channel. These structures will be spaced to capture transient wood added to the system naturally and strategically to replace what has been depleted from historic levels.
   - Benefits include increasing instream channel diversity through promoting Nooksack River salmon's food web production, predator refuge for juvenile salmon, and potential flood relief.
   - Feasibility concerns: Private landowner, Whatcom County Flood Division, and Whatcom Diking District cooperation. Feasibility facilitators: Increased public education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

b) Improve sediment and water storage on the floodplain by:
   - Lowering, setting back, or breaching levees to allow more frequent flooding and sediment storage on the floodplain upstream of Marine Drive, with the objective to restore sediment delivery to the estuary by more historic means.
   - Benefits include improved floodplain function, riparian restoration, and reduced sediment load in delta channels.
   - Feasibility concerns: Private landowner, Whatcom County Flood Department, and Whatcom County Diking District cooperation; additional surveying to model flood effects; and property acquisition. Feasibility facilitators: In addition, preservation land purchases potential, and financial aid from Whatcom County Flood Fund.

c) Implement Best Management Practices (BMPs) for agriculture and animal husbandry through:
   - The use of native vegetation buffers and filter strips near streams, integrating natural pest management to replace the use of chemical pesticides, limiting manure spreading for fertilization to drier summer months, and excluding livestock intrusion into stream and drainage channels.
   - Resulting benefits improve floodplain function and water quality by greatly reducing fecal coliform levels and water temperature, improving dissolved oxygen concentrations, and the reducing fine sediment in stream channels.
   - Feasibility concerns: private landowner/farmer cooperation. Feasibility facilitators: Department of Ecology, increased public education, and the

efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

d) Restore historic riparian stand vegetation by:
   - Planting native forest and scrub-shrub vegetation species along stream channels and their floodplains.
   - Benefits of this project include water quality improvement through increasing shade with taller, trees and shrubs to reduce solar heating of channels. Food web production would increase with more leaf litter dropped into the channel. Instream diversity would improve with increased wood recruitment for fish and invertebrate habitat. Increased riparian vegetation would improve stream bank stabilization. Floodplain function would improve with increased populations of wildlife and insects in the floodplain and the establishment of a native seed bank capable of reproducing and maintaining natural riparian habitat.
   - Feasibility barriers: landowner cooperation. Feasibility facilitators: Increased public education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

e) Reconnect floodplain wetlands and relict channels to the Nooksack channel complex by:
   - Removing barriers to flow, such as dikes, bars, or dams.
   - Benefits include increased floodplain function and filtering of pollutants, increased water quantity, improved water quality, instream diversity and habitat abundance.
   - Feasibility barriers: Whatcom County Flood Department, Whatcom County diking districts, Whatcom County Roads Department, and landowner cooperation. Feasibility facilitators: Increased public education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife). In addition, there exists land purchase potential.

2. Nooksack Delta

a) Improve floodplain connectivity by:
   - Lowering, breaching or removing levees along river channels along the main channel, its tributaries and distributaries.
   - Benefits include improved floodplain function with free passage of flow and sediment during flood events, improved water quality, and increased water quantity.
   - Feasibility barriers: Whatcom County Flood and Roads departments, landowner, and Whatcom County Diking District cooperation. Feasibility facilitators: Increased public education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource

managers (Tribes and the State of Washington Department of Fish and Wildlife). In addition, lands impacted by these options are currently owned by or slated to be owned by resource managers (WDFW and LNR). FEMA and DOT funding exists for such projects.

b) Remove pilings at head of Kwina Slough (Figure 84).
   - Benefits include improved instream diversity by increasing wood recruitment into the channel for pool formation, and increasing habitat for invertebrates; increased juvenile rearing habitat abundance through improved connection; and improved water quality provided by cooler river water flushing the channel year round through shaded, side channel habitat.
   - Feasibility barriers: Landowner, county roads and county flood cooperation. Feasibility facilitators: Increased public education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

Figure 84. The pilings at the head of Kwina Slough during high winter flows.

c) Breach the dike along the right bank of Kwina Slough below Marine Drive to improve fish habitat by:

   1. Reconnecting the Howell wetland complex (Figure 85) and Smuggler's Slough to Kwina Slough, providing unobstructed passage for water, nutrients, fish, and other aquatic organisms.

2. Restoring connectivity and historic function of Smuggler's Slough between the two deltas, increasing transition habitat for juvenile salmon leaving the Nooksack River.
3. Improving drainage under Marine Drive with beaver-deceiving technology and a larger culvert.
4. Improving exchange and drainage between wetland habitat and Kwina Slough side channel fish habitat.

- Benefits include improved floodplain function, increased juvenile coho rearing habitat in the wetland complex, increased water quantity to the delta, improved water quality through wetland filtration of surface waters, and increased habitat abundance to the estuary.
- Feasibility concerns: The need for further hydraulic modeling and surveying to analyze potential flood impacts; landowner, Whatcom County diking district, Whatcom County Roads Department, and Department of Transportation cooperation; and land acquisition. Feasibility facilitators: Increased public education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

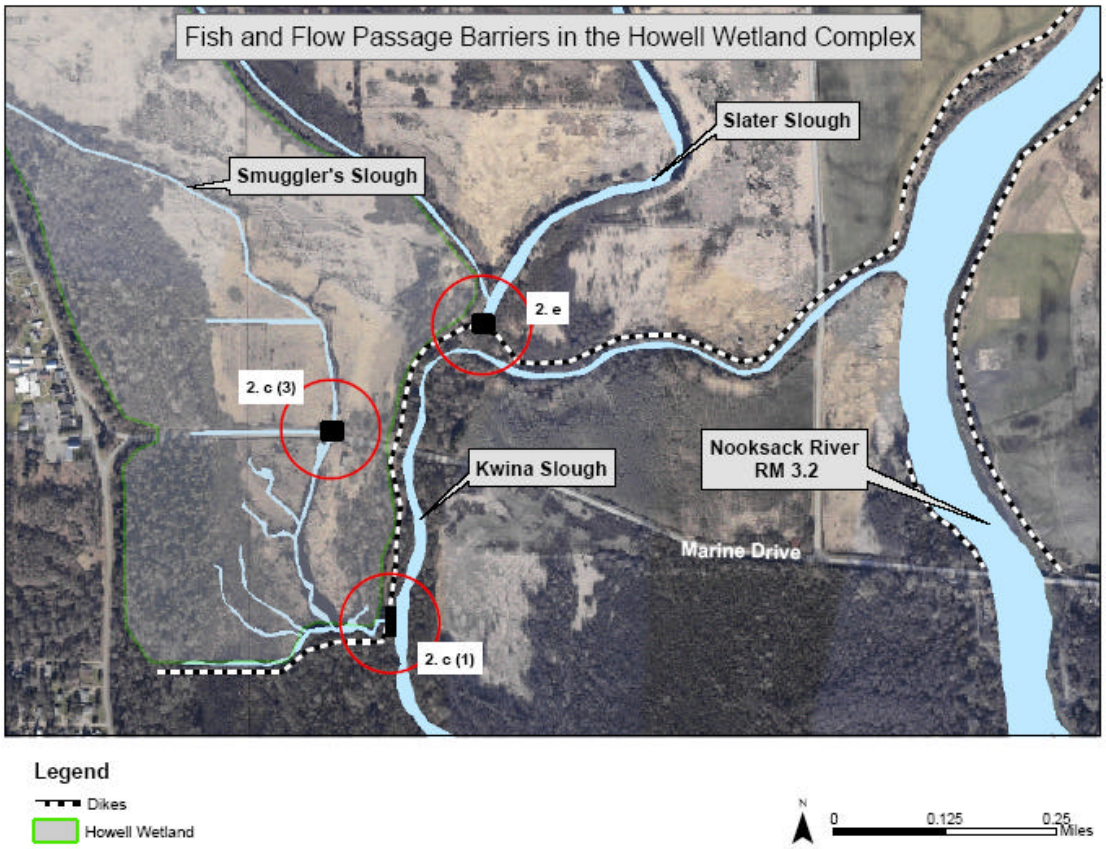

Figure 85. Area map of Smuggler's Slough and its connections with Slater and Kwina Sloughs.

d) Remediate a non-functioning tidegate in the lower section of the Kwina Slough dike by:
   - Updating the existing tidegate with one that is fish passable.
   - Benefits include: improved drainage of the floodplain into side channel habitat, improved flood conditions over Marine Drive; increased rearing habitat for juvenile salmon; and increased water quantity into the estuary.
   - Feasibility concerns: The need for further hydraulic modeling and surveying to analyze potential flood impacts; landowner, Whatcom County diking district, Whatcom County Roads Department, and Department of Transportation cooperation; and land acquisition. Feasibility facilitators: Increased public education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife). In addition, pending land purchases may facilitate this project.

e) Reconnect Slater Slough with the Nooksack River estuarine channel network by:
   - Breaching the Kwina Slough dike at the mouth of Slater Slough, or installing a fish-passable tidegate at the site, and excavating the relict channel to again pass water to and from the river.
   - Benefits include an increase in fish habitat; restored floodplain function of Smuggler's and Slater Sloughs; increased instream diversity from improved opportunities for fish refuge and feeding; increased water quantity in estuarine side channel habitat; and flood relief potential.
   - Feasibility barriers: Landowner, Whatcom County Flood Department, and diking district cooperation. Feasibility facilitators: Increased public education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

3. Lummi Delta

a) Improve passage between Lummi River and Nooksack River by:
   - Replacing the collapsed culvert that links the Nooksack River mainstem to the Lummi River channel (Figure 86).
   - Benefits include improved floodplain function with a more consistent flow regime; potential flood benefits; improved water quality (decreased temperature and increased dissolved oxygen) in the Lummi River; increasing potential osmoregulatory habitat; and providing an alternative route for some outmigrant juvenile salmon to eelgrass habitat and abundant food resources in Lummi Bay.
   - Feasibility barriers: Current water quality issues in the Nooksack River being transferred to Lummi Bay; the need for hydraulic and topographic modeling; land acquisition; and cooperation from the Whatcom County diking district, flood control and roads departments, Department of Transportation, and landowners. Feasibility facilitators: Increased public education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington

Department of Fish and Wildlife). In addition, there is potential for restoration habitat purchase funding.

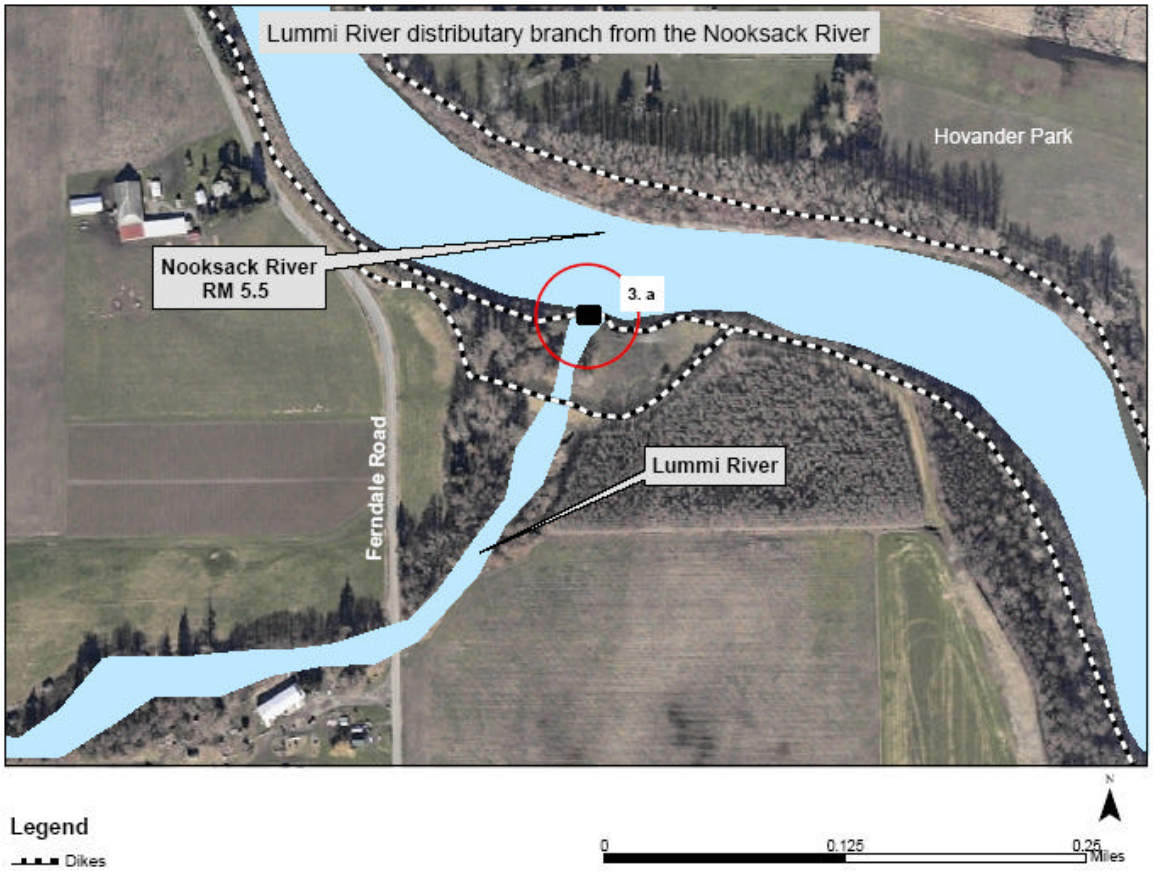

Figure 86. Location of the Lummi River culvert on the Nooksack River.

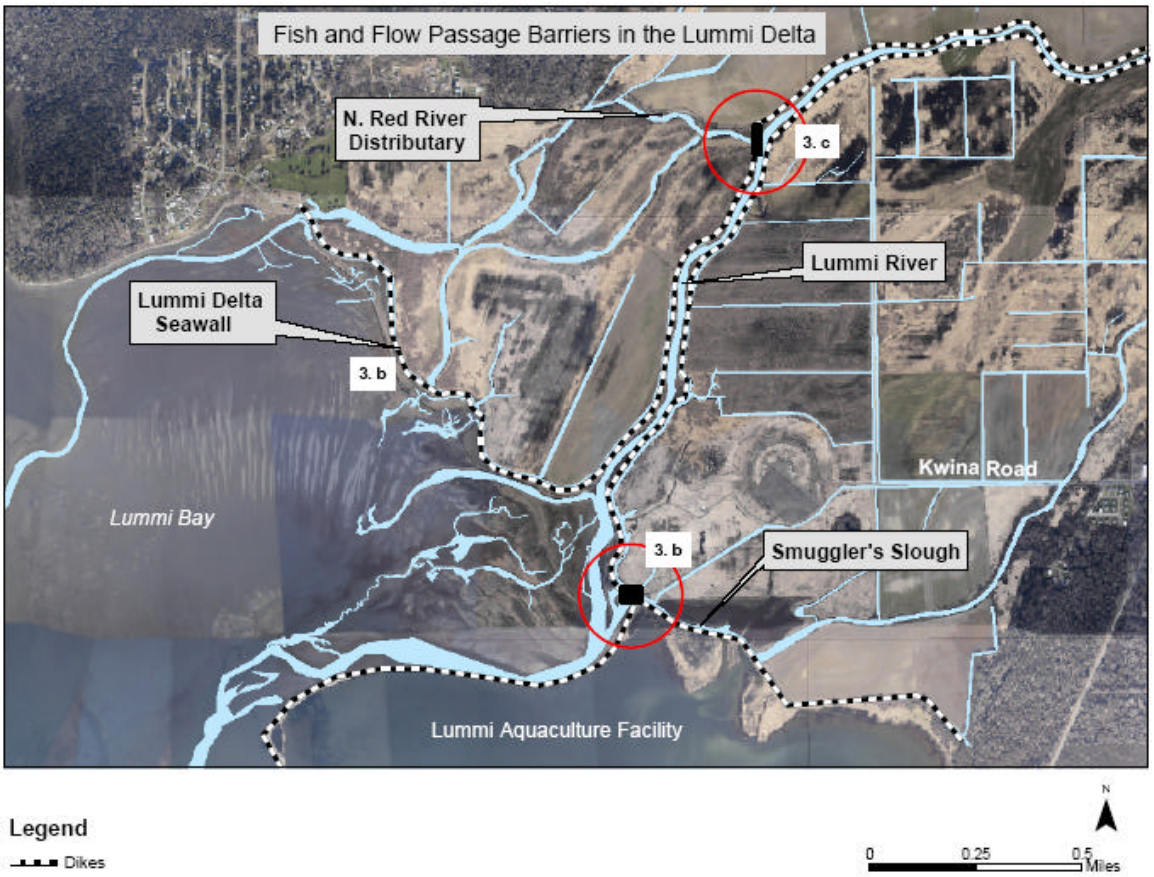

Figure 87. Lummi Delta restoration project alternatives.

b) Restore hydrology of tidal channels and salt marsh by:
- Removing the Lummi Delta-spanning seawall dike west of Lummi Aquaculture site (Figure 87).
- Benefits include increased habitat abundance: improved fish access to 1,550 acres of salt marsh with intermittent scrub-shrub vegetation, and 12.9 stream miles of relict channel habitat plus 14.8 miles of ditches with channel habitat potential. In addition, increased habitat diversity, improved water quantity in the delta, improved water quality through wetlands cleansing of surface water, increased estuarine production of food resources for fish, and restored floodplain function of Smuggler's Slough.
- Feasibility barriers: Landowner cooperation, and the purchase of divided ownership parcels; high project costs. Whatcom County Roads and Flood Department cooperation may also be a barrier to feasibility. The wetlands behind the dike are capable of reducing flood impacts; however, hydraulic modeling of relict channels and their floodplains would be required to assess the extent of potential flood activity. Flood impacts would be compounded by other potential restoration projects that influence the area, such as dike breaching on Kwina Slough. Feasibility facilitators: Increased public

education, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife). In addition, development mitigation funding may exist.

c) Reconnect the North Red River distributary channel of the Lummi River by:
   - Breaching the lower Lummi River dike at its confluence with the N. Red River distributary (Figure 78).
   - Benefits include the improvement of instream diversity by restoring historic distributary habitat, an increase in osmoregulatory and rearing habitat abundance, restored floodplain function, and improved water quality (fine sediment settlement onto the floodplain, and reduced temperatures).
   - Feasibility barriers: Landowner and Whatcom County Flood Department cooperation. Flooding on the property of the Sandy Point Golf Club would be mitigated by a higher dike along its S. and E. border with Lummi Delta. Feasibility facilitators: Increased public education, funding for the purchase of restoration lands, development mitigation funding, and the efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

4. Pocket Estuaries and Nearshore

Recovering these estuaries and the nearshore as rearing habitat for juvenile salmon would benefit not only Nooksack River salmon, but salmon from other watersheds that migrate through these areas enroute to sea or their natal streams.

a) Restore historical estuarine processes in the Squalicum Creek estuary by:
   - Removing 13 acres from 6 separate parcels (A-F, Figure 88) of fill and associated industry and restoring salt marsh rearing habitat for salmon at the current site of Mt. Baker Plywood.
   - Rerouting Squalicum Creek through its historic channel along the bluff into restored salt marsh.
   - Benefits include increasing salt marsh habitat abundance, and the restoration of 0.36 miles of upper intertidal shoreline. Habitat diversity would increase through the restoration of salt marsh and tide flat. Estuarine processes would be restored through the reconnection of the stream channel to salt marsh habitat. The removal of barriers to drift cell transport between Bellingham and the Nooksack River would improve nutrient exchange and sediment transport to and from the Nooksack Delta.
   - Feasibility barriers: High cost; landowner and industry cooperation; Department of Transportation, Washington State Department of Natural Resources (WADNR), Port of Bellingham, and City of Bellingham cooperation. Feasibility facilitators: Increased public education, the Endangered Species Act, and efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes

and the State of Washington Department of Fish and Wildlife). Gradual restoration through several alternatives is possible.

Figure 88. Restoration options to restore historic function of Squalicum Creek estuary.

b) Restore some of the 80% of historic Whatcom Creek salt marsh and tide flat lost to development by:
   - Removing artificial fill (A-F, Figure 89) from the estuarine floodplain at the mouth of Whatcom Creek to reconnect 16.5 acres in the historical estuarine floodplain to Whatcom Creek and tidal hydrology.
   - Benefits include restoration of three-quarters of a mile of intertidal shoreline for use by forage fish, invertebrates, salmon, and trout; increased floodplain function in restored salt marsh, increased juvenile salmon rearing habitat, and improved instream habitat diversity.
   - Feasibility barriers: High cost, landowners and industrial interests, particularly the ReStore and the Parberry Recycling compound next door. The Bellingham Parks Interpretative Center would have to be relocated. WADNR, Port of Bellingham, and the City of Bellingham cooperation would be imperative. Feasibility facilitators: Increased public education, the

Endangered Species Act, and efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife). Gradual restoration through several alternatives is possible.

Figure 89. Restoration options to restore historic function of Whatcom Creek estuary.

c) Recover historic salt marsh and mud flat habitat in the Padden Creek estuary lost to development by:
   - Removing artificial fill (A-C, Figure 90) from the estuarine floodplain.
   - Benefits include increased habitat abundance and improved habitat diversity (over a mile of intertidal shoreline, and 27 acres of salt marsh and tide flat), and restored floodplain function through reconnection of tidal prism to Padden Creek hydrology.
   - Feasibility barriers: Landowner and industry cooperation, as well as the cooperation of the Department of Transportation, Burlington Northern Railway, WADNR, City of Bellingham, and the Port of Bellingham. Feasibility facilitators: Increased public education, the Endangered Species Act, and efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife). Gradual restoration through several alternatives is possible.

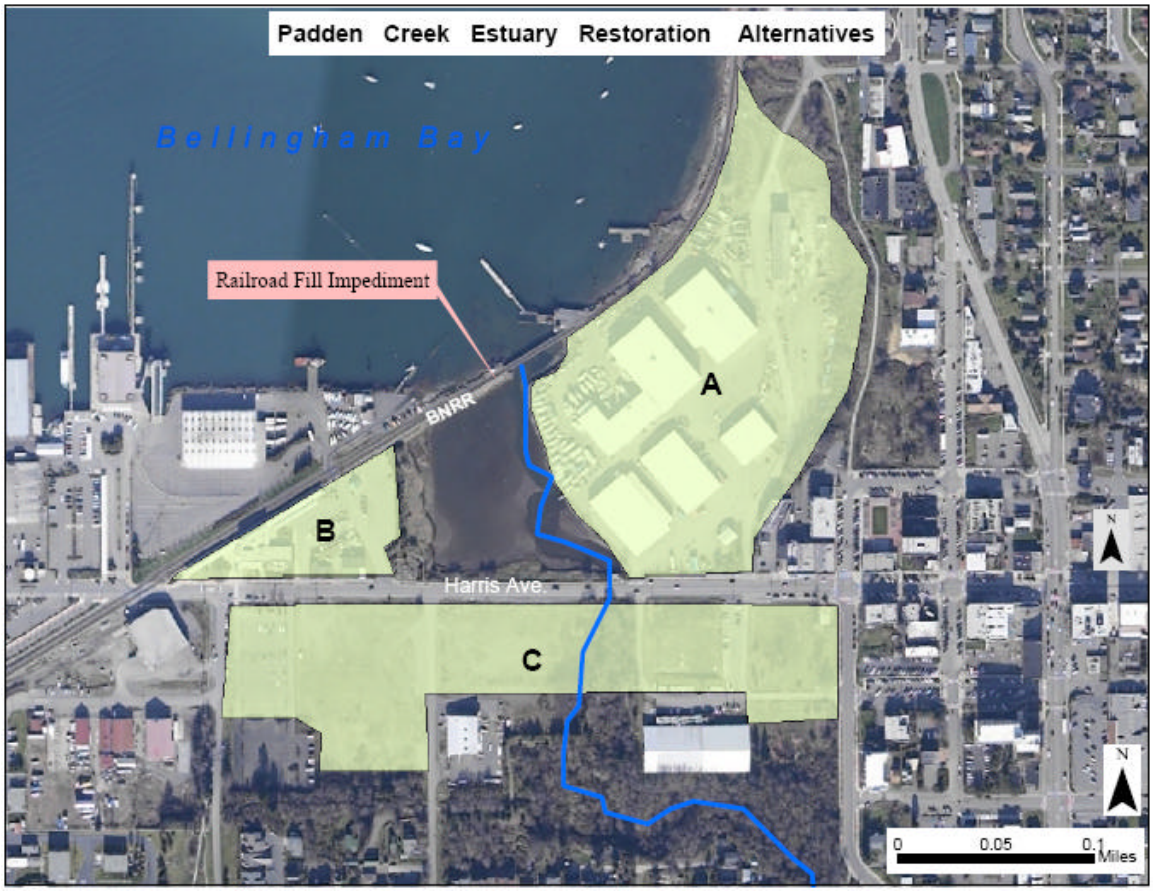

Figure 90. Restoration options to restore historic function of the Padden Creek estuary.

d) Modify nearshore bulkheading and armoring by:
   - Replacing bulkhead materials with an elevated beach berm.
   - Benefits include the reduction of beach scour, restoration of the littoral sediment supply and its movement; the increase in habitat diversity through the restoration of backshore vegetation and the natural accumulation of driftwood; and flood benefits.
   - Feasibility barriers: Landowner, Whatcom County Flood Department, and WADNR cooperation. Feasibility facilitators: Increased public education, the Endangered Species Act, and efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

e) Mitigate for existing nearshore bulkheading and armoring by:
   - Artificially nourishing scoured beach habitat.
   - Benefits include the restoration of the littoral sediment supply and its movement, and the reduction of wave-induced erosion.
   - Feasibility barriers: Landowner, Whatcom County Flood Department, and WADNR cooperation. Feasibility facilitators: Increased public education, the Endangered Species Act, and efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

5. Conservation and Protection

a) Improve the protection of undeveloped floodplain and shorelines:
   - Habitat in the estuary not currently developed, including floodplain and shorelines, must be protected by development moratoriums.
   - Impacts of past development are felt as resources are strained, and species struggle to survive in an environment significantly different from conditions just eighty years ago.

b) Protect woody debris on streambanks and shorelines from removal:
   - Driftwood and log jams should be granted protection from harvesters and managers.
   - The vital role of wood in the estuary should make its removal from shorelines and streambanks unlawful.
   - Feasibility barriers: Current dependence on this resource as a local energy source.

c) Increase protection and conservation of all nearshore habitat in the Nooksack River estuary:
   - Those areas not yet impacted by growth could be protected by a state and county moratorium on development of shorelines. High quality habitats to

protect include nearshore areas with unobstructed tide and beach exchange, forage fish spawning gravels, and eelgrass beds.

- Benefits of these protections include nearshore production of forage fish and culturally important shellfish and Pacific salmon, and sustained nearshore habitat diversity for juvenile salmon feeding, resting and predator avoidance.
- Feasibility barriers: Political will, private landowners, industry, WADNR, Whatcom County, Port and City of Bellingham cooperation. Feasibility facilitators: Increased public education, the Endangered Species Act, and efforts of conservation groups (NSEA, CREP, Whatcom County Critical Areas Ordinance) and resource managers (Tribes and the State of Washington Department of Fish and Wildlife).

Bibliography

ADFG (Alaska Department of Fish and Game). 2004. Ecosystem Description: Estuarine Environments. http://www.habitat.adfg.state.ak.us/geninfo/kbrr/coolkbayinfo/kbec_cd/html/ecosys/estuarin/eelgrass.htm

Aitkin, J. K. 1998. The importance of estuarine habitats to anadromous salmonids of the Pacific northwest: A literature review. USFWS Aquatic Resources Division, Lacey, WA. Bulletin August, 1998.

Allan, D. J. 1996. Stream Ecology: Structure and Function of Running Waters. 2nd ed. Chapman and Hall, London, England. 388pp.

Allen, M.A., and T.J. Hassler. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates – Chinook Salmon. USFWS Biological Report 82(11.49). USACE, TR EL-82-4. 26pp.

Anchor Environmental. 2001. Fish distribution and periodicity in WRIA 01. Final Draft, October, 2001. Prepared for: City of Bellingham Public Works Department. Seattle, WA.

Apfelbaum, S.I. and C.E. Sams. 1987. Ecology and control of reed canary grass (*Phalaris arundinacea* L.). Natural Areas Journal 7: 69-74.

ASHE. 2004. Use of Wetlands for Stormwater Treatment. Report to the American Society of Highway Engineers, Scanner Newsletter, January 27, 2004. Uniontown, PA. http://www.highwayengineers.org

Averill, D., D. Myers, and S. Redman. 2004. Proposed working hypotheses for a regional nearshore salmon recovery plan. Prepared for the Nearshore Policy Group of the Puget Sound Action Team.

Bailey, J. E., B.L. Wing, and C.R. Mattson. 1975. Zooplankton abundance and feeding habits of fry of pink salmon, *Oncorhynchus gorbuscha*, and chum salmon, *O. keta*, in Traitor's Cove, Alaska, with speculations on the carrying capacity of the area. Fish. Bull. 73: 846-861.

Bargman, G. 2001. WDFW Studies the Cause of Cherry Point Herring Decline. *In*: Fish and Wildlife Science. WDFW online science magazine: http://wdfw.wa.gov/science/articles/herring/

Bauer, W. 1974. The drift sectors of Whatcom County marine shores: their shoreforms and geohydraulic status. Report to the Whatcom County Planning Commission, Whatcom County, Washington. Contract No. II-305-15.

Beamer, E., A. McBride, R. Henderson, and K. Wolf. 2003. The importance of non-natal pocket estuaries in Skagit Bay to wild chinook salmon: an emerging priority for restoration. Technical Report to Skagit System Cooperative, LaConner, WA.

Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. L. Murphy, K. V. Koski, and J. R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present and future. Pages 143-190 in E.O. Salo and T.W. Cundy, editors. Streamside Management Forestry and Fishery Interactions. Univ. of Wash., Institute for Forest Resources, Contribution 57, Seattle, WA.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.

Blakley, A., B. Leland, J. Ames, eds. 2000. The 2000 Washington State Salmonid Stock Inventory (SASI): Coastal Cutthroat Trout. WDFW, Olympia, WA. 265pp.

Boggs, S. 1987. Principles of Sedimentology and Stratigraphy. Macmillan Publishing Company, New York, NY. 784pp.

Bortleson, G. C., M. J. Chrzastowski, and A. K. Helgerson. 1980. Historical changes of shoreline and wetland at eleven major deltas in the Puget Sound region, Washington. U.S. Geological Survey, Hydrologic Investigations Atlas HA-617, Denver, Colorado.

Brennan, J.S., K.F. Higgins, J.R. Cordell, and V.A. Stamatiou. 2004. Juvenile salmon composition, timing, distribution, and diet in marine nearshore waters of central Puget Sound, 2001-2002. King County Dept. of Natural Resources and Parks, Seattle, WA. 164pp.

Brett, J. R. 1952. Temperature tolerances in young Pacific salmon, genus *Oncorhynchus.* J. Fish. Res. Board Canada. 9(6):265-323.

Burgner, R.L. 1998. Life history of sockeye salmon, *Oncorhynchus nerka*. Pages 3 – 117. I*n* C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver.

Bush, Richard A. 2003. Juvenile Steelhead Residence and Growth Patterns in a California Coastal Lagoon. *At:* http://johnmuir.ucdavis.edu/aeal/projects/estuarine.html

Chang, Hai-Yang. 1967. Hydraulics of rivers and deltas: unpublished PhD dissertation, Colorado State University. 176pp.

Chang, H.H. 1988. Fluvial Processes in River Engineering. John Wiley and Sons. 432pp.

Clark, W.C. and J.E. Shelbourn. 1985. Growth and development of seawater adaptability by juvenile fall chinook salmon (*Oncorhynchus tshawytscha*) in relation to temperature. Aquaculture 45:21-31.

Collias, E. E. and C.A. Barnes. 1966. Physical and chemical data for Puget Sound and approaches : January 1966-December 1966. University of Washington. Seattle. 466pp.

Collins, B.D., and A.J. Sheikh. 2002. Historical Riverine Dynamics and Habitats of the Nooksack River. Interim Report Prepared for the Nooksack Indian Tribe. 93 pp.

Collyer, C.T. 1998. Current patterns and suspended sediment transport through the Inner Harbor, Bellingham Bay, Bellingham, Washington**.** Western Washington University Masters Thesis.

Columbia Encyclopedia. 2004. 6th ed. [Annelida]. New York: Columbia University Press, 2001-2004. www.bartleby.com/65/. Sept. 16, 2004.

Cordell, J. R., C. Tanner, and J. K. Aitkin. 1999. Fish assemblages and juvenile salmon diets at a breached-dike wetland site, Spencer Island, Washington 1997-98. Univ. Washington School of Fisheries, Fish. Res. Inst., FRI-UW-9905. Seattle, Washington.

Cowardin, L.W., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. US Dept. of the Interior. FWS/OBS-79/31.

Currence, N. Fisheries/habitat biologist, Nooksack Natural Resources. Personal communication, May 10, 2004.

Custer, H. 1857. U.S. Northwest Boundary Survey. *"Sketch of the lower part of the Nucsac River."* Made Aug. 25, 1857. From notebook "*Reconnaissance of Sumas Prairie, Frazer's River, Whatcomb Lake etc. 1857-1858, H. Custer.*" RG 76 Series Entry 202, Reconnaissance Notes 1857-58.

Custer, H. 1858. *{Sketch map from reconnaissance of Lummi Bay, Lake Whatcom, Nooksack River and Whatcom Trail.}* From reconnaissance of June 7-24, 1858. RG 76 Series 69, alternately in files with maps 71-80 and 75-80.

Cuomo, C., and G.A. Zinn. 1997. Benthic Invertebrates of the Lower West River. In: Restoration of an urban salt marsh: an interdisciplinary approach. Yale School of Forestry and Environmental Studies Bulletin Series, Number 100. p. 152-161.

Deardorff, L.V. 1992. A brief history of the Nooksack River's delta distributaries. Lummi Natural Resources Department.

DNR. 1996. Washington State Department of Natural Resources GIS layer found in: Nearshore Habitat Program. Puget Sound Intertidal Habitat Inventory 1995 CD-ROM. 1997.

DOE. 2002. Focus sheet: Fecal coliform bacteria and Washington State's water quality standards. Technical Report 02-10-010. March 2002.

Downing. 1983. The coast of Puget Sound, its processes and development. Washington Sea Grant Publication, University of Washington Press.126 pp.

Dunford, W.E. 1975. Space and food utilization by salmonids in marsh habitats of the Fraser River estuary. M.S. thesis. University of British Columbia, Vancouver, BC. 81 pp.

Dunphy, G. Watershed Biologist, Lummi Natural Resources. Personal communication, May 5, 2004.

EPA Website. 2003. Accessed June 2, 2004. Last updated on Friday, January 17th, 2003. http://www.epa.gov/owow/wetlands/types/marsh.html

Fairbridge, R.W. 1980. The estuary: its definition and geodynamic cycle. In Chemistry and Biochemistry of Estuaries. Edited by Olausson, E. and I. Cato. Wiley and Sons. pp 1-35.

First, L., and J. Freimund. 2003. Northern Lummi River distributary channel area wetland mitigation banking assessment. Lummi Nation Water Resources Technical Report, November 2003.

Graff, L., and J. Middleton. 2003. Wetlands and Fish: Catch the Link. NOAA/NMFS Department of Habitat Conservation. Publication available through this address: http://www.nmfs.noaa.gov/habitat/

Gray, A., C.A. Simenstad, D.L. Bottom, and T.J. Cornwell. 2002. Contrasting functional performance of juvenile salmon habitat in recovering wetlands of the Salmon River estuary, Oregon, U.S.A. Restoration Ecology 10 (3) 514-526.

Gustafson, R.G. and G.A. Winans. 1999. Distribution and population of river and sea-type sockeye salmon in western North America. Ecology of Freshwater Fish, 8:181-193.

Galiano and Valdez. 1792. Three historic maps: “Carta Esférica.”

GBNEP. 1994. The state of the bay: a characterization of the Galveston Bay ecosystem. F.S. Shipley and R.W. Kiesling, eds. Technical report to the Galveston Bay National Estuary Program. Pub. # GBNEP – 44.

Glova, G.J., and M.J. Duncan. 1985. Potential effects of reduced flows on fish habitats in a large braided river, New Zealand. Trans. Amer. Fish. Soc. 114:165-181.

Gregory, R. S. and C. D Levings. 1996. The effects of turbidity and vegetation on the risk of juvenile salmonids, *Oncorhynchus* spp., to predation by adult cutthroat trout, *O. clarkii*. *Environmental Biology of Fishes*. 47: 279–288.