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FIR ISLAND FARM RESTORATION FEASIBILITY STUDY

FISHERIES BASELINE MEMO

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1. INTRODUCTION

Though the Skagit River delta has been the focus of a significant body of fisheries related study, limited sampling and research has been specifically focused in the tidal blind channels, tidal estuarine habitats and upland drainages adjacent to and within WDFW's Fir Island Farm. This baseline memo will provide highlights from the larger body of fisheries study in the Skagit River delta and will summarize the fisheries studies specific to WDFW's Fir Island Farm Restoration Feasibility Study site.

2. SKAGIT RIVER ESTUARY- GENERAL

2.1 Fish Species

A variety of fish species and life stages are present in the central Fir Island region of the Skagit River delta. Fish sampling in Brown Slough (1995-2003) and Dry Slough (2008) have captured juvenile Chinook salmon, juvenile Chum salmon, juvenile Coho salmon, juvenile Pink salmon, juvenile Sockeye salmon, juvenile Steelhead trout, Cutthroat trout, Bull trout, Surf smelt, Starry Flounder, Staghorn Sculpin, Three-spine Stickleback, Prickly Sculpin, Shiner Perch, and Peamouth Chub (Beamer et al.1998, Beamer unpublished data 1995-2003; Skagit Fisheries Enhancement Group, 2008).

2.2 Fish Related Estuarine Habitat Functions

The Puget Sound is a large estuary complex that contains several large river estuaries including the Skagit River (Redmond et al. 2005). Estuaries are defined as the mixing zone of freshwater from river outflows and the saltwater from the ocean, and are typically found within partly enclosed tidal inlets including sheltered bays, inlets, lagoons, and river deltas (Little 2000). Estuaries are among the most biologically productive and diverse ecosystems on Earth, and provide rich nursery habitats for salmon and other species. The Skagit delta can be delineated into two major areas: the freshwater tidal delta and the estuary (Beamer et al. 2005). The estuary includes the lower freshwater areas of the Skagit River delta where saltwater mixes with freshwater, Skagit Bay, Swinomish Channel, and Padilla Bay (Beamer et al. 2007). The upper end of the estuary is situated within the lower regions of the north and south fork Skagit, and extends several miles upstream during summer and fall low flow conditions, but shifts outward into Skagit Bay during higher river flows conditions (Yang and Khangaonkar 2006; 2009). WDFW's Fir Island Farm is located adjacent to Skagit Bay between the north and south forks of the Skagit River in the estuary area of the Skagit delta. The

front of Skagit Bay where the Fir Island Farm is located is one of the only remaining areas in the Skagit delta where the freshwater-saltwater mixing that defines estuary habitats is sustained throughout the year. The results of hydrodynamic modeling completed for the Skagit delta (Yang and Khangaonkar 2006) indicate that most of the areas in the north and south fork are dominated by freshwater during high flow periods of the year, when a freshwater plume extends from the north and south forks into Skagit Bay.

Skagit River estuarine habitats provide the following four main interrelated functions for juvenile salmon: physiological transition from freshwater to saltwater, foraging and growth, predator avoidance, and migratory corridors (Simenstad et al. 1982, Beamer et al. 2005).

2.3 Physiological Transition

For anadromous fish species, the mixing zone of fresh and salt water of the estuary is critical for the successful physiologically transition of juvenile and adult life stages between freshwater and saltwater habitats. Anadromous fish species of the Skagit River that migrate through the Skagit delta and estuary include Chinook salmon, Chum salmon, Coho salmon, Pink salmon, Sockeye salmon, steelhead trout, cutthroat trout, and bull trout. The species that are most dependent upon the estuary are Chinook salmon, chum salmon, pink salmon (Healy1991; Quinn 2005).

2.4 Foraging and Growth

The Skagit River estuary produces a significant amount of plant material called detritus that is a major source of food supply for small invertebrates that are in turn a primary prey of juvenile salmonids and forage fish species. This estuarine detritus also provides the primary base for the nearshore marine food web (Smith et al. 2005).

Certain prey items appear to be selectively chosen over others depending on the salmonid life history stage. For example, juvenile chum salmon feed on a certain type of copepod that lives on the bacteria near decaying eelgrass (Simenstad et al.1982), while prey items for small Chinook juveniles includes midges, crab larvae, flies, water fleas and other insects and crustaceans (Healey 1991). The intertidal, shallow sub-tidal, blind channel and distributary channel habitats in the estuary provide juvenile salmonids with access corridors to estuary habitats producing preferred prey species (Shreffler and Thom 1993). In addition, the interaction of tides and channel habitats provides a delivery system that transports preferred prey species from estuary habitats that are otherwise not accessible by juvenile salmonids (Smith et al. 2005).

On average a Skagit ocean type juvenile Chinook salmon will rear in the estuary approximately 35 days (Beamer et al. 2005). The results of an ongoing otolith study links juvenile Chinook salmon survival potential in Skagit Bay to rearing time in the Skagit tidal delta (Beamer, E., pers. comm., SRSC, 2010). The growth rates of juvenile Chinook were found to be greater in estuary areas of the Skagit compared to freshwater habitats (Beamer and Larsen 2004). The increased rearing time and faster growth rates

in the estuary produces larger juvenile Chinook salmon entering Skagit Bay compared to Chinook life history types that don't have an extended rearing period (i.e., fry outmigrants), or don't rear in the high productivity habitats found in the estuary. The marine survival for larger juvenile Chinook salmon entering Skagit Bay was assumed to be greater than the survival for smaller juveniles, with delta tidal rearing juveniles having an average smolt-to-adult survival rate of 0.5% (Beamer et al., 2005). The marine survival rates of juvenile Chinook salmon in the Puget Sound significantly increased as a function of outmigrant size (Duffy et al. 2005). Juvenile Chinook growth rates, in turn, were found to be dependent upon diet composition and food availability in the nearshore and estuary areas of the Puget Sound, with juvenile growth rates highest in areas where insects, gammarid amphipods, decapods (crab larvae), and forage fish are abundant (Duffy et al. 2010). Survival to adult has been shown to be much lower for non-estuary rearing Chinook (Reimers 1973; Levings et al. 1989). A population and life history model completed for Skagit Chinook found that estuary residency of outmigrating smolts results in higher ocean survival rates, thus improving adult return rates (Greene and Beechie 2004). The availability of food resources is considered to be the primary factor limiting the density and growth rates of juvenile Chinook in the Skagit delta (Greene and Beamer 2005).

2.5 Predator Avoidance

Intertidal and shallow subtidal habitats provide juvenile salmonids protection and refuge from bird and fish predators, while blind channel and side-channel estuary habitats serve as refuge from high water river discharge events.

Growth and survival are interrelated as growth rate can affect survival as a result of how rapidly the fish can "outgrow" portions of their predator population (Beamer et al., 2005). Parker (1971) showed that smaller fish in juvenile salmon populations were eaten at a higher rate than larger fish. Juvenile salmon are generally distributed based upon water depth, with the depth of the water occupied by the fish increasing as the size of the fish increases (McCabe et al. 1986).

Declines in available prey in the estuary have been shown to result in small juvenile salmonids migrating more quickly to other areas in search of prey (Simenstad et al., 1980). The expenditure of extra energy for this migration is thought to slow growth and lead to an increased risk of predation (Smith et al., 2005).

2.6 Juvenile Salmon Migration

Juvenile salmon use of estuarine habitats varies by species and by the different life history types within a species. Life history variation is important to buffer populations against changes in survival at different life stages that may result from natural or human caused catastrophes (e.g., drought, flood, volcanic eruptions, tsunamis, oil spills) (Beamer et al., 2005).

Ocean type juvenile Chinook salmon migrate to the marine environment within a few days to a few months after emerging as fry from fresh water incubation (Healy 1991).

Residency of ocean type juvenile Chinook salmon in the lower riverine and estuary environments ranges from 6 to 189 days (Simenstad et al., 1982). Beamer and Henderson (1994) documented the presence of ocean-type Chinook within the lower Skagit River between February and June. Stream type juvenile Chinook salmon, which spend at least a year in freshwater before migrating to the estuary, move directly into the offshore marine habitats without extended utilization of estuary or nearshore habitats (Simenstad et al., 1982). Based on WDFW Skagit River Mount Vernon smolt trap data between 1998 and 2009, the 30-day window with the highest percent of sub yearling Chinook salmon migrants is March 3 and April 1 (personal communication Mara Zimmerman WDFW, 2010). The overall average peak of juvenile Chinook salmon in the tidal delta occurs throughout April (personal communication Eric Beamer).

Juvenile Coho salmon typically spend a full year or more rearing in freshwater prior to outmigrating to the marine environment. Individual residency of yearling coho in the estuary can range from 4 to 32 days (Simenstad et al., 1982). Beamer and Henderson (1994) documented the presence of yearling coho within the lower Skagit River between February and June.

Juvenile Chum salmon migrate to the lower river and estuary soon after emerging from freshwater incubation. Individual residency of juvenile chum in the estuary can range from 6 to 40 days (Simenstad et al., 1982). Beamer and Henderson (1994) documented the presence of yearling coho within the lower Skagit River between February and June.

Juvenile Pink salmon migrate to the lower river and estuary soon after emerging from freshwater incubation. Pinks do not appear to be dependent upon estuarine habitats except as a zone of intermediate salinity that allows acclimatization to marine waters (Healy, 1992). Beamer and Henderson (1994) documented the presence of yearling coho within the lower Skagit River between February and April.

Juvenile Sockeye salmon spend a full year or more rearing in freshwater prior to outmigrating to the marine environment. Juvenile sockeye do not appear to be dependent upon estuarine habitats except as a zone of intermediate salinity that allows acclimatization to marine waters (Healy, 1992). Beamer and Henderson (1994) have only documented a single yearling sockeye in the Skagit estuary and that was in February.

The estuarine channels serve as migration corridors for juvenile salmonids, while deeper water distributary channels provide migration corridors for adults (Shreffler and Thom 1993). Distributary channels provide critical migration and movement routes between habitats.

2.7 Habitat Type and Connectivity

Major habitat types found in the Skagit estuary include delta mudflats, lagoon pocket estuaries, nearshore beaches, the offshore areas of Skagit Bay, and the vegetated delta. These areas can be further separated into blind channels, distributary channels,

shallow intertidal habitats, subtidal fringe habitats, and surface waters (Beamer et al. 2007). These habitat areas provide a wide variety geomophological, substrate, current, salinity, temperature, food resource, and vegetation conditions that supports a diversity of fish including salmonids (salmon, cutthroat trout, and bull trout), small pelagic fishes (including Pacific herring, Pacific sand lance, and surf smelt), sculpins, flatfish, and other species such as three-spine sticklebacks and gunnels (Beamer et al. 2007). Of these habitat types, vegetated blind channels situated along Skagit Bay and Padilla Bay were found to support the highest densities of juvenile Chinook salmon, with densities exceeding 15,000 fish per hectare (1.5 fish per sq-meter) in vegetated blind channels along Skagit Bay. Vegetated distributary channels situated in the lower north and south forks of the Skagit River, and along the Swinomish Channel, had the second highest use by juvenile Chinook among estuary habitat types, with juvenile Chinook densities exceeding 7,000 fish per hectare (0.7 fish per sq-meter) in the shallow vegetated distributary channels of the lower north and south fork Skagit River. In comparison, non-vegetated intertidal flats and the subtidal fringe areas of nearshore beaches had much lower densities of juvenile Chinook, with densities within the intertidal flats of Skagit Bay exceeding 700 fish per hectare (0.07 fish per meter), and densities with the subtidal fringe areas of nearshore beaches exceeding 300 fish per hectare (0.03 fish per sq-meter) (Beamer et al. 2007). Densities of juvenile Chinook at sites in the freshwater tidal areas of the Skagit delta were found to exceed 10,000 fish per hectare (1.0 fish per sq-meter) during the spring smolt outmigration period (Beamer et al. 2005), which is lower than densities observed in estuary blind-slough habitats, but similar to densities observed in shallow vegetated distributary habitats of the lower Skagit delta.

Substantially lower densities of juvenile Chinook (approximately 3,000 to 5,400 fish per hectare) were measured at estuary and freshwater sites where tidal and riverine processes are constrained by dikes and tide gates, including Brown's and Dry Slough (situated within Fir Island Farm project areas), Deepwater Slough, and Fisher Slough (South Fork Skagit)(Beamer et al. 2005; Beamer et a. 2010). Monitoring studies of the Deepwater Slough restoration project found that juvenile Chinook re-colonized restored habitats the first year following construction, and that densities increased to over 10,000 fish per hectare (1.0 fish per sq-meter) three years following restoration (Beamer et al. 2006). The results of the Deepwater Slough study are promising, as they indicate that restoration projects that restore natural tidal and channel processes to impaired habitats within the Skagit delta can result in rapid improvements in juvenile Chinook numbers.

The function of any given habitat depends on its spatial position in the landscape and its relationship to and connectivity with other habitats. Congleton et al. (1981) showed that juvenile salmon abundance is not homogeneous across the Skagit River estuary. Beamer et al. (2005) showed that habitat connectivity in the Skagit River estuary influences juvenile salmon abundance in many freshwater tidal and estuarine habitats. Habitat connectivity may describe how well the migratory pathways are connected for fish moving between freshwater and estuarine rearing areas. (Beamer et. al. 2001). Beamer et al. (2005) defined landscape scale connectivity as the relative distances and pathways that salmon must travel to find habitat. He also considered habitat connectivity at the local scale which he described as the availability of tidal channel

habitats to juvenile salmon in relation to the tidally influenced water depths in the channels.

All of the historic distributary channels across Fir Island have been disconnected from the Skagit River through post settlement dike construction. Consequently, the historic migratory pathways for anadromous fish species across Fir Island to the central Fir Island delta have been disconnected and the migratory pathway to the central Fir Island delta for juvenile salmon out-migrating the Skagit River is now longer and more difficult. Never-the-less, migration modeling suggests that a large number of juvenile Chinook salmon moving through the complex distributary network of South Fork Skagit River will head northward along the front of Skagit Bay towards Deception Pass (Beamer et al. 2005). By improving local connectivity to Skagit Bay, and given the adjacency of the project to large numbers of fish migrating out of the South Fork Skagit along the bay front, the Fir Island Farm restoration project has to potential to significantly improve the estuary rearing capacity of juvenile Chinook in the Skagit River delta.

2.8 Tidegates

The historic distributary channels across Fir Island have also been disconnected from Skagit Bay through the installation of tidegates. The low-lying land in the Skagit delta requires tidegates and floodgates to provide adequate drainage. Tidegates are one-way check valves at the end of the drainage system that allow drainage water to flow to a marine water body during a low tide cycle and then close to prevent saltwater from entering a drainage system when the tide rises (Skagit Delta Tidegates and Fish Initiative Implementation Agreement. 2008). The primary point of access for fish between the Skagit delta and the historic distributary channels is at those intersections where the gravity flow drainage is managed by a culvert fitted with some sort of tide regulating feature. Though tide gates do not completely block the upstream passage of fish, upstream passage is restricted to very narrow windows of the tide cycles during which the tide gate is open and the discharge velocity does not exceed the upstream swimming capabilities of the fish. The window for upstream passage is longer for larger fish than smaller fish because of their stronger swimming capabilities. The downstream passage of fish through a tidegate is also limited to low tide cycles when the water surface elevation upstream of the tide gate is sufficiently greater than the water surface elevation downstream of the tide gate to create the head differential necessary to open the tide gate (Drainage Maintenance Plan for Skagit County Consolidated Diking District #22 September 2005). Fish sampling in the vicinity of the tidegates in Wiley Slough and Dry Slough has resulted in very few juvenile salmonids captured upstream of the tidegates.

2.9 Habitat Quality

Different fish species and different life stages of a fish species can have different tolerances to water quality parameters. The water temperature, salinity, dissolved

oxygen, and turbidity characteristics of an estuarine channel or drainage watercourse can influence what species will be present, when and for how long they will be present.

After reviewing a number of Fir Island drainage watercourses upstream of tidegate structures during the Skagit Drainage and Fish Initiative planning process, WDFW staff in consultation with Skagit River System Cooperative staff generally concluded that juvenile salmon rearing in the Skagit estuary could possibly immigrate into the lower reaches of tidegated watercourses to forage on available prey. However, it was also generally concluded that the upstream distribution and duration of residence for these immigrating fish is limited by degraded water quality.

3. WDFW'S FIR ISLAND FARM FEASIBILITY STUDY AREA

The Fir Island Farm Restoration Feasibility Study encompasses all of the estuarine and freshwater watercourses bounded by Fir Island Road to the north, the tidal marsh habitat extending approximately 1000 feet south of the existing Skagit Bay flood dike, the dike along the west side of Brown Slough and approximately 200 feet east of Dry Slough. Watercourses waterward of the existing flood dikes and tidegates include natural blind tidal channels associated with Brown Slough and Dry Slough, natural tidal marsh blind channels and manmade blind tidal channels (borrow ditches). Watercourses landward of the existing flood dikes and tidegates include the remnant channels of Dry Slough and Claude O Davis Slough, the managed tidal blind channel in Brown Slough and assorted manmade drainage channels.

4. BROWN SLOUGH BASELINE

4.1 Habitat Connectivity

Brown Slough was historically a distributary channel of the North Fork Skagit River that discharged into Skagit Bay in the central Fir Island delta region. Brown Slough was disconnected from the North Fork Skagit River in approximately 1948 by a flood dike (personal communication Stan Nelson CDD#2, 2010). The flood dike terminated the downstream migration of juvenile salmonids to the central Fir Island delta via Brown Slough. Consequently, the migratory pathway for juvenile salmon out-migrating the Skagit River is longer and more difficult. Juvenile salmon out-migrating the Skagit River can only access the central Fir Island delta by entering the delta at the mouth of the North Fork or South Fork, substantially adjusting physiologically to saltwater and then migrating along the Fir Island tidal delta to the central island delta. Brown Slough has a connectivity index of .0221 compared to .040 for the areas in closer proximity to the mouths of the North Fork and South Fork (Beamer et al 2005).

The flood dike between the North Fork Skagit River and Brown Slough also terminated the downstream transport of sediments to the central Fir Island delta via Brown Slough. In 2011, Shannon and Wilson compared 1937 and 2010 aerial photographs and concluded that areas along the exterior margins of the vegetated marsh in the central Fir Island delta vicinity have retreated landward between 400 and 1000 feet which correspond to a loss of approximately 75 acres of tidal marsh. Philip Williams, 2004

noted that under the current sediment supply conditions for the central Fir Island delta, the delta marsh has been eroding and will continue to erode.

4.2 Tidegates

Brown Slough was disconnected from Skagit Bay at Fir Island Road in approximately 1948 (personal communication Stan Nelson CDD#2, 2011) by the installation of a 48" diameter culvert with a top hinge tidegate. Though isolated from Skagit Bay at Fir Island Road in approximately 1948, Brown Slough continued to be tidally influenced south of Fir Island Road until1990 when emergency dike repairs necessitated the construction of a new flood dike across Brown Slough approximately 2000 feet downstream of Fir Island Road. Two 48" diameter culverts with top hinge tidegates were installed into the new flood dike to maintain the existing upland drainage in Brown Slough to Skagit Bay. Between 1990 and 1994, the new flood dike and tidegates prevented tidal inundation of Brown Slough between Fir Island Road and the new flood dike. In 1994, as a condition for retaining the new flood dike, an additional 48" diameter culvert with a screw gate style top hinge tidegate was installed by CDD#22 into the 1990 flood dike. The design and operation of the screw gate style tidegate allows sufficient tidal inundation to maintain approximately 3.6 acres of tidal channel and 9.6 acres tidal marsh upstream of the 1990 flood dike. The screw gate style tidegate allows fish passage through the 1990 flood dike. The operation of the new screw gate style tidegate was and is strictly regulated through the state and federal permits authorizing the retention of the new flood dike. The following generally summarize the operation protocols for the screw gate style tidegate that were set forth in the district's 1996 Hydraulic Project Approval for managing the tidegate:

- The combination sluice/flap gate shall be maintained in a full open position from February 1 through October 15 of any year.
- The combination sluice/flap gate may be set to a one half open position from October 16 through January 31 of any year.
- The combination sluice/flap gate may be set to a full closed position when the Skagit River water level at the riverside staff gauge in Mount Vernon reaches the 31 foot mark and the river stage is rising.
- Subsequent to closure of the combination sluice/flap gate, the gate shall be immediately returned to a full open position February 1 through October 15 or to a one half open position October 16 through January 31 when the Skagit River water level at the riverside staff gauge in Mount Vernon drops below the 31 foot mark and the river stage is falling.

There are currently 4 culverts with top hinge tidegates in Brown Slough. There one 48-inch culvert with a top hinge tidegate under Fir Island Road. There are also three 48-inch culverts with top hinge tidegates at the 1990 flood dike with one of the 48-inch tidegates having a screw gate feature that allows the gate to be raised incrementally above the culvert opening.

4.3 Fish Sampling Data

Fish have not been sampled in Brown Slough upstream of the Fir Island Road tidegate. In the spring of 1995, the Skagit River System Cooperative (SRSC) aggressively sampled the tidally influenced portion of Brown Slough downstream of Fir Island Road. Sampling occurred both upstream and downstream of the 1990 flood dike. SRSC captured eleven fish species. All eleven species were capture between the new 1990 dike and Fir Island Road. The captured fish species included Chinook salmon, juvenile Chum salmon, juvenile Coho salmon, Cutthroat trout, Surf smelt, Three-spine Stickleback, Staghorn Sculpin Starry Flounder, Prickly Sculpin, Starry Flounder, Shiner Perch, and Peamouth Chub. Three-spine Stickleback was the most abundant species captured with surf smelt the second most abundant species captured. Juvenile Chinook salmon and juvenile chum salmon were the most abundant salmon species. The SRSC concluded that fish were able to find, occupy and outmigrate from the habitat upstream of the 1990 dike in a similar pattern to those fish that did not navigate the open screw gate style tidegate. That fish passage through open screw gate style tidegate was not a problem (Beamer and LaRock, 1998).

SRSC annually sampled Brown Slough for juvenile Chinook salmon between 1996 and 2003. Sampling occurred both upstream and downstream of the 1990 dike (Eric Beamer unpublished data). SRSC 1995 and 1996 data demonstrate that immediately following the installation of the 1994 screw gate style tidegate, the number of juvenile Chinook salmon captured upstream of the 1990 dike exceeded the number captured downstream. Beginning in 1997 and continuing through 2003, this pattern of juvenile Chinook salmon distribution has gradually reversed itself to where the 2003 data demonstrate that the number of juvenile Chinook salmon captured downstream of the 1990 dike significantly exceed the number captured upstream.

5. DRY SLOUGH BASELINE

5.1 Habitat Connectivity

Dry Slough was historically a distributary channel of the North Fork Skagit River and discharged into Skagit Bay in the central Fir Island delta region. Dry Slough was disconnected from the North Fork Skagit River in approximately 1951 (personal communication Stan Nelson CDD#22, 2010) through by a flood dike (personal communication Stan Nelson CDD#2). The flood dike terminated the downstream migration of juvenile salmonids to the central Fir Island delta via Dry Slough. Consequently, the migratory pathway for juvenile salmonids out migrating the Skagit River is currently longer and more difficult in that the central Fir Island delta can only be accessed by entering the delta at the mouth of the North Fork or South Fork, substantially adjusting physiologically to saltwater and then migrating a considerable distance along the Fir Island delta. Dry Slough has a connectivity index of .0221 compared to .040 for the areas in closer proximity to the mouths of the North Fork and South Fork (Beamer et al 2005).

The flood dike between the North Fork Skagit River and Dry Slough also terminated the downstream transport of sediments to the central Fir Island delta via Dry Slough. In 2011, Shannon and Wilson compared 1937 and 2010 aerial photographs and concluded that areas along the exterior margins of the vegetated marsh in the central Fir Island delta vicinity have retreated landward between 400 and 1000 feet which correspond to a loss of approximately 75 acres of tidal marsh. Philip Williams, 2004 noted that under the current sediment supply conditions for the central Fir Island delta, the delta marsh has been eroding and will continue to erode.

5.2 Tidegates

Though isolated from the North Fork Skagit River in 1951, Dry Slough continued to be tidally influenced until1964 when a flood dike and tidegates were installed across the mouth of Dry Slough (personal communication Bob Hayton, Hayton Family Farm, 2011). Between 1951 and 1964, farmland adjacent to Dry Slough was protected from tidal inundation by bay front flood dikes and flood dikes along the east and west sides of the slough. There are currently two 48-inch diameter culverts with top hinge tidegates at the mouth of Dry Slough.

5.3 Fish Sampling Data

The tidegates at the mouth of Dry Slough severely restrict fish passage between Dry Slough and Skagit Bay. The Skagit Fisheries Enhancement Group sampled fish inhabiting the mouth of Dry Slough between March and June of 2008 (SREG 2008 Report). Fish sampling has occurred upstream and downstream of the existing Dry Slough tidegates. Between March and June of 2008, nine fish species were captured downstream of the tidegates including juvenile Chinook salmon, juvenile chum salmon, juvenile coho salmon, juvenile pink salmon, stickleback, sculpin, starry flounder, sand lance and shiner perch. During this period, only two species were captured upstream of the tidegates including juvenile Chinook salmon and stickleback. Of the 210 juvenile salmon that were captured, only one juvenile salmon was capture upstream of the tidegates. The Dry Slough fish sampling results are consistent with the fish sampling results for Wiley Slough presented by the Skagit River System Cooperative in the Wiley Slough Restoration Design Report 2005. The 2005 Wiley Slough Restoration Design Report concluded that salmonids are almost completely absent above the Wiley Slough tidegates though juvenile salmon were found just downstream of the tidegates and in adjacent sloughs.

6. CLAUDE O DAVIS SLOUGH BASELINE

6.1 Habitat Connectivity

Claude O Davis was historically a distributary channel that branched off of Dry Slough in the central region of the Fir Island delta south of Fir Island Road. As a consequence of disconnecting Dry Slough from the North Fork Skagit River in 1951, Claude O Davis was also disconnected from the North Fork Skagit River. Disconnecting Dry Slough from the North Fork Skagit River not only terminated the downstream migration of

juvenile salmonids in Dry Slough but also in Claude O Davis Slough. Consequently, the migratory pathway for juvenile salmonids leaving the Skagit River is currently longer and more difficult in that the central Fir Island delta can only be accessed by entering the delta at the mouth of the North Fork or South Fork, substantially adjusting physiologically to saltwater and then migrating a considerable distance through the estuary along the Fir Island delta. Claude O Davis Slough has a connectivity index of .022 compared to .040 for the areas in closer proximity to the mouths of the North Fork and South Fork (Beamer et al 2005).

The flood dike between the North Fork Skagit River and Dry Slough also terminated the downstream transport of sediments to the central Fir Island delta via Dry Slough and via Claude O Davis Slough. In 2011, Shannon and Wilson compared 1937 and 2010 aerial photographs and concluded that areas along the exterior margins of the vegetated marsh in the central Fir Island delta vicinity have retreated landward between 400 and 1000 feet which correspond to a loss of approximately 75 acres of tidal marsh. Philip Williams, 2004 noted that under the current sediment supply conditions for the central Fir Island delta, the delta marsh has been eroding and will continue to erode.

6.2 Tidegates

Claude O Davis Slough was disconnected from Skagit Bay in the 1930s (personal communication Stan Nelson CDD#2, 2011) by the installation of two 48” diameter culverts with top hinge tidegates.

6.3 Fish Sampling Data

Fish have not been sampled in Claude O Davis Slough. Given its similarity to Dry Slough, it is reasonable to assume that the baseline fish utilization in Claude O Davis Slough is similar to that described above for Dry Slough.

7. MANMADE WATERCOURSES BASELINE

The manmade watercourses within the upland area of the study site are managed to provide drainage for the farmland portion of the study site and for adjacent upstream neighboring farms. Fish have not been sampled in these manmade watercourses. Juvenile salmon access to and presence in these manmade watercourses is limited by the tidegates in Dry Slough and Claude O Davis Slough and by water quality.

The manmade watercourses in the tidal delta area of the study site are remnant borrow areas where native delta sediments were excavated to construct the existing flood dikes. They are immediately adjacent to and parallel with the waterward toe of the existing flood dikes. These borrow ditches are tidally inundated and function as tidal blind channels. To the extent that they are connected to existing natural tidal marsh channels and accessible to juvenile salmon, it is reasonable to assume that they provide juvenile salmon rearing habitat.

8. BASELINE HISTORIC CHANNEL ANALYSIS

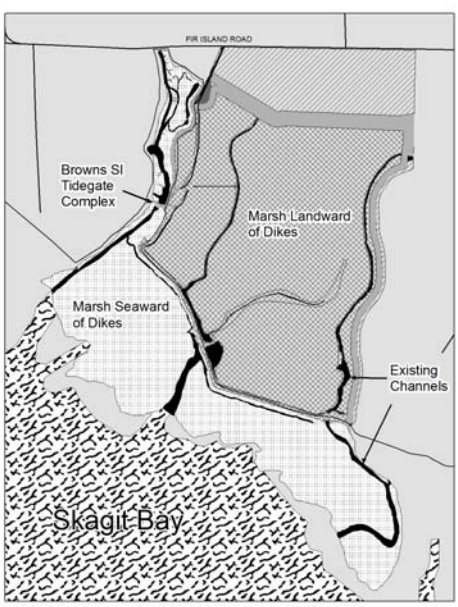
Predictions of the estuarine channel area for each restoration alternative was calculated with the application of a model to predict the formation of new channels on the marsh plain in combination with a delineation of the channels that exist currently. Each alternative was evaluated for the total predicted channel area of their entire post-restoration footprint as described below. Additionally the components of each alternative landward of the dikes and seaward of the dikes were evaluated separately in order to illustrate that the benefits of marsh plain restoration extend beyond the restoration site.

Hood (2004) demonstrated that the marsh plain area benefitting from an estuary restoration action extends beyond the restoration site footprint. Modeling of the channel formation response of marsh habitat restoration has shown that channel formation is related disproportionately to the size of restoration area. In other words a large marsh plain restoration will create and maintain a greater channel/marsh ratio than a small marsh plain restoration.

To estimate the expected benefit from each restoration a geometric model for South Fork Skagit River (SF) marshes as described in Hood 2007 was used:

$$\text{Restored channel area(ha)} = \begin{matrix}\text{SF channel surface} \\ \text{area regression} \\ \text{elevation}\end{matrix} * \text{restored area}^{\text{SF surface channel regression slope}}$$

The Fir Island Farms site is located just outside of the area described by Hood (2007) as Skagit River South Fork marsh (SF) in the area referred to by Hood as the Bay Fringe (BF). Observations of channel generation of a similar site just SE of the Fir Island Farms site indicated that the SF regression would be more accurate than the BF regression to predict how the channels will form in response to restoration. For more information regarding this determination please see the Geomorphology Baseline Report.



For each alternative three factors were used to estimate the predicted channel formation response including (see figure); area of restored tidal inundation landward of the dikes; area of vegetated marsh seaward of the dikes; and area of existing channels landward of the dikes. Using the model described above, a value was calculated for the channel formation expected from the entire project site including restored tidal areas landward of dikes and existing vegetated tidal areas seaward of dikes combined. The resulting figure was added to the area of existing channels landward of dikes for a total gross channel area for each alternative. The net channel area was calculated by subtracting the existing channels seaward of the dikes from the gross channel area for each alternative.

Existing channels were delineated from an aerial photo using a geographical information system (GIS). The aerial photo was taken in the spring of 2007 (March – April) with a resolution of one foot. Borrow ditches (ditches along the dikes excavated to provide dike material) were excluded from the channel area. Marsh area was calculated with a GIS; area landward of the dikes reflects the proposed scenario for each alternative. Area seaward of the dikes was delineated by identifying the most seaward extent of the marine vegetation and then calculating the area between this “veg-line” and the existing dikes. The area associated with Browns Slough upstream of the Browns Slough tidegate complex was considered marsh area seaward of the dikes.

Existing channels landward of the dikes are the remnants of former distributary channels. While it is acknowledged that these channels are larger than what can be formed and/or maintained by tidal hydrology alone, it was assumed that due to the lack of a sediment source, the channels would remain post project construction in their current configuration for the indefinite future. Therefore the existing channels were added to the balance of total expected channel area resulting from the marsh restoration. The decision to use the existing channels in this way was decided partially in response to the need to determine the relative contribution of alternatives that focus on the restoration of tidal processes to existing channel areas only (alternatives 4, 5 and 6). While it is acknowledged that this method may not be a precise representation of the expected benefits from the tidal marsh restoration, the calculations are valuable for determining the relative habitat benefit among alternatives.

In order to account for the limitations of channel habitat formation upstream of self regulated tidegates and the Browns Slough tidegate complex, a simple modifier was used. It was assumed that the restricted tidal exchange allowed by a SRT limits the formation and maintenance of tidal channels; therefore the predicted channel area was reduced by applying a modifier of 50%. While there is no SRT at Browns Slough, the open culvert in the tidegate complex is restricted hydraulically and is assumed here to have an affect similar to a SRT.

The net expected tidal channel benefit for each alternative was determined as follows;

Net tidal channel benefit = estimated new channel formation + existing channels landward of dikes* – existing channels seaward of dikes*

* A modifier was applied to areas upstream of proposed SRTs and for the existing channels upstream of the Browns Slough tidegate complex.

9. BASELINE CHINOOK SMOLT PRODUCTION

We employed two methods to estimate the number of Chinook smolts that would be produced by the different restoration alternatives. The first was the model described in the Skagit Chinook Recovery Plan for estimating the carrying capacity of juvenile Chinook for the Skagit freshwater delta and estuary (Greene and Beamer 2005). In reviewing this method, we found that the Skagit Chinook Recovery Plan model accurately predicted juvenile Chinook densities in disturbed habitat areas where tidal

and riverine flows were restricted, and in freshwater tidal habitats in the upper Skagit River delta. However, we found that this model substantially underestimated juvenile Chinook densities in undisturbed habitats of the lower Skagit River delta, including the estuary areas located at the lower end of the North and South Fork Skagit, and undisturbed habitats along the front of Skagit Bay. We developed a second method to more accurately estimate juvenile Chinook densities in natural and restored estuary habitats in the lower Skagit River and along Skagit Bay. We refer to this method as the "reference site model", since it uses Chinook densities measured by SRSC in 2003 (Beamer et al. 2005) at five undisturbed estuary sites located at the lower end of the North and South Fork Skagit River.

9.1 Skagit Chinook Plan Model

The Skagit Chinook Plan model is based upon two statistical relationships, the first between juvenile Chinook densities and four habitat variables, and the second between an index of these four variables and habitat connectivity. The variables used in the first relationship were discharge, water temperature, salinity, and tidal drop, and these were measured along with juvenile Chinook densities at six study sites in the Skagit delta and estuary between 1992 and 2002. These four habitat values together explained 36% of the variation observed in juvenile Chinook densities among the six sites.

The second statistical relationship showed that the habitat index (combination of discharge, water temperature, salinity, and tidal drop) was significantly correlated with "connectivity", an index of channel distance and branching developed for the Skagit Chinook Recovery Plan (Beamer et al. 2005). The connectivity index combines the distance downstream from Skagit forks (confluence of North and South Fork Skagit) and the amount of channel branching at a given point in the delta. Connectivity values decrease as the distance from the Skagit Forks increases, and the amount of delta branching becomes greater. The connectivity index was found to explain 80% f the variation found in the habitat index.

The first relationship (juvenile densities versus habitat index) was then mathematically combined with the second relationship (habitat index versus connectivity index) to produce a composite statistical relationship between juvenile densities and connectivity. Connectivity explained 29% of the variability in juvenile Chinook observed at the six study sites (i.e., 0.36 for first relationship multiplied by 0.80 for second relationship). The Skagit Chinook Plan model thus assumes that juvenile Chinook densities increase with increasing connectivity (Beamer et al. 2005). The model predicts that Chinook juvenile densities would be highest in the upper freshwater areas of the delta near the Skagit Forks, and would progressively decline in a downstream basis as the distance from the forks became greater and as delta channels become more and more branched. This relationship might be expected provided that number of outmigrating fry was limited, and assuming that access to habitats became more difficult with increasing distance and channel branching.

The carrying capacity of juvenile Chinook salmon was then estimated for the freshwater tidal and estuary habitats found in the Skagit delta. The carrying capacity value is an

estimate of the maximum density of juveniles that could be attained given that the number of fry entering the delta was not a limiting factor (this would be expected in good spawning years). Competition for limited food resources was considered to be the most likely factor controlling the maximum density of juveniles in the Skagit delta (Greene and Beamer 2005). The maximum density of juvenile Chinook for both freshwater delta and estuary habitats was calculated to be 1.31 juvenile Chinook per cubic meter. The equation used to predict the carrying capacity of juvenile Chinook based upon local connectivity index values was:

$$\text{Density (fish/m3)} = 2.718^{(-1.648 - 0.751 * (-1.345 * \ln(\text{Connectivity}) - 4.298) + 1.31)}$$

The density value predicted by this equation was then converted from a volumetric measure to an area measure by multiplying the value by 0.64 meters, the average depth of habitat assumed for the Skagit delta (Beamer et al. 2005). This density value was then multiplied by the time period in which the delta is used by juvenile Chinook (150 days), and then divided by the average residency period of an individual fish (35 days), to estimate the total number of smolts produced per square meter of habitat.

9.2 Reference Site Model

We completed a validation review of the Skagit Chinook Plan model by comparing densities measured at 11 sampling sites by SRSC in 2003 with the densities predicted at each site by the model. We found that the model acutely predicted densities in the freshwater areas of the upper Skagit delta, and in disturbed (hydromodified and partially isolated) estuary habitats. The Skagit Chinook Plan model underestimated densities in undisturbed estuary and freshwater tidal sites located at the lower end of the Skagit River delta. The model predicted densities between 0.2 and 0.4 juveniles per square-meter in these areas, while the actual densities measured in 2003 were between 0.9 and 1.3 juveniles per square-meter.

We developed a simple reference site model for predicting the density of juvenile Chinook for natural and restored habitats in Skagit estuary habitat areas, including the Fir Island Farm project areas. We used the average juvenile density values measured by the SRSC in blind channels at four estuary sites in the lower Skagit River delta in 2003 (Ika, Catttail Slough, Freshwater Pond, and Tom Moore Slough). The average density of juvenile Chinook measured in these areas was 1.1 fish per square meter (4,452 fish per acre). This density value is expected to be fairly close to the carrying capacity value for these habitats, since fry outmigrant numbers estimated at WDFW's smolt trap in 2003 were relatively high (greater than 4,500,000 outmigrants).

We multiplied this estimated density for estuary habitats by 150 (total days of estuary habitat use by juvenile Chinook), and then divided this by 35 (average estuary residency of individual juvenile Chinook) to calculate the annual Chinook smolt production at the Fir Island Farm project under restored conditions.

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