SKAGIT CLIMATE SCIENCE CONSORTIUM

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Subject: Skagit Climate Science Consortium (SC^2) Comments on the Draft Feasibility Report and Environmental Impact Statement for the Skagit General Investigation

Thank you for this opportunity to review and comment on the Draft Feasibility Report and Environmental Impact Statement for the Skagit General Investigation. Addressing the significant flood risk in the Skagit Valley is an endeavor of the utmost importance, which is only made the more critical by our understanding of how climate change will increase this already significant threat. The Skagit Climate Science Consortium (SC^2) is a 501 c (3) nonprofit comprised of scientists working with local people to assess, plan, and adapt to climate related impacts in the Skagit Valley. SC^2 member research scientists come from federal, municipal, tribal, and university organizations and bring expertise in hydrology, engineering, geomorphology, estuarine ecology, fisheries biology, forestry, climate science, oceanography, and coastal geology.

In our collective view, the Draft Feasibility Report and Environmental Impact Statement (DFREIS) associated with the Skagit General Investigation (GI) does not meet the basic requirement of due diligence in analyzing proposed engineering alternatives and their environmental impacts. The following letter seeks to convey and document why the scientists participating in SC^2 and signatories to this letter have come to this conclusion.

The time frame of the analysis for the GI is 2020-2070, a time period when risk is expected to grow due to increasing development in the Skagit floodplain and climate change (Hamlet et al. 2010, 2013; Lee et al. 2011, 2014; Tohver et al. 2014). Three issues related to the incorporation of climate change in the DFREIS stand out as most crucial:

1. The DREIS does not quantify the performance and environmental impacts of the proposed alternatives for projected changes in future conditions that will result from climate change,
2. The DFREIS does not adequately evaluate impacts to ecosystems resulting from the proposed alternatives in conjunction with anticipated climate related changes, and
3. The DFREIS does not include relevant and recent literature, including information that presents alternative viewpoints, or disagrees with study assumptions.

Potential changes in flood risk have a direct and unambiguous bearing on the management objectives investigated in the study. Just as future population estimates are commonly incorporated in water planning studies affected by changing water demand, the GI needs to incorporate climate change as a fundamental element of the analysis affecting the defined planning horizon. Unless climate change impact pathways are included, it is unclear whether the preferred alternative will perform adequately in achieving the fundamental management objective encompassed by the study (reductions in flood risk), or whether the selection of this alternative as the preferred one is robust in the face of conditions that are already changing.

In the past 50 years, glacial cover in the Skagit Basin declined 19% (Dick, 2013), the mean Nov-April freezing level has risen approximately 600 ft. since 1949 (http://www.wrcc.dri.edu/cwd/products/), the mean annual flood has increased in the unregulated portions of the basin (Sauk River, USGS gauge #12189500, http://waterdata.usgs.gov), and colder parts of the watershed are accumulating less snow in winter, resulting in a shift from a spring- to a fall-dominant flood regime (e.g. in the Sauk River). These changes affect current baseline conditions and are likely to have profound impacts on the performance of specific alternatives (including the no action alternative) during the stated GI planning period.

The Skagit GI has a Tentatively Selected Plan (TSP) projected to cost $225 million dollars plus $800,000 annually for Baker Dam operations. An expenditure of this magnitude will likely be the most significant, if not the only effort of its kind for many decades, and presents an important and unique opportunity for the valley to prepare for flooding exacerbated by climate change. Furthermore, if the changes identified in the TSP ultimately prove to be inadequate in coping with future flood risks, it is questionable that the region will be able to secure the resources to conduct additional analysis or make expensive, time-consuming changes or improvements to recent infrastructure investments of this scale. Proposed alternatives put forward as part of the GI need to be explicitly and thoroughly tested under the conditions they will likely encounter, including climate change (increasing peak flows, increasing sediment loads, and sea level rise). The U.S. Army Corps of Engineers' cursory, and largely qualitative method of analysis of climate change impacts raises a number of fundamental questions and concerns regarding study outcomes:

1. Do the proposed study alternatives meet fundamental objectives related to reducing flood risk if floods increase in magnitude as projected?
2. Is the current TSP a robust choice when climate change impacts are considered in the analysis?
3. Will other elements of the existing flood control infrastructure (e.g. the Mt. Vernon flood wall and other portions of the existing levee system) perform

adequately with the combination of stronger levees in the lower basin and increasing flood frequency and magnitude?

4. What are the environmental impacts in the lower Skagit River channel, delta, and estuary when increasing peak flows and increasing sediment loads are combined with the preferred alternative of an increasingly channelized river system?
5. Given the interaction between sea levels and surface-groundwater in the Skagit Delta, what are surface-groundwater interactions currently and under projected sea level rise scenarios? How will study alternatives be influenced by and themselves influence groundwater levels that strongly affect flooding, drainage and drainage maintenance costs, and agricultural production?

In addition to the limitations discussed above, the DFREIS frequently presents information about climate change in a confusing and inconsistent manner. For example, in a footnote, the plan dismisses most potential impacts of climate change due to uncertainty in climate model projections; yet, on page 87 the plan states, "The Earth's atmosphere is changing, the climate system is warming." Similarly, while the current draft of the DFREIS makes qualitative use of current scientific information on climate change (primarily in Sections 4 and 5) to identify potential impact pathways and speculate on potential outcomes related to different alternatives, the study does not make appropriate use of well-established vulnerability assessment practices used by federal, state, and local agencies such as the U.S. Bureau of Reclamation, Bonneville Power Administration, Northwest Power and Conservation Council, U.S. Fish and Wildlife, U.S. Park Service, U.S. Forest Service, WA State Department of Ecology, Seattle Public Utilities, and Seattle City Light to prepare for climate change. Some recent examples of high-visibility planning studies in the Pacific Northwest that incorporate climate change include:

- The Columbia River Basin Climate Impacts Assessment

(http://www.usbr.gov/pn/climate/crbia/index.html);
- River Management Joint Operating Committee studies in the Columbia River Basin (http://www.usbr.gov/pn/climate/planning/reports/index.html); and
- The Stehekin River Corridor Implementation Plan (National Park Service, 2013).

The U.S. Army Corps of Engineers (USACE) has been a central participant in several studies focused on climate change impacts on flooding in the Columbia River Basin, which makes the omission of climate change impacts in the Skagit DFREIS all the more noteworthy.

A number of key published analyses have been omitted from the current DFREIS that would help to quantify future flood risk and identify viable, cost-effective solutions to changing conditions. These peer-reviewed papers and reports are cited in context below and listed at the end of the attachment. Scientists from SC^2 presented much of this information to the USACE and other stakeholders at a public workshop in 2012, a meeting at the Seattle District office with the GI team in June 2013, and an open house in April 2014. A thorough and well-designed initial study on the effects of sea level rise, storm surge, and increased flood risk (Hamman, 2012) was provided to the USACE, but it appears not to have been utilized in the DFREIS. By design, this study used the same hydrodynamic model developed and used by Federal Emergency Management Agency (FEMA) and USACE in previous studies. Through these past communications, SC^2 scientists have repeatedly highlighted three main climate change impact pathways that increase flood risk in the Skagit valley: increasing peak flows, increasing sediment load, and sea level rise. These are discussed in more detail below.

Increasing Peak Flows

The magnitude of Skagit River floods is projected to increase dramatically as a result of climate change due to rising freezing levels, changing snowpack and soil moisture dynamics, increased atmospheric moisture transport, and other factors (Hamlet et al. 2010, 2013; Mantua et al. 2010; Tohver et al. 2014; Salathe et al. 2014; Lee et al. 2011, 2014). Using daily time step simulations of regulated flows at Mount Vernon prepared by Lee et al. (2014) the regulated historical 100-year flood is 163,000 cubic feet per second (cfs) for years 1916-2006, while the mean of five 2080s climate change projections for the 100-year event is 244,000 cfs. This represents an increase of 49% based on a medium emissions scenario. A flood of this magnitude in the simulated historical probability distribution would correspond to a 1400-year event. For comparison, a historical 250-year flood would be about 190,000 cfs, and the 500-year flood is about 210,000 cfs.

Despite the projections of increased river flooding from previous studies cited above, the hydraulic modeling included in the DFREIS does not address changes in flood frequency and magnitude resulting from climate change, even though a host of design endpoints depend upon the ability of design alternatives to mitigate large floods ultimately protecting human life and property. Instead, climate change impacts are discussed informally in the document. For example, in Sections 5.1.7 and 5.3 the DFREIS states that "the level of protection provided by the CULI alternative could fall from 0.4% ACE to 1% ACE over the 50 year period of analysis". Thus, while broadly acknowledging the potential impacts of climate change on study outcomes, the document does not provide appropriately detailed analysis of performance of specific alternatives with regard to a) flood risk reduction benefits, b) long-term economic costs, and c) ecological impacts.

Analysis of changing flood risks in the Sauk River basin is also not apparently included in the study, even though it is the largest uncontrolled sub-basin in the Skagit Watershed. Peak flows in the Sauk River create local impacts, and are an important indicator of unregulated hydrologic change in the basin. As noted in the introduction, peak flows in the Sauk have been significantly increasing in magnitude over the past 80 years. The mean annual flood in the Sauk calculated for water year 1970-2009 is 37% larger than the mean annual flood calculated for 1930-1969. Likewise the frequency of extreme peak flows on the Sauk River has also been increasing, with 4 events over 50,000 cfs observed in the 40 year period between 1930 and 1969, and 10 events over 50,000 cfs observed in the 40 year period between 1970 and 2009 (source of peak flow data: http://waterdata.usgs.gov/wa/nwis/uv?site_no=12189500). Climate change projections for the Sauk are similar to those cited above for the Skagit main stem: About a 40-50% increase in the 100-year flood by the 2080s relative to 1970-1999 (see http://warm.atmos.washington.edu/2860/products/sites/?site=6020; Hamlet et al. 2013; Tohver et al. 2014).

Increasing Sediment Yield

Another important way climate change is likely to affect flood risk is through increased sediment transport and deposition in the lower Skagit valley. Potential increases in sediment delivery to the lower Skagit Valley from the upper basin relate to changes in a number of factors: increasing flood flow erosion of river banks; increasing winter soil moisture and landslide risks (Hamlet et al. 2013; Strauch et al. 2014); increased exposure of steep slopes, no longer buried beneath deep snowpack, to direct rainfall and increased surface runoff (Hamlet et al. 2013); as well as increased exposure of unconsolidated sediments in steep terrain as glaciers retreat (Czuba et al, 2012). This potential impact pathway is not addressed in the DFREIS, but could lead to increased channel aggradation, loss of channel conveyance capacity and increased erosion of levees, and impacts to the estuary.

It is well known that as sea level rises the bed of a coastal river also rises, leading to increased rates of sediment aggradation and river avulsion (Blum & Törnqvist 2000; Taha 2006; Stouthamer &Berendsen 2007, Bridge 2008). Thus the bed of the lower

Skagit River is likely to increase in elevation more rapidly than it has in the past because of the accelerated rate of future sea level rise. Observations of river morphology also highlight important changes in channel elevation. Preliminary cross-section elevation data collected in late 2012 by the USGS indicate that significant aggradation in select reaches, including at Mount Vernon, has occurred with up to 10 feet of sediment deposition since the last survey conducted for the GI in 1999. This observed increase in river bed elevation is expected to decrease the effectiveness of existing or proposed levees. This information was shared with the USACE at a July 2013 meeting, but apparently was not considered in the DFREIS.

The DFREIS suggests sediment deposition is expected between river miles 18-22, where the bed material changes from gravel to sand. We recommend that the USACE use quantitative estimates, either from the literature or via modeling, to identify the likely extent of the issue between river miles 18 and 22 and other areas where channel capacity and flood conveyance will be reduced. Model estimates should include dynamic updating of geomorphology over time based on sedimentation and erosion patterns.

It has long been known that the use of levees and other flow control structures influence sediment transport downstream, which can have significant impacts to important habitats that support ecosystems and valued species. For example, much has been learned from the Mississippi Delta (Alexander et al. 2012). The DFREIS should include an assessment of how climate change impacts will interact with the different alternatives to affect Tribal, State, and other Puget Sound recovery goals. For example, achieving no net loss of habitat and reaching the Puget Sound Partnership's 2020 goal of increasing eelgrass habitat may be affected when climate change impacts are considered along with the alternatives or TSP. Grossman et al. (2011) shows the extent that the Skagit Delta and tidal flats have been transformed from a calm, mud dominated environment to an energetic, sandy tidal flat in response to the emplacement of the Skagit River levees and their influence on focusing flow and sediment to Skagit Bay. The result of stream flow rerouting and focusing has caused chronic sediment disturbance through sediment abrasion and bypassing that fragments important eelgrass beds. These changes can adversely impact forage fish like herring that use eelgrass for spawning substrate, Chinook and other salmon that use eelgrass during nearshore residency, and benthic fauna that are food resources for many fish and birds. Changes in sediment export from river deltas due to flow rerouting can also affect shellfish. These types of impacts directly influence the Puget Sound Partnership's and NOAA's salmon recovery targets; therefore, they should be evaluated for each proposed GI alternative in the context of projected climate change in order to comprehensively assess their costs and benefits.

<u>Sea Level Rise</u>

The DFREIS does not adequately take into account the effects of sea level rise. Three important influences on flooding related to sea-level rise should be considered: (1) The full range of projected sea level rise, (2) Recent changes in tidal channel bathymetry, and (3) Estuarine mixing, which affects the sedimentation rate and distribution.

The selection of the low, medium, and high sea level positions used for the DFREIS sea level rise impact analyses does not reflect the best available science which shows a higher range of projections and a maximum projected sea level position greater than that used by USACE. For example, three resources available include:

1. The National Academy of Sciences 2012 report titled "Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future" that projects sea level positions along the *uplifting* outer Washington Coast (available at: http://www.nap.edu/catalog.php?record_id=13389);
2. The Mote et al. (2008) report titled "Sea Level Rise in the Coastal Waters of Washington State" which estimates future sea level positions within the

subsiding regions of Puget Sound by Mote et al. 2008 (available at: http://www.cses.washington.edu/db/pdf/moteetalslr579.pdf); and

3. The NOAA Seattle Tide gage 9447130 (available at: http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=9447130)

The science of sea level rise is rapidly changing. Recent projections of sea level rise published by the National Academy of Sciences (2012), for example, are substantially higher than those published by Mote et al. (2008), which were based on the 2007 IPCC projections. Different studies also use different rates of vertical land movement, which is a source of potential confusion. The National Academy of Sciences report, for example, assumed that Puget Sound is experiencing the same rate of uplift as the Pacific Coast, whereas Mote et al. (2008) attempted to account for the lower rates of vertical land movement for Puget Sound.

The NOAA Seattle tide gage contains one of the longest records of sea level rise along the US West Coast. It records a rate of sea level rise of 2.06±0.17 millimeters per year. The National Academy of Sciences (NAS) 2012 assessment suggests two upper values for future sea level positions at 2030, 2050, and 2100 that reflect a mean and a maximum scenario. The mean for 2050 and 2100 are 0.54 feet and 2.03 feet respectively, and the maximum for 2050 and 2100 are 1.57 feet and 4.70 feet respectively. (All values are relative to sea level in the year 2000.) A linear interpolation between the 2050 and 2100 maximum estimates for the year 2070 would result in a value of 3.78 feet, substantially higher than the 2.15 feet used in the DFREIS analyses. Two caveats with this approach, however, are that (1) the NAS 2012 estimates are for the outer Washington coast which is known to be uplifting and are thought to under predict rates of relative sea level rise within Puget Sound and Whidbey Basin, and (2) the rate of sea level rise between present and 2100 is expected to rise exponentially, not linearly, so interpolations of the NAS 2012 results for the year 2070 within Puget Sound and Whidbey Basin are likely to underestimate future sea level. Other NOAA tide gauges in the area including Port Townsend also indicate similar rates of sea level rise.

The Mote et al. 2008 report considered vertical land movements within Puget Sound and Whidbey Basin more comprehensively than the National Academy of Sciences' 2012 report. The Mote et al. 2008 report proposes three estimates (very low, medium and very high) for future sea level rise at 2050 and 2100. A linear interpolation between the 2050 and 2100 very high estimates for the year 2070 would result in a value of 2.76 feet, again higher than the selected 2.15 feet used in the DFREIS analyses. As above, using a linear interpolation for future sea level position likely underestimates the risk as the rate of sea level rise is expected to rise exponentially.

The future influence of sea level rise and tidal inundation depends strongly on the stream channel bathymetry and hydraulic gradient. A slight change, even at the scale of several inches, in sea level rise can have a strong effect on inundation in low-sloping areas. The DFREIS uses bathymetry data from 1999. As noted earlier in this letter, updated USGS information from 2012 shows significant changes including up to 10 feet of sedimentation in select reaches of the lower Skagit Valley and near Mount Vernon. Such geomorphic changes since 1999 likely affect any hydrodynamic model results and the ability to simulate future influences of sea level rise in a spatially explicit way to inform flood hazards along the Skagit River. Current and improved bathymetry data should be included in the DFREIS modeling.

Finally, flocculation within the estuarine mixing zone is an important factor governing sedimentation. The interaction of rising sea level and changing flows, (including lower summer low flows), will enable greater tidal inundation thus influencing sediment deposition rates. These interactions are critical and should be included in any assessment of future sedimentation to adequately assess future flood risk.

The remainder of our comments, provided as appendices, focus on specific sections of the DRFEIS and are listed in the attached document by section number in the DFREIS. Also included in the attached document are the full citations for those referenced in this letter. We also invite you to review our website at: http://www.skagitclimatescience.org, which has graphs, charts and additional information on climate change and flood risk in the Skagit Valley.

We appreciate the opportunity to provide our comments, and we hope that we will be able to work in partnership with the USACE and other local partners to prepare for climate change in the Skagit basin by better incorporating climate information in the General Investigation. We would be happy to discuss our conclusions in more detail or provide additional information as needed. For questions or follow-up, please contact Dr. Alan F. Hamlet (email: hamlet.1@nd.edu, phone: 574-631-7409), or Carol Macilroy (email: cmacilroy@gmail.com, phone: 206.293.4741).

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"Any opinions, findings, or conclusions expressed in this letter are those of the authors and do not necessarily reflect the views of the organizations or agencies with which they are affiliated or employed."

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Skagit Climate Science Consortium Specific DFREIS Comments

Section 2.4

The problem statement should make mention of potentially increasing flood frequency and magnitude due to climate change that may overwhelm existing infrastructure and/or "flood fighting" practices, resulting in increased impacts to infrastructure and/or public safety. Likewise, because climate change adaptation strategies are already needed in the basin to cope with non-stationary flood statistics, this study presents an opportunity to not only mitigate the impact of "normal" 19th and 20th-century floods, but also to plan for and mitigate potentially higher flood risks in the future.

There is an important distinction to be made between the current problem statement on page 10 and those problems that emerge when attempting to mitigate a future with larger and more frequent floods. First, the proposed infrastructure alternatives need to be tested for feasibility and performance under an altered flood regime because they may be damaged or otherwise perform inadequately during larger floods. Second, the economic analysis identifying the least expensive alternative may be quite sensitive to changes in the risk of flooding due to the cost of more frequent repairs to the proposed infrastructure. This is not considered in the current economic analysis. In other words, infrastructure that appears to be the most cost effective for mitigating 19th and 20th century floods may not be the most cost effective means for dealing with 21st century flooding if flood risks increase as projected.

Increases in sediment transport projected to accompany increased peak flows in the future are also a concern, particularly for alternatives that use relatively narrow river channels with levees as the primary means of flood mitigation. In addition to the broader impacts on the estuary and delta discussed in the letter, increases in sediment loading could result in increased erosion pressure on the levee system, adverse changes on the bay front, and negative consequences to fish.

Section 3.1.1

The statement that Ross Dam provided incidental flood regulation between 1920 and 1950 is incorrect. Construction on Ross Dam was not initiated until 1937, and the dam was not completed until 1949. The reservoir was filled to a lower level in 1953, and reached its present maximum pool elevation in 1967.

Section 3.2

This section omits a number of climate change risks that will likely occur over the next 50 years. Specific concerns related to the lack of adequate treatment of climate change issues are discussed in more detail elsewhere in this letter.

Section 3.2.1

The DFREIS states "Hydrologic and geomorphic conditions in the upper Skagit River Basin are not expected to change significantly over the next 50 years." (pg 39)

This statement is directly at odds with the current scientific research and modeling from published studies. Specifically:

- Expected increases in flood flows (Hamlet et al. 2010, 2013; Lee et al. 2011, 2014; Mantua 2010; Tohver et al. 2014; Salathé et al. 2014). For example, current estimates project that the 5% ACE (the extent of current flood protection in the Skagit) will become a 30% ACE (e.g., the 20-year event will become a 3-year event) on average by the final decades of this century (2070-2099 relative to 1970-1999; results are similar for 2070).
- Expected increases in sea level. This is discussed in Section 4 of the report, though low/intermediate estimates are not consistent with published estimates (e.g., NRC 2012).

- Expected increases in fluvial suspended sediment transport. Sediment transport is projected to increase by a factor of 2-6 relative to 2010 levels by 2100, based on a recently refined sediment rating curve for the Skagit at Mount Vernon (Lee et al. 2014).
- Loss of 19% of the Skagit watershed's glaciers since the late 1950s (Dick, 2013).

A footnote in the DFREIS claims that climate change effects are uncertain and therefore have been excluded from the analysis. Estimates of the historical 100-year flood, future population, and land-use projections are also uncertain; yet, we include them, cognizant of their limitations, in studies like this one because they are an important driver of impacts. The same can be said for climate change impacts to peak flows. Sea level rise projections are also uncertain, and for the Skagit include uncertainties regarding rate of vertical land movements, which are widely considered to be trending downward in the Skagit lowlands (e.g. land subsidence; NAS 2012; Mote et al. 2008; http://www.panga.cwu.edu/demo_vms/velo_map.html). Despite uncertainties, these impacts must be included in studies of this kind because of their impact on study outcomes. SC^2 has shared these results and associated datum, which include quantitative estimates of uncertainty, with USACE including simulations from hydrologic models, sediment yield, and GIS analyses; yet, these resources do not appear to have been used in support of the DFREIS.

The analysis does not have sufficient scope, as it focuses only on sea level rise and not on hydrologic changes, nor the dynamic interaction of sedimentation on bed elevations through time, which affect flood conveyance and ecosystem impacts. Furthermore, initial modeling studies that incorporate hydrologic changes (Hamman 2012) have demonstrated that changes in river flooding are likely the most important driver leading to increased depth of inundation in the lower basin under climate change scenarios, once again highlighting the need to address these factors in long-term planning.

Section 4.1

Groundwater levels strongly affect flooding, drainage and drainage maintenance costs, and agricultural production. Given the interaction between sea level and surface-groundwater interactions in the Skagit Delta, what are surface-groundwater interactions currently and under projected sea level rise scenarios? How will the alternatives be influenced by, and themselves influence, groundwater levels? How are these considerations accounted for in the alternative benefits and cost comparisons, particularly in maintenance and operational costs related to pumping ponded water off of lands and to a higher sea?

A recent report shows that the groundwater table beneath farmland in the lower Skagit flats west of Mount Vernon is strongly influenced by present tidal variation and water surface elevations of the Skagit River (Savoca et al. 2009). This would suggest that future groundwater levels associated with changes in river stage and sea level position would be required to assess flooding, surface ponding, and the feasibility and performance of any alternatives intended to reduce hazards or economic impacts to farmers in the Skagit floodplain.

Sections 4.1.4 and 4.1.5

Levee setbacks in the lower river and upper delta, when designed to improve fish habitat, provide low-velocity rearing habitats that are currently very rare in the lower Skagit River as a consequence of an extensive levee and dike system. Low-velocity areas that possess complex large woody debris and riparian cover are critical to the growth and survival of juvenile Chinook salmon in the lower Skagit. These areas also provide important rearing habitat for juvenile steelhead and coho and important foraging habitat for anadromous bull trout. The scarcity of rearing and flood refuge habitats in the lower Skagit is currently a major factor limiting the production of all six independent Chinook salmon populations in the Skagit Basin (Skagit Chinook Recovery Plan 2005; Skagit Watershed Council Strategic Approach 2010). Rearing and refuge habitat become even more important in light of climate change, because these areas will become critical to the survival of juvenile salmonids as sea level rise and flood events become more frequent and extreme over time. Habitat mitigation and restoration measures should be considered for all alternatives that not only maintain current habitat but also "storm-proof" juvenile salmonids from further increases in sea level rise and peak flows resulting from climate change. Such measures may be critical to ensuring the long-term persistence of ESA-listed fish in the Skagit Watershed.

Table 4.3: Environmental Consequences of Alternatives

The DFREIS analysis of sedimentary processes and their effects on tidal marsh persistence is frequently based on incorrect or questionable assumptions. It also inaccurately characterizes current conditions and trends and does not appropriately account for the complexity of the system. For example, the statement that "Islands and marsh areas should continue to grow at near current rates [at the North and South Fork mouths]…", is at odds with observations of steadily declining marsh progradation rates since 1937 and recent tidal marsh erosion (Hood 2012, Hood et al. 2014). Another example is the over simplified statement that "Under the climate change scenario, higher discharges would likely result in higher sediment yields. …higher sediment yields would likely cause increased deposition around the mouths of the North and South Forks." In fact, large proportions of the river's sediment load likely bypass the tidal marshes as a result of high plume momentum caused by river constriction through the construction of levees and the elimination of historical river distributaries across Fir Island and elsewhere in the delta (cf. Falcini et al. 2012). Furthermore, both of these statements appear to focus on marsh progradation, which is declining and reversing, while the importance of marsh aggradation to counteract sea-level rise is not included. The effect of project structure on sediment routing, and consequently marsh aggradation, appears to not be included at all. The proximity of levees to the river (setback versus not setback) and the presence of distributaries or bypasses will affect the momentum of the river plume, and thereby affect retention of suspended sediments in tidal marshes and consequently marsh aggradation and progradation. Consideration of the project structure (including all alternatives) on sediment routing in the delta, and consequently on tidal marsh persistence, under future accelerated sea-level rise appears to be cursory and lack the rigor necessary in evaluating alternatives and their potential impacts and consequences.

With sea level rise, the area within the estuary and extent of flocculation of fine particles contributing to sedimentation does not seem to have been considered. Table 4.3 provides a summary of environmental consequences (both positive and negative impacts) for each of the alternative actions. For the most part, this table focuses on negative impacts. For the Joe Leary Slough Bypass alternative, this table fails to list potential positive impacts with regards to Geomorphology and Sediment Transport (4.6) and Aquatic Habitat (4.13), and only lists potential negative impacts. An example of a potential positive impact would include increased sedimentation to Padilla Bay, which has been shown to be cut off from its historic source of sediments (the Skagit River) and is currently eroding. Combined with sea level rise, this loss of sediments and its impacts on habitat and aquatic species is an important impact pathway. Additional sediments (when the bypass is operational) could potentially compensate for both increasing rates of sea level rise and for current loss of sediments (Kairis and Rybczyk 2010). Yet, these are not noted as potentially positive impacts.

Potential benefits for Padilla Bay with the Joe Leary Slough Bypass Alternative are not addressed. Given that Padilla Bay has been shown to be subsiding (Kairis and Rybczyk 2010), additional sediment from the bypass could help maintain the Bay's current elevation, thus preventing water depths that are too deep to sustain eelgrass.

Despite statements to the contrary in this section of the DFREIS, there is extensive literature that suggests pulsing events (e.g. sediment transport during large floods) are critical to many wetland and aquatic habitats for maintaining elevation (Day et al. 2000, McKee et al. 2009, Rybczyk and Cahoon 2002). These factors have not been adequately considered in the assessment of alternatives.

Section 4.15.1.1

Projected increases in flood magnitude and frequency have many implications for most fish species in the Skagit, adding to cumulative impacts from increasingly intense summer low flows and increased water temperatures (Mantua et al. 2010). For example, there are several juvenile life history forms of Chinook in the Skagit, the most important being estuary/freshwater tidal delta and riverine (parr migrant) forms, both of which migrate out as subyearlings; a stream-type life history form, which migrate out as yearlings; and fry migrant life history forms that use pocket estuary habitat (SRSC and WDFW 2005). All of these life history forms are important to the abundance, productivity, and diversity of the six independent Chinook salmon populations in the Skagit River watershed (NWFSC 2006), and also to the recovery of the entire Evolutionarily Significant Unit for ESA delisting (Ruckelshaus et. al 2006). The estuary/freshwater delta rearing area generally includes the North and South Fork Skagit downstream of the forks at Mt Vernon, Skagit Bay, Swinomish Channel, and Padilla bay.

Peak flows have a major impact on the survival of Chinook salmon eggs and fry, and the abundance of outmigrating smolts in the Skagit River basin (Kinsel et al. 2007). Consequently, increasing peak flows in the project area caused by climate change would adversely impact all of these Chinook life history forms. The predicted increases in velocities under a 1% ACE flood under the CULI Alternative may seem small, but velocities will still be much too high for juvenile fish throughout the lower Skagit because of the lack of suitable velocity refuge habitat. Also, high-flow events that cause significant impacts are projected to become much more frequent in future scenarios (Mantua et al. 2010). Egg-to-smolt *survival* rates for juvenile Chinook in the Skagit are less than 1% during a 1% ACE flood (WDFW smolt trapping data) as a consequence of redd scouring and fry mortality due to high velocities. Survival rates will decline even further under the more frequent high flows predicted under climate change. Ocean-type Chinook fry are also present in the river during the winter, (Chinook fry are present in the river typically after mid-January following redd emergence.), and these fry are especially vulnerable to high flows.

The various alternatives presented in the DFREIS can help reduce cumulative impacts (particularly for yearling fish) if designed to provide refuge habitat during flood events. Unless rearing and flood refuge habitat are protected and restored in the lower Skagit River, all of these life history forms will likely decline as a result of changes in hydrological patterns caused by climate change.

Section 4.2.1.3

The analysis of cumulative impacts to fish due to bank hardening would benefit greatly if alternatives including extensive use of rip rap (e.g.170,000 cubic yards) were compared to existing conditions in terms of added lineage of hardened bank (e.g. in addition to 60% currently modified below Sedro-Woolley).

Section 4.9.1

It would probably be more accurate to call subsurface material “sediment” than “soil” in discussion of borings. Why was the presence of woody debris not mentioned in borings? Would the presence of the wood not compromise levee stability?

Soils have been mapped in the upper basin within North Cascades National Park.

Due to projected changes associated with a warming climate, it is important to know where the most valuable soil types are in terms of water storage, groundwater recharge, and water temperature mitigation, and how these natural resources are affected by the alternatives evaluated in the DFREIS.

Section 6.17

Skagit Wild and Scenic River officially starts at Bacon Creek – not Ross Dam. The area between Ross Dam and Bacon Creek is suitable, but Congress has not acted to include it in the system.

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