Appendix C
Salmon Productivity Calculations for Smith Island Restoration Project

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INTRODUCTION

Calculating gains in returning salmon from one restoration project is a difficult prospect given the uncertainty in multiple variables. While the Smith Island Restoration Project is an important component of the *Snohomish River Basin Salmon Conservation Plan*, it is only one element of a recovery strategy that includes harvest, hatchery and habitat improvements implemented by multiple jurisdictions across the watershed. The only way to measure its benefit is through the implementation of an estuary system-wide monitoring strategy. Given these uncertainties, the scientific community cautions against providing such estimates. Nevertheless, decision-makers and the public want information on the fish benefits of a large-scale project such as Smith Island Restoration Project upfront to evaluate the gains relative to the costs. The estimate produced should be viewed as an order-of-magnitude estimate rather than an absolute value.

TIDAL CHANNEL AREA

The area proposed for tidal marsh restoration is approximately *166 hectares* (413 acres). Tidal channel area in marshes is scaled to the size of the marsh and is also likely influenced by other factors such as the size of adjacent distributary or mainstem channel and shape (Hood 2007). The accessibility of tidal channels to fish is also directly influenced by the size and depth of water at inlet locations and distance from source areas (Beamer et al. 2005), which will presumably increase over time in terms of connections and tidal channel area at Smith Island. To some extent the subsidence that has occurred at Smith Island will actually increase the depth of water and tidal prism volume such that channel depth and tidal channel development are likely to be greater than at reference locations. Tidal inundation of the channel network is expected to be greater at Smith Island as a fraction of the tidal cycle, thereby promoting greater rearing opportunity. These uncertainties are difficult to quantify, but suggest simple estimates of expected tidal channel area are conservative and that habitat quantity will increase over time. For this Appendix, the estimate for the Smith Island Restoration Project channel area following restoration is *11.04 hectares* (27.28 acres). This number is an average of the observed Skagit River South Fork and North Fork channel densities (Hood et al. 2005). It should be noted that given the variability and incomplete understanding of tidal channel scaling, Hood cautions against extrapolating scaling patterns to other river deltas.

SMOLT PRODUCTION

Chinook smolt density in blind tidal channels is highly variable throughout the outmigration, from year to year and from site to site. Smolt density is influenced by population characteristics, site characteristics, food availability, connectivity with other habitats as well as other factors. To develop the estimate, ten regional studies were evaluated that report smolt densities in tidal channels. We selected average maximum density values between March and June to estimate likely densities that would be present at the peak of the outmigration at the Smith Island project area. The average maximum Chinook smolt density from the studies was *5200 smolts/hectare* (0.21 smolts per acre). The maximum rather than the seasonal mean values were used because the estimate is already conservative. Specifically, it is based on one group of juveniles occupying the site per season rather than a continuum of juveniles migrating through the site. Chinook salmon exhibiting the ocean-type life history strategy occupy estuary habitat from two weeks to two months (35 days is the estimated residence time in the Skagit, Beamer et al. 2005). Although not used here, for contrast, in the Skagit, seasonal average density of sub-yearling Chinook in tidal delta habitat was nearly 16,000 smolts/hectare when there was high outmigration abundance. This suggests that as Snohomish Basin salmon populations recover and outmigration abundance increases, fish density at Smith Island should increase though may not attain the same density as observed in the Skagit River. Likely annual smolt production from the Smith Island Restoration Project was estimated at approximately 43,000 by multiplying channel area by smolt density by an estuarine survival factor of *0.77* calculated in the Skagit River estuary. Given the variability and uncertainty around the density and survival numbers, smolt production estimates should be viewed as an order-of-magnitude estimate rather than an absolute value.

MARINE SURVIVAL

Marine survival is highly variable from year to year depending on ocean conditions. It is also influenced by the quality of estuarine habitat available because fish that reside in the estuary longer grow larger, and thus are more likely to survive in the marine environment. The challenge of calculating a reasonable marine survival estimate is further confounded by harvest (some estimates reported include harvest while others do not) and lack of data on marine survival in wild populations. Most values reported in the literature are for hatchery populations, and these values are much lower than values reported for wild populations. Three studies were evaluated that report marine survival for wild populations pre-harvest. In the Skagit River during a 4 year period, marine survival ranged from 1.6 to 3.9%, with a mean value of 2.6 (Beamer et al., 2000). For the estimate of likely returning adults, a figure of 2% was selected, the lowest of the marine survival estimates for wild populations. It should be noted that marine survival estimates for Snohomish River basin hatchery Chinook is much lower than the wild stock marine survival estimates.

ADULT SALMON RETURNS

The estimated annual return based on the estimates of channel area, smolt production and marine survival is calculated as follows:

	110,400	square meters of blind tidal channel
x	0.52	Chinook salmon smolts per square meter
x	77	percent estuary survival
x	2	percent marine survival
=	900	Chinook salmon per year (884 rounded)

Given the uncertainty and variability, this number has significant error; positive and negative. This study estimates the low end of the range at approximately 120 Chinook per year and the high end at 3,700 Chinook per year. To calculate the actual range and confidence interval, running a Monte Carlo simulation model is recommended using ranges for each of the three main independent variables: tidal channel area, smolt production and marine survival. Put in the context of Chinook salmon population status in the Snohomish Basin, the adult returns per year cited here for Smith Island represent a 31% increase over the average adult spawning population from 1996-2000 (SBSRF 2005). The value of this single project for the recovery of Snohomish Basin Chinook salmon relative to many other smaller actions or projects is considerable.

HARVEST VALUE OF SALMON

Calculations for the potential harvest value of salmon produced by the Smith Island Restoration Project are divided into the following steps:

1. Find average retail price of wild Chinook salmon.
2. Calculate number of adult Chinook salmon returning to the Snohomish River basin annually as a result of the Smith Island Restoration Project.
3. Multiply retail price of Chinook (#1 above) by numbers of Chinook (#2 above)

These steps are outlined in more detail below:

AVERAGE RETAIL PRICE OF WILD CHINOOK SALMON

Average retail prices of wild Chinook salmon are extremely difficult to obtain and can vary substantially from year to year. Consider this extract from a comprehensive analysis of salmon fisheries in North America.

"We are unaware of any reliable source of data on "average" U.S. retail prices for fresh and frozen salmon. Although it is easy to go into a store and see what a particular salmon product is selling for in that particular store in that particular week, it is very difficult to determine "average" or even "typical" prices of salmon sold in a particular area—much less the entire country. This is especially the case because quantities sold vary dramatically between different stores and

at different times. A store with a high price may be selling far less salmon than a store with a low price" (Knapp 2007).

In determining a suitable price (per pound) for wild Chinook salmon, this study took the average of three advertised retail prices. The approach was conservative in at least two respects:

- Prices were taken from established retailers who are likely to have relatively stable, low prices. To illustrate, two of the retailers are located in Pike Place Market, Seattle, and have been in operation since 1911 and 1965 respectively. These retailers are also "direct" in the sense that they are located geographically close to a harbor and likely have strong ties to fishermen, so their prices may be lower than other retail outlets such as supermarkets.
- Prices were based on the per-pound prices of *whole* salmon, rather than per-pound prices of other salmon products such as boneless skinless fillets. This pricing eliminates the potential effect of price markups on value-added salmon products. In reality, not all Chinook salmon would be sold as whole fish to consumers, and economic measures which count 'final value' (i.e. GDP) would likely measure a higher per-pound retail value on average.

The per-pound retail prices for salmon as of February 21, 2011 are as follows:

- $11.82 per lb. ($165.50 per 13-14 lbs., head on, gutted). http://www.seattleseafoods.com/salmon/alaskan-king-salmon-chinook-salmon/chinook-king-salmon-troll-caught-headed-and-gutted-iqf
- $13.99 per lb. ($279.80 price per 20 pound fish, whole wild troll-caught Chinook salmon). http://www.pikeplacefish.com/salmon.html
- $15.25 per lb. (9-10 lbs., $152.50, whole wild Chinook salmon) http://www.freshseafood.com/store/detail.aspx?sn=FreshSalmon&id=1&cat=1

The average of these three values equals $(11.82 + 13.99 + 15.25)/3 = $13.69 per lb.
If the average weight of a harvested Chinook salmon is 15 pounds (Tulalip Tribes, personal communication, 2010), then each whole fish has a retail value of approximately $205.35.

ESTIMATED ANNUAL CHINOOK RETURNS

Analysis by Snohomish County and the Tulalip Tribes estimates that the proposed project will produce approximately 900 returning Chinook annually.

FINAL HARVEST VALUE OF CHINOOK

Combining the retail value of Chinook with the estimated annual Chinook returns, the salmon harvest value of the Smith Island Restoration Project was estimated:

- 900 Chinook per year embody a retail value of (900 Chinook/year x $205.35/Chinook) = $184,815.00 per year

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