Technical Memo

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To: CCT Sr. Fisheries Management Staff (Randy Friedlander, Bret Nine, Kirk Truscott)

CC: UCUT Fish Committee

***Goals*:**

1. Explain the redd capacity methodology from the Hanrahan et al. (2004) assessment of Lake Rufus Woods Chinook spawning potential to help managers understand the reasons for the wide range of model outputs so that they can choose an appropriate objective(s) for the reintroduction of Summer/Fall Chinook Salmon.
2. Explain the updated methodology that will be used in the evaluation of potential Chinook habitat in the riverine section of Lake Roosevelt (Kettle Falls to the Canadian border).

Introduction:

A habitat assessment in the Columbia River is needed for Chinook salmon upstream of Chief Joseph and Grand Coulee dams to fulfill Phase 1 planning objectives and to help determine strategies for reintroduction of anadromy to those blocked areas (NPPC 2014; Columbia Basin Tribes and First Nations 2015). Methods for quantifying potential spawning habitat and redd capacity of summer-fall Chinook salmon have been published for Lake Rufus Woods, upstream of Chief Joseph Dam (Hanrahan et al. 2004). However, an analysis of potential spawning habitat and redd capacity has not yet been performed for the Columbia River upstream of Grand Coulee Dam in Lake Roosevelt. The objective of this technical memo is to explain the methods of the Lake Rufus Woods analysis, particularly how redd capacities were estimated and the advantages and disadvantages of the varying methodologies to help managers decide how best to use the information from Hanrahan et al. to choose a spawn escapement objective (or range) for that area. Additionally, this information is important to deciding which methodology is most appropriate for estimating potential habitat and redd capacity in the Lake Roosevelt reach.

Spawning Habitat and Redd Capacity Methodology:

In the Lake Rufus Woods analysis, potential summer-fall Chinook salmon habitat and redd capacity was calculated using a several-tiered approach. First, a geomorphic analysis was applied to the most-riverine, upper ~30km of the reservoir, where Chinook salmon would be presumed to spawn if re-introduced, to classify habitats into “Potential” and “Not Suitable” spawning habitats. Of those areas deemed “Potential” habitat, a binary analysis was then performed to classify each 3x3m cell within this area as either “Suitable” or “Not Suitable” based on published criteria defining suitable fall Chinook spawning habitat (i.e., depth, velocity, substrate, and channel-bed slope; see Table 1, Hanrahan et al. 2004). Lastly, of the habitat calculated as “Suitable”, a suitability index analysis was performed to rate the quality of this habitat on a scale from 0 (poor) to 1 (optimum).

Once the locations and area (m^2) of suitable habitats were quantified, redd capacity was calculated using four different methods:

$$C = \frac{Suitable\ Habitat\ (m^2) * correction\ factor}{Average\ redd\ size\ (m^2)} \tag{1}$$

, where *C* is the redd capacity or estimated number of redds, *Suitable Habitat* is the area of habitat calculated as "Suitable" above, *correction factor* is a proportion varying from 0.05 to 0.3 (in 0.05 increments) based on proportions of suitable habitat actually used by spawning fall Chinook in the Hanford Reach (per citations in Hanrahan et. al 2004), and *Average redd size* is published values of fall Chinook redd sizes in the Columbia River varying from 17–23m^2, however calculations in Hanrahan et al. only used 21 and 23 m^2. This estimate is generally considered to overestimate redd capacity because it does not consider inter-redd spacing. Therefore, a second method considered inter-redd spacing:

$$C = \frac{Suitable\ Habitat\ (m^2) * correction\ factor}{Average\ redd\ size\ (m^2)\ including\ inter-redd\ spacing} \tag{2}$$

, where *inter-redd spacing* varies from published values of 2.8–3.4m. This estimate is considered a more conservative, realistic estimate because inter-redd spacing is included[1]. The third and fourth methods estimated redd capacity only using the highest-quality habitat identified from the habitat suitability index:

$$C = \frac{Habitat\ with\ SI\ from\ 0.76\ to\ 1.0\ (m^2)}{Average\ redd\ size\ (m^2)}\quad \text{, and} \tag{3}$$

$$C = \frac{Habitat\ with\ SI\ from\ 0.76\ to\ 1.0\ (m^2)}{Average\ redd\ size\ (m^2)\ including\ inter-redd\ spacing} \tag{4}$$

, where *Habitat with S.I. from 0.76 to 1.0* indicates 'optimal' habitat quality from the suitability index analysis.

Redd Capacity Estimates:

The Lake Rufus Woods methodologies resulted in a wide range of redd capacity estimates that varied from 1,058–6,951 (eq. 1), 207–1,599 (eq. 2), 4,169–4,566 (eq. 3), and 818–1,051 (eq. 4) using 50% exceedance flows through the study area. This variability in redd capacity estimates, depending on the method used, is considerable and is thus an important consideration when determining the 'best' or most scientifically robust method for estimating redd capacity estimates from the Lake Rufus Woods assessment, as well as which method(s) would be most robust for estimating redd capacity in Lake Roosevelt.

Caveats and Considerations:

It is important to consider that the Lake Rufus Woods analysis used several assumptions based on the Hanford Reach fall Chinook salmon population. Although it could be argued that summer-fall Chinook salmon spawning in Lake Rufus Woods or Roosevelt may ultimately differ from Hanford Reach fall Chinook spawners, the amount of high quality data from the Hanford Reach and the proximity of the

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[1] Although this assumption may be valid for fall Chinook spawning in the Hanford Reach of the Columbia River, Summer Chinook spawning in high quality tributary habitat (e.g., Lower Similkameen River, Wenatchee River near Leavenworth) are known to create redds very close together and even superimposed on one another.

population to Lake Rufus Woods and Roosevelt makes it a reasonable population for comparison purposes.

Another caveat is the correction factors varying from 0.05–0.3 that were used to scale equations 1 and 2 based on the proportion of suitable habitat that fall Chinook salmon have historically used in the Hanford Reach of the Columbia River, and whether these correction factors would apply to spawning habitat estimates in Lake Rufus Woods or Roosevelt. It is arguable, however, that these correction factors may only be applicable in the relatively low escapement years used to calculate the correct factor and may not be as relevant in higher escapement years. The escapement years used to determine the correction factor were 1986, 1991, 1994, 1995, and 2001 with respective escapement estimates of 72,559, 31,971, 48,857, 38,381, and 44,140. From 1986–2015, average Hanford Reach escapement was 62,643; contemporary escapements from 2010–2015 varied from 65,724 to 233,927. It is possible that in these recent high escapement years (e.g., 2013), Chinook salmon likely used 30% or more of potentially suitable habitat (Bob Mueller, PNNL, personal communication). From a preliminary analysis of digitized redds in the Hanford Reach in 2013 (escapement = 157,484) as compared to a probabilistic spawning map produced using a modified equation from Geist et al. (2008), spawning Chinook salmon may have used more than 30% of the suitable habitat (Figure 1); however, further analysis would need to be conducted to quantify actual habitat use.

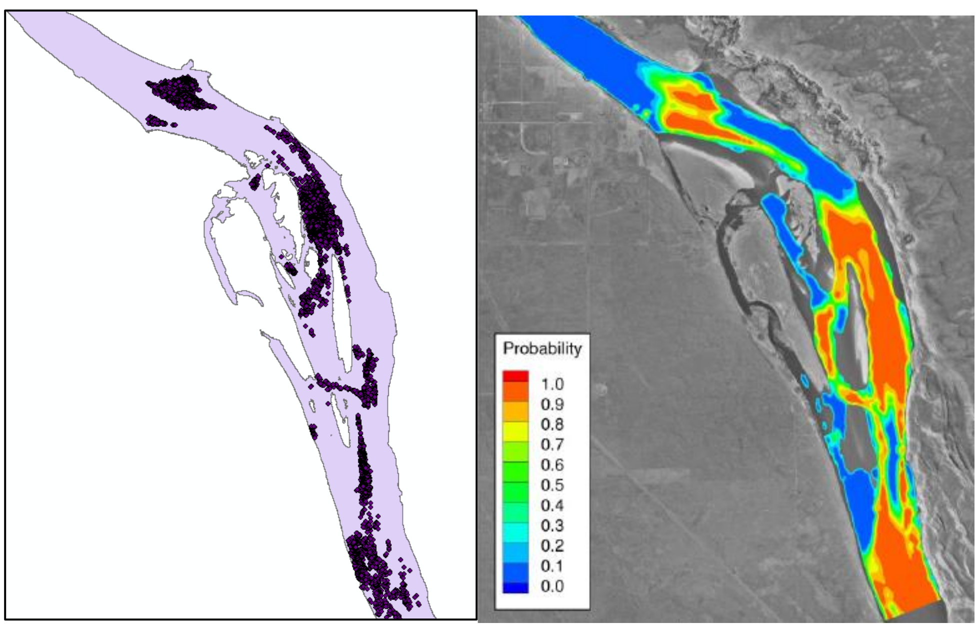

Figure 1. Digitized fall Chinook salmon spawning redds near F-slough of the Hanford Reach of the Columbia River, 2013 (left panel) and a spawning map of the same reach showing fall Chinook salmon spawning probability based on a modification equation from Geist et al. 2008 (right panel).

A further consideration in addition to the number of estimated redds in Lake Rufus Woods or Lake Roosevelt is the number of estimated adult spawners per redd. It is estimated that the mean number of spawners per redd in the Hanford Reach from 1964–2014, based on escapement values and yearly flights to enumerate redds, was 9.2 (SD = 6.5), with a median of 8.4. Summer/Fall Chinook spawning in tributaries downstream of Chief Joseph dam generally have fewer fish per redd. For example, CCT and

WDFW use the sex ratio at Wells Dam to estimate fish per redd in the Methow and Okanogan which averaged 2.98 between 1989 and 2015 (Hillman et al. 2016).

Lake Roosevelt Methodology:

The proposed methodology for quantifying spawning habitat and redd capacity in Lake Roosevelt is simpler than the Lake Rufus Woods assessment, primarily due to a 2008 publication (Geist et al. 2008) that specified a probabilistic spawning equation for Chinook salmon based on Hanford Reach data. Inputs to the equation include depth, velocity, substrate, and channel-bed slope (similar to Table 1 in Hanrahan et al. 2004), and the output is a probability that an area is suitable for Chinook salmon spawning (see right panel, Figure 1). In short, hydrodynamic simulations of the Lake Roosevelt Reach (Kettle Falls to the International Border) would be conducted similar to the Hanrahan et al. publication to produce these hydrodynamic variables for each computational cell of the model for three steady-discharge flows (10, 50, and 90% exceedance flows during the fall spawning period, averaged over a number of specified years–e.g., 1976–present). The output data from these simulations will then be input into a spawning probability equation similar to the equation used to calculate the data used for Figure 1 (right panel). The total area of each probability bin (bin size 0.1 from 0–1) will then be summed and redd capacity estimates would be calculated and reported for each probability (likelihood of spawning) bin.

Conclusions:

There is a wide range of potential spawner escapement possibilities from the information provided in Hanrahan et al. and this memo should help managers understand the reasons behind that variation. Additionally, Hanrahan et al. did not expand the redd capacity estimates to number of spawners, but simply noted that fish per redd estimates are generally higher than two. At the most conservative end of the evaluation, Lake Rufus woods has the capacity for approximately 200 redds, and with three fish per redd the resulting spawn escapement objective would be 600 spawners. Using the least conservative assumptions about redd size, spacing and the percent of usable habitat the Hanrahan et al (2004) study estimated a capacity of 6951 redds, and with three fish per redd the potential spawner capacity would be approximately 20,000 spawners for Lake Rufus Woods. The variability in redd capacity estimates will likely be similarly large for the Lake Roosevelt reach; each estimate will be dependent on the assumptions and methodology used to calculate capacity. However, it is expected that quantifying spawning habitat potential in this way will provide fisheries managers with the best available science to develop an appropriate estimate, or range of estimates, to be used for life cycle modeling scenarios and establishing reintroduction objectives. It may not be necessary (or possible) to pick one number for an objective, given the uncertainty and assumptions that went into this (and future) modeling exercise. Rather, the best approach may be to begin testing assumptions (e.g., quantifying summer-fall Chinook redd size and inter-redd spacing; comparing hydrological variables of chosen spawning areas in reintroduced areas vs. the Hanford Reach) and monitoring performance to better understand how fish will actually utilize the habitat once they have access to it. Managers may want to consider a ramping up approach where they experimentally test the utilization of habitat given releases of one, two, or three thousand spawners.

References:

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