Memorandum **June 6, 2017**

To: John Palmer, USEPA Region 10

From: Peter Leinenbach, USEPA Region 10

Subject: Evaluation of the potential cold water refugia created by tributaries within the Lower/Middle Columbia River based on NorWeST temperature model

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Current august mean water temperatures for rivers in the Pacific Northwest were obtained from the "Norwest" project (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html) (**Figure 1**). Specifically, there are 191 tributaries modeled by the NorWeST project that discharge into the Lower/Middle Columbia River (i.e., Illustrated by the small white dots in **Figure 1**). In order to evaluate the potential for tributary discharge to provide cold water refuge for migratory salmon in the Lower/Middle Columbia River, modeled tributary stream temperatures for these 191 tributaries were compared to observed Columbia River temperatures[1].

Figure 1. Illustration of Norwest predicted stream temperatures for the Lower/Middle Columbia River
[August mean stream temperature for the 1993-2011 period]

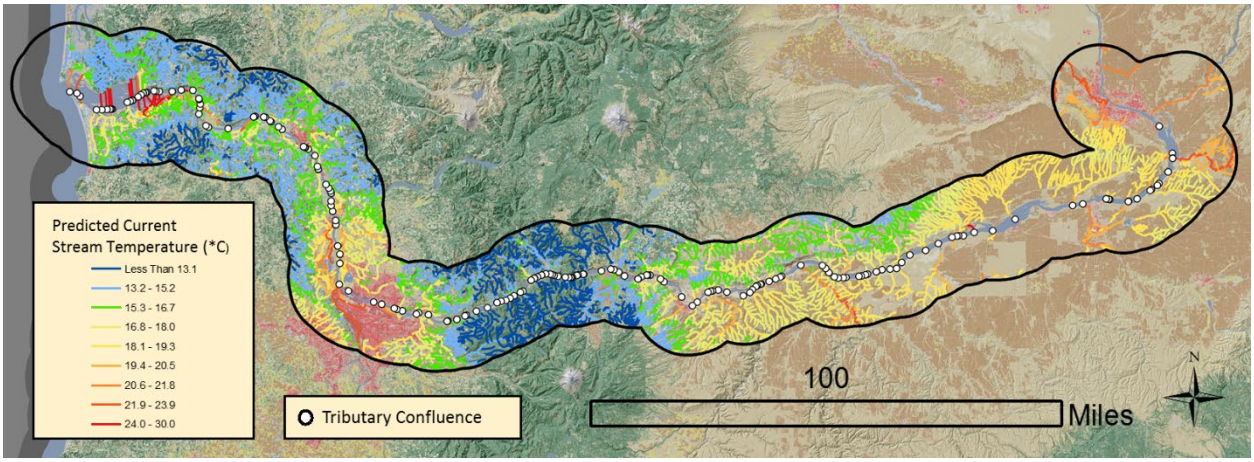

Figure 2 shows that many tributary streams were much cooler than the Columbia River. Very cold tributaries (defined as tributaries temperature more than 4*C cooler than the Columbia) are primarily located west of the Cascade mountains, however cooler tributaries are located throughout the Lower/Middle Columbia River. It is important to note that there is a very large range of stream flows within these tributaries, ranging from <1 cfs to 8591 cfs[2]. Accordingly, the potential for a tributary to provide cold water refugia is partially dependent on the discharge of the tributary (**Figure 2- Bottom Image**).

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[1] Only Columbia River sites with more than 2 years of data were included in the analysis for this figure.
[2] Average (1971-2000) August flows were derived from the Extended Unit Runoff Method (EROM) model in NHDPlusV2 – http://www.horizon-systems.com/NHDPlus/NHDPlusV2_17.php

Figure 2. Modeled August Mean Stream Temperatures within Tributaries that Discharge into the Lower/Middle Columbia River

[The size of the tributary markers in the bottom image is relative to the tributary flow level]