MEMORANDUM

Date: June 4, 2021
To: Kim Marcotte and Ann Costanza, Anchor QEA, LLC
From: Larry Karpack, WSE
cc: Heather Page and Matt Kuziensky, Anchor QEA, LLC
Re: Modeling climate change conditions for the Chehalis Basin Strategy

Background

Since 2011, multiple hydrologic and hydraulic modeling studies have been conducted for the Chehalis River basin to evaluate flood damage reduction alternatives and aquatic species habitat restoration projects. The modeling considers existing hydrologic conditions as well as projected future hydrologic conditions resulting from the effects of climate change. The most recent hydraulic modeling for the Chehalis Basin Strategy (CBS) has been conducted using a RiverFlow2D 2-dimensional hydraulic model developed by Watershed Science and Engineering in 2019 (WSE, 2019a). Hydrologic inputs to that model were adapted from an earlier study of basin hydrology by WEST Consultants for the US Army Corps of Engineers (WEST, 2012). The 2012 study included development of basin-wide hydrologic inputs corresponding to the 2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year floods. Balanced inflow hydrographs were developed for the mainstem Chehalis River and major tributaries. These inflow hydrographs included nested inflows for durations ranging from 15-minutes to 15 days. The existing condition hydrologic inputs were then scaled up to account for projected climate change as described below.

Effects of Projected Climate Change as Modeled for SEPA Draft EIS

The effects of climate change on flood flows in the Chehalis Basin were investigated using the Distributed Hydrology Soil Vegetation Model (DHSVM). Long time sequences of meteorologic inputs were developed for two global climate models (GCMs) and used as input to the DHSVM model. These models were run for the simulation period 1970 to 2099. Output data from the DHSVM model were extracted at key locations throughout the watershed and subject to frequency analysis. The periods of analysis used were historical (1970-2015), mid-century (2016-2060), and late-century (2055-2099). The two GCMs considered were ACCESS 1.0 RCP 4.5, which generally predicts near the lower end of climate change effects, and GFDL CM3 RCP 8.5, which generally predicts near the higher end of climate change effects. Initial climate change modeling and analysis was conducted by WSE in 2019 (WSE, 2019b). This analysis indicated that by mid-century flood flows in the Chehalis Basin would increase by approximately 12% over existing conditions for both the low end and high-end projections. By late century, however, the projections diverged with the low-end projection remaining near this same level (12% above existing conditions) while the higher end projection showed an increase of 26% above existing conditions. The hydrologic analyses suggested that these projected increases were relatively consistent across all flood return periods, durations, and locations in the basin. Therefore, adjusted future inflows to the hydraulic model were developed by simply scaling all existing conditions model inputs (every ordinate in the inflow hydrographs) by the same amount (i.e. 12% for mid-century and either 12% (low end) or 26% (high end) for late century).

In late 2019, an error was discovered in the meteorological inputs that were used in the development of the GFDL CM3 RCP 8.5 GCM projection. At that time WSE conducted additional hydrologic modeling using a corrected set of meteorological inputs. The updated hydrologic model results showed an average increase of 50% in late-century flood flows for the GFDL CM3 RCP 8.5 simulation compared to 26% in the earlier analysis (Anchor QEA, 2019). The results for mid-century conditions were consistent with the previous results. Because the climate projections used in the SEPA Draft EIS were near the middle of the range of results seen in other studies modeling the RCP 8.5 scenario, it was determined through consultation with CIG that the assumptions used in the SEPA Draft EIS analyses were still reasonable and the determinations of probable significant impact would remain unchanged with the updated climate change predictions.

Post SEPA Draft EIS Modeling of Projected Climate Change

In addition to showing higher overall projected flow increases, the updated GFDL modeling showed significant spatial variability across the basin, with larger projected increases in some areas (specifically the upper basin) and smaller projected increases in other areas (the lower basin). In late 2020 and early 2021, the UW CIG conducted additional analyses to characterize the spatial distribution of precipitation across the basin for 12 different GCMs (Mauger, 2021). Those analyses, together with WSE's earlier modeling of the corrected GFDL CM3 meteorological inputs, were used to define a spatially distributed set of inflow scalars for use in the hydraulic modeling. Those scalars ranged from 40% increases in the Satsop, Wynoochee, Humptulips and other lower basin tributaries, to 65% increases in the Elk Creek, Lincoln Creek, and Bunker Creek basins. The full set of spatially distributed flow scalars used for late-century high-end climate conditions are depicted in Figure 2 of the *Chehalis Basin: Extreme Precipitation Projections Memorandum* (Mauger, 2021), reproduced below for the reader's convenience. Similar to the earlier future conditions modeling the new spatially distributed scalars were applied to all inflow values (every time step) in each of the design flood events.

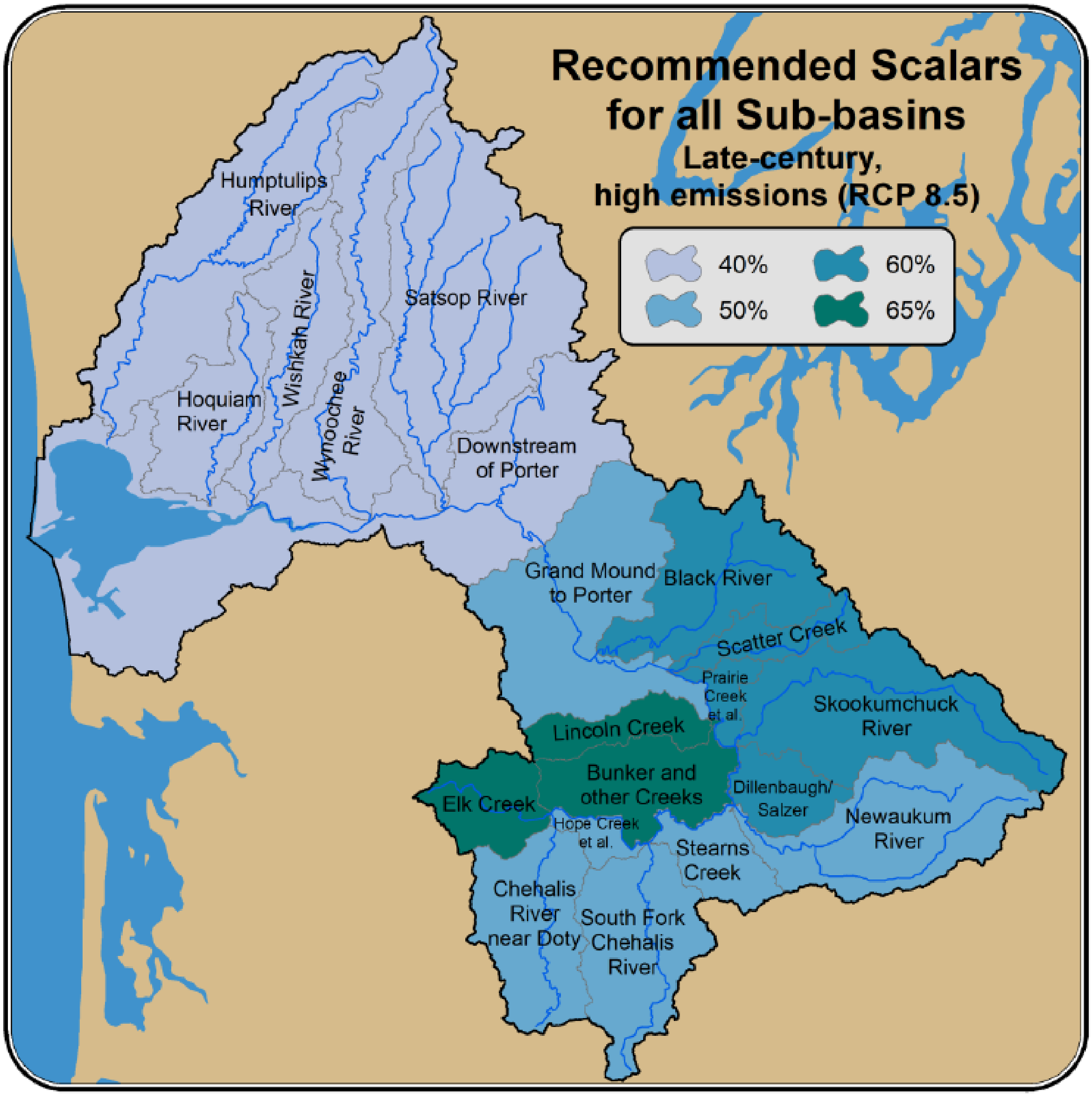

Figure 2. Recommended spatial distribution of scalars representing the high-end projected changes in precipitation for the Chehalis basin. As in Figure 1, all changes are expressed as a percent change for late-century (2055-2099) relative to historical (1970-2015).

Hydraulic Model Runs

Hydrologic inputs to the hydraulic model were developed for eight design flood events (2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year floods) and four climate scenarios (existing climate conditions, mid-century climate conditions, late-century mid-range climate conditions, and late-century high-end climate conditions). However, only a subset of these were run using the RiverFlow2D model. The runs that have been made to date are listed below in Table 1.

Table 1
RiverFlow2D Hydraulic Model Runs Completed to Date

CLIMATE CONDITION	FLOW INCREASE RELATIVE TO EXISTING CONDITIONS	DESIGN FLOOD EVENTS SIMULATED NO ACTION	WITH FRE
Existing Conditions		10-, 100-, 500-year events	10-, 100-year events
Mid-Century	12%	10-, 100-year events	10-, 100-year events
Late-Century Mid-range	26%	2-, 10-, 20-, 100-, 500-year events	2-, 10-, 20-, 100-, 500-year events
Late-Century High-end	40 to 65% spatially varied	2-, 10-, 20-, 100-, 500-year events	2-, 10-, 20-, 100-, 500-year events

References

Anchor QEA and ESA (Environmental Science Associates), 2019. Climate Change Projections and Draft SEPA EIS Documentation. Memorandum to Diane Butorac, Washington State Department of Ecology. December 8, 2019.

CIG (Climate Impacts Group), 2019. Differences Between the Old and New GFDL CM3 Projections. Memorandum by Guillaume Mauger, Climate Impacts Group, UW. October 30, 2019.

Mauger, G.S., 2021, Chehalis Basin: Extreme Precipitation Projections, Memorandum prepared for the Office of the Chehalis Basin, Climate Impacts Group, University of Washington, Seattle, February 4, 2021.

WEST Consultants, 2012, Chehalis Basin Ecosystem Restoration General Investigation Study Baseline Hydrology and Hydraulics Modeling Revised Hydrologic Analysis Report, Report prepared for US Army Corps of Engineers , January 16, 2012.

WSE, 2019a. Technical Memorandum to: Bob Montgomery, Anchor QEA, LLC. Regarding: Chehalis River Existing Conditions RiverFlow2D Model Development and Calibration. February 28, 2019.

WSE, 2019b. Memorandum to: Bob Montgomery, Anchor QEA, LLC. Regarding: Chehalis River Basin Hydrologic Modeling. February 28, 2019.