How Will Climate Change Affect the Stillaguamish Watershed?

Prepared by the University of Washington Climate Impacts Group, June 2015

Climate

Rapid warming is expected this century and the heaviest rain events are projected to become more intense. All scenarios project warming for the Stillaguamish Watershed as a result of rising greenhouse gas emissions. Although annual precipitation is not expected to change significantly, heavy rainfall events are expected to intensify and summers are expected to be drier.

Coasts

Sea level rise and ocean acidification will continue to affect the Stillaguamish delta. Both are projected to rise substantially under all greenhouse gas scenarios. Sea level rise in the Puget Sound region reflects the combined effects of a rising global sea level and subsidence of land surfaces due to plate tectonics, among other factors.

Water

The Stillaguamish watershed is projected to experience decreasing snowpack and widespread changes in streamflow timing, flooding, and summer minimum flows but little change in average annual streamflow volume. Warmer winter temperatures will reduce snowpack volume in the Stillaguamish watershed and shift the timing of snowmelt earlier (Figure 1). Lower snowpack in the upper watershed will also contribute to lower streamflow volume during the summer months. Flood risk increases in the fall/winter months due to expected increases in extreme precipitation and shifts in seasonal precipitation from snow to rain over larger portions of the watershed. While these seasonal changes are large, annual streamflow volumes are not projected to change substantially.

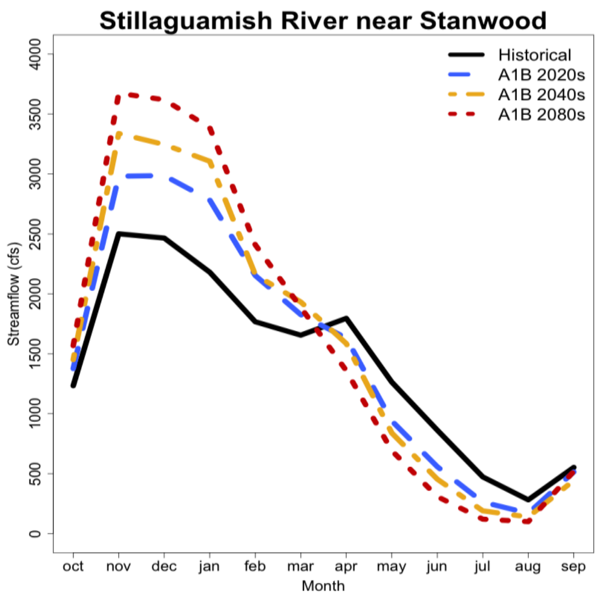

Figure 1. Change in the seasonality of streamflow, showing monthly average runoff for the water-year (Oct-Sep), for the 20th century (1916-2006; black line), the 2020s (2010-2039; blue line), the 2040s (2030-2059; gold line), and the 2080s (2070-2099; red line), all based on a medium (A1B[1]) greenhouse gas scenario. *Source: http://warm.atmos.washington.edu/2860*.[2]

Water Quality

Stream temperatures in the Stillaguamish are projected to increase, along with sediment loading and possibly landslides. Warming air temperatures and declining snowpack result in warmer stream temperatures, while a receding snowline and increasing winter rain will cause greater erosion, increasing the sediment supply to rivers. Although future landslides are difficult to predict, several studies indicate that future conditions will favor an increase in landslide risk for the Stillaguamish.

---

[1] To make projections, climate scientists use greenhouse gas scenarios – "what if" scenarios of plausible future emissions – to drive global climate model simulations of the earth's climate. Wherever possible, scenarios used in this document include both a low and a high emissions scenario of 21st century greenhouse gas emissions.

[2] Hamlet, A.F., M.M. Elsner, G.S. Mauger, S-Y. Lee, I. Tohver, and R.A. Norheim. 2013. An overview of the Columbia Basin Climate Change Scenarios Project: Approach, methods, and summary of key results. *Atmosphere-Ocean* 51(4):392-415, doi: 10.1080/07055900.2013.819555: http://warm.atmos.washington.edu/2860/

Observed and Projected[1] Changes

Temperature	
Annual Temp - Observed[3]	Increase in average historical temperature (1895-2014) for nearby stations Everett: +0.71 ± 1.05°F Sedro Woolley: +1.19 ± 1.11°F
Annual Temp – Projected[4]	Projected increase in average annual temperature for the 2050s (2040-2069), relative to 1970-1999, for the Stillaguamish watershed: Low emissions (RCP 4.5): +4.4°F (range: +3.0 to +5.6°F) High emissions (RCP 8.5): +5.7°F (range: +4.5 to +7.3°F)
Frost-free season[4]	Longer freeze-free period expected (average for the Stillaguamish watershed). Low emissions (RCP 4.5): +16 days (range: +12 to +22 days) High emissions (RCP 8.5): +22 days (range: +16 to +28 days)

Precipitation	
Seasonal Precipitation - Observed[3]	No historical trend in seasonal precipitation; large variations from year-to-year.
Seasonal Precipitation – Projected[4]	Increased winter precipitation and decreased precipitation in summer (2050s relative to 1970-1999), for the Stillaguamish watershed: *Winter (Oct-Mar)* Low emissions (RCP 4.5): +8% (range: +2 to +18%) High emissions (RCP 8.5): +9% (range: +4 to +19%) *Summer (Apr-Sep)* Low emissions (RCP 4.5): −8% (range: −19 to 0%) High emissions (RCP 8.5): −8% (range: −21 to +1%)
Heavy Precipitation - Projected[4]	Increased maximum daily precipitation totals in Stillaguamish watershed (2050s relative to 1970-1999): Low emissions (RCP 4.5): +13% (range: +7 to +25%) High emissions (RCP 8.5): +16% (range: +3 to +29%) Recent research indicates that heavy precipitation events may be larger than what is projected in the above models.[5]

[3] Menne, M. J., Williams Jr, C. N., & Vose, R. S. (2009). *The US Historical Climatology Network monthly temperature data, version 2*. Bulletin of the American Meteorological Society, 90(7), 993-1007.
[4] Integrated Scenarios of the Future Northwest Environment: https://www.nwclimatescience.org/node/231
[5] Salathé, EP, AF Hamlet, CF Mass M Stumbaugh, S-Y Lee, R Steed (2014) Estimates of 21st Century Flood Risk in the Pacific Northwest Based on Regional Scale Climate Model Simulations. *J. Hydrometeorology*

Water Supply	
Snow	
Spring Snowpack – Projected[4]	Substantial declines in April 1st snowpack, 2050s relative to 1970-1999, for the Stillaguamish watershed: Low emissions (RCP 4.5): −66% (range: −75 to −54%) High emissions (RCP 8.5): −73% (range: −88 to −55%)
Streamflow	
Winter – Projected[4]	Increases in winter (October–March), 2050s relative to 1970-1999, for the Stillaguamish watershed: Low emissions (RCP 4.5): +28% (range: +20 to +44%) High emissions (RCP 8.5): +32% (range: +19 to +52%)
Summer – Projected[4]	Decreases in summer (April–September), 2050s relative to 1970-1999, for the Stillaguamish watershed: Low emissions (RCP 4.5): −24% (range: −29 to −16%) High emissions (RCP 8.5): −27% (range: −34 to −18%)
Flooding – Projected[2]	Most models indicate increases in volume associated with the 100-year (1% annual probability) flood event, 2040s (2030-2059), relative to 1970-1999, for the North Fork Stillaguamish: Low emissions (B1): +12% (range: −15 to +38%) Moderate emissions (A1b): +20% (range: +5 to +57%)
Low flows – Projected[2]	Most models indicate decreased volumes associated with the 7-day lowest flow in 10 years, 2040s (2030-2059), relative to 1970-1999, for the North Fork Stillaguamish: Low emissions (B1): −16% (range: −30 to +1%) Moderate emissions (A1b): -22% (range: −31 to −7%)

Water Quality	
Stream temperatures – Projected	*Char*[6]*:* Decline in number of river miles within thermal thresholds for char spawning/rearing (mean August stream Temp. <54°F[7]): Historical (1993 – 2011): 205 miles 2040s, Moderate emissions (A1b): 78 miles (−62% loss) 2080s, Moderate emissions (A1b): 27 miles (−87% loss) *Salmonids*[6]*:* Decline in number of river miles within thermal thresholds for core summer salmonid habitat (mean August stream Temp. <60°F): Historical (1993 – 2011): 650 miles 2040s, Moderate emissions (A1b): 580 miles (−10% loss) 2080s, Moderate emissions (A1b): 410 miles (−36% loss)

[6] NorWest Regional Database and Modeled Stream Temperatures: http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html
[7] Note that these thresholds are actually intended for 7-day average stream temperatures, not monthly averages. This means that the projections shown here are optimistic – an overestimate of suitable habitat.

Sediment & Landslides	Loss of snowpack and glaciers due to warmer temperatures contributes to the exposure of highly mobile sediment sources and increases in flood flows, which triggers faster sediment movement. Geomorphic hazards, like debris flows and landslides, could also increase in response to decreasing snowpack and glaciers.[8],[9] Increasing heavy precipitation may increase erosion rates and also threaten slope stability.

Oceans	
Sea Level – Observed[10]	Historical rise in sea level (Seattle is the closest long-term gauge) Seattle, WA: +0.8 in./decade (1900-2008)
Sea Level – Projected[11]	Rising for all scenarios Seattle, WA: +4 to +56 inches (2100, relative to 2000)
Ocean Acidification – Observed[12]	Global increase in ocean acidity since 1750 +26% *(decrease in pH: −0.1)*
Ocean Acidification – Projected[12]	Global Increase by 2100 for all scenarios (relative to 1986-2005). Low emissions (RCP 4.5): +38 to +41% High emissions (RCP 8.5): +100 to +109%

This document was prepared by the Climate Impacts Group to support interviews planned as part of the ***Integrating Climate Resilience in Puget Sound Floodplain and Working Lands Programs*** project.

For more information on climate change impacts in Washington, see *Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers* (2013), available at http://cses.washington.edu/cig/reports.shtml, or contact the Climate Impacts Group (cig@uw.edu, 206-616-5350).

[8] Miller, D.J. (2004) Landslide Hazards in the Stillaguamish basin: A New Set of GIS Tools. A report prepared for the Stillaguamish Tribe of Indians, Natural Resource Department

[9] Lee, S-Y., and A.F. Hamlet. 2011. Skagit River Basin Climate Science Report. A summary report prepared for Skagit County and the Envision Skagit Project by the Department of Civil and Environmental Engineering and the Climate Impacts Group, University of Washington, Seattle. September, 2011.

[10] NOAA Sea Level Trends: http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

[11] (NRC) National Research Council 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.* Washington, DC: The National Academies Press

[12] (IPCC) Intergovernmental Panel on Climate Change. 2013. *Working Group 1, Summary for Policymakers.* Available at: http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf