Samish Indian Nation

Climate Change
State of Scientific Knowledge



June 2018

ACKNOWLEDGEMENTS[1]

This project would not have been successful without the combined efforts of the Climate Change Working Group and support of the Samish Indian Tribe Council. The collaborative approach taken by the Samish Indian Nation proved invaluable in evaluating potential climate impacts, and identifying and prioritizing the key areas of concern. With this project, the Samish Indian Nation has created a foundation for on-going climate adaptation planning and made a crucial step towards mainstreaming climate change considerations into its on-going planning and operations.

CLIMATE CHANGE WORKING GROUP

The group is currently comprised of the following representatives:

Leslie Eastwood	Tribal member, General Manager
Dana Matthews	Tribal Council Secretary, Health and Human Services Director
Jackie Ferry	Cultural Director/Tribal Historic Preservation Officer
Toby McLeod	Tribal member, Natural Resources Department

Additional members may be recruited to the group from the Samish Community.

Staff support for the Working Group and preparation of this report was provided by Stacy Clauson, Climate Adaptation Assistant. This report was revised in May of 2018 by Fletcher Wilkinson, Climate Adaptation Specialist.

FUNDING

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UPDATES

This report was updated in June of 2018. Updates include:

- Sea level rise projections
- All projections updated to most recent findings as of June, 2018
- Updated list of Working Group members
- Samish TEK related to climate change

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KEY TERMS

Adaptation (climate change): Actions in response to actual or expected climate change and its effects, that lessen harm or exploit beneficial opportunities. It includes reducing the vulnerability of people, places, and ecosystems to the impacts of climate change.

Climate: The "average weather" generally over a period of three decades. Measures of climate include temperature, precipitation, and wind.

Climate Change: Any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period of time (decades or longer). Climate change may result from natural factors and processes and from human activities that change the atmosphere's composition and land surface.

Exposure: The presence of people, assets, and ecosystems in places where they could be adversely affected by hazards.

Greenhouse Gas (GHG): Any gas that absorbs infrared radiation in the atmosphere; examples include carbon dioxide, methane, nitrous oxide, ozone, and water vapor.

Planning Area: An area in which the tribal government manages, plans, or makes policy affecting the services and activities associated with built, human, and natural systems. For example, within the sector Utilities, you might have planning areas of Water and Electricity.

Priority planning areas: Planning areas of importance to the tribal government or community which are vulnerable to climate change impacts.

Resilience: Ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to absorb stress and change.

Sector: General grouping used to describe any resource, ecological system, species, management area, etc. that may be affected by climate change. For example, Transportation, Utilities, Water Resources, Forest Resources, Human Health, or Cultural Resources and Traditions.

Sensitivity: How much a system is directly or indirectly affected by changes in climate conditions (e.g., temperature and precipitation) or specific climate change impacts (e.g., sea level rise, increased water temperature). If a system is likely to be affected as a result of projected climate change, it should be considered sensitive to climate change.

Vulnerability: The susceptibility of a system to harm from climate change impacts. It's a function of how sensitive the system is to climate and the adaptive capacity of the system to respond to such changes. Generally, systems that are sensitive to climate and less able to adapt to changes are vulnerable to climate change impacts.

EXECUTIVE SUMMARY

Under direction of the Tribal Council, the Samish Department of Natural Resources has begun a climate change adaptation planning process to identify how the Samish can prepare for and strengthen our resilience to extreme weather developments, sea level rise, and other impacts of climate change. This report contains an overview of the state of scientific knowledge on predicted climate impacts in the Samish Traditional Territory. This report is aimed at helping Tribal staff and members better understand anticipated climate stressors, and incorporate this information into future vulnerability assessment and identification and selection of adaptation strategies and actions.

This report is organized into the following sections:

- Section 1 provides a brief overview of climate change science; and
- Section 2 details climate change impacts; and
- Section 3 identifies data gaps that require additional data collection and/or supplemental monitoring.

The report identifies some of the following ways that climate is predicted to change by the end of this century, summarized as follows:

- Air temperatures will increase significantly, with the largest increases in the summer months (June through August).
- Precipitation patterns are anticipated to change in timing and intensity. Overall declines are projected in summer precipitation. Warming will cause a greater proportion of winter precipitation to fall as rain (not snow) in mid-elevations. Heavy rainfall events are projected to occur more frequently and be more intense.
- Freshwater and ocean temperatures are increasing.
- Sea levels are projected to rise, causing coastal areas to be at a greater risk of erosion and storm surges.
- The Pacific is becoming more acidic, though additional data is needed to determine the degree of acidity changes in the Salish Sea.
- Dissolved oxygen levels are projected to decline.
- Salinity levels will fluctuate with changes to streamflow, decreasing in winter and increasing in summer months. These changes will cause corresponding adjustments in the rate of exchange and flushing that occurs between the Puget Sound and the North Pacific.
- Marine waters are likely to be become increasingly stratified in winter months. Stratification impacts natural upwelling and mixing patterns, which can influence dissolved oxygen and nutrient levels.

- Changes in the climate are projected to increase the growth rate of algal species that cause Harmful Algal Blooms (HABs). Increasing acidity of waters is anticipated to increase the toxicity of some HABs.

Many secondary system impacts may stem from these changes in the climate, summarized as follows:

- Snowpack and glacier area will decrease, and there is predicted to be a shift from snow to rain winter precipitation in mid-elevation watersheds.
- Snowmelt is predicted to occur increasingly earlier in the season.
- Streamflow volume is predicted to increase in winter and decrease in spring and summer. Peak streamflow is projected to occur earlier in the season.
- Reductions in summer streamflow will result in less water supply available in the summer, increasing drought stress.
- Increases in fall and winter streamflow will increase flood risk along rivers and coastal areas.
- Elevated sea levels, combined with low summer stream flows, are predicted to increase saltwater intrusion into groundwater sources
- Runoff from more frequent and intense extreme precipitation events will result in increased introduction of pathogens and prevalence of toxic algal blooms, with corresponding impacts to water quality, habitat and human health.
- Lower runoff in summer could mean less dilution of stream waters, resulting in more concentrated nutrient and bacteria loads and resulting impacts to water quality, habitat, and human health. In addition, lower summer precipitation combined with warmer summer temperatures will stress streamside vegetation, impacting stream cover and temperatures.
- Increased risk of landslide and rates of erosion in winter and spring.
- Increased feeder bluff erosion in coastal areas.
- Increased sediment loading with changes in streamflow in fall, winter and spring, further impairing water quality and decreasing habitat areas, increasing flood risk, and endangering infrastructure improvements.
- Increased fire frequency, severity, intensity, and total area burned.
- Declining air quality.
- More intense, frequent, or severe insect outbreaks as well as outbreaks in places where historical insect activity was low or unknown.
- Many ecological systems are predicted to be highly vulnerable to climate change impacts, ranging from marine waters to alpine fields and covering large areas of Samish Traditional Territory.
- Plant and animal species are predicted to respond to the impacts of climate change by altering their current geographic distribution or the timing of significant biological events.

INTRODUCTION

OVERVIEW

Since time immemorial, the Samish people have lived and prospered on the land and water of the Salish Sea in Washington State. Over time, the Samish people have successfully navigated a variety of changes while maintaining a strong connection to the resources, rich lands, and waters of our region. While many of us may have moved away, we are still connected to this place and through it, to each other.

Through our strong connection with the natural world, we are beginning to see changes, such as an increase in extreme weather events and in the number of species struggling to survive and adapt.

Changes in climate conditions have the potential to impact natural processes in the ocean and forests, damaging habitats and the wildlife that live there. Impacts associated with extreme weather events, like flooding, pose an increased risk of injury, illness and loss of businesses and homes. Sea levels will rise with continued ocean and atmospheric warming, potentially submerging culturally important places and traditional use areas. Together, the changes can influence human health and wellbeing by affecting the food we eat, the air we breathe, and the water we drink. Understanding the threats that climate change pose can help us work together to lower risks and mitigate issues.

As a community, the Samish are considering how these changes impact our culture and traditions, our community facilities and investments, the natural resources that surround and sustain us. Tribal members agree on the need to focus energy towards Seven Generation planning throughout the Tribe's traditional territories[2]. The Samish Indian Nation Tribal Council has recognized that this long-term planning must take climate change into account.
Under direction of the Tribal Council, we have begun a climate change adaptation planning process to identify how the Samish can prepare for and strengthen our resilience to extreme weather developments, sea level rise, and other impacts of climate change.

ADAPTATION PLANNING

The Samish Indian Nation endeavors to be a climate resilient community preparing for potential impacts of climate change, so that our children and our grandchildren can be healthy, prosperous, and enjoy our natural resources and cultural traditions.

[2] 2016 5 Year Plan objective 2.7.4 "Define a 7 Generation Vision concurrent with Comprehensive Plan)" and goal 6.2 "Establish and maintain a natural resource presence and participation throughout Samish Traditional Territory."

It is the Samish's intention to build resilience into policies, programs, projects and infrastructure. The Samish Climate Adaptation Plan is a part of this effort. The Climate Adaptation Plan will guide current and future decision makers in developing policies and programs to prepare for the impacts of climate change and build resiliency into everyday operations and short and long-term infrastructure investments.

Adaptation planning is a multi-staged process, depicted in Figure 1. One of the first steps in preparing for a changing climate is to understand more about the future climate conditions, potential impacts, and gaps in knowledge, so that the Samish can prioritize our limited resources and focus our energies on addressing key issues of significant concern for the tribe. The *Samish Indian Nation Climate Change State of Scientific Knowledge* has been designed to respond to this need. As such, this report is a component of Step 1 in Figure 1, and is intended to provide background information on climate science in the region, including an initial scoping of potential impacts to Samish planning priorities. The information generated from this report will provide baseline information that can be used to evaluate climate impacts and vulnerabilities and begin to identify actions to prepare for the potential damages from climate change and build resiliency.

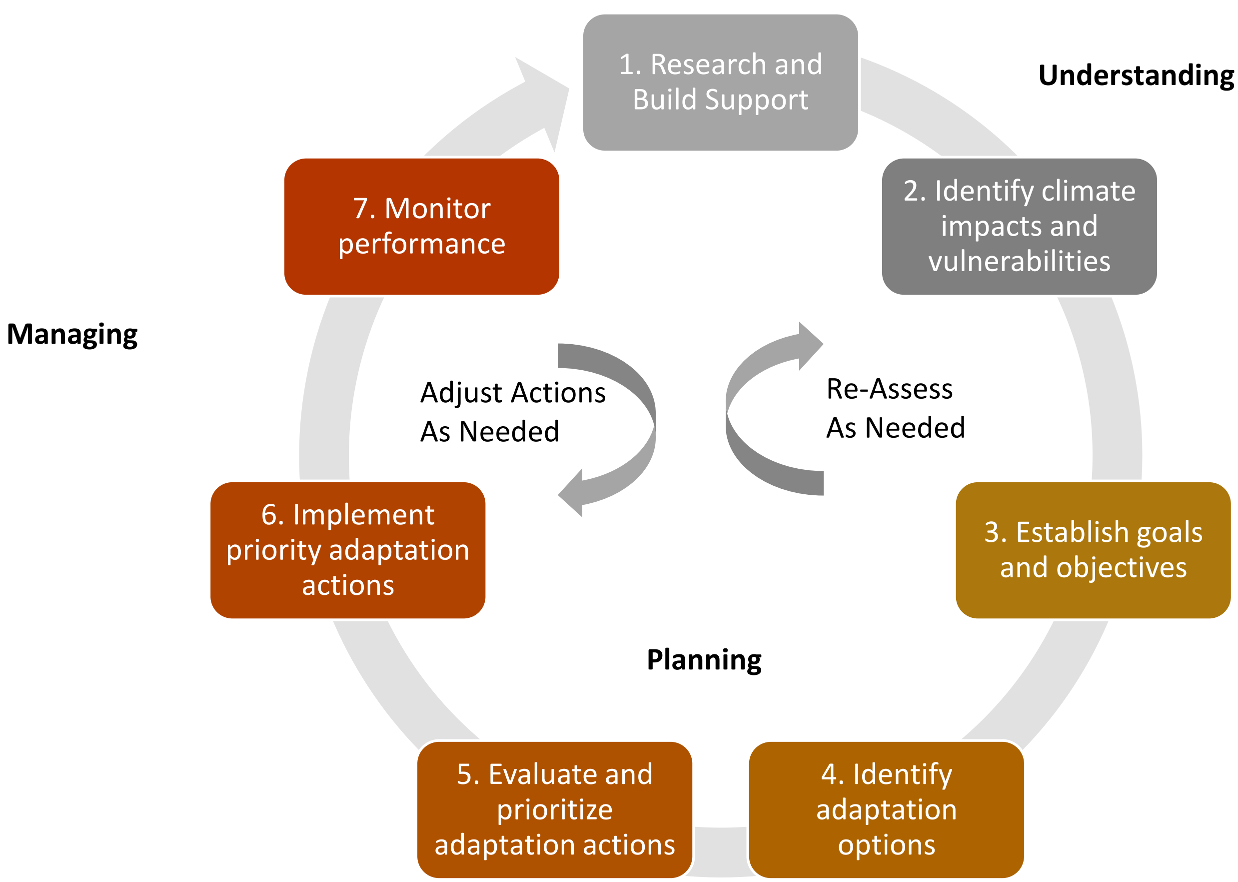


Figure 1: Climate Change Adaptation Planning Cycle. Adapted from "Quick Guide to Climate-Smart Conservation."

TARGET AUDIENCE

This report was designed as a technical reference document for individuals interested in understanding the state of science on climate change within the Samish Traditional Territory. It is anticipated that information contained in this report will serve as inputs to a future vulnerability assessment process, describing potential exposure and impacts.

The report is detailed and, in many cases, uses language specific to a scientific study. As a result, it is aimed primarily at resource managers. We expect the audience for this report to be Samish Indian Nation Department of Natural Resources staff, as well as agency staff from other government and non-government institutions that the tribe may collaborate with on their adaptation planning efforts.

REPORT ORGANIZATION

This report is organized into the following sections:

- Section 1 provides a brief overview of climate change science; and
- Section 2 details climate change impacts; and
- Section 3 identifies data gaps that require additional data collection and/or supplemental monitoring.

WHAT IS CLIMATE CHANGE?

WEATHER AND CLIMATE

Before describing changes in the climate, it is first important to note the crucial differences between climate and weather. While both are used to describe temperature, precipitation (rain or snow), humidity, wind and seasons, weather describes what we experience in the near-term and climate describes what we expect, based on typical patterns from the long-term average of weather conditions, such as over a period of 30 years (see Figure 2).

Weather is a snapshot of conditions in the near-term; weather happens on any given day, month or season. In contrast, climate is the collection of means and extreme events over several decades or more. The term "climate" includes conditions in the atmosphere and ocean, and is often described in terms of the intensity, frequency, and duration of severe and non-severe weather events.

Climate patterns allow us to have a general sense of the weather to expect at any given time. Because it is defined by long-term averages, it is more consistent and predictable than weather;

just think of how we associate seasons and events with typical weather patterns. For example, in the northern United States we can assume it will snow in the winter and rain in the spring.

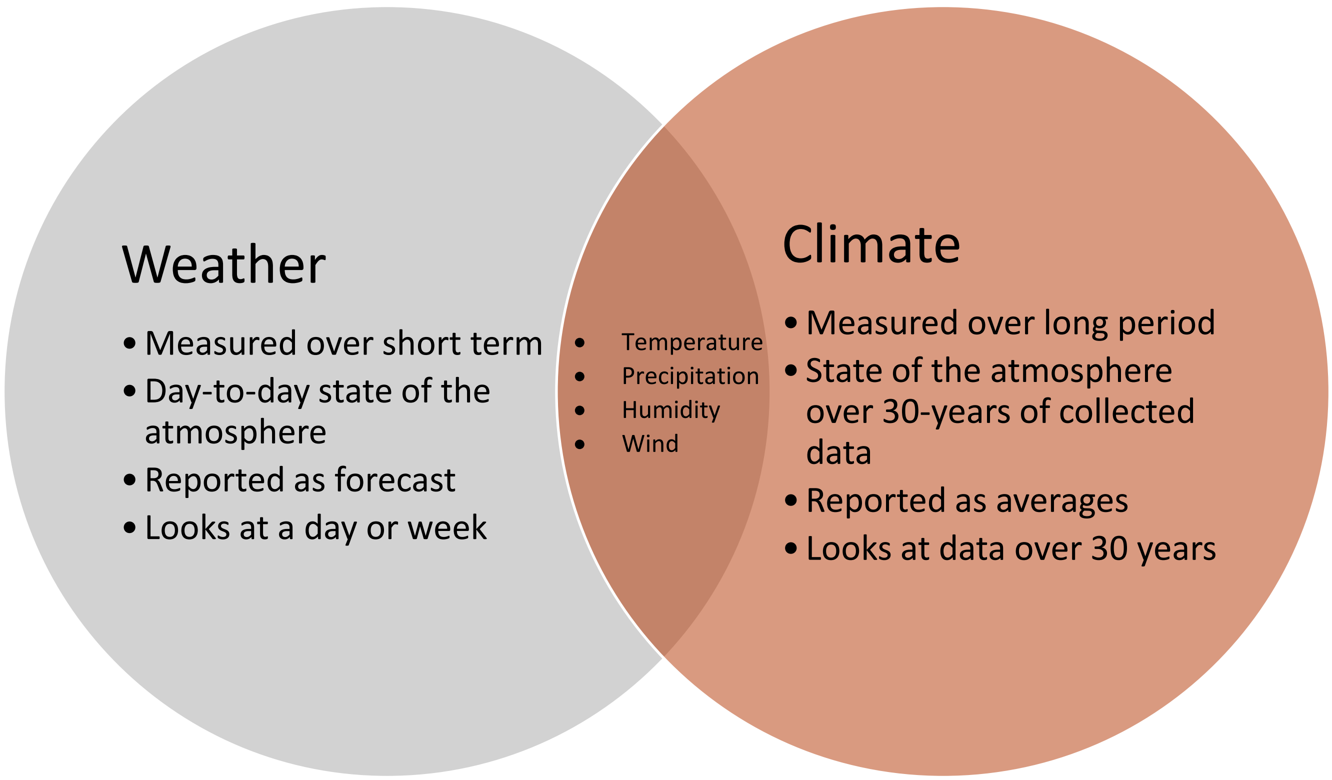


Figure 2: Differences and overlap of weather versus climate

INDICATORS OF CLIMATE CHANGE

Current patterns in climate data show that our planet's temperature, comprised of both surface and ocean temperatures, is rising. Based on data from the U.S. National Climatic Data Center, globally the 27 warmest years since 1880 all occurred in the 30 years from 1987 to 2017; the warmest year was 2016 followed closely by 2017 and 2015. In the United States, there is a similar trend, and the warmest year on record was 2012, followed by 2016. This warming has been accompanied by diminishing ice and snow and rising sea levels (IPCC 2014).

Scientists studying the climate system have identified changing atmospheric conditions, in particular the build-up of certain heat-trapping gasses, as key contributors to this observed warming trend (see Figure 3).

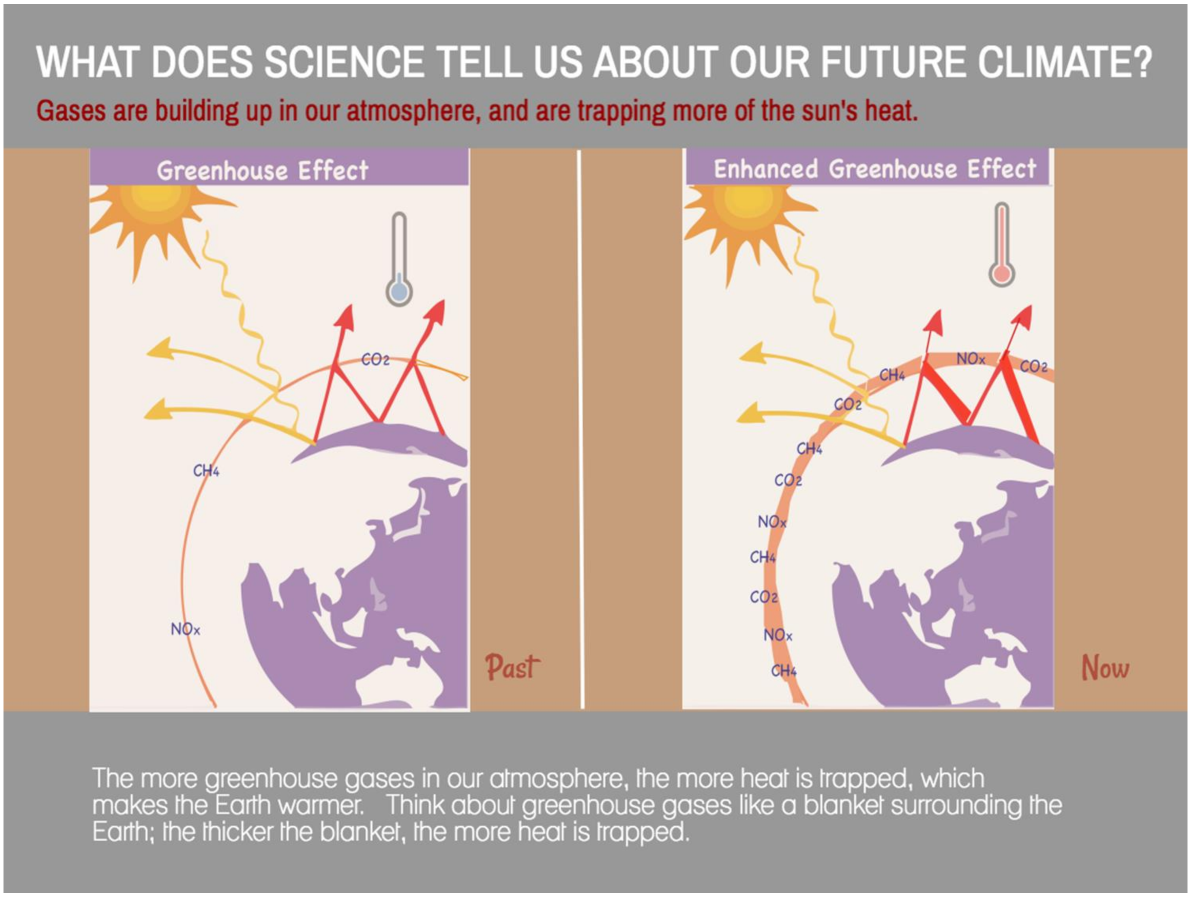


Figure 3: Infographic about greenhouse gas effect. The atmosphere is like a blanket that surrounds the earth - when we burn fossil fuels like coal and natural gas for energy, we add carbon dioxide to this blanket, which is like thickening the blanket. The thicker a blanket gets, the more heat it traps underneath. The "blanket effect" leads to warming, which disrupts the climate.

The primary drivers of climate are: incoming solar radiation, Earth's revolution and rotation, the surface features of the land, and the composition of the atmosphere. Together these components regulate our long-term weather patterns, or climate. In this system, energy from sun goes through different pathways: 1) about 30 percent is reflected back into space by particles in the atmosphere or bright ground surfaces; 2) about 23 percent is absorbed by the atmosphere; and 3) about 47 percent is absorbed by the Earth's surface, including the ocean, and converted to heat, which warms the surface. This warming is known as the greenhouse effect (see Figure 3).

To maintain our typical climate patterns, the portion of energy that is absorbed by the Earth's surface (47 percent) must return to the atmosphere and eventually escape into space. If conditions in the atmosphere change, however, and heat that would normally leave the atmosphere and escape into space is instead trapped and re-emitted toward the surface, it will amplify the warming of the Earth.

Scientists have observed conditions in the atmosphere changing, and in ways that are amplifying the warming of the Earth. In particular, scientists studying the climate have observed that the atmospheric concentrations of carbon dioxide, methane and nitrous oxide are at higher levels than the previous 800,000 years (IPCC 2014). These heat-trapping gases are known as greenhouse gases (GHGs) because they absorb the heat that is re-emitted from the surface, not allowing that energy to escape into space. This amplifies the otherwise naturally-occurring energy cycle that maintains our climate, increasing temperatures (Figure 4).

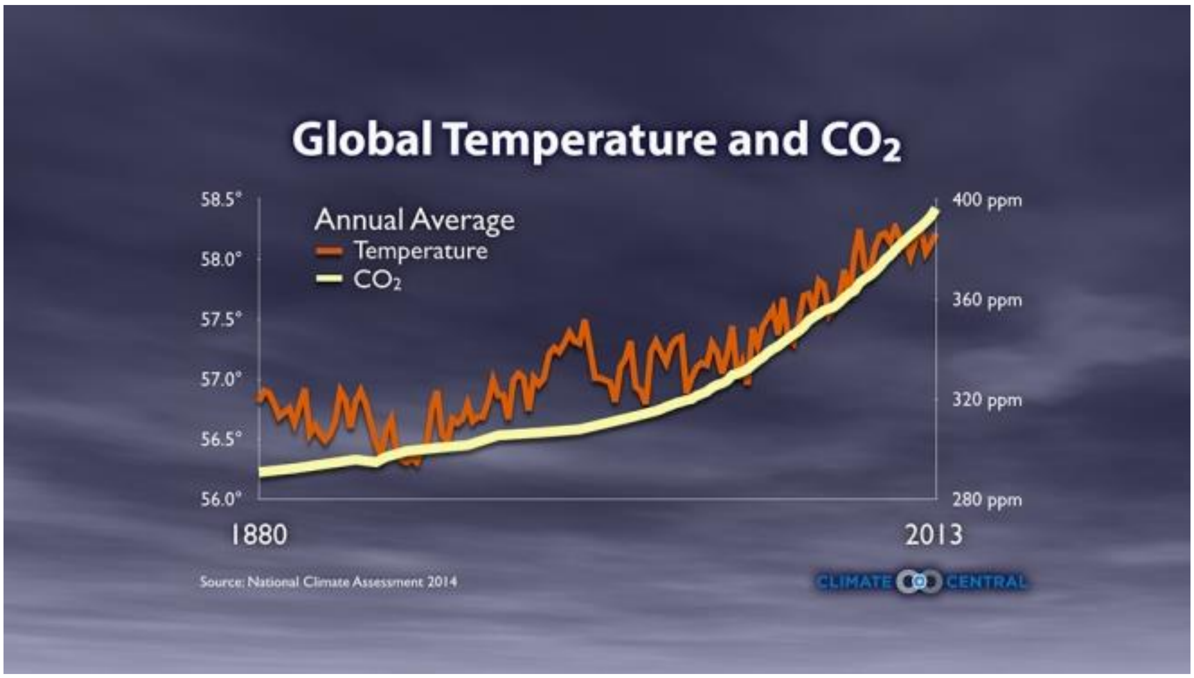


Figure 4: The levels of CO2 in the atmosphere have been increasing, together with the temperature (Climate Central, based on data from the National Climate Assessment 2014).

Greenhouse gases are continuing to build-up in the atmosphere, and temperatures have been showing as associated increase (Figure 4). Scientists project that air and ocean temperatures will continue to increase, in some cases at a faster rate than observed previously, posing significant risks to human health, water quality and supply, coastlines, and other natural resources that are vital to the Samish tribal members' opportunities, quality of life, and cultural identity. Further, scientists note that even if the build-up of greenhouse gases was

> "Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems."
>
> Intergovernmental Panel on Climate Change. (2014). Climate Change 2014 Synthesis Report.

halted, there is currently so much excess greenhouse gas in the atmosphere that temperatures will continue to rise in the near-term future. As a result, scientific consensus is moving away from a discussion of whether or not impacts will occur towards a discussion of the severity and timing of the impacts.

TRADITIONAL KNOWLEDGE AND OBSERVED CHANGES

During the course of this project, a number of Samish elders were interviewed to capture their stories and preserve a record of their local and traditional knowledge about this area. This verbal history, often referred to as traditional knowledge, is an important proxy that can be used to understand historical changes in local climate conditions.

Elders described a number of conditions that have changed in this area during their lifetimes. Most often mentioned is warming winter temperatures and less snowfall than before. Additionally, interviewees often mentioned less salmon and other fish than before as well as these fish being smaller than previously.

A number of other negative changes specifically related to traditional and cultural use plants were also noted, though these are not detailed in this report due to their sensitive nature.

CLIMATE CHANGE IMPACTS

The following provides an overview of the changing climate conditions and its potential impacts to underlying natural systems.

OVERVIEW

Conceptually, there are a series of different interactions that must be considered to understand the impacts stemming from changes in climate. First, there are climate change drivers, such as conditions in the atmosphere and ocean; when these conditions change, they influence changes in underlying natural systems (e.g., water cycle, natural resources, and ecosystems), which then exert pressure on other natural, cultural, and economic systems, impacting the communities that rely on these systems (Figure 5).

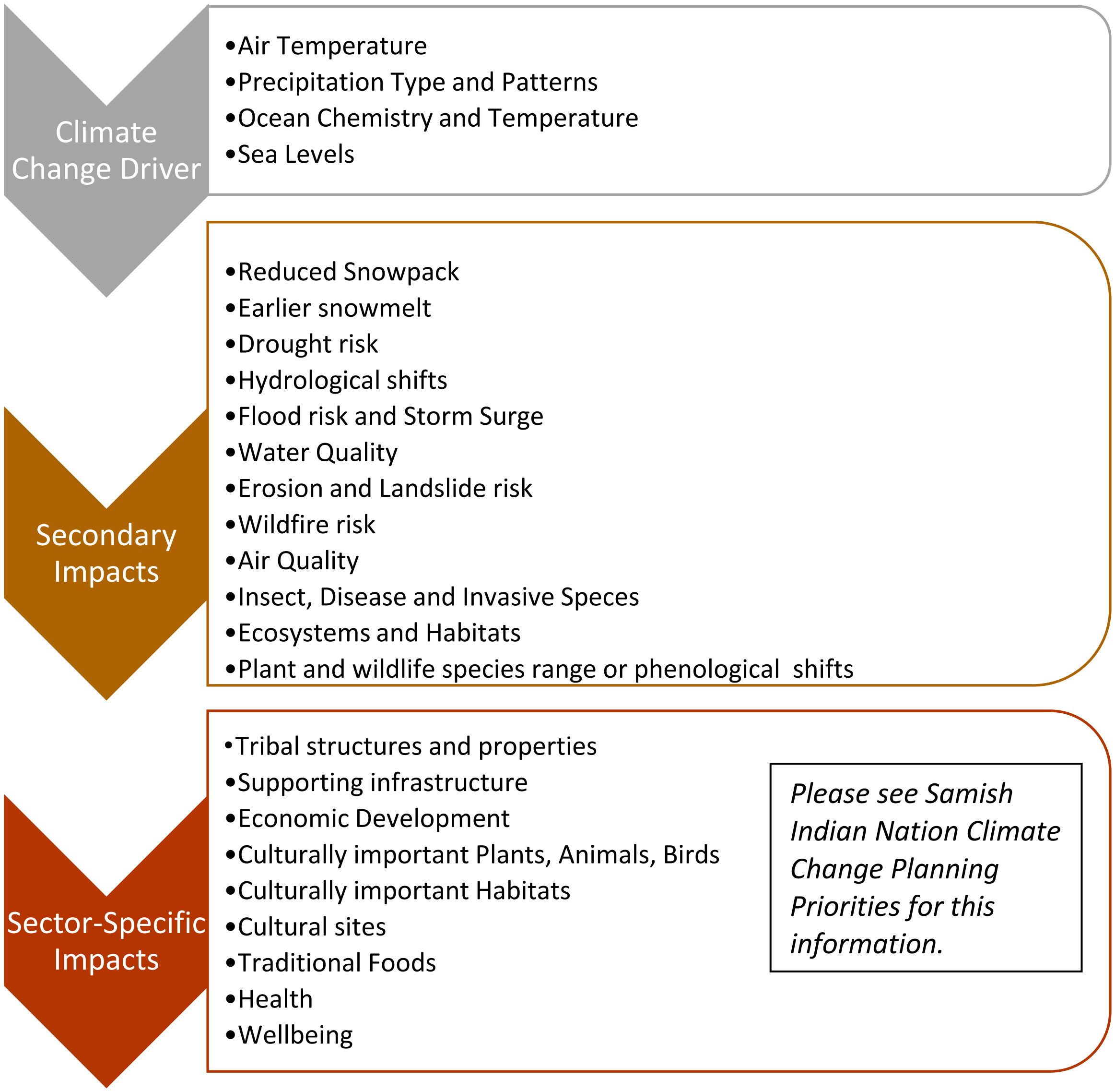


Figure 5: Conceptual model of impacts from climate change. Adapted from Skagit Climate Science Consortium http://www.skagitclimatescience.org/skagit-impacts-overview/)

This assessment will first start with an overview of climate change drivers, and then address secondary impacts that will stem from these drivers. Through this assessment process, the Samish Indian Nation will identify, catalog, and prioritize the tribe-specific challenges that will arise from these climate change drivers and system changes, referred to as Sector-Specific Impacts in Figure 5. This information will be contained in the companion report, *Samish Indian Nation Climate Change Planning Priorities*.

CLIMATE PROJECTIONS

Changes in climate are projected by scientists using complex climate models that are built and calibrated using current and past climate data to simulate future climatic conditions under a range of different greenhouse gas (GHG) emissions scenarios. Emissions scenarios are determined by the Intergovernmental Panel on Climate Change (IPCC), an international consortium of hundreds of experts who analyze and synthesize climate change research (Table 1). These scenarios are designed to reflect of a variety of potential future conditions that are dependent upon how effectively the causes of climate change are mitigated. Throughout this report, projections based on the High emissions (RCP 8.5) are provided[4] and are focused on the end of century (2100)[3].

Emission scenarios are periodically updated; as a result, some information in this report may contain scenarios from earlier IPCC emissions scenarios.

Table 1: Overview of IPCC Climate Change Scenarios (IPCC 2014)

Emission Scenario	Ranking	Description	Equivalent to these Previous Scenarios
RCP 2.5	Very Low	Reflects aggressive GHG reduction and sequestration efforts (50% reduction in emissions by 2050 relative to 1990 levels and near or below zero net emissions by 2100)	-
RCP 4.5	Low	GHG stabilize by mid-century (2050) and fall sharply thereafter	SRES B1
RCP 6.0	Moderate	GHG increase gradually until stabilizing in the final decades of 21st century	SRES A1B
[4]**RCP 8.5**	High	Assumes continued increases in GHG emissions until 2100 (CO2 concentrations more than triple by 2100 relative to pre-industrial levels)	SRES A2 or SRES A1F1

While climate change is occurring globally, the impacts of climate change will vary regionally. To address this regional variability, the global climate models have been downscaled based upon statistical down sampling by the University of Washington Climate Impacts Group (CIG) to the area encompassing the Salish Sea and watersheds draining to the Salish Sea (Mauger et al 2015). This report focuses on impacts within the Samish Traditional Territory (Figure 6), as well as adjoining areas that historically were important for trade or, looking forward, may be

[3] As part of its review of climate projections, the Climate Adaptation Working Group decided to focus on the year 2080 (or later), in keeping with traditional practices that focus on preparing for the Seventh Generation.
[4] As part of its review of climate projections, the Climate Adaptation Working Group decided to focus on the High emissions scenario, using a precautionary principle that considers the upper end of impacts. As a result, predictions from a High emissions scenario will be reported where available.

important for preserving culturally important species that need to shift their range in response to climate change impacts.

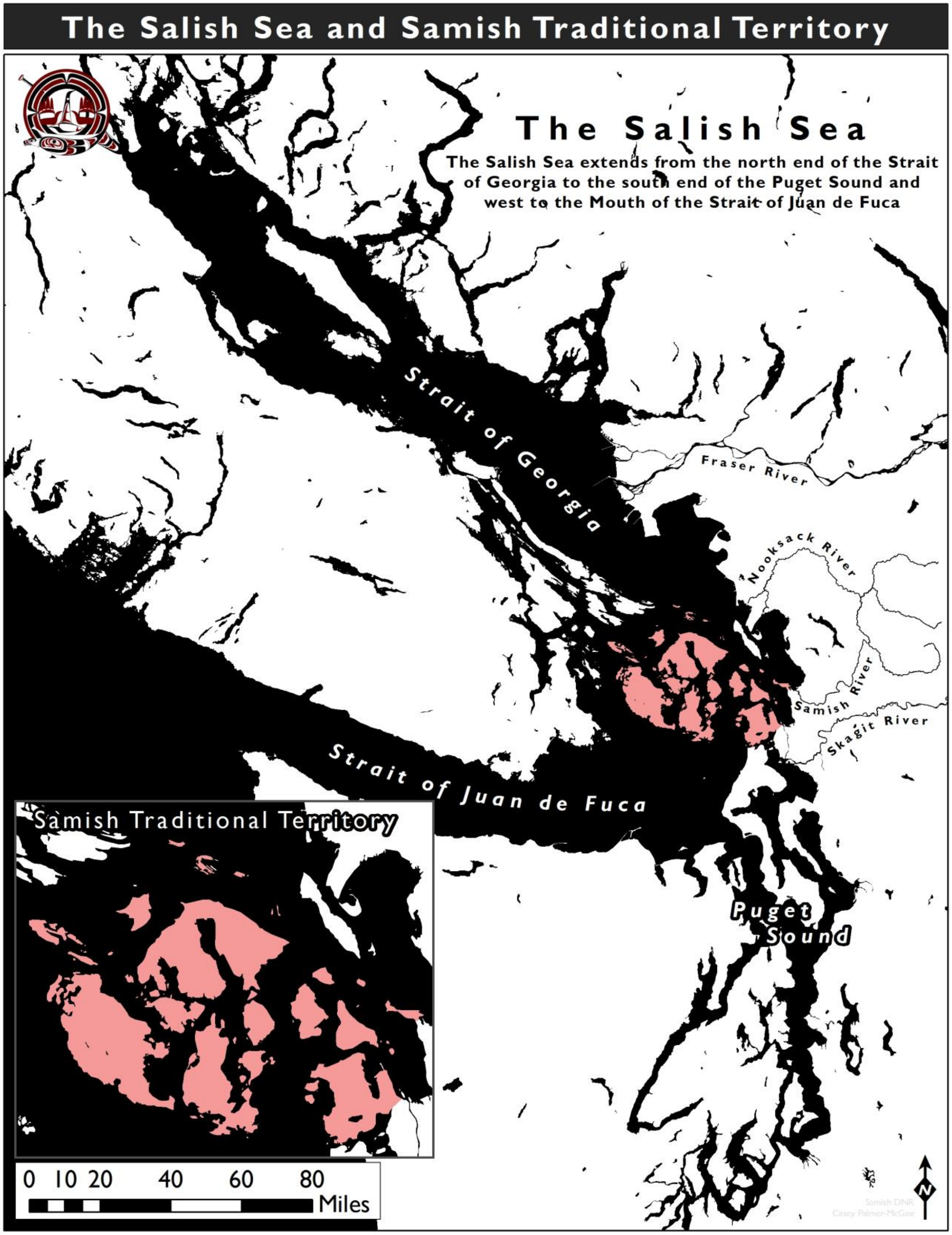


Figure 6: Samish Indian Nation Traditional Territory

Climate projections are typically provided at different time intervals, with estimates of future conditions provided for mid-century (2040s) and end of the century (2080s). The amount of warming is generally consistent for all emissions scenario through mid-century; this is because a certain amount of warming is already "locked in" due to past emissions (Mauger et al 2015). The most significant changes between the models therefore is present after 2050, where temperature increase is more closely dependent on the amount of future greenhouse gases emitted. Throughout this report, projections are provided for the end of the century[5].

It is also important to note that variability in local meteorological conditions (e.g. abnormally wet or dry periods) will continue to be an important part of the local conditions. Important patterns of natural variability for the Salish Sea region include the El Niño/Southern Oscillation (ENSO, otherwise known as El Niño and La Niña) and the Pacific Decadal Oscillation (PDO).

CLIMATE CHANGE DRIVERS

This section provides an overview of how climate has changed and is projected to change within the Traditional Territory[6] of the Samish Indian Tribe (Figure 6). The climate change science in this Assessment is primarily based on data provided by scientists in Washington State, including those that are a part of the University of Washington Climate Impacts Group (CIG).

[5] As part of its review of climate projections, the Climate Adaptation Working Group decided to focus on the end of the century, consistent with Seventh Generation planning.

[6] As part of its review of climate projections, the Climate Adaptation Working Group decided to focus on impacts within Samish Traditional Territory. In addition, adaptation planning may also focus on areas adjacent to these traditional territories, where cultural or ecologically important plants or animals may shift in response to the changing climate.

Summary of Key Changes:

- ***Air temperatures will increase significantly, with the largest increases in the summer months (June through August).***
- ***Precipitation patterns are anticipated to change in timing and intensity. Overall declines are projected in summer precipitation. Warming will cause a greater proportion of winter precipitation to fall as rain (not snow) in mid-elevations. Heavy rainfall events are projected to occur more frequently and be more intense.***
- ***Freshwater and ocean temperatures are increasing.***
- ***Sea levels are projected to rise, causing coastal areas to be at a greater risk of erosion and storm surges.***
- ***The Pacific is becoming more acidic, though additional data is needed to determine the degree of acidity changes in the Salish Sea.***
- ***Dissolved oxygen levels are projected to decline.***
- ***Salinity levels will fluctuate with changes to streamflow, decreasing in winter and increasing in summer months. These changes will cause corresponding adjustments in the rate of exchange and flushing that occurs between the Puget Sound and the North Pacific.***
- ***Marine waters are likely to be become increasingly stratified in winter months. Stratification impacts natural upwelling and mixing patterns, which can influence dissolved oxygen and nutrient levels.***
- ***Changes in the climate are projected to increase the growth rate of algal species that cause Harmful Algal Blooms (HABs). Increasing acidity of waters is anticipated to increase the toxicity of some HABs.***

Table 2 Summary of Climate Change Driver changes by mid and end of century

Climate Change Driver	Change by 2040s (avg., relative to 1970 – 1999)	Change by 2080s (avg., relative to 1970 – 1999)
Annual Average Temperature	+5.5°F	+9.1°F
Summer Average Temperature	+6.8°F	+11°F
Winter Average Temperature	+4.9°F	+8.3°F
Annual Average Precipitation	+5%	+6.9%
Summer Average Precipitation	-22%	-27%
Winter Average Precipitation	+11%	+15%

INCREASING TEMPERATURES

The following provides an overview of changes in air temperatures, including annual and seasonal temperatures, as well as extreme events.

AVERAGE ANNUAL TEMPERATURE

Over the last half-century, the Salish Sea region has warmed, with the average annual temperature in lowland areas increasing 1.3°F from 1895 to 2014 (Mauger et al 2015). This warming trend has been more pronounced in the last three decades; between 1980-2014, average annual temperature was above the century's average for all but six years.

In 2015, the Northwest experienced its warmest year on record (NOAA 2017); annual average temperatures were 3.3°F above the 20th century average (NOAA 2017). Despite the higher than average temperatures, this is less of an increase than anticipated in future climate years.

Impacts from this warming are already being experienced, including changes in streamflow and snowmelt, with corresponding reductions in the supply of water, and well as fluctuations in weather events.

The region is expected to see rising temperatures continue throughout the 21st century, though the amount of change is anticipated to increase dramatically after 2050 (Table 3).

Table 3: Projected change in average temperature, based on High emissions scenario (Mauger et al 2015).

Climate Change Driver	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Annual Average Temperature	+9.1°F	+7.4°F to +12°F
Summer Average Temperature	+11°F	+8.8°F to +15°F
Winter Average Temperature	+8.3°F	+6.0°F to +10°F

Projections for the High IPCC emission scenario anticipates an increase in annual average air temperature of +9.1°F (on average) by the end of the 21st century, relative to the 1970-1999 period (Mauger et al 2015). This increase is almost ten times the increase observed between 1895 and 2014.

The warming projected to occur in winter is likely to impact the type of precipitation that falls (e.g., snow or rain), particularly in lowland hills. This type of change is likely to cause significant impacts to other environmental variables, discussed below.

SEASONAL TEMPERATURE VARIATION

Warming is projected for all seasons, but the largest increases are anticipated during the Summer season (June through August), as depicted in Figure 8. Projections for the High IPCC emission scenarios anticipate an increase in summer air temperature of +11°F on average) by the end of the 21st century, relative to the 1970-1999 period (Table 3) (Mauger et al 2015).

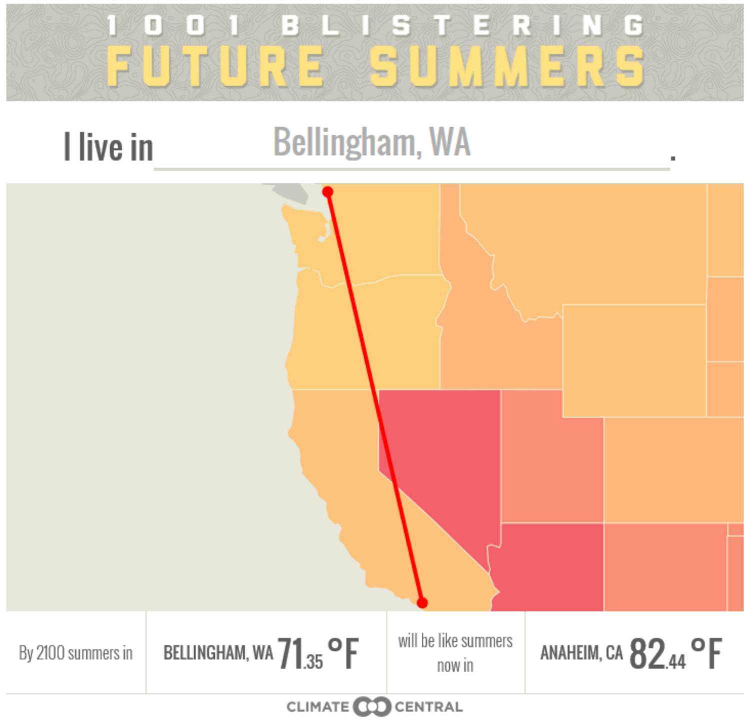


Figure 7: Illustration of projected summer temperature change. Source: Climate Central 2014.

Summer 2015 had the highest recorded average summer temperatures in the Puget Sound lowlands, at 4.7°F above the average summer temperature as measured from 1901 to 2000 (NOAA 2017). The predicted increase is therefore more than twice that experienced in 2015.

By the end of this century, summer climate in Bellingham region is projected to resemble coastal Southern California (Figure 7), a place that struggles with water availability, which has temperatures and water cycles that the plants and animals from the Pacific Northwest may not be able to adjust, and where health can be impacted by extreme heart and poor air quality, which is exacerbated by the warm air temperatures.

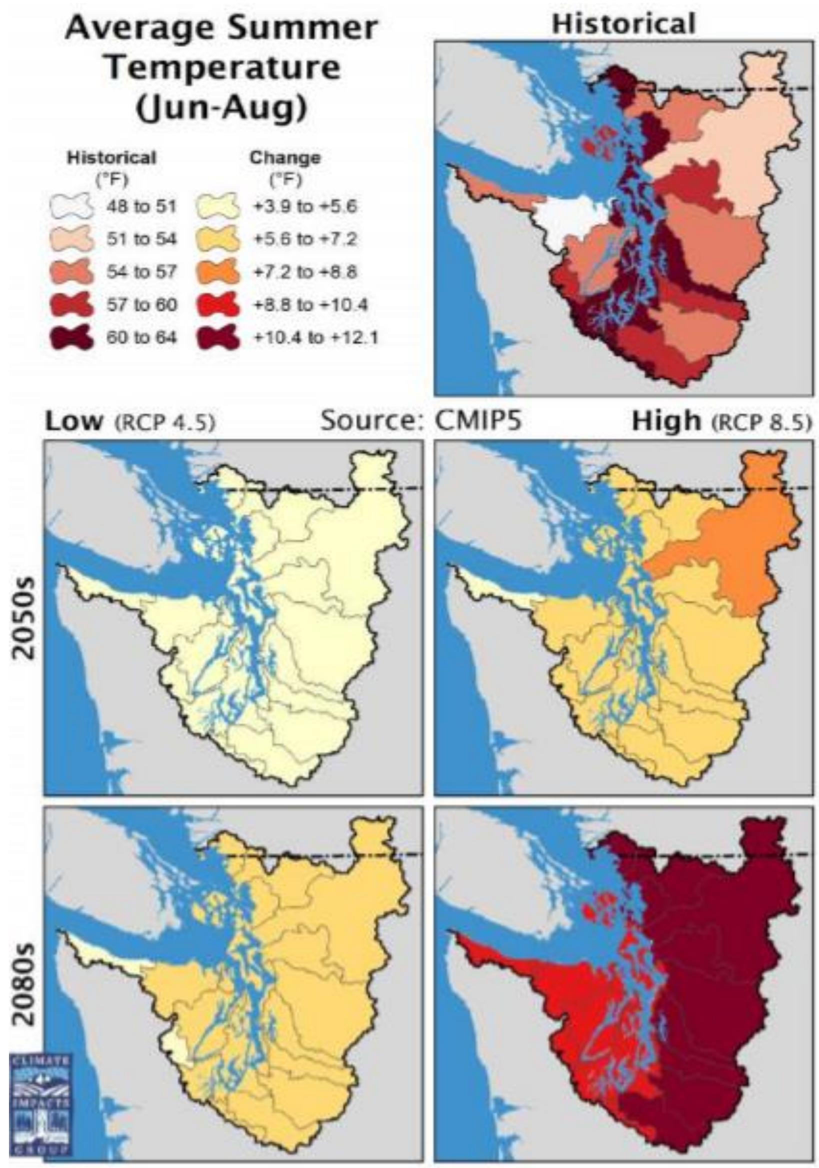


Figure 8: Average Summer Temperature for Low (RCP 4.5) and High (RCP 8.5) IPCC emissions scenario. Figure source: Mauger et al., 2015. Figure created by Robert Norheim, Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report. Data source: Mote et al 2015.

HEAT WAVES

While average temperature is projected to increase, another key change is the frequency and duration of extreme heat events, which are projected to become more frequent and intense.

Extreme high daytime summer temperatures are anticipated to increase by +12 °F by the end of the 21st century, under the IPCC High emissions scenario (see Figure 9) in the San Juan area, and an average of +9.8° F in the Salish Sea region. In 2015, the highest August temperature in the City of Anacortes was recorded at 91° F, more than 16° F higher than maximum temperatures in August as recorded in the Puget Sound lowlands between 1901 and 2000 (NOAA 2017). This

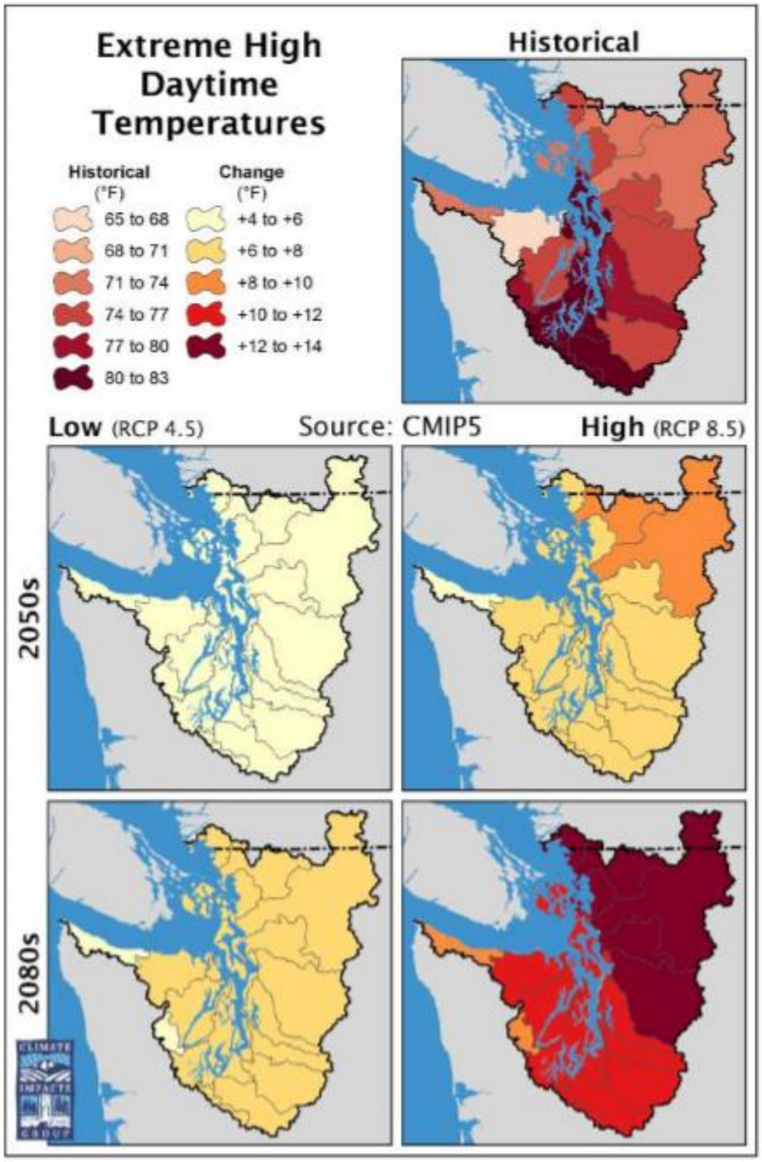


Figure 9: Changes in Extreme High Daytime Temperature for Low RCP (4.5) and High RCP (8.5) IPCC emissions scenarios. Figure source: Mauger et al., 2015. Figure created by Robert Norheim, CIG, based on the CMIP5 projections used in the IPCC 2013 report. Data source: Mote et al 2015.

warm temperature is illustrative of conditions that may be considered “normal” by the end of the century under the High Emissions Scenario.

Table 4: Projected changes in Heat Waves, based on High emissions scenario (Mauger et al 2015).

Climate Change Driver	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Extreme High Daytime Temperatures	+9.8°F	+5.3°F to +15.3°F
# Days over 90 °F	+17 days	N/A

Projections by the Centers for Disease Control (CDC) estimate that the northern Salish Sea region will average up to 16 extreme heat days/year by 2080 (Figure 10). The historical average is less than one.

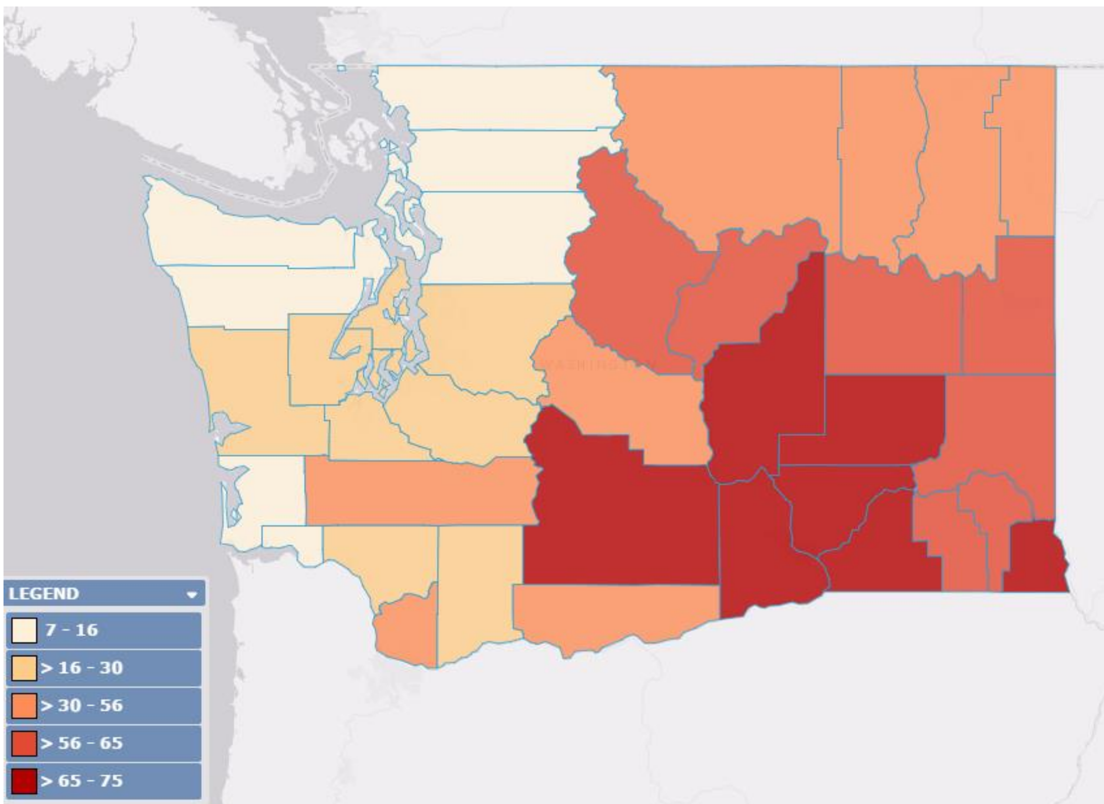


Figure 10: Projected increase in number of days over 90° in Washington State by 2080 under High Emissions scenario. Figure source: CDC National Environmental Public Health Tracking Network.

Hotter and more humid summers increase the risk from heat-related illnesses like heat exhaustion and heat stroke. Washington State already averages approximately 3 heat stress related hospitalizations for every 100,000 population, or approximately 200-300 hospitalizations per year (Washington Tracking Network). This rate is likely to increase with more extreme heat days.

In addition, extreme heat exacerbates underlying health conditions like diabetes, heart and kidney disease. A study in King County identified a 78 percent increase in diabetic-related mortality on an extreme heat day and an 8 percent increase in emergency calls (Isaksen et al 2015), as compared to a non-heat day.

CHANGING PRECIPITATION PATTERNS

The following provides an overview of changes in precipitation patterns, including annual and seasonal precipitation, as well as extreme events.

AVERAGE ANNUAL PRECIPITATION

The region has traditionally experienced high natural variability in precipitation patterns. In the future, changes in annual average precipitation are not anticipated to be significant (Table 5), but in general winters will likely be wetter and summers drier. Precipitation intensity may also increase.

Table 5: Projected change in average precipitation, based on High emissions scenario (Mauger et al 2015).

Climate Change Driver	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Annual Average Precipitation	+6.9%	+1.0% to +9.4%
Summer Average Precipitation	-27%	-53%° to +10%
Winter Average Precipitation	+15%	+6.2%° to +23%

SEASONAL PRECIPITATION VARIATION

Seasonally, summers are projected to be drier. Projections for the High IPCC emission scenario anticipate a decrease in summer precipitation of -27 percent (on average) by the end of the 21st century, relative to the 1970-1999 period (Mauger et al 2015) (Figure 11). For comparison, the summer 2015 precipitation deficit in the Puget Sound lowlands was approximately 30 percent less than the average between 1901 and 2000 (NOAA 2017).

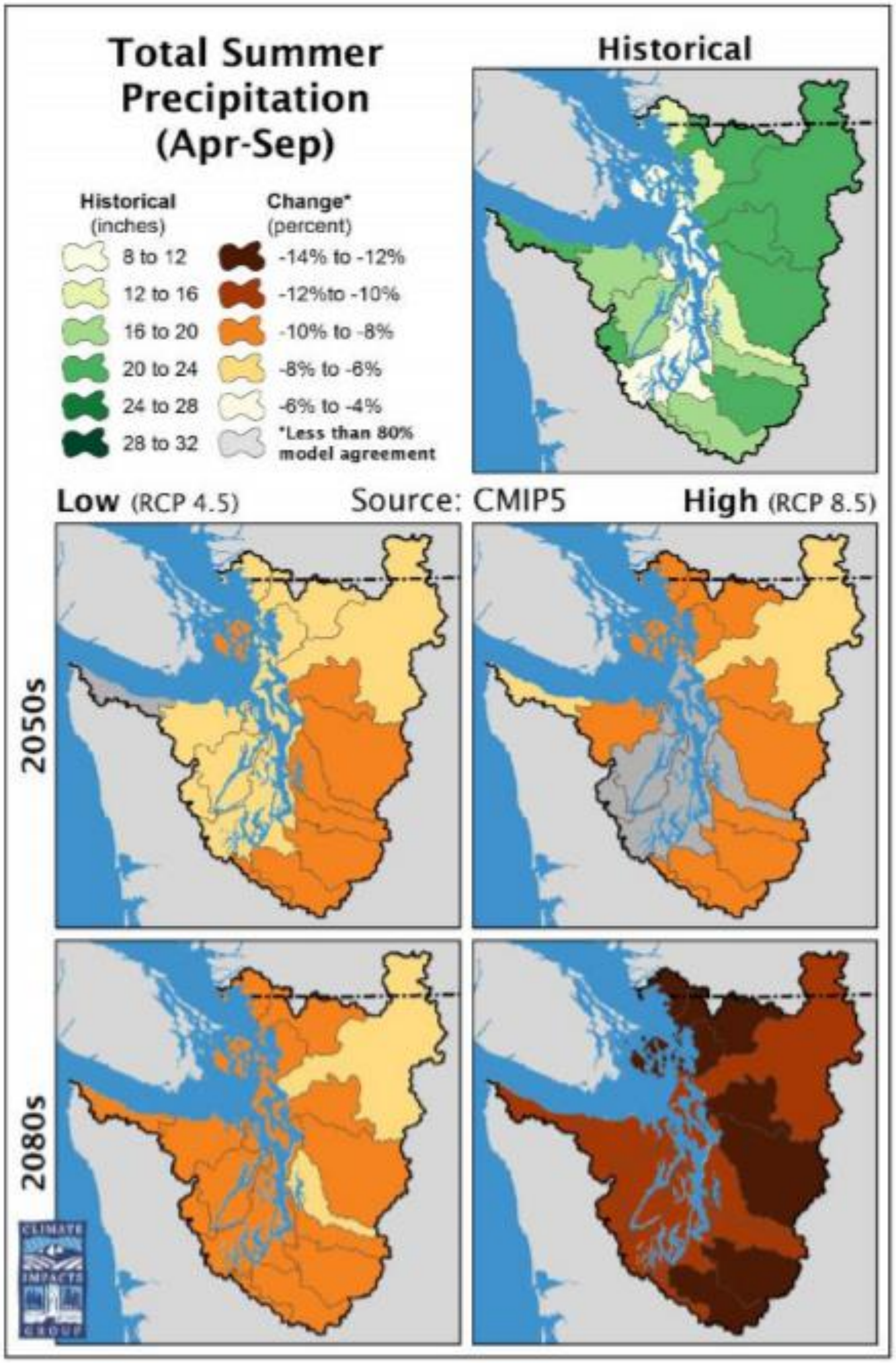


Figure 11: Changes in Summer Precipitation for Low (RCP 4.5) and High (RCP 8.5) IPCC emissions scenarios. Figure source: Mauger et al., 2015. Figure created by Robert Norheim, Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report. Data source: Mote et al 2015.

Changes for other seasons are less clear; most climate models project winter, spring and autumn to be wetter, but some models predict drier conditions. However, all models predict heavier precipitation events, which is addressed further below.

HEAVY RAIN EVENTS

Heavy rainfall events have been on the increase. In the past decade (2005 – 2014), the Seattle area has experienced 82 percent more heavy downpours (the top 1 percent of all rain and snow days), compared to a 10-year period in the 1950s (1950-1959) (Climate Central 2015).

Heavy rainfall events are projected to become more frequent and intense, with a projected +22% increase in the amount of rainfall occurring during the heaviest one percent of all daily events under the High IPCC emissions scenario for the 2080s (2070-2099) (Mauger et al 2015) (Figure 12 and Table 6). In addition, there is anticipated to be a significant increase in the number of days that exceed the heaviest one percent of all daily events, from 2 days/year in the period from 1970-1999 to a projected 7 days/year in the 2080s (2070-2099). The change in the frequency and intensity of rainfall events is likely to increase the frequency and intensity of winter flooding events, especially for communities that are already at risk for flooding.

Table 6: Projected change in precipitation events, based on High emissions scenario (Mauger et al 2015).

Climate Change Driver	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
24-Hour Precipitation Amount	+22% increase in annual 99^{th} percentile of 24-hour precipitation	+5 to +34% increase in annual 99^{th} percentile of 24-hour precipitation
# Days with Heavy Rainfall Events	+5 days/year that region exceeds historical 99^{th} percentile of 24-hour precipitation	+4 to 9 days/year that region exceeds historical 99^{th} percentile of 24-hour precipitation

To illustrate the scale of change, in La Conner, the record single day rainfall is 3.23 inches, and the average for a typical Spring season would be 4.88 inches. Under modeled conditions, in 2100 during a heavy precipitation event, La Conner could receive 4.625 inches in one 24-hour period, which is almost equivalent to a total historical spring season rainfall amount.

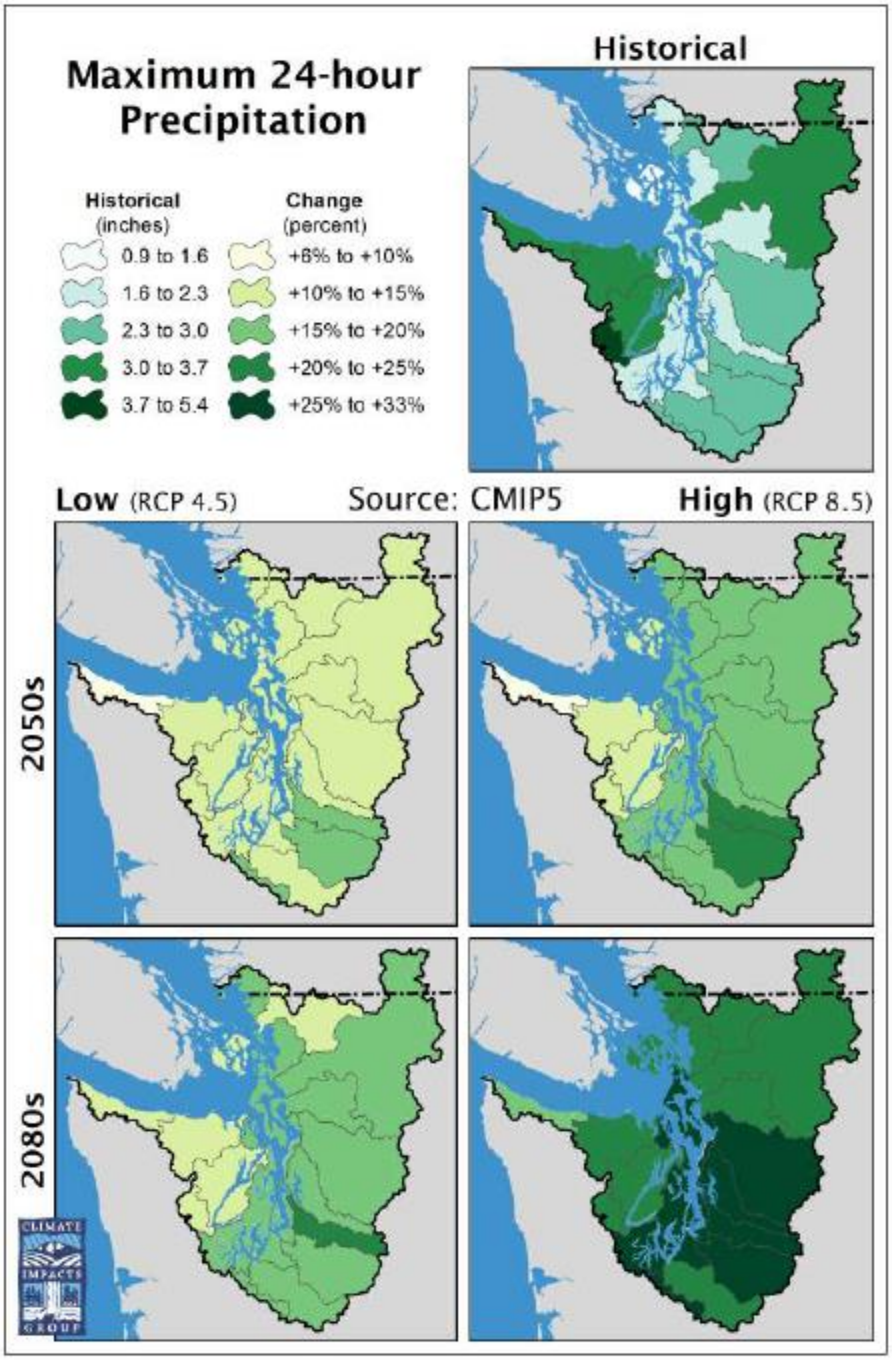


Figure 12: Changes in Maximum 24-hour Precipitation for Low (RCP 4.5) and High (RCP 8.5) IPCC emissions scenarios. Figure source: Mauger et al., 2015. Figure created by Robert Norheim, CIG, based on the CMIP5 projections used in the IPCC 2013 report. Data source: Mote et al 2015.

WATER TEMPERATURE

The following provides an overview of changes in water temperatures, including freshwater and marine waters.

FRESHWATER TEMPERATURE

Stream temperatures are increasing, with rates of summer warming of 0.4° F per decade between 1980 and 2009 (WDFW 2015).

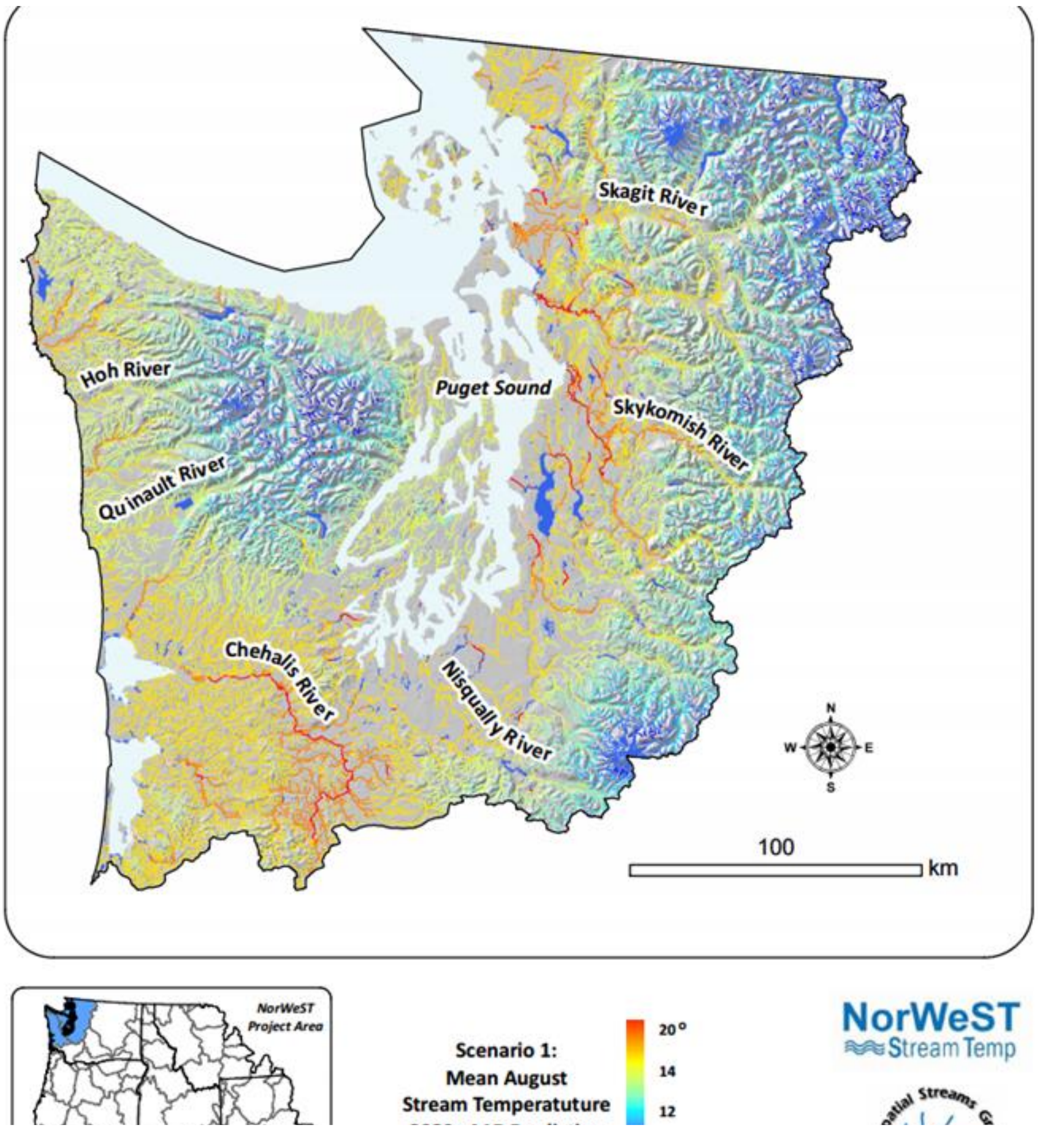


Figure 13: Predicted change in mean August stream temperatures in Western Washington, based on Moderate emissions scenario. Figure source: Isaak et al 2016.

The warmer air temperatures and resulting changes in streamflow timing will increase water temperatures in watersheds throughout the Puget Sound region. The amount of time that rivers exceed thermal thresholds is also anticipated to be longer as a result of these changes.

Rivers draining to the Salish Sea are anticipated to increasingly experience average August stream temperatures that are stressful to salmon (more than 64° F, as depicted in orange-red or red in Figure 13) and char (more than 54° F, as depicted in yellow-green or higher in Figure 13). There is also anticipated to be an increase in the number of miles that exceed temperatures that are lethal to certain fish populations such as salmon, as well as the duration of time that this thermal tolerance is exceeded (Table 7). For example, rivers within the Samish Watershed are anticipated to experience a 27-mile increase in temperature above 64° by the 2080s (2070-2099, relative to 1970-1999) (Isaak et al 2011).

Increases are most significant in the lower elevation, downstream portions of watersheds where rivers slow down and widen[7].

Table 7: Projected change in number of miles that exceed thermal tolerances for Salmon species (64°) and char species (54°), based on Moderate emissions scenario (Isaak et al 2011).

Climate Change Driver	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Increase in # miles that exceed thermal tolerance for cold water species	Skagit Watershed: +566 miles > 54° + 121 miles > 64° Samish Watershed: +14 miles > 54° + 27 miles > 64°	Skagit Watershed: N/A Samish Watershed: N/A

Stream temperatures are a key factor in the quality of Pacific Northwest aquatic habitat. Salmon are affected by water temperatures at each of their life stages.
For examples, when exposed to higher water temperatures, salmon become more susceptible to pathogens, suffer higher mortality, and stop or slow their migration. Dissolved oxygen levels, an essential resource for many aquatic animals, are also reduced at higher temperatures.

OCEAN TEMPERATURE

Surface and subsurface water temperatures in Salish Sea and the Northeast Pacific Ocean have been warming (Figure 14). The Salish Sea surface and subsurface temperatures increases have ranged from +0.8 to +1.6 °F from 1950 to 2009 for stations located at Admiralty Inlet, Point Jefferson, and in Hood Canal (Mauger et al 2015). Temperature in the Salish Sea is influenced

[7] It is also important to note that there is natural variability in stream temperatures over space and time. Salmon and other coldwater fish species are adapted to this natural variability. Research is still trying to characterize the thermal variability that is present in stream systems, how this might change under new climate conditions, and as a result, the sufficiency of habitats supporting salmon migration and rearing.

by many factors, including from inflows from the Northeast Pacific Ocean, which is also warming.

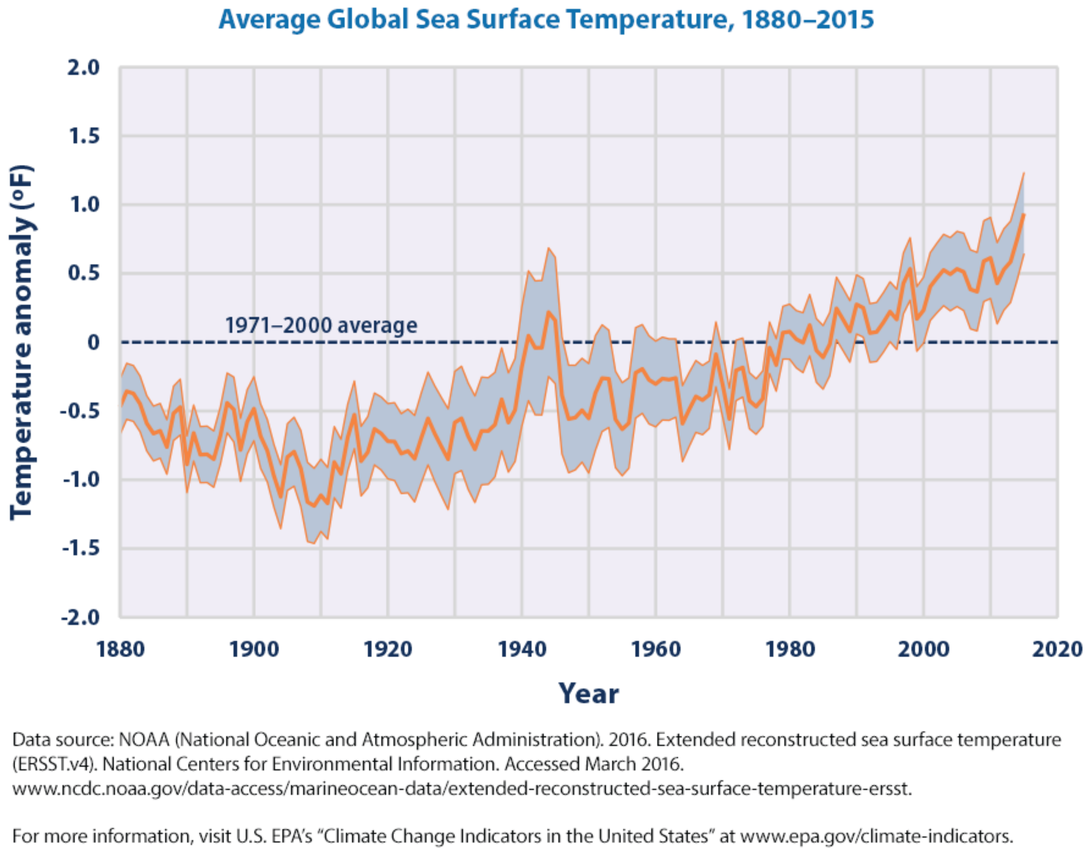


Figure 14: Average Global Sea Surface Temperature, 1880-2015. Figure Source: US EPA

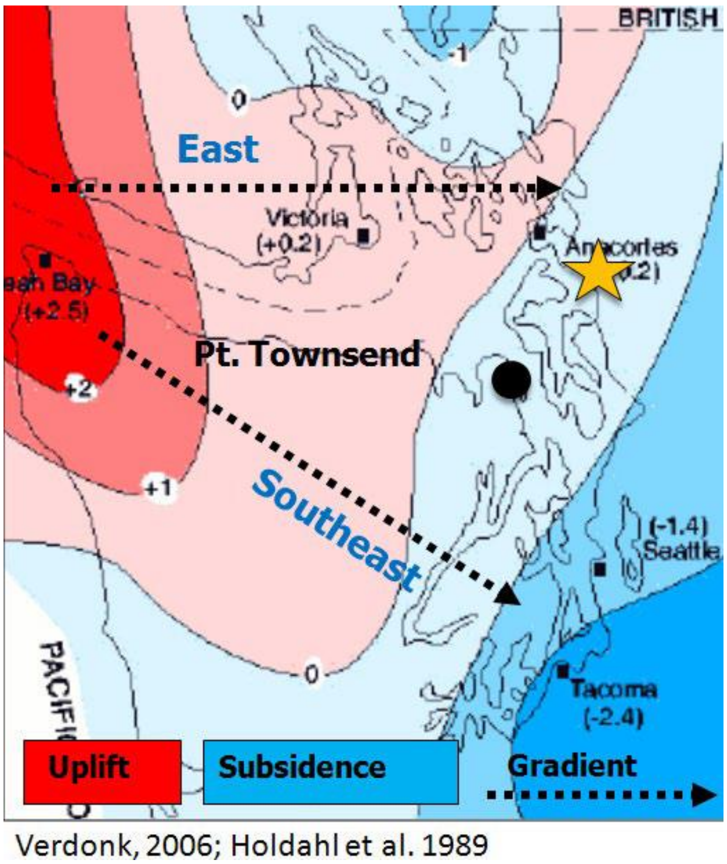
Specific projections of surface temperature changes in the Salish Sea are not available, though the warming trend that has been occurring (with an increase of between +0.8 and +1.6° F between 1950 and 2009) is projected to continue. Surface temperatures in the Northeast Pacific Ocean are projected to warm by about +2.2° F by the 2040s (2030-2059, relative to 1970-1999) (Mote and Salathé, 2010), though continuing variability from El-Nino and La-Nino patterns may obscure this long-term trend.

The warming marine waters may result in range shifts, with some traditional species migrating north outside of the area, and new species migrating into the area from the south.

CHANGING SALISH SEA

The following provides an overview of changes in sea levels and water chemistry, including pH and Dissolved Oxygen.

SEA LEVEL RISE



Sea level rise is expected to vary across Washington State in response to several factors. In general, sea level rise is associated with thermal expansion caused by warming of the ocean (since water expands as it warms), together with increased melting of land-based ice, such as glaciers and ice sheets and, to a lesser degree, changes in precipitation patterns as more falls as rain instead of snow. However, localized factors such as ocean currents, sedimentation, wind patterns, and the global distribution of glacier melt also can affect the rate of sea level rise. In addition, throughout the Salish Sea region tectonic activity has resulted in differing patterns and rates of land elevation uplift or subsistence. In the Skagit shoreline area, the land is subsiding, which means that the rate of sea level rise is likely to be greater than modeling under current elevations would otherwise suggest (Figure 15). Different shoreforms will also respond differently to sea level rise.

Figure 15: Western Washington sits on the edge of the North American continental plate, under which the Juan de Fuca oceanic plate is subducting. This subduction tends to produce uplift in the western extent of the region over time ('uplift' shown in red), whereas the Puget Sound area is subsiding ('subsidence' shown in blue). Figure Source: Skagit Science Consortium 2015. Data Source: Verdonk 2006 and Holdahl et al. 1989.

Over the last century, sea level has risen within the Salish Sea. For example, in Seattle, readings from a tide gauge indicated that the water level had risen eight inches between 1900 and 2008. This trend is projected to continue, with sea level projected to increase by an average of +56 inches by 2080 under a High emissions scenario, relative to 2000.

Table 8: Sea level rise projections for the Year 2080, relative to year 2000, in the Seattle area. Projections (middle column) represent RCP 8.5 high emissions scenario projections, while ranges (right column) represent the range from low to extreme emissions scenario projections. Source: NOAA Global and Regional Sea Level Rise Scenarios for the United States[8]

Climate Change Driver	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Sea Level Rise	+56 inches	+9 to +72 inches[9]

Figure 16 visually represents what a High emissions scenario might mean, depicting the inland extent and relative depth of inundation from 0 to 6 feet above current mean higher high water (MHHW). Many of the coastal wetlands, tidal flats and beaches within the Samish Traditional Territory are projected to be impacted, declining in quality and extent due to sea level rise, particularly where upland migration of habitats is hindered by bluffs or structures such as bulkheads and other shoreline armoring, dikes, or where natural sources of sediment are limited. It is estimated that with a sea level rise of 27 inches (far less than the high emissions scenario), there would be a corresponding loss of 40 percent of freshwater tidal areas in Whatcom, Skagit Bay, and Snohomish (Washington Department of Ecology 2012). Emerging studies point to evidence that higher than previously expected levels of Antarctic ice sheet melt will significantly increase the likelihood of High to Extreme sea level rise scenarios.[10]

[8] National Oceanic and Atmospheric Administration. (2017). *Global and Regional Sea Level Rise Scenarios for the United States.* https://coast.noaa.gov/slr/#/layer/sce/5/-13516410.219960485/6145063.219246512/9/satellite/112/0.8/2050/interLow/midAccretion

[9] Scientific research into sea level rise continues to evolve, and a recent report by NOAA (Sweet et al 2017) introduced new scenarios, with the High-scenario under this report indicating as much as 8.25-feet of sea level rise in the Seattle area by 2100. The probability of the high scenario remains low, but new evidence regarding the Antarctic ice sheet may increase the probability (Sweet et al 2017). The scenario depicted in Figure 16 is the middle of the Intermediate-High scenario of Sweet et al 2017.

[10] https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

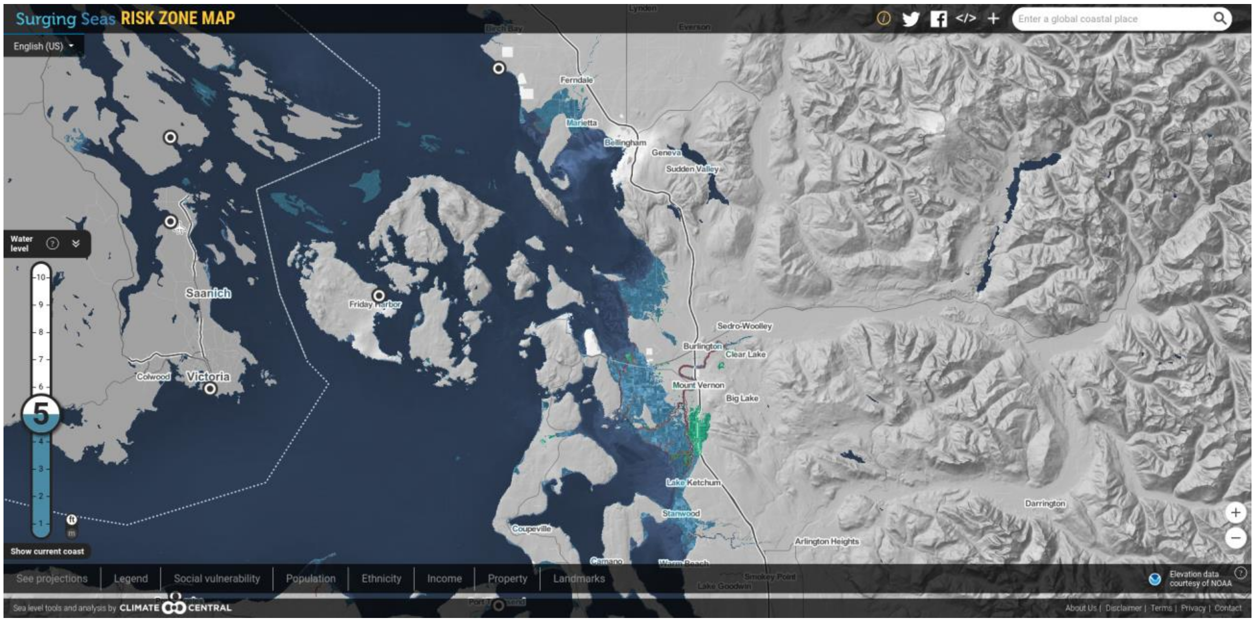


Figure 16: Visualization showing estimate of areas potentially inundated by 5-foot increase in sea levels (shown in blue, with darker blue indicating greater depth of water). Inundation is shown as it would appear during MHHW—the average of the higher high-water height of each tidal day observed over the National Tidal Datum Epoch. The data in the maps do not consider natural processes such as erosion, subsidence, or future construction. Figure Source: Climate Central Surging Seas Risk Zone Map.

Most recently, in January 2017, the National and Oceanic Atmospheric Administration (NOAA) issued a technical report that added an “extreme” sea level risk scenario, supplementing high, intermediate and low categories that have also been used in past reports (Sweet et al 2017). The new term reflects recent research suggesting that some parts of the Antarctic ice sheet may begin to collapse much sooner than previously anticipated, particularly if ongoing emissions of heat-trapping gases like carbon dioxide and methane remain high. Under the new “extreme” scenario, sea level rise is projected to increase by over 10 feet by 2100 in the Seattle area (Figure 17) (Climate Central 2017, based on data from Sweet et al 2017). Under this new scenario, lowland areas of the Skagit-Samish watershed, including Bayview and La Conner, are severely impacted by sea level rise.

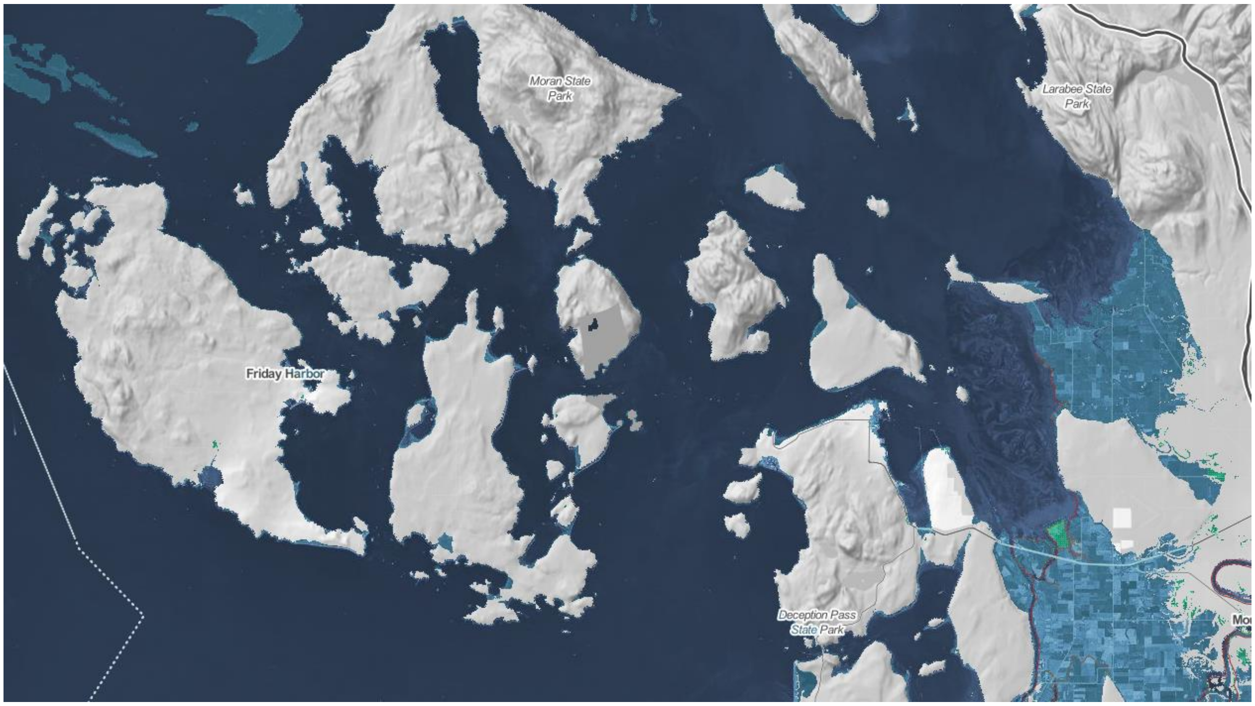


Figure 17: Visualization showing estimate of areas potentially inundated by over 9.5-foot increase in sea levels (shown in blue, with darker blue indicating greater depth of water), reflecting a mid-range "extreme" scenario, based on Sweet et al 2017. Figure Source: Climate Central.

Shoreline armoring is a secondary impact associated with sea level rise and increased storm surge. A preliminary climate assessment of the Puget Sound identified shoreline armoring as a high risk under changing climate conditions (Siemann and Whitely Binder 2017), as landowners may respond to these threats by strengthening existing armoring, adding new armoring, and resisting efforts to remove armoring. The consequences of this type of armoring are significant, and increase degradation of marine habitats, reduced connectivity between nearshore and uplands areas, loss of sediment supply, and loss of area for potential migration of habitats and species.

WATER CHEMISTRY

Acidity/pH

The world's oceans absorb carbon dioxide (CO_2) from the atmosphere. As the oceans soak up excess carbon emissions, the chemistry of the seawater changes, lowering the pH of the water, also known as ocean acidification.

The Salish Sea and Washington's coastal waters are particularly vulnerable to ocean acidification because of their location and other factors, including:

- Seasonal upwelling, which brings CO_2-rich waters to the surface.

- High rates of algal growth, promoted by nutrient inputs, that ultimately reduce the oxygen content of local waters.
- Industrial emissions of acidic gases.

As atmospheric CO_2 levels continue to climb and other system inputs continue to change, this situation is projected to worsen, though lack of long-term ocean acidification monitoring data makes projections in the Salish Sea difficult to make. In contrast, in the North Pacific, where on-going monitoring is present, pH is projected to decline by -0.2 to –0.3 units by the end of the 21st century, translating to a 100-150 percent increase in ocean acidity (WDFW 2015).

Table 9: Predicted decrease in pH for the North Pacific by the Year 2080, based on Low and High Emissions Scenario. Source: WDFW 2015.

Climate Change Driver	Change in pH by 2080s (range, Low and High Emissions Scenario)
Ocean Acidification (North Pacific) > 50°N	-0.2 to –0.3 pH units

Organisms that produce a calcium carbonate shell, ‘calcifiers’ like shellfish, are considered particularly vulnerable to ocean acidification because such conditions lead to a reduction in the carbonate ion needed for calcification. As a result, calcifiers must use more energy to pull carbonate ions out of the water to build their shells. Calcium carbonate also dissolves more easily as acidity increases. These changes can result in slower growth and/or higher mortality among calcifiers, especially in shellfish larvae and juvenile shellfish.

The declining pH has already altered the development of shellfish in parts of Salish Sea. The production of oyster seeds needed to support the region’s oyster farms has plummeted in recent years, with growers attributing this loss to ocean acidification (Campbell 2012). Many farms now must import the oyster larvae.

It is estimated that more than 30 percent of Puget Sound’s marine species are calcifiers, including oysters, clams, scallops, mussels, abalone, crabs, geoducks, barnacles, sea urchins, sand dollars, sea stars and sea cucumbers (Washington Department of Ecology 2012). Other species also rely on a stable pH. For example, seaweeds produce calcium carbonate structures. Declining pH is also anticipated to impact pteropods and copepods, which are a key food source for many animals, including juvenile salmon. Acidification has also been found to impact salmon physiology and behavior (Ou et al 2015).

Dissolved Oxygen

Dissolved oxygen levels in the Strait of Georgia portion of the Salish Sea have been declining, with oxygen levels declining by roughly -13 to -29 percent between 1971 to 2009 (Mauger et al

2015), primarily due to coastal upwelling of water with low dissolved oxygen levels. Records are not sufficiently long to determine overall trends in the Salish Sea. However, scientists have projected a decrease in oxygen concentrations.

Models project that by 2070 (2065-2069, relative to 1999-2008) dissolved oxygen could decrease by more than –1 mg/L in the Strait of Juan de Fuca and dissolved oxygen could decline by more than –0.6 mg/L in Central Puget Sound and Hood Canal.

Table 10: Predicted decrease in levels of dissolved oxygen predicted by the Year 2070, based on Moderate Emissions Scenario. Source: Mauger et al 2015.

Climate Change Driver	Change in DO by 2070
Dissolved Oxygen	–1 mg/L in the Strait of Juan de Fuca –0.6 mg/L in Central Puget Sound and Hood Canal

These declines are influenced by many factors, both climatic and non-climatic, and the proportion of change due to climate change has not been quantified.

This change in oxygen concentrations can be problematic for some species that are not adapted to periods of low oxygen; this risk may be higher for slower organisms that are unable to move from hypoxic zones. In general, hypoxic conditions tend to lead to reductions in diversity and in body size of organisms, and can specifically alter an organism's behavior, growth, reproductive success, and survival for species that are not adapted to such conditions. For example, survival of species such as rockfish and Dungeness crab has been observed to decline during hypoxic events (Morgan and Siemann 2011). The Oregon coast is now facing annual threats from hypoxia, and scientists suspect that there may be several factors attributing to this risk, including warmer water holding less oxygen; increased stratification of ocean waters, reducing the mixing of waters; and changes in upwelling of deep waters, bringing this low oxygenated water to the near surface.

Salinity

Salinity, along with water temperature, is an important parameter that governs the density of seawater, which is a major factor controlling mixing between surface and deep waters, as well as flushing of the Puget Sound. Increasing amounts of freshwater inflow, because of changes in hydrology, can cause the salinity of surface waters and density of the surface waters to decrease. The opposite is true in cases when freshwater inflow is limited.

In winter, when increases in freshwater inflows are predicted, this change in density can form a density gradient between the Salish Sea and the North Pacific Ocean; the greater the density difference between the waters, the greater the rate of exchange between the waters. Table 11 contains projections for the increase in the inflow of saline waters to the Puget Sound under a Moderate Emissions Scenario.

In summer, when freshwater inflows are projected to decline, the change can reduce the rate of exchange. This lower rate of exchange in waters can lead to increases in exposure to contaminants and pollutants, and increase the retention of some organisms, like plankton (Mauger et al 2015).

Table 11: Predicted change in mean tidal inflow to marine sub-basins, based on Moderate Emissions Scenario. Source: Khanganonkar et al 2016.

Climate Change Driver	Change in inflow by 2070
Strait of Juan de Fuca	+ 4%
Admiralty Inlet to Puget Sound	+2%
Whidbey Basin through Possession Sound	+2%
Hood Canal	+3%

At the same time, waters within the Salish Sea may begin to stratify if water density increases with depth. Conditions promoting stratification are more likely to occur with increasing freshwater inflows, predicted to occur in winter months, which bring less dense water to marine surface waters. Stratification limits mixing between surface and deep layers, resulting in less deep-water nutrients making it to surface waters, and less oxygen from the surface making it to deeper waters.

Beyond changes in mixing, changes in salinity can also impact species composition. In the Skagit river estuary, Khanganonkar et al (2016) predict that salinity will increase, shifting the habitat from primarily freshwater to brackish (Table 12).

Table 12: Predicted increase in salinity levels in the Skagit estuary during low-flow summer months, based on Moderate Emissions Scenario. Source: Khanganonkar et al 2016.

Climate Change Driver	Change in salinity by 2070
Salinity	+ 1 psu

Nutrients

Nutrient levels have been increasing, primarily due to changes in land cover and development. However, the Pacific Ocean remains the largest source of nutrients in the southern portion of the Salish Sea (Mauger et al 2015). While nutrient levels are predicted to increase (+51% in rivers by 2070 under a Moderate Emissions Scenario as reported by Mauger et al (2015)), this is largely the result of future changes in land cover and development. Lower summer streamflow levels, however, may intensify the concentration of nutrients.

Algae

Changes in the climate are projected to increase the growth rate of algal species that cause Harmful Algal Blooms (HABs). A number of factors promote the growth of the species, including increases in water temperature and changes in salinity. In addition, increasing acidity of waters addressed above, is anticipated to increase the toxicity of some HABs. HABs that formed in 2015 along the West Coast of Northern California Oregon, and Washington caused shellfish harvest and fishery closures up and down coast.

Table 13: Predicted increase in conditions favorable to harmful algal blooms, based upon Moderate Emissions Scenario. Source: Mauger et al 2015.

Climate Change Driver	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
# of days with favorable conditions for HABs	+13 days	N/A
Timing of favorable conditions for HABs	+2 months earlier, +1 month later (May – December rather than July – November)	N/A

SECONDARY IMPACTS

The following section begins to address system changes that may stem from these drivers.

Summary of Key Changes:

- ***Snowpack and glacier area will decrease, and there is predicted to be a shift from snow to rain winter precipitation in mid-elevation watersheds.***
- ***Snowmelt is predicted to occur increasingly earlier in the season.***
- ***Streamflow volume is predicted to increase in winter and decrease in spring and summer. Peak streamflow is projected to occur earlier in the season.***
- ***Reductions in summer streamflow will result in less water supply available in the summer, increasing drought stress.***
- ***Increases in fall and winter streamflow will increase flood risk along rivers and coastal areas.***
- ***Elevated sea levels, combined with low summer stream flows, are predicted to increase saltwater intrusion into groundwater sources***
- ***Runoff from more frequent and intense extreme precipitation events will result in increased introduction of pathogens and prevalence of toxic algal blooms, with corresponding impacts to water quality, habitat and human health.***
- ***Lower runoff in summer could mean less dilution of stream waters, resulting in more concentrated nutrient and bacteria loads and resulting impacts to water quality, habitat, and human health. In addition, lower summer precipitation combined with warmer summer temperatures will stress streamside vegetation, impacting stream cover and temperatures.***
- ***Increased risk of landslide and rates of erosion in winter and spring.***
- ***Increased feeder bluff erosion in coastal areas.***
- ***Increased sediment loading with changes in streamflow in fall, winter and spring, further impairing water quality and decreasing habitat areas, increasing flood risk, and endangering infrastructure improvements.***
- ***Increased fire frequency, severity, intensity, and total area burned.***
- ***Declining air quality.***
- ***More intense, frequent, or severe insect outbreaks as well as outbreaks in places where historical insect activity was low or unknown.***
- ***Many ecological systems are predicted to be highly vulnerable to climate change impacts, ranging from marine waters to alpine fields and covering large areas of Samish Traditional Territory.***
- ***Plant and animal species are predicted to respond to the impacts of climate change by altering their current geographic distribution or the timing of significant biological events.***

REDUCED SNOWPACK AND GLACIER RETREAT

Snowpack in the Salish Sea region is already in a period of decline, with a decrease of approximately 25 percent in the spring snowpack levels between the 1950s to 2006 (Mauger et al 2015; WDFW 2015). Similarly, glaciers within the region are in decline, with a 56 percent loss of glaciers in the North Cascades between 1900 and 2009.

In the Skagit-Samish River watershed — home to the most glacial ice in the United States outside of Alaska — an estimated 12.4 square miles of ice has been lost since 1959 (Riedel and Larrabee 2016). That is an area about the size of the city of Mount Vernon (Cauvel 2016), and is equivalent to about 100 years of Skagit County water supply at the current rate of consumption Riedel and Larrabee 2016). This trend is projected to continue, and there is concern that many glaciers will retreat entirely. This is predominately because of changing air temperatures and precipitation patterns, which will cause snow to accumulate less in winter and melt more rapidly in spring and summer. The average winter freezing level elevation in the Skagit has already increased 650 feet since 1959 (Skagit Climate Science Consortium 2015).

In the future, spring snowpack is projected to decline by −74 percent, on average, by the 21st century, as compared to the period 1970-1999, under a High IPCC emissions scenario (Table 14).

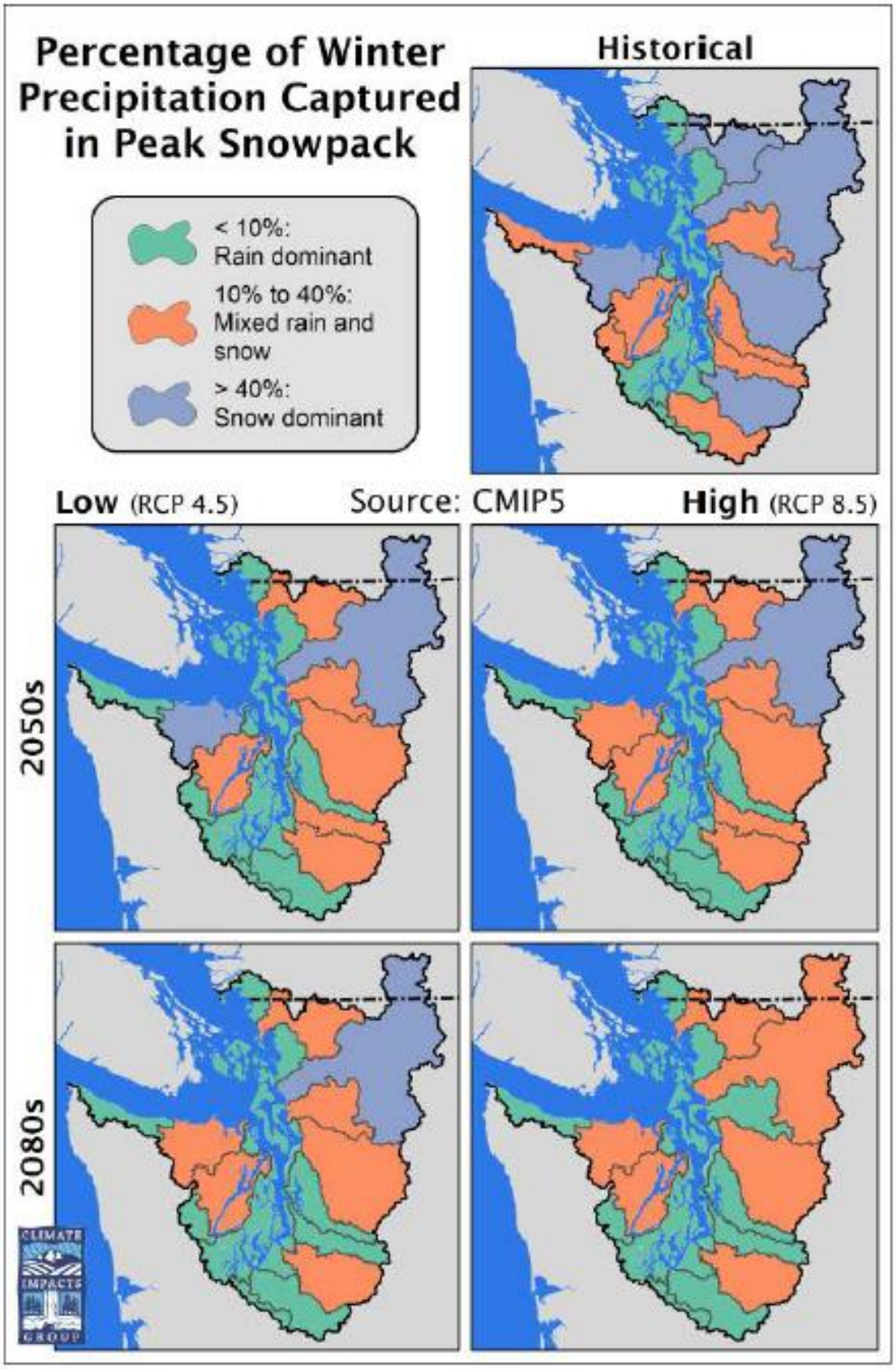


Figure 18:Predicted changes in Winter Precipitation Captured in Snowpack Precipitation for Low (RCP 4.5) and High (RCP 8.5) IPCC emissions scenarios. Figure source: Mauger et al., 2015. Figure created by Robert Norheim, CIG, based on the CMIP5 projections used in the IPCC 2013 report.

Table 14: Predicted change in Winter Snowpack, based on High emissions scenario (Mauger et al 2015).

Secondary Impact	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Winter Snowpack	-74%	-85% to -59%

The greatest changes are projected for mid-elevation basins, where precipitation is increasingly projected to be rainfall rather than snow in the winter months (see orange areas depicted in Figure 36). Under the High emissions scenario, by the end of the 21st century the region will no longer have any snow dominant watersheds, and only a few remaining that can be classified as mixed snow and rain (Hamlet et al 2013).

EARLIER SNOWMELT

Snowmelt is occurring earlier because of warming air temperatures; already, snowmelt has been occurring up to 30 days earlier in some locations in the Cascade Mountains during the latter half of the 20th century (WDFW 2015). Snowmelt is projected to occur increasingly earlier, up to three to four weeks sooner than the 20th century average by 2050 (WDFW 2015).

Snowmelt timing, in turn, has impacts on a range of environmental conditions, including earlier timing of peak streamflow; earlier timing of water infiltration into soils, making slopes less stable during spring; montane wetland extent and water levels,

Table 15: Projected change in Winter Snowmelt, based on Moderate Emissions Scenario (WDFW 2015).

Secondary Impact	Change by 2050s (avg., relative to 20th Century)
Snowmelt	+3-4 weeks earlier

HYDROLOGICAL SHIFTS

Changes in the timing, amount, and type of precipitation, coupled with air temperature changes have significant impacts on the magnitude and timing of streamflow. Historically, the Skagit River has produced the highest monthly volumes of streamflow during the spring and early summer months as melting snow filled the river.

Because warming will mean less snow and more fall and winter precipitation falling as rain, scientists project the river will shift to more rain-dominant behavior in the future with peak monthly flows occurring in the fall and winter months (Figure 19). As a result, the timing of peak streamflow may shift earlier in the season. For example, in the Skagit watershed peak streamflow is projected to occur approximately six weeks earlier, on average, by the end of the 21st century under the Moderate IPCC emissions scenario.

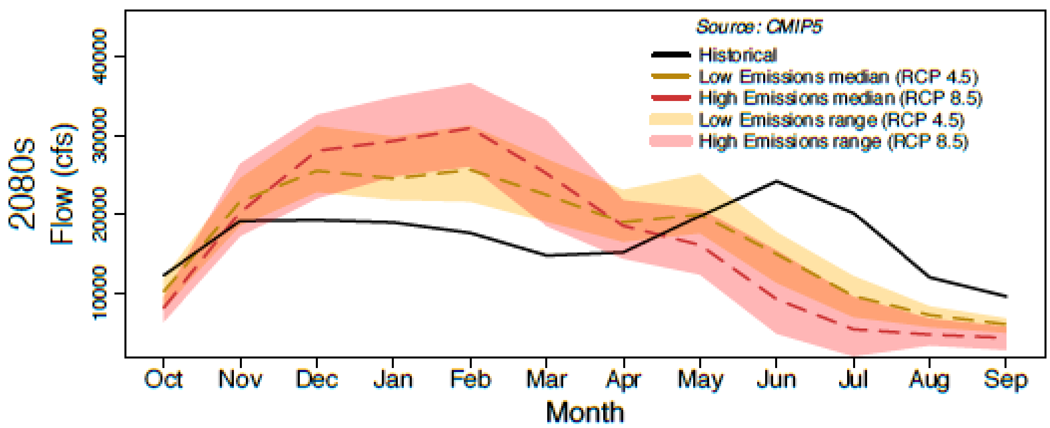


Figure 19: Monthly graph of streamflow estimated for the Skagit Watershed for 2080s (Mauger et al 2015), comparing historical (black) to the range of future projections.

The Samish River watershed, which has not traditionally been snow-dominant, maintains a similar hydrograph as the historical norm (Figure 20). As a result, in the Samish watershed, change in peak streamflow is not predicted to be as significant, with the peak occurring approximately one week earlier.

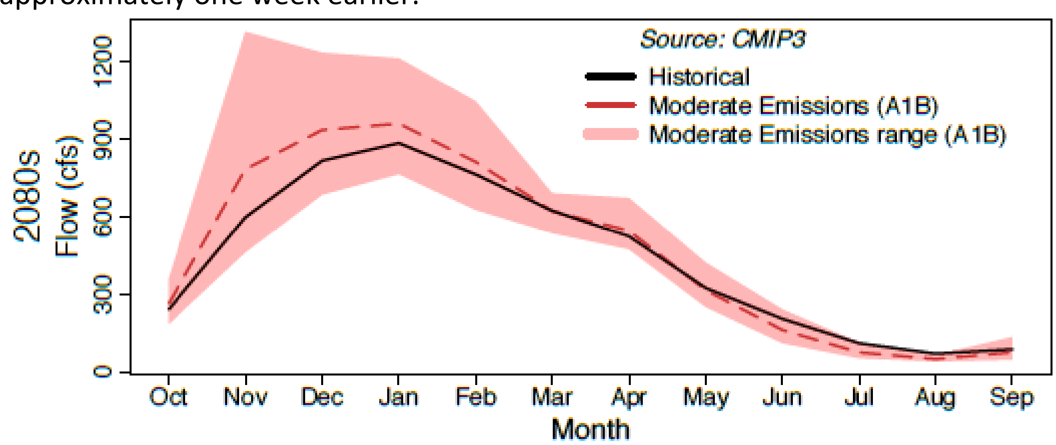


Figure 20: Monthly graph of streamflow estimated for the Samish Watershed for 2080s (Mauger et al 2015), comparing historical (black) to the range of future projections.

Looking forward, while annual streamflow will largely remain stable (Table 16), the timing of streamflow is projected to change, reflecting this shift in the hydrological cycle. As a result, streamflow volume is projected to increase in winter and decrease in spring and summer throughout the Salish Sea region, with the most significant changes in the mid-elevation basins.

This results in a corresponding increase in winter runoff volumes (Figure 21), which could cause flooding and other impacts. In contrast, decreasing streamflow and runoff in summer months may lead to drought risk.

There are ecological impacts associated with these changes. High flow events can scour streambeds and increase siltation and, as a result, are likely to impact fall spawning species that have eggs in streambed gravel during winter months (Washington Department of Fish and Wildlife, 2011). Conversely, reductions in summer baseflows would adversely impact habitat for invertebrates and fish, increasing temperatures, cutting fish off from floodplain habitat, concentrating pollutants, and reducing overall productivity in the system. Reduced summertime flow, in combination with increased temperatures, is likely to limit rearing habitat for salmon species that rear in freshwater for one or more years, as well as increase mortality rates for summer-run adults (Washington Department of Fish and Wildlife, 2011).

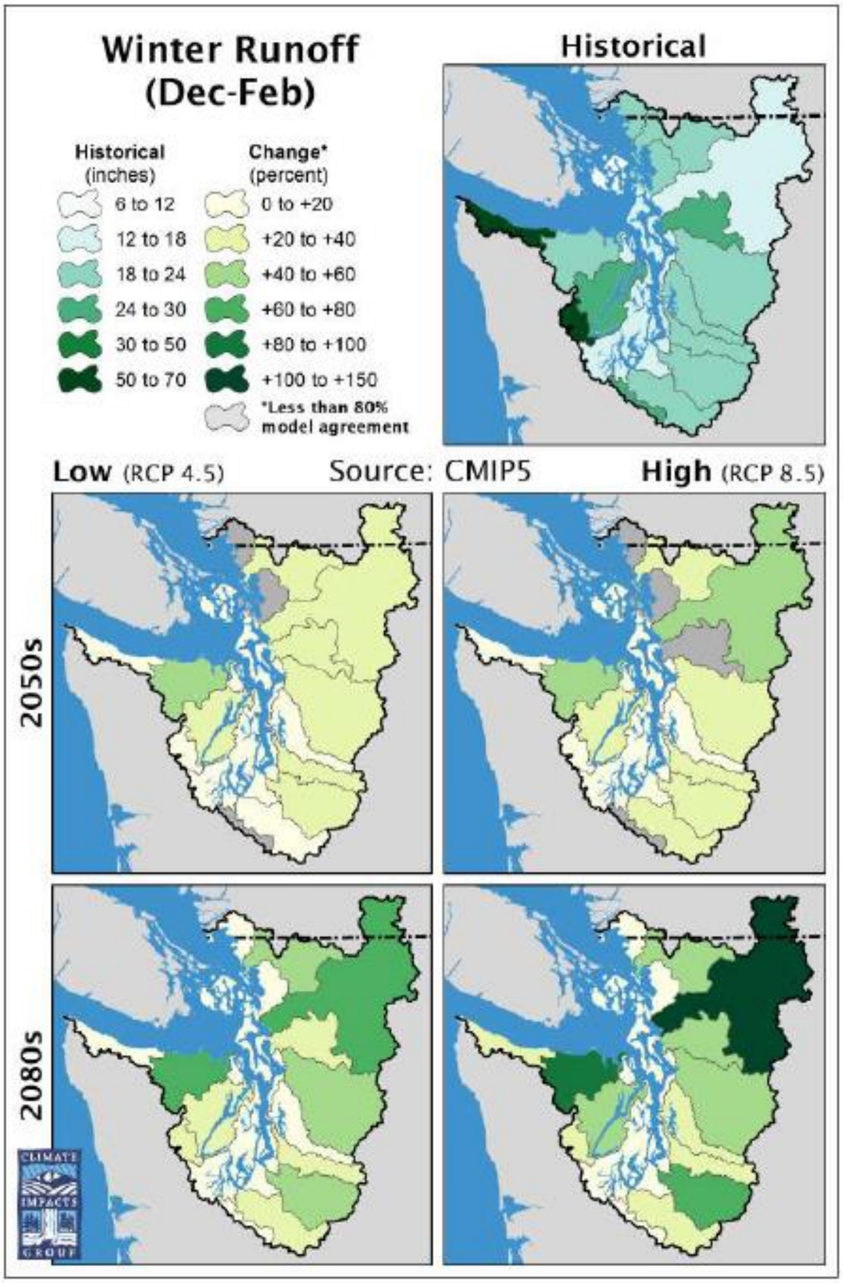


Figure 21: Changes in Winter Runoff for Low (RCP 4.5) and High (RCP 8.5) IPCC emissions scenarios. Figure source: Mauger et al., 2015. Figure created by Robert Norheim, CIG, (based on the CMIP5 projections used in the IPCC 2013 report. Data source: Mote et al 2015).

Table 16: Predicted change in streamflow, based on High emissions scenario (Mauger et al 2015).

Secondary Impact	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Annual Streamflow	-2%	-12 to +2%
Peak Streamflow timing	Skagit: -33 days Samish: -7 days	Skagit: N/A Samish: N/A
Winter Streamflow	+60%	+43 to 77%
Summer Streamflow	-29%	-41 to -20%
Summer Minimum Streamflow	Skagit: -71% Samish: -31%	N/A

DROUGHT RISK

Drought is currently defined in state law when less than 75 percent of normal water supply is projected to be available and the reduced water supply will cause undue hardships (WAC 173-166-030). Warmer weather and changing precipitation could result in reduced snowpack (and associated snowpack storage), earlier runoff, less summer precipitation, and increased evapotranspiration, resulting in less water supply available in the summer (Table 17).

Table 17: Predicted change in summer minimum streamflow, based on Moderate emissions scenario (Mauger et al 2015).

Secondary Impact	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Summer Minimum Streamflow	Skagit: -51% Samish: -18%	Skagit: -65 to -38% Samish: -26 to -7%

These conditions resemble the drought that Washington experienced during 2015, and are consistent with the potential for increased frequency and intensity of drought conditions predicted by climate change models.

As part of Puget Sound Partnership efforts to restore and protect Puget Sound, a climate change assessment was completed in 2017 (Siemann and Whitely Binder 2017). This assessment identified summer streamflow as a high risk under changing climate conditions, due to the projected shift from snow to rain in mid and high elevations, reduced snowpack, earlier spring snow melt and lower summer precipitation.

Figure 22 depicts the historical and projected summer water deficit, which indicates where water availability exceeds water demand. Light to deep brown areas indicate where a water deficit occurs, and water demands exceed water availability. Water availability is already limited in many locations throughout the Salish Sea region, and becomes more limited to varying degrees in most watersheds, including the San Juan islands, Lower Skagit-Samish and Island watersheds.

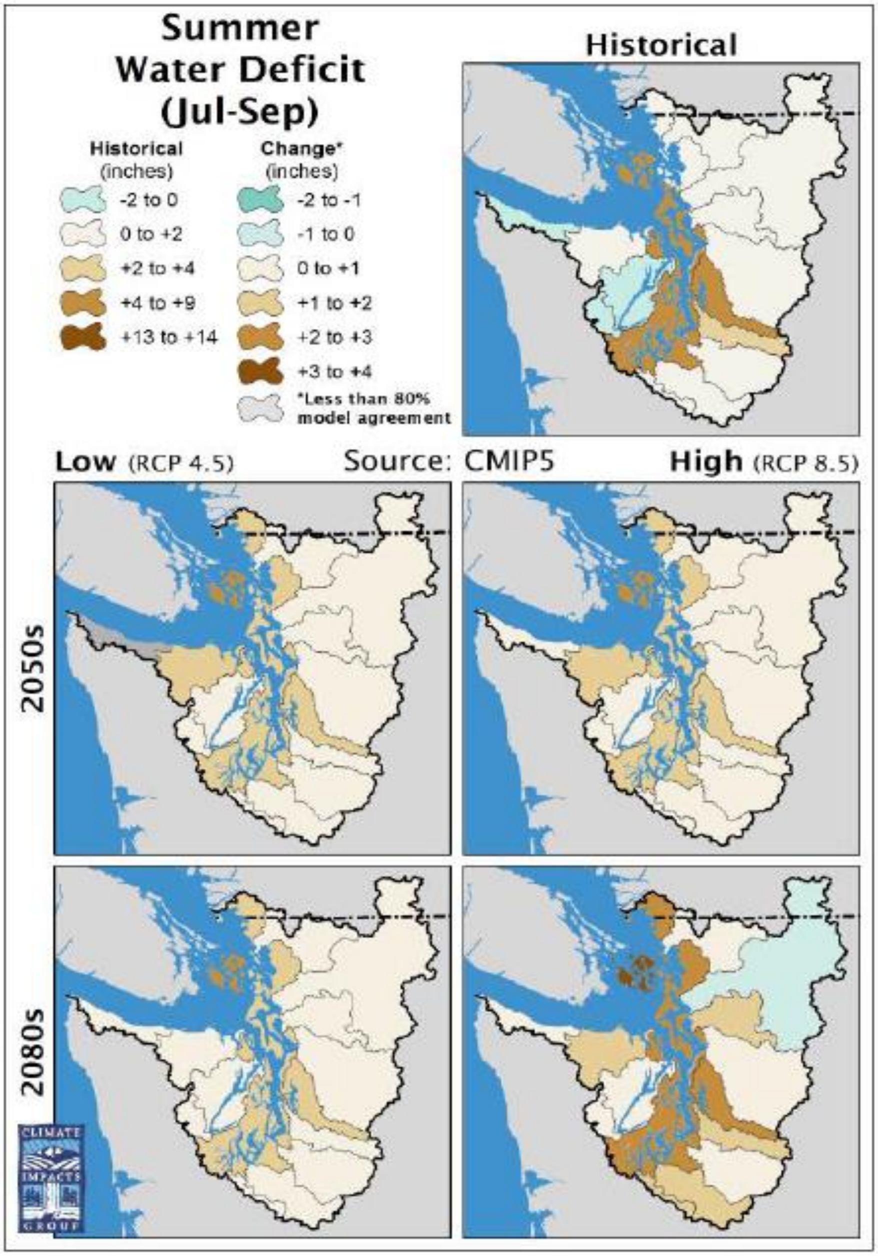


Figure 22: Predicted changes in Summer Water Deficit for Low (RCP 4.5) and High (RCP 8.5) IPCC emissions scenarios. Figure source: Mauger et al., 2015. Figure created by Robert Norheim, CIG, based on the CMIP5 projections used in the IPCC 2013 report. Data source: Mote et al 2015.

FLOOD RISKS AND STORM SURGE

RIVERS

Changes in streamflow, combined with intensifying heavy rain events and increased precipitation falling as rain, are likely to increase flood risk along river systems.

The highest river flows are expected to increase +18 to +55 percent, on average, for watersheds throughout the Salish Sea region, including the Samish and Skagit watersheds by the 2080s (2070-2099) relative to the period from 1970 to 1999 (Mauger et al 2015). Because of the changes in precipitation patterns, existing dams are not anticipated to reduce the future flood risk substantially, as most of the flow associated with floods originates below the dams (Skagit Climate Science Consortium 2015).

Projections suggest that peak flows during a 100-year flood event will increase throughout the watersheds draining to the Salish Sea. The increase is projected to be greatest in the Skagit watershed (Figure 23 and Table 18), where under a High IPCC emissions scenario, the streamflow associated with a 100-year flood event is projected to increase on average by 147 percent by the 2080s (2070-2099, relative to 1970-1999).

Table 18: Predicted changes in river-associated flooding, based on Moderate or High emissions scenario (Mauger et al 2015; Hamman et al 2016).

Secondary Impact	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Streamflow associated with 100-year Flood (Moderate)	Skagit: +42% Samish: +23%	Skagit: +4 to 86% Samish: -9 to +60%
Streamflow volume associated with 100-year Flood (High)	Skagit: +147% Samish: +60%	N/A N/A
Size of 100-year flood area (High)	Skagit: +74%	N/A

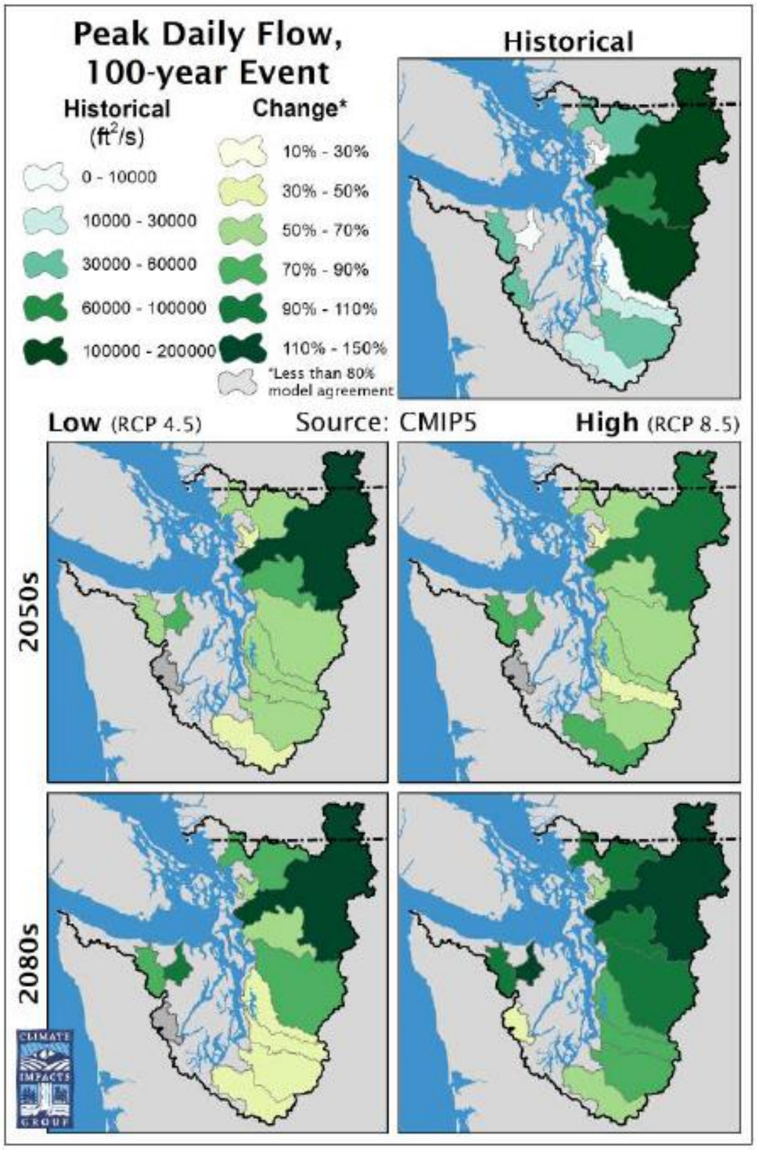


Figure 23: Predicted changes in Peak Daily Flow, 100-year flow, for Low (RCP 4.5) and High (RCP 8.5) IPCC emissions scenarios. Figure source: Mauger et al., 2015. Figure created by Robert Norheim, CIG, based on the CMIP5 projections used in the IPCC 2013 report. Data source: Mote et al 2015.

These projections may underestimate actual flood risk threats, particularly for coastal communities that also must contend with the impacts of sea level rise. Higher sea levels can increase the risk of flooding along tidally influenced rivers, such as the Skagit River, by increasing the height of tides pushing upstream against the downstream flow of a river - when a river flood meets this increased height, it can cause extreme flooding. Further contributing to flood risk, the highest tides of the year coincide with the seasons of strongest storms and the biggest river floods.

When this additional consideration was taken into account, streamflow projections for the Skagit River during a 100-year storm event were increased to +74 percent, on average, by the 2080s (2070-2099, relative to 1970-1999) (Hamman et al 2016).

The change in area impacted by potential flooding is depicted in Figure 24.

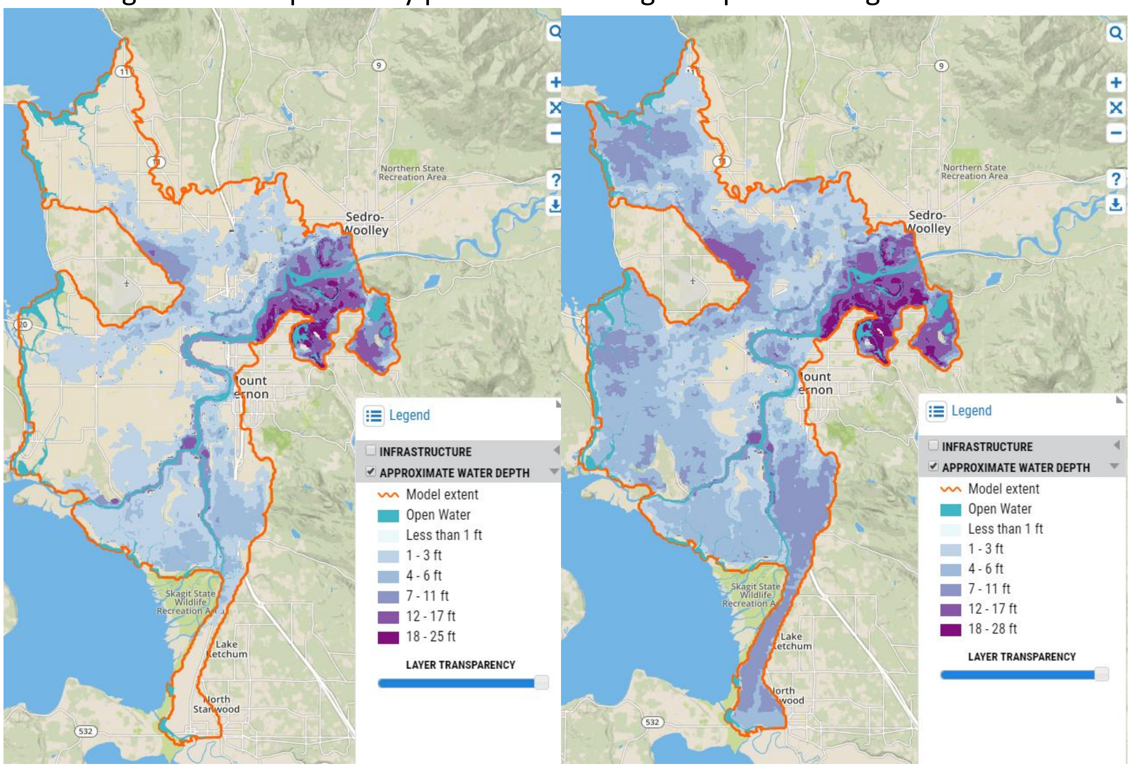


Figure 24: Current and future (2080s) extent of projected 100-year floodplain in the Skagit Valley, based on estimated sea level rise of 29-inches and showing levees intact. Source: Skagit Climate Science Consortium.

Flooding has the potential to not only impact infrastructure and homes, but also habitat areas. Increased frequency of extreme events such as flooding, debris flows, and landslides may alter habitats and cause local extinctions of aquatic species.

COASTAL AREAS

Rising sea levels can combine with storm surges caused by wind, waves, and changes in barometric pressure, exacerbating coastal flooding impacts. As a result, higher sea levels could allow storm surges to reach new areas, causing more frequent inundation and erosion. It is therefore predicted that sea level rise will cause winter storms and king tides to have a greater impact.

For example, what is now a 100-year coastal storm event, having a 1 percent annual chance of occurring, is predicted to have a higher probability of occurring by 2100, turning a 1-in-100-year flood event into an annual event (Skagit Climate Science Consortium 2015; Mauger et al 2015).

Table 19: Predicted changes in coastal storm frequency, based on High emissions scenario (Mauger et al 2015).

Secondary Impact	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Coastal Storm Frequency	From 100-year to annual event	N/A

Rising sea levels increase the risk of flood, as depicted in Figure 25, which shows that by 2080 there is estimated to be a 100 percent likelihood of a flood of 5 feet or more above current high tide level, if sea levels were to rise by approximately 3 feet.

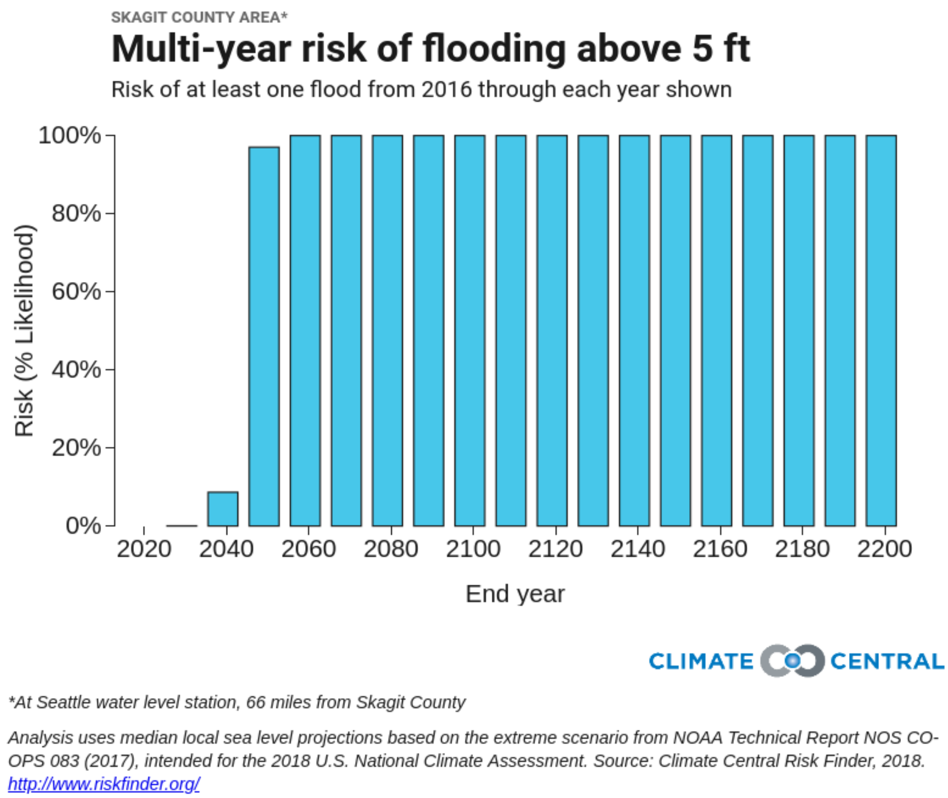


Figure 25: Probability of flood of 5 feet or more above current high tide level between Years 2020 and 2200 (Climate Central 2017).

Climate Central has developed a Risk Finder tool to estimate impacts from sea level rise, coastal flooding, or both. Based on this tool, the following resources and assets are projected to be impacted in a 5-foot flood scenario:

Table 20: Predicted coastal risks for Skagit and San Juan counties based on flood of 5-feet above current high tide level (Climate Central 2017).

Resource/Asset	Skagit County Total Exposure	San Juan County Total Exposure
Acres of land	41,600	7,680
Population	2,931	324
High social vulnerability	130	0
Housing Units	1,587	626
Property ($ billions)	1	0.4
Road miles	120	53
EPA-listed sites (contamination risk)	27	2
Schools	5	0

Figure 26 depicts estimated property loss from a 5-foot flood. Skagit County is third out of all counties in Washington for total exposure of homes on land below 4 feet. Skagit County is in the top half if ranked by its percentage of homes exposed, and it is second if all Counties are ranked by exposure after excluding areas that appear isolated or protected (Climate Central 2017).[11]

[11] Climate Central. (2017). *Surging Seas: Sea Level Rise Analysis.* http://sealevel.climatecentral.org/

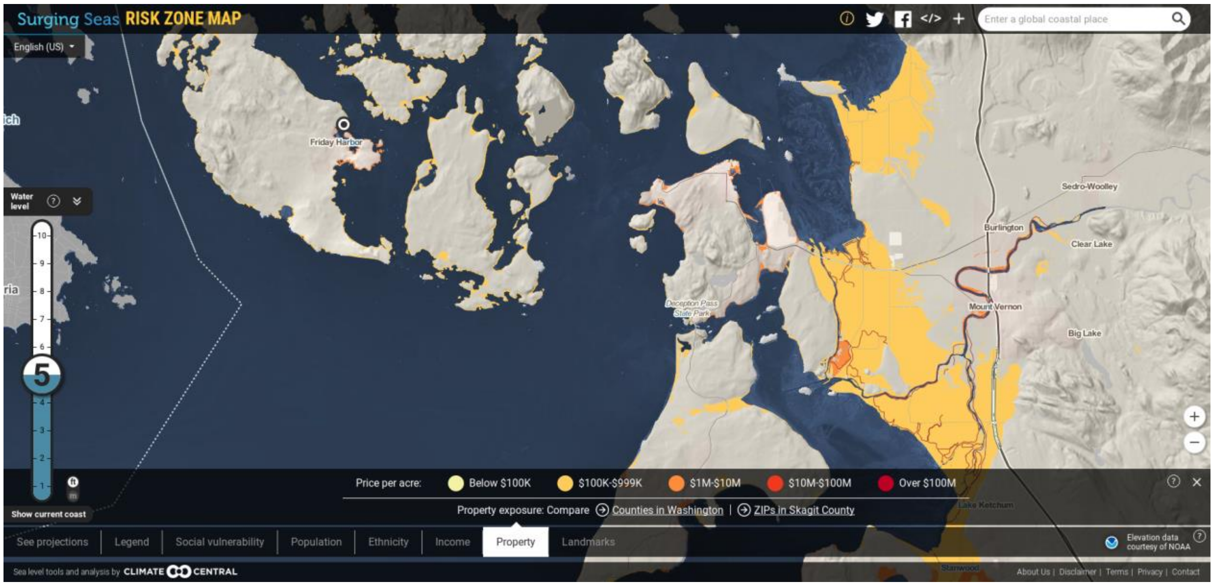


Figure 26: Visualization of Skagit County property at risk from a flood of 5-feet above current high tide level (Climate Central 2017).[12]

WATER QUALITY

GROUNDWATER

Saltwater intrusion is already a concern in parts of the Samish Traditional Territory, particularly in San Juan and Island counties. Guemes Island has experienced significant seawater intrusion along its northern coast and in limited areas of its southern coast. Elevated sea levels, combined with low summer stream flows, both increase the likelihood of saltwater intrusion into groundwater sources (Mauger et al 2015), but there are no specific projections that quantify this change.

In addition, shallow groundwater aquifers provide an important input into streams; reductions in groundwater levels as a result of decreased precipitation can lead to large reductions in streamflow, and vice-versa. Further, the interface between streams and groundwater is an important site for pollution removal by microorganisms. Their activity will change in response to increased temperature and increased or decreased streamflow as climate changes, and this is predicted to affect water quality (Mauger et al 2015). Siemann and Whitely Binder (2017) note that in areas where groundwater storage is limited, such as Orcas Island, meeting summer low flow targets is expected to become increasingly difficult and many streams that are currently perennial are likely to go seasonally dry.

[12] Climate Central. (2017). *Surging Seas: Sea Level Rise Analysis.* http://sealevel.climatecentral.org/

FRESHWATER

Watersheds within the Traditional Territories are already stressed by several factors. Figure 27 identifies freshwater systems in the Samish Traditional Territory that are currently stressed by a range of factors.

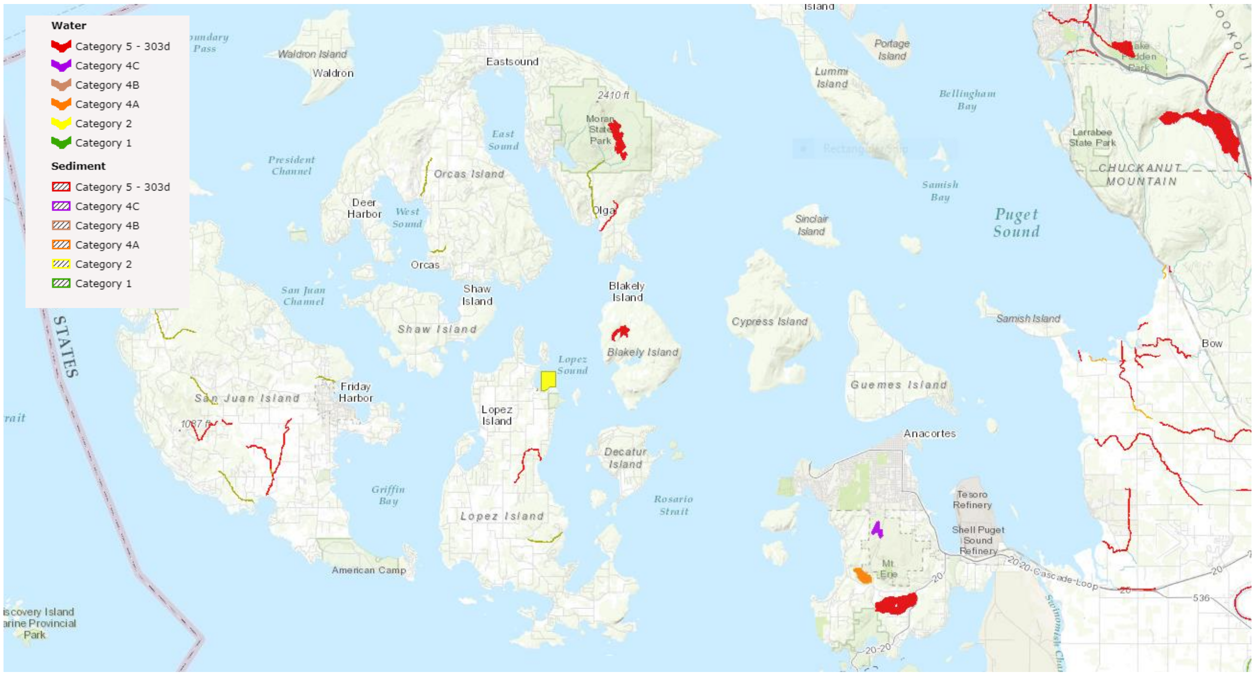


Figure 27: Freshwater or sediments that either have been identified as a "Water of Concern" (Category 2) or a "Polluted Water" (Category 4 and 5).

The *Puget Sound Vital Signs*, as set of monitoring measures used to gauge the health of the Puget Sound, contains information on trends in water quality. For freshwater quality, the *Vital Signs* has created a water quality index that combines eight measures of water quality (dissolved oxygen, pH, temperature, fecal coliform bacteria, nitrogen, phosphorous, suspended sediments, and turbidity). Both the Skagit and Samish rivers have monitoring stations with long-term records enabling calculation of the water quality index. Table 21 overviews the water quality index for these rivers.

Table 21: Water Quality Index for Samish and Skagit Rivers, based on records from 1995-2015 (DOE 2017).

Stream	Water Quality	Measure of Concern
Samish	Moderate, showing no significant change over time	Nitrogen
Skagit	Moderate, showing no significant change over time	Suspended solids

As part of Salmon Recovery efforts in the Puget Sound, scientists have also evaluated the level of impact from different stressors in freshwater watersheds and marine basins (McManus et al

2014). Table 22 identifies the top 5 current stressors impacting the San Juan and Skagit-Samish Watersheds, as evaluated through this process. In this context, stressors are the human activities or natural processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of ecosystems. Geographic information on stressors within the region are combined with an assessment of the intrinsic vulnerability of each watershed to determine relative potential impact to specific watersheds.

Table 22: Top 5 Current Stressors with greatest Potential Impact to Freshwater Systems in San Juan and Skagit Watershed (in order of predicted impact). Source: McManus et al 2014.

Stressor	Description
San Juan Watershed	
Non-point source conventional water pollutants	Presence or loading of nutrients, sediment, turbidity and oxygen demanding substances from non-point sources. Sources of this stressor include activities that generate wastewater that is discharged from municipal and industrial sewers and treatment plants. Stress from non-point sources and temperature changes are evaluated separately.
Non-point source, persistent toxic chemicals in aquatic systems	Presence or loading of persistent toxics from non-point sources, such as runoff from developed areas and roads, including from historic (legacy) sources and small (less than 10 gallons) spill events. Sources of this stressor include activities that contribute pollutants to surface water runoff, including that discharged through stormwater conveyance systems.
Altered low flows from withdrawals	Reduction of low flows in surface waters related to water withdrawals for human use and consumption.
Conversion of land cover for transportation & utilities	Conversion of land cover to one dominated by transportation and service corridors. This stressor has to do with the reduction in extent and quality of habitat due to conversion, including conversion by dredging.
Altered peak flows from land cover change	Reduction of low flows in surface waters related to changes in land cover and the associated surface hardening and changes in hydrology.
Skagit-Samish Watershed	
Conversion of land cover for natural resource production	Conversion of land cover to one dominated by natural resource production such as through agriculture and timber production in terrestrial environments and aquaculture in marine and nearshore environments. This stressor has to do with the reduction in extent and quality of habitat due to conversion.
Conversion of land cover for transportation & utilities	Conversion of land cover to one dominated by transportation and service corridors. This stressor has to do with the

	reduction in extent and quality of habitat due to conversion, including conversion by dredging.
Non-point source conventional water pollutants	Presence or loading of nutrients, sediment, turbidity and oxygen demanding substances from non-point sources. Sources of this stressor include activities that contribute pollutants, including that discharged through stormwater conveyance systems.
Timber harvest	Removal of timber for human use.
Non-point source, persistent toxic chemicals in aquatic systems	Presence or loading of persistent toxics from non-point sources, such as runoff from developed areas and roads, including from historic (legacy) sources and small (less than 10 gallons) spill events. Sources of this stressor include activities that contribute pollutants to surface water runoff, including that discharged through stormwater conveyance systems.

Other existing stressors of concern in the Skagit-Samish watershed include shoreline hardening; shading of shallow water; other structural barriers to water, sediment, and debris flow; point source and non-point source persistent toxic chemicals in aquatic systems; and point-source conventional water pollutants. In the San Juan watershed, The San Juan watershed dams as fish passage barriers is also an existing stressor of concern.

Climate change will likely exacerbate stressors that are already degrading the quality of streams and waterways. In evaluating the potential future impact of climate change as part of Puget Sound Salmon Recovery Efforts, McManus et al (2014) identified changes in air temperatures and precipitation amounts and patterns to be the most significant future climate-related stressors within both watersheds. Changes in air temperatures is anticipated to impact terrestrial species in these watersheds, and act as a driver of other stressors (see Air Temperature section above).

Changes in precipitation amounts and patterns is predicted to impact terrestrial systems and species. In addition, this driver causes changes in hydrology that are predicted to have significant secondary impacts to a variety of systems. For example, runoff from more frequent and intense extreme precipitation events will result in increased introduction of sediments, nutrients and pathogens. This can increase the incidence of toxic algal blooms, with corresponding impacts to water quality, habitat and human health.

Conversely, lower runoff in summer could mean less dilution of stream waters, resulting in more concentrated nutrient and bacteria loads and resulting impacts to water quality, habitat, and human health. In addition, lower summer precipitation combined with warmer summer temperatures will stress streamside vegetation, impacting stream cover and temperatures. Lower-elevation, downstream waterways with slower and wider characteristics will be most affected by increased temperatures, and the amount of time these and other rivers exceed thermal thresholds will likely lengthen, as addressed in more detail above.

For these reasons, a preliminary climate assessment of the Puget Sound identified freshwater quality as a high risk under changing climate conditions (Siemann and Whitely Binder 2017), through impacts will likely vary by location depending on the current health of the system.

MARINE WATERS

The marine basin in which the Traditional Territories are situated also are stressed by several factors. Figure 28 identifies specific areas within the marine basin that are currently stressed by a range of factors.

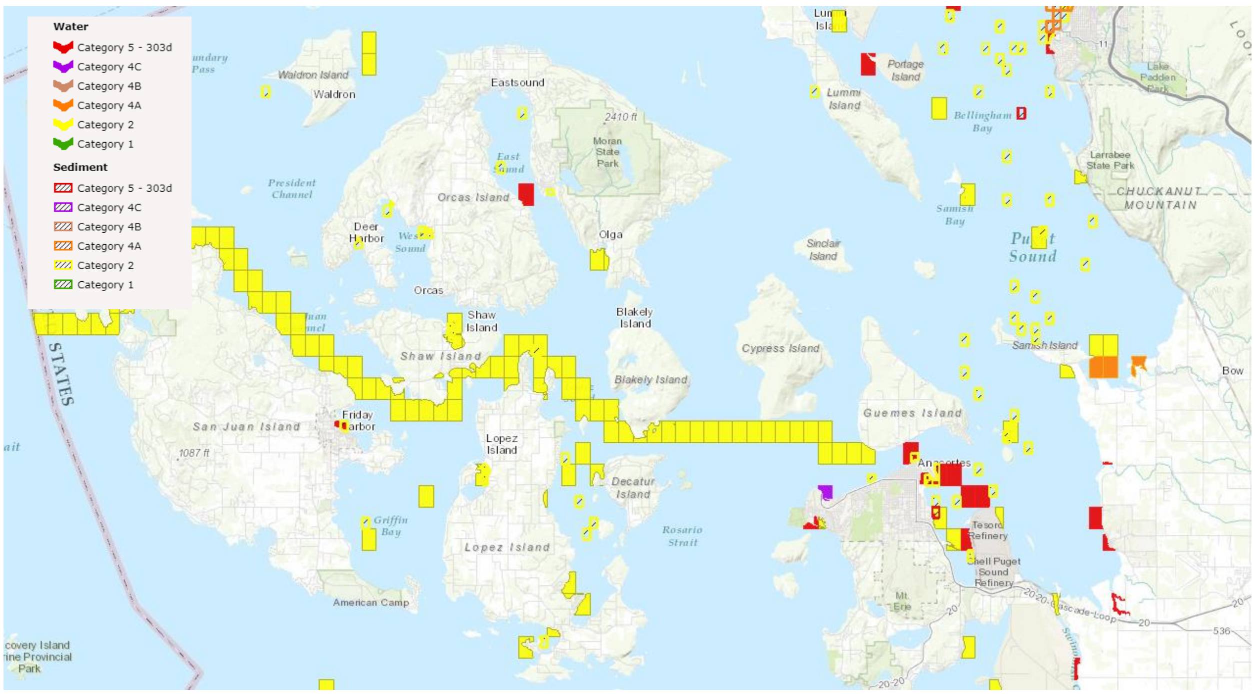


Figure 28: Marine water or sediments that either have been identified as a "Water of Concern" (Category 2) or a "Polluted Water" (Category 4 and 5).

Marine water quality refers to many aspects of water such as temperature, salinity, oxygen, nutrient levels, algae biomass, and pH. Marine water quality in the Salish Sea is affected by many varied factors including weather, climate and natural circulation patterns, inflow from rivers and streams, discharges from wastewater treatment plants and industries, offshore ocean conditions, erosion and storm-water runoff, ground water, and other pollution.

The *Puget Sound Vital Signs*, as set of monitoring measures used to gauge the health of the Puget Sound, contains information on trends in marine water quality. For marine water quality, the *Vital Signs* has created a water quality index that combines information on four major components that affect eutrophication: (1) Ambient nutrient concentration, (2) estuarine Enrichment of nutrients, (3) Impact of nutrients, and (4) Ventilation, the renewal of water and oxygen through estuarine processes. The Marine Water Condition Index has been getting worse over time, as reported by the *Vital Signs*.

There are multiple existing water quality concerns throughout the Salish Sea, including:

- Increasing water temperatures.
- Increasing salinity levels in summer, corresponding with low flows. The summer droughts led to more vertical mixing but slower overall flushing, which can amplify exposure to contaminants and pollutants.
- Changes to patterns of mixing and flushing, which can influence dissolved oxygen and nutrient levels.
- Increases in the frequency and severity of harmful algal blooms (HABs), which can lower oxygen levels and introduce toxins that enter the food web.
- Ocean acidification.
- Intensification of nitrogen inputs from surface waters during low flows. Combined with higher than normal temperatures, this has resulted in a decline in water quality.

As part of Salmon Recovery efforts in the Puget Sound, scientists have also evaluated the level of impact from different stressors in marine basins (McManus et al 2014). Table 23 identifies the top 5 current stressors impacting the San Juan Island/Georgia Strait Basin, as evaluated through this process. In this context, stressors are the human activities or natural processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of ecosystems. Geographic information on stressors within the region are combined with an assessment of the intrinsic vulnerability of each watershed to determine relative potential impact to specific marine basins.

Table 23: Top 5 Current Stressors with greatest Potential Impact to Marine Waters in the San Juan Island/Georgia Strait Basin (in order of predicted impact). Source: McManus et al 2014.

Stressor	Description
Conversion of land cover for transportation & utilities	Conversion of land cover to one dominated by transportation and service corridors. This stressor has to do with the reduction in extent and quality of habitat due to conversion, including conversion by dredging.
Conversion of land cover for natural resource production	Conversion of land cover to one dominated by natural resource production such as through agriculture and timber production in terrestrial environments and aquaculture in marine and nearshore environments. This stressor has to do with the reduction in extent and quality of habitat due to conversion.

Species disturbance – marine	Alteration in the feeding, breeding, or resting behaviors of marine birds, fish, or other aquatic species due to human presence or activities (e.g., recreation, vessel traffic, military exercises) or artifacts and debris associated with activities (not including pollution or derelict fishing gear).
Derelict fishing gear	Mortality associated with entanglement in abandoned nets and other fishing gear.
Non-point source, persistent toxic chemicals in aquatic systems	Presence or loading of persistent toxics from non-point sources, such as runoff from developed areas and roads, including from historic (legacy) sources and small (less than 10 gallons) spill events. Sources of this stressor include activities that contribute pollutants to surface water runoff, including that discharged through stormwater conveyance systems.

Climate change will likely exacerbate stressors that are already degrading the quality of marine waters. In evaluating the potential future impact of climate change as part of Puget Sound Salmon Recovery Efforts, McManus et al (2014) identified changing ocean conditions to be the most significant future climate-related stressor within the San Juan Islands and Georgia Strait Basin. This includes water temperature, patterns and magnitude of upwelling events, nutrient and oxygen levels, and decrease in pH, addressed more fully in the Changing Salish Sea section above.

A preliminary climate assessment of the Puget Sound identified marine water quality as a high risk under changing climate conditions (Siemann and Whitely Binder 2017). More intense heavy rain events are expected to increase runoff and contribute to more pollutant and nutrient runoff to marine waters. Harmful algal blooms are expected to increase in frequency and extent as air and marine water temperatures increase. Marine waters are expected to become more acidic, and harmful algal blooms may become more toxic with increasing ocean acidification. Increased residence time of water in Puget Sound could also amplify the effects of nutrients and pollutants on water quality.

Marine sediment water quality was also identified as being at high risk (Siemann and Whitely Binder 2017). Increases in the toxicity of runoff is a concern, as well as the potential failure of stormwater and water treatment systems under changing climate conditions. Sea level rise and the potential for new disturbance of coastal brownfield sites is also a concern. In addition, higher temperatures can increase salinity, enhancing toxics entering the marine system. These potential impacts are likely to vary in extent and magnitude based on location-specific factors.

EROSION AND LANDSLIDE RISKS

LANDSLIDE RISK

The region presently contains areas that are susceptible to landslide or erosion risks (Figure 29 and Figure 30). As the patterns and timing of precipitation and streamflow change, the risk of landslides and erosion in winter and spring seasons is predicted to increase, subsequently increasing the amount of sediment that is transported downstream. Several other factors can combine with these processes to increase erosion and landslide risk, including: higher air temperatures, which breakdown soil; changes in precipitation patterns, which can increase winter soil moisture and expose areas previously protected by snowpack to erosion; increased risk of wildfire and other threats to forest health; and other changes the land cover or land use (Mauger et al 2015). In addition, higher streamflows could undercut the banks of rivers, making steep slopes more vulnerable to failure. Sea level rise could have similar effects on steep bluffs along marine shorelines.

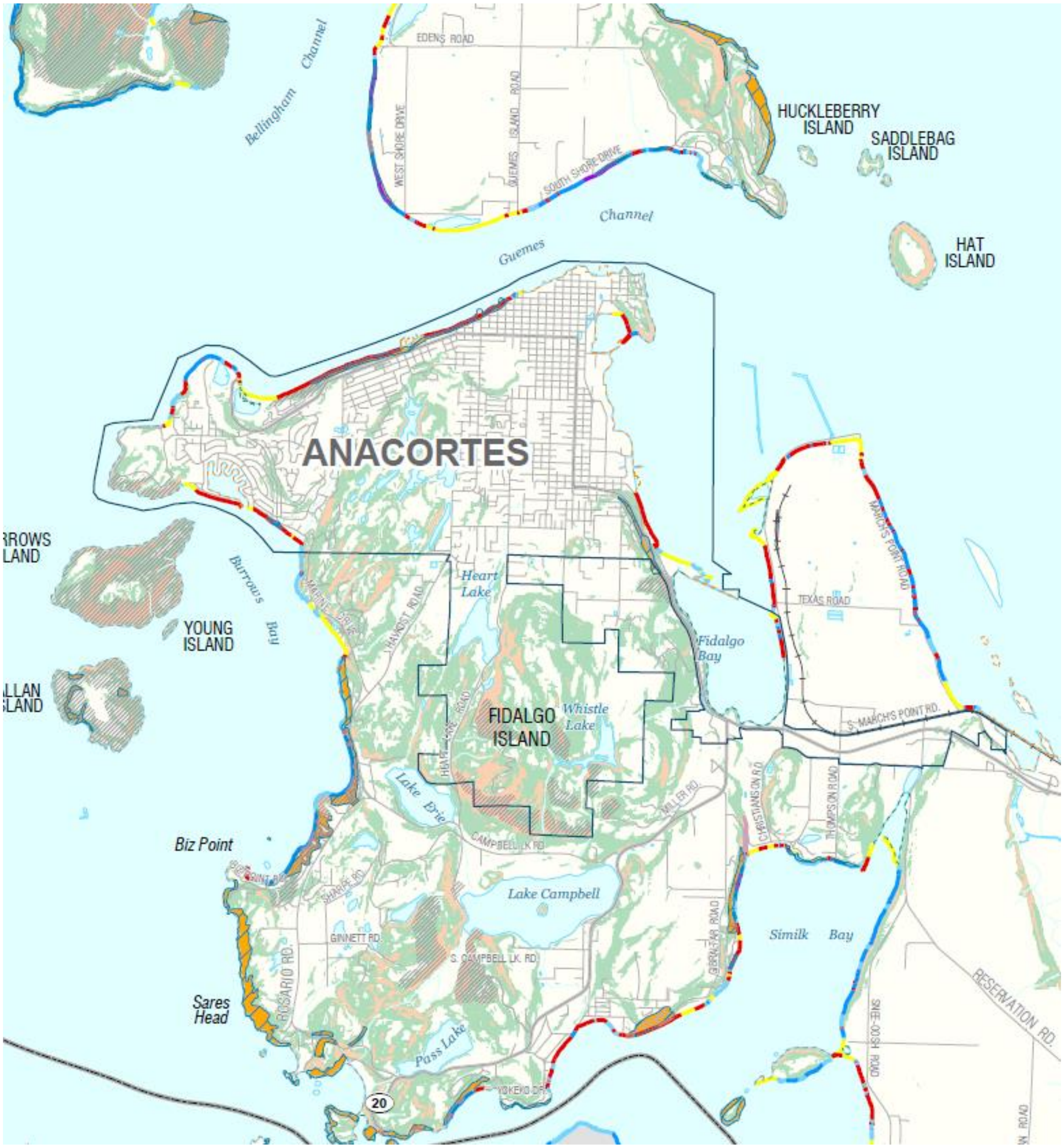


Figure 29: Potential Landslide and Erosion Areas, Anacortes and surrounding area. (Note: Green areas depict 15-40 percent slope, brown areas depict +40 percent slope, hatched areas depict unstable slopes) ("Skagit County Potential Landslide and Erosion Areas" 2016).

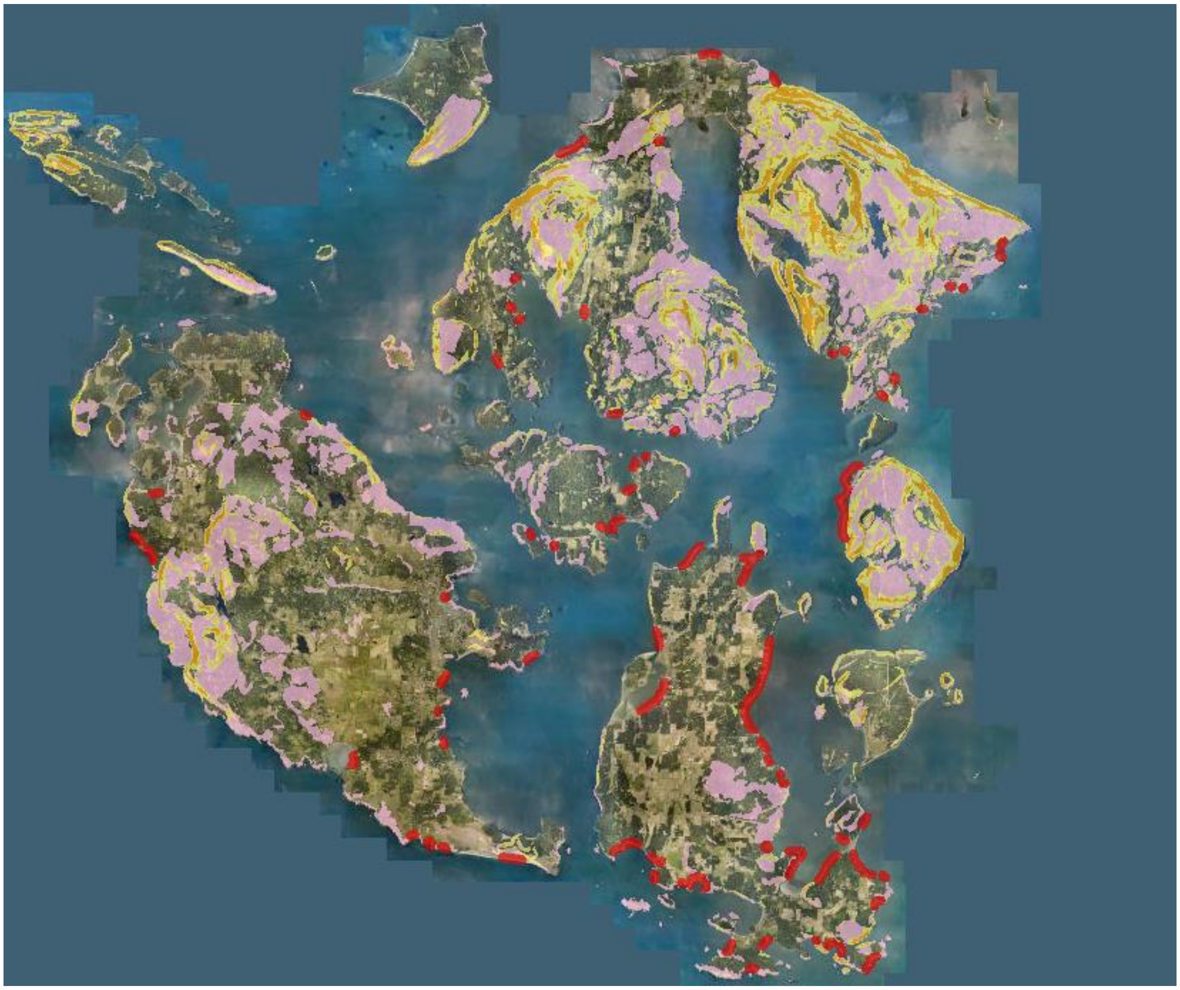


Figure 30: Potential Landslide and Erosion Areas, San Juan Islands. (Note: Red areas indicate unstable bluffs, orange indicate slopes greater than 50 percent, yellow indicates slopes greater than 15 percent, and purple indicate soils that are susceptible to erosion) ((San Juan County - Polaris Property Search, n.d.).

There are no current studies containing predictions of landslide hazard in the region under changing climate conditions; however, some of the indicators of landslide activity are predicted to change in ways that would increase the risks. Winter soil water content, an indicator of landslide risk, is projected to increase up to +35 percent along the slopes of the Cascade Mountains (Mauger et al 2015) (Table 24). In addition, heavier rainfall events that can trigger landslides, are projected to become more common and more intense (Table 24).

Table 24: Projected changes in landslide risk (Mauger et al 2015)

Secondary Impact	Change by 2040s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Winter soil water content	+35%	N/A
24-Hour Precipitation Amount	+22% increase in annual 99th percentile of 24-hour precipitation	+5 to +34% increase in annual 99th percentile of 24-hour precipitation
# Days with Heavy Rainfall Events	+5 days/year that region exceeds historical 99th percentile of 24-hour precipitation	+4 to 9 days/year that region exceeds historical 99th percentile of 24-hour precipitation

EROSION AND SEDIMENTATION IN RIVERS

Similarly, climate change is projected to lead to increased rates of erosion and sediment transport in winter and spring and lead to a decrease in summer. Similar processes (changes in precipitation patterns, glacier retreat, and changes in vegetation and wildfire risk) are anticipated to trigger these increases.

The Skagit River is currently the largest source of sediment loading to the southern extent of the Salish Sea, and sediment loading in this system is greater than +1.5 times the natural rate (Mauger et al 2015). Historic channelization and diking have eliminated many areas where the river historically deposited sediment; as a result, sediment is building up within the river as well as being deposited in marine waters.

Under future climate conditions, sediment loading is predicted to increase (Table 25 and Figure 31), further impairing water quality and decreasing habitat areas, increasing flood risk, and endangering infrastructure improvements.

Table 25: Predicted changes in sediment loading, based on Moderate emissions scenario (Lee et al 2016).

Secondary Impact	Change by 2080s (avg., relative to 1970 – 1999)	Range (min. to max., relative to 1970 – 1999)
Average annual sediment loading	Skagit: +149%	N/A
Peak winter sediment loading	Skagit: +376%	+140 to 730%
Summer sediment loading	Skagit: -76%	-90 to -60%

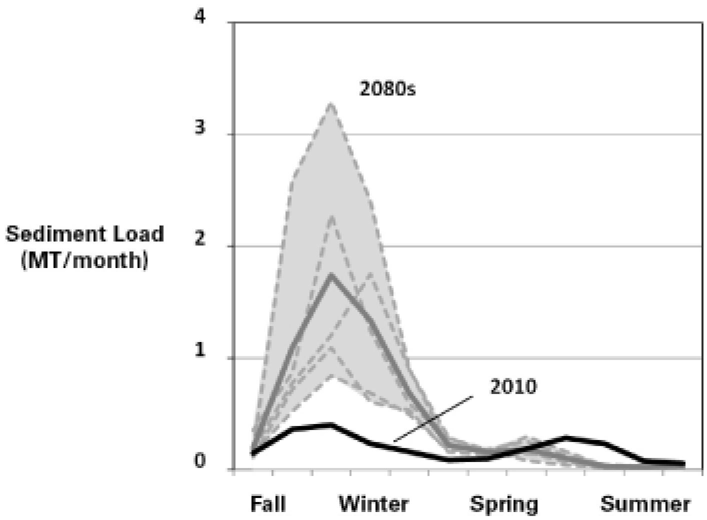


Figure 31: Increase in projected sediment loads (in millions of tons per month) Gray bands and dark gray line: Range of five future climate projections and mean of the future projections, respectively. (Skagit Climate Science Consortium 2015)

Increased sediment loading may reduce the capacity of stream channels, which can heighten flood risk. Increased streamflow runoff in winter and spring may also scour stream channels, removing important substrate and habitat features for salmon and other species. Increased turbidity and presence of suspended sediments can impact water quality for aquatic species.

EROSION AND SEDIMENTATION IN COASTAL AREAS

Coastal bluffs are also anticipated to be impacted by changes, including increasing sea levels and changing precipitation patterns. In San Juan County, historical mean erosion rates across feeder bluffs ranged from -0.26 to -0.93 ft./yr. and averaged -0.47 ft./yr. between 1960 and 2009 (MacLennan et al 2014). In their study of sea level rise in San Juan County area, MacLennan et al (2014) predicted that coastal bluffs in San Juan County will recede by -75 to – 100 ft. by 2100 (relative to 2000). This corresponds to a doubling, on average, of the current rate of recession (Table 26).

Table 26: Predicted change in feeder bluff erosion in San Juan County, under a High emissions scenario (MacLennan et al 2014)

Secondary Impact	Change by 2080s (avg., relative to 2000)
Coastal bluff erosion	Areas with short fetch (<5 miles exposure): Additional -0.68 ft./year than historical mean Areas with long fetch (>5 miles exposure): Additional -1.07 ft./year than historical mean

Changes in the pattern and quantity of sediment transport may have varying impacts to habitat and water quality in coastal areas. Scientists currently differ on whether estuary and coastal wetlands resilient to climate change. On one hand, increased sediment load may offset shallow water or estuary habitat lost because of sea level rise (Lee et al 2016). However, a combination of sea level rise and wave-generated erosion may overwhelm sediment supply, resulting in loss of tidal marshes (Hood et al 2017). With respect to water quality, increased turbidity and presence of suspended sediments can impact water quality for aquatic species and can disrupt eelgrass beds, which provide habitat for shrimp, crab and rockfish.

Further, if coastal erosion increases, property owners may react by building more bulkheads, which can deprive some beaches of needed sediment, accelerating erosion of the beach, and at the same time increase risk of landslide in other areas.

WILDFIRE RISK

Wildfire is a relatively uncommon process in Western Washington, but nonetheless there are areas with heightened risks that may have available fuel material or have been previously affected by fire (Figure 32 and Figure 33).

Under changing climate conditions, wildfire risk is projected to increase, including in areas previously unaffected by fire. Past fire records show a strong correlation between warm, dry summers and higher rates of area burned in the Pacific Northwest, as warm temperatures and low soil moisture and drought combine to increase fire risk. The 2015 fire season, the largest in recent records, was fueled by these conditions.

Research suggests that the area burned west of the Cascade crest could more than double by the late 21st century (Mauger et al 2015), though additional research is needed to understand how fire risk and severity may be impacted by changing climate conditions.

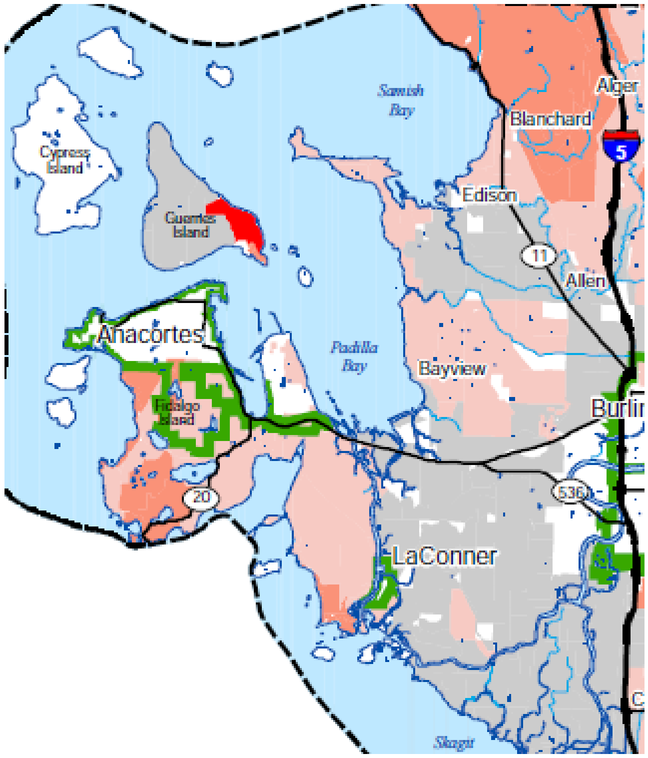


Figure 32: Existing areas of wildfire risk in western Skagit County. Red areas indicate extreme fire hazard, dark salmon indicate high risk, light salmon indicate moderate, and grey areas indicate no fire risk Source: Skagit County, based on NFPA 299 Risk Assessment. Fire risk west of the Cascades is predicted to more than double by the late 21st century. ("FIRE - 4 Skagit County Wildland-Urban Interface Fire Risk Assessment Based on NFPA 299 Risk Assessment" 2003).

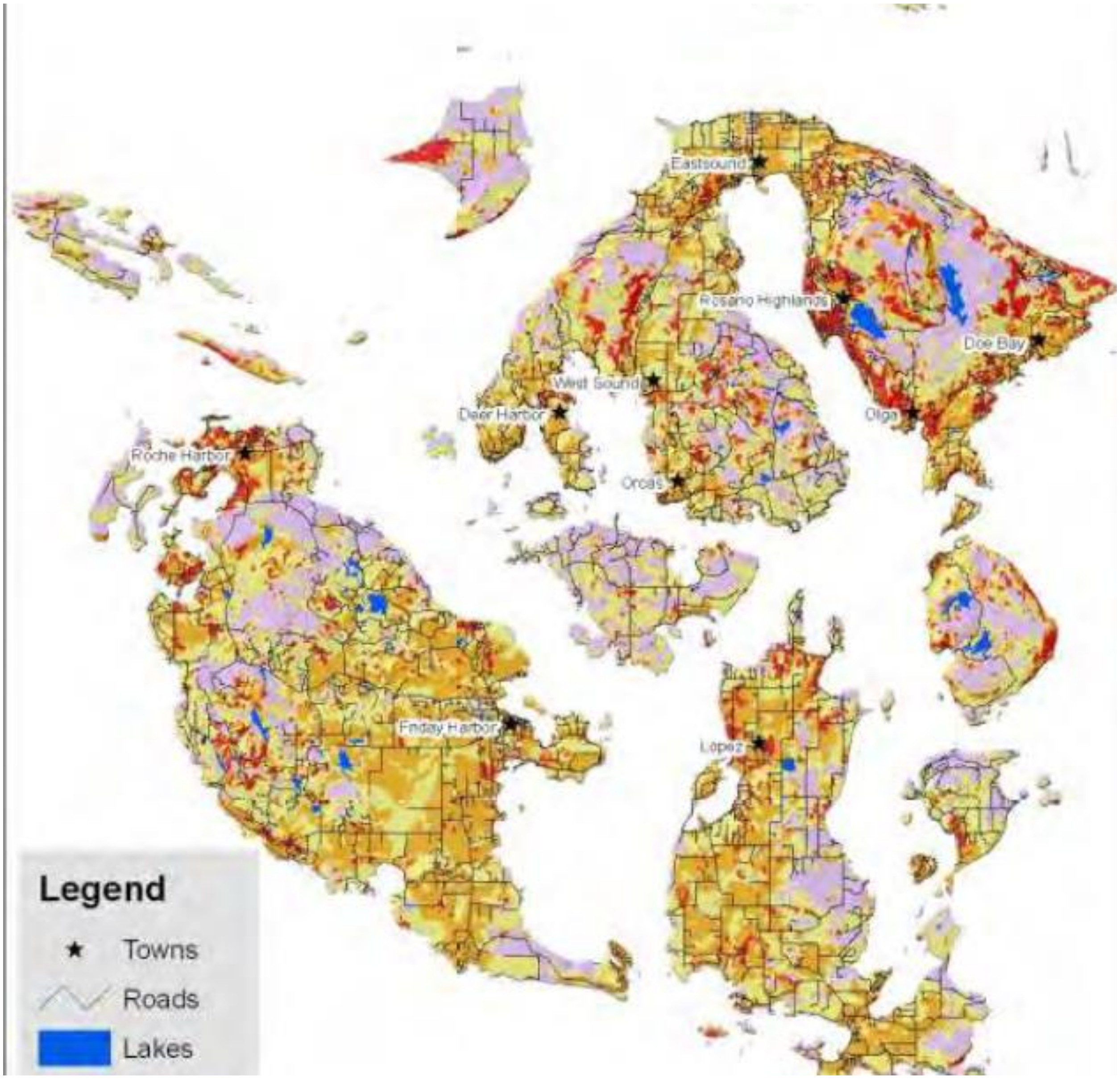


Figure 33: Existing areas of wildfire risk in San Juan County. Red areas indicate extreme fire hazard, orange indicate high risk, yellow indicate moderate, and pink areas indicate lower fire risk (San Juan County Community Wildfire Protection Plan steering committee 2012).

AIR QUALITY

In general, air quality in Whatcom and Skagit counties, along with Bellingham, ranks among the country's cleanest in terms of ozone and fine-particle pollution (American Lung Association 2017). However, there is regional variation, with some areas experiencing poorer air quality, particularly areas near high-volume transportation corridors and industrial activities.

Climate change impacts may adversely impact air quality within the region. Higher ozone levels are associated with higher temperatures. As a result, as temperatures increase, it may lead to increases in ground-level ozone pollution, particularly in urban areas, if ozone precursor emissions remain unchanged (Mauger et al 2015). Ground-level ozone (a key component of smog) is associated with a variety of health problems, including respiratory issues and asthma attacks ("2014 National Climate Assessment" 2014). Figure 34 depicts an increase in in ozone-related premature deaths in the Salish Sea region, associated with increasing temperatures and ozone levels.

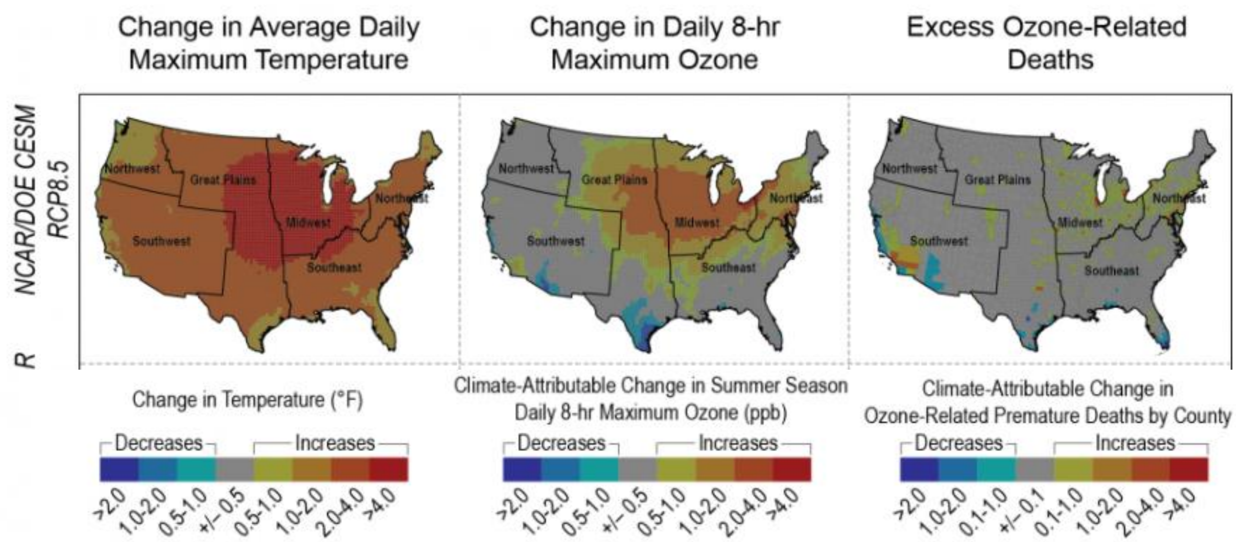


Figure 34: Projected Change in Temperature, Ozone, and Ozone-Related Premature Deaths in 2030 under a High Emissions Scenario (Source: "The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment" 2016).

In addition, heat waves are often associated with air stagnation, which can cause fine particulate matter (PM2.5) to accumulate (Mauger et al 2015). Dry conditions and wildfire activity can also lead to short-term increases in particulate air pollution. Historically, wildfire causes some of the worst air pollution days of the year in the Salish Sea region. Figure 35 depicts how air quality levels varied in 2015, when fires in British Columbia and eastern Washington impacted the region.

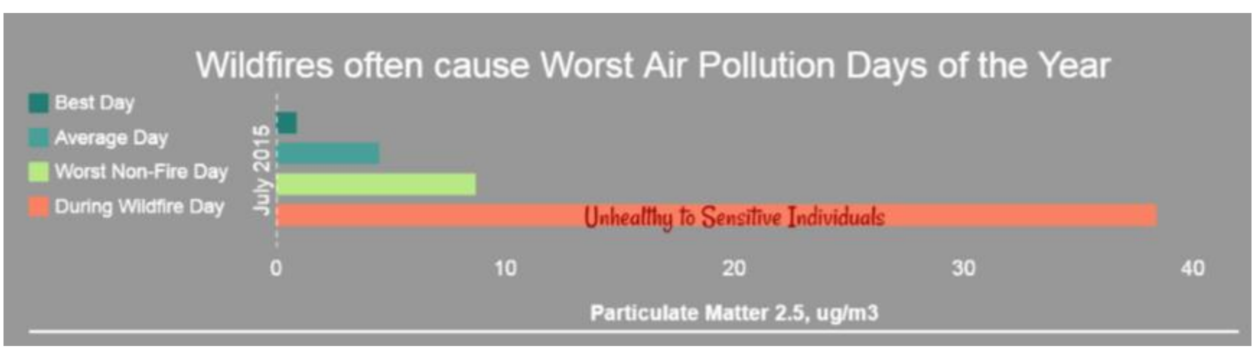


Figure 35: Difference in air quality on regular days versus wildfire days. Data source: Northwest Clean Air Agency.

Small particles that compose PM2.5 can impact lung and heart health. Numerous scientific studies have linked particle pollution exposure to a variety of problems ("Health and Environmental Effects of Particulate Matter (PM)" 2016), including:

- Premature death in people with heart or lung disease,
- Nonfatal heart attacks,
- Irregular heartbeat,
- Aggravated asthma,
- Decreased lung function, and
- Increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing.

Therefore, increase in wildfire frequency and severity will likely lead to an increase in adverse respiratory and cardiac health outcomes. For these reasons, a preliminary climate assessment of the Puget Sound identified air quality as a high risk under changing climate conditions (Siemann and Whitely Binder 2017).

In general, the region ranks low in terms of challenging places to live with allergies (both fall and spring as reported by Asthma and Allergy Foundation of America (2016)). Like air pollutants, there is also regional variation in allergen levels, depending upon topography, landscape and other factors. Increasing temperatures and levels of carbon dioxide enable some plants to increase pollen production, exacerbating allergies (Mauger et al 2015). In addition, due to phenological changes some trees are blooming sooner and, as a result, the pollen season is becoming increasingly longer. These changes are anticipated to lead to increases in asthma episodes and other allergic illnesses ("The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment" 2016).

INSECT, DISEASE AND INVASIVE SPECIES

Insect and disease response to climate change is likely to be species- and host-specific, making it difficult to generalize. However, recent climate has been related to more intense, frequent, or severe insect outbreaks as well as outbreaks in places where historical insect activity was low or unknown ("Climate Change in the Northwest Implications for Our Landscapes, Waters, and Communities" 2013). Some specific diseases and pathogens of concern in forested areas are predicted to be more prevalent, including: mountain pine beetle[13], spruce and other bark beetles, western spruce budworm, Swiss needle cast, sudden oak death, and *Armillaria* root disease ("Climate Change in the Northwest Implications for Our Landscapes, Waters, and Communities" 2013).

[13] Other research suggests that mountain pine beetles may not expand their range, as it becomes too warm to support outbreaks.

Other diseases already present in Washington that impact animals and birds include notoedric mange, which is a risk to western gray squirrel populations; West Nile virus; avian botulism, which occurs principally in waterfowl and other birds living in an aquatic environment; and hair loss syndrome, which causes hair loss, emaciation and often death in Columbian white-tailed deer (WDFW 2015). Other diseases of current concern include hoof disease in elk, avian influenza, and white nose syndrome in bats. It is not known how these diseases will be impacted by climate change.

Some diseases transmitted by food, water, and insects are likely to increase due to higher temperatures, heavier rainfall and more flooding, causing impacts to human health. Some infectious diseases of concern to human health include: tick-related diseases, mosquito-borne diseases, waterborne illnesses, harmful algal blooms, rodent-related diseases, and food-borne illnesses (Washington Department of Ecology 2012).

Invasive species already present in Washington with the potential for serious ecological impacts include: Japanese and giant knotweed, parrot feather, barred owls, bullfrogs, European green crab, cord grass (*Spartina*), Eurasian water milfoil, Scot's broom, and some species of non-native predatory fish. Some invasive species of concern in the Salish Sea include cordgrasses (*Spartina*), Japanese eelgrass, wireweed (*Sargassum muticum*), oyster drill, varnish or dark mahogany clam, European green crab, and the American bullfrog (WDFW 2015). Species with the potential to aggressively outcompete native species include zebra mussels and mitten crabs.

Climate change in some cases will increase the success of invasive species, and in other cases potentially decrease their success and make eradication more feasible. As an example, zebra mussels, whose habitat includes freshwater lakes and streams, may begin to inhabit higher altitude lakes but may begin to find some lower altitude areas in its current extent uninhabitable (U.S. EPA 2008).

Atlantic salmon net pens exist within the Samish Traditional Territory and the Salish Sea. A recent collapse of a net pen near Cypress Island has brought the issue of non-native finfish aquaculture and its impacts on native salmon to the forefront. Containment structures and anchoring for these facilities may be impacted by rising sea levels and storm surge, increasing the risk of future structural failures and unplanned releases of non-native Atlantic salmon that may outcompete native salmon for critical resources, such as prey and preferred habitat.

ECOSYSTEMS AND HABITATS

Climate is a major shaping force for vegetative communities that makeup different habitats. Droughts, wildfires, reduced snowpack, shifted flood timing, and heat stress can cause habitat loss or fragmentation and increase mortality of some species.

The Washington State Department of Fish and Wildlife (WDFW) has conducted a climate change vulnerability assessment using ecological systems as a framework for evaluating potential impacts (WDFW 2015). Figure 36 depicts ecosystems that have been identified by WDFW as being at high vulnerability[14] from the impacts of climate change and are also located within the Traditional Territory of the Samish Indian Nation, or in neighboring areas where species range may shift under future climate conditions.

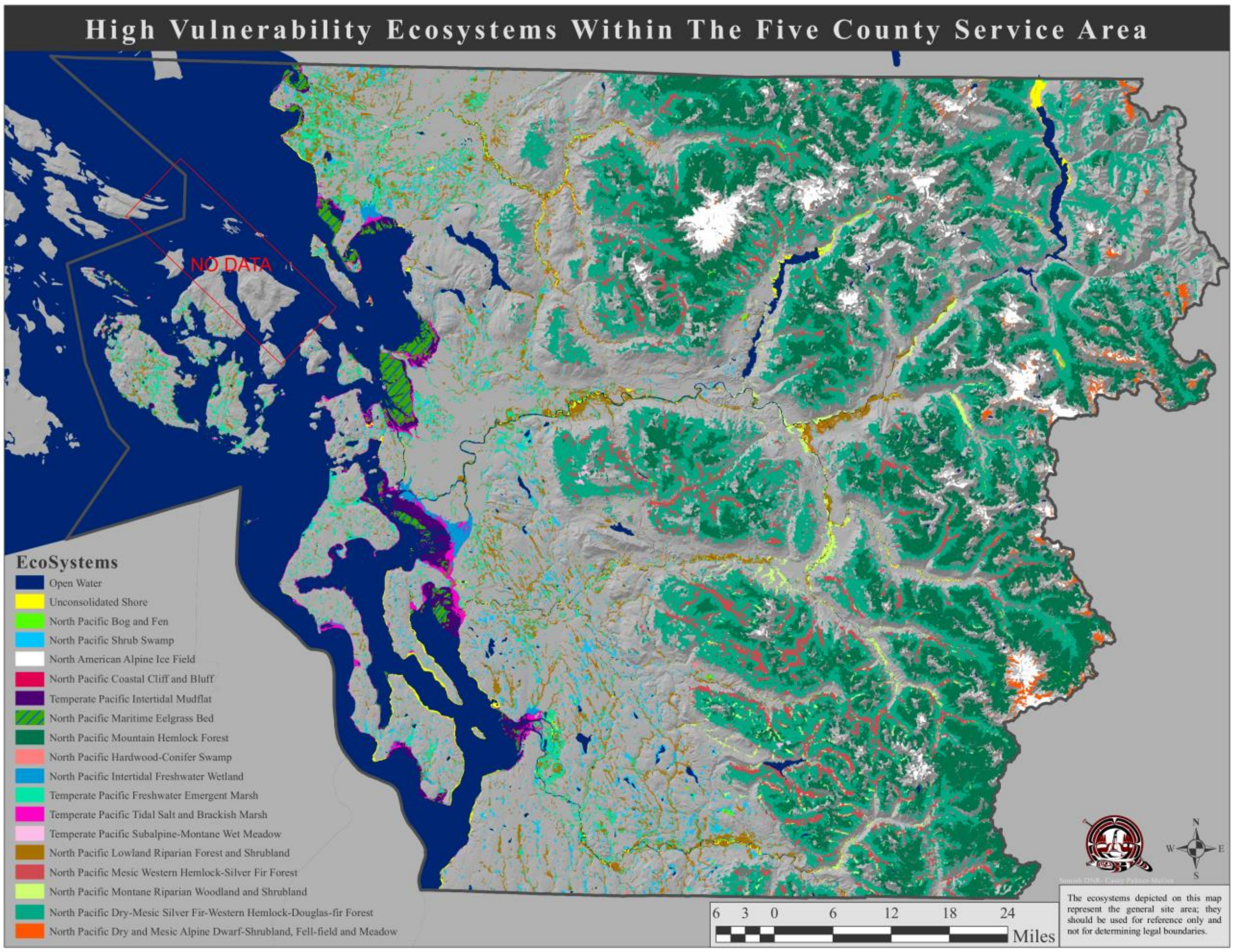


Figure 36: Ecosystems predicted to have High Vulnerability to Climate Change Impacts. Data Source: WA DNR.

The following describes these high vulnerability ecological systems in more detail.

[14] WDFW's analysis uses different levels of confidence in their assessment of risk and vulnerability, including high confidence and less than high confidence, as well as identifies some systems likely to be at high risk, but have not been specifically evaluated.

TERRESTRIAL ECOSYSTEMS

North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This system occurs above the tree line of high alpine areas in the Cascade Range area. It occurs on slopes and in depressions where snow lingers, the soil has become relatively stabilized, and the water supply is constant. Species with close association within these ecological systems are White-tailed Ptarmigan and Olympic Marmot.

Climate change, which may result in reduced snowpack and encroachment by trees and shrubs, is a major stressor.

North American Alpine Ice Field (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This system includes glaciers and perennial snow and ice features. Climate change is a major stressor to this system due to the decline of glaciers and reduction in snowpack.

North Pacific Montane Riparian Woodland and Shrubland (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This ecological system occurs throughout mountainous areas, on steep streams and narrow floodplains above foothills but below the alpine environment. This system is likely to be impacted by changes in hydrology, reduced snowpack and earlier snowmelt, drought and declining summer and spring stream flows and increasing winter flood frequency and volume. Plants within this system are likely to experience reduced seedling regeneration and tree growth and increased mortality from insects and more frequent fires.

Temperate Pacific Montane Wet Meadow (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This ecological system occurs in open wet depressions, basins and flats among montane and subalpine forests. They may have surface water for part of the year, but depths rarely exceed a few centimeters. Soils are mostly mineral and may show typical hydric soil characteristics, and shallow organic soils may occur as inclusions. This system is likely to be impacted by changes in hydrology, reduced snowpack and earlier snowmelt, drought and declining summer and spring stream flows.

North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This ecological system comprises much of the major lowland forests of western Washington, occurring throughout low-elevation western Washington, except on extremely dry or moist to very wet sites.

This system is likely to be impacted by changes in hydrology, reduced snowpack and earlier snowmelt, drought and declining summer and spring stream flows and increasing winter flood frequency and volume. These systems may also become more susceptible to damage from of insects, disease and fire.

North Pacific Mesic Western Hemlock-Silver Fir Forest (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This ecological system is found in mid-montane maritime climatic zones on the wettest portions of the North Cascades in Washington (north of Snoqualmie River). This system is likely to be impacted by changes in hydrology, reduced snowpack and earlier snowmelt, drought and declining summer and spring stream flows and increasing winter flood frequency and volume. These systems may also become more susceptible to damage from of insects, disease and fire.

North Pacific Mountain Hemlock Forest (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This ecological system comprises much of the major forests in subalpine elevations in the coastal mountains of western Washington.

This system is likely to be impacted by changes in hydrology, reduced snowpack and earlier snowmelt, drought and declining summer and spring stream flows and increasing winter flood frequency and volume. These systems may also become more susceptible to damage from of insects, disease and fire.

FRESHWATER ECOSYSTEMS

North Pacific Bog and Fen (in Figure 36)

The ecological system has been identified as having high vulnerability, and high confidence in the vulnerability ranking.

This is a wetland system that occurs in peatlands, generally at elevations less than 1500 feet, where annual precipitation ranges from 35-120 inches. This system is typically found in river valleys, around lakes and marshes, or on slopes. Species that may be associated with this habitat include the Olympic Mudminnow. This ecological system is already stressed by land use conversion activities (such as agriculture), as well as activities that have altered the natural hydrology (such as road building or channelization).

Climate change poses an additional stressor, as this system is sensitive to drier climate conditions that can lead to habitat conversion or range contraction, increased invasion of dry-adapted species. These conditions may present particularly in the summer season, which is likely to have decreased precipitation, less stored water in snowpack, and reduced water availability and recharge. In addition, a shift from snow to rain that enhances winter/spring flood risk may increase erosion.

North Pacific Hardwood-Conifer Swamp (in Figure 36)

The ecological system has been identified as having high vulnerability, and less than high confidence in the vulnerability ranking.

This ecological system is located predominately in coastal areas with glacial depressions, river valleys, at the edges of lakes and marshes, and on slopes where there are seeps. Examples of this system mainly occur on flat to gently sloping lowlands below 1500 feet elevation, though they are found in higher elevation forests when shallow soils occur over bedrock.

Species that may be closely associated with this habitat include the Oregon Spotted Frog. This ecological system is already stressed by land use conversion activities (such as forestry), as well as activities that have altered the natural hydrology (such as road building or channelization) and invasive species such as reed canary grass and Himalayan blackberry.

Climate change poses an additional stressor, as this system is generally adapted to high moisture levels, making them vulnerable to changes in hydrology, reduced snowpack and earlier snowmelt, drought, and altered streamflow. These areas may experience shifts to more drought-adapted vegetation. Drought may also exacerbate fire risk.

North Pacific Lowland Riparian Forest and Shrubland (in Figure 36)

The ecological system has been identified as having high vulnerability, and less than high confidence in the vulnerability ranking.

This system occurs along low-elevation, alluvial floodplains that are confined by valleys and inlets or lower terraces of rivers and streams.

Species that may be closely associated with this habitat include the Columbian White-tailed Deer, Cascade Torrent Salamander, and Oregon Spotted Frog. This ecological system is already stressed by previous attempts to manage water (e.g., dams, levees, diversions), land use conversion (forestry), and the spread of exotic and invasive plants such as reed canary grass and blackberry

Climate change poses an additional stressor, as this system is generally adapted to high moisture levels, making them vulnerable to changes in hydrology, reduced snowpack and earlier snowmelt, drought, and altered streamflow.

Temperate Pacific Freshwater Emergent Marsh (in Figure 36)

The ecological system has been identified as having high vulnerability, and less than high confidence in the vulnerability ranking.

This system is characterized by seasonally to permanently flooded wetlands found in depressions, along streams, and shorelines, generally in lowland areas. A consistent freshwater source is essential to the function of this system. Species that may be closely associated with this habitat include the Oregon Spotted Frog and Tiger Salamander. This ecological system is already stressed by roadway construction and development, as well as invasive species such as American bullfrogs and broadleaf cattails.

Climate change poses an additional stressor, potentially impacting the recharge of wetlands, leading to wetland drying. Sea level rise could introduce brackish or saltwater to these systems, resulting in conversion of this habitat to tidal flat, transitional marsh, or saltmarsh. In addition, species composition may change because of climate change impacts. Changes in winter precipitation type and timing, as well as earlier runoff, could positively (e.g., create side channels or additional habitat) or negatively (e.g., reduced opportunities for water storage and recharge, increased erosion) impact these habitats.

North Pacific Shrub Swamp (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This ecological system is characterized by deciduous broadleaf tall shrublands that are in depressions, around lakes or ponds, or river terraces where water tables fluctuate seasonally (mostly seasonally flooded regime) in areas that receive nutrient-rich waters.

This system is likely to be impacted by changes in hydrology, reduced snowpack and earlier snowmelt, drought and declining summer and spring stream flows and increasing winter flood frequency and volume. Drought periods may also exacerbate fire risk.

Open Water (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

Open freshwater systems are comprised of a variety of features including streams and rivers, potholes and small American Beaver ponds, to large lakes and reservoirs. All freshwater and anadromous fish as well as other aquatic species rely on open water for at least part of their life history.

This system is impacted by many existing stressors, including increasing temperatures, droughts, physical barriers, declining water quality, dredging and other forms of alterations, and alteration of typical processes. Climate change is predicted to exacerbate these existing stressors.

MARINE AND COASTAL ECOSYSTEMS

Coastal ecosystems are on the front-line of change, and are predicted to be a system that experiences early impacts from a changing climate. For example, warming temperatures are expected to impact these systems, since shallower waters such as bays, estuaries, and wetlands warm more quickly than deeper ocean waters (Washington Department of Fish and Wildlife, 2011). In addition, sea-level rise could inundate coastal habitats such as marshes, beaches, and tidal flats if these systems cannot shift upland quickly enough, or if habitats are prevented from doing so because of development or shoreline hardening, such as bulkheads (Washington Department of Fish and Wildlife, 2011).

North Pacific Intertidal Freshwater Wetland (in Figure 36)

The ecological system has been identified as having high vulnerability, and less than high confidence in the vulnerability ranking.

This ecological system is generally found in at outlets of large rivers, such as the Skagit River Delta. Species that may be closely associated with this habitat include the Columbian White-tailed deer and Peregrine falcon. This ecological system is already stressed by hydrological modifications, especially those that alter tidal exchange (e.g., jetties, dikes, and dams). Other stressors include historic urbanization, logging, filling and other activities in or near wetlands. Invasive weeds, such as reed canary grass, giant knotweed, and purple loosestrife have also degraded these wetlands.

Climate change poses an additional stressor, potentially impacting the recharge of wetlands, leading to wetland drying. In addition, species composition may change because of climate change impacts. Changes in winter precipitation type and timing, as well as earlier runoff, could positively (e.g., create side channels or additional habitat) or negatively (e.g., reduced opportunities for water storage and recharge, increased erosion) impact these habitats.

Intertidal freshwater wetlands are also vulnerable to rising sea levels and intrusion of brackish water that can lead to vegetation changes, increased eutrophication, and expansion of invasive plant species.

Temperate Pacific Tidal Salt and Brackish Marsh (in Figure 36)

The ecological system has been identified as having high vulnerability, and less than high confidence in the vulnerability ranking.

The ecological system occurs in large bays on the outer coast and around the waters of the Salish Sea. Occurrences are confined primarily to inter-tidal portions of estuaries, coastal lagoons and bays, and behind sand spits or other locations protected from wave action. Species that may be closely associated with this habitat include the Island Marble. Many stressors related to development, transportation and agriculture contribute threats to this ecological system.

Climate change poses an additional stressor. Changes in precipitation may lead to fluctuations in salinity levels (e.g., increased salinity with decreased precipitation), which could lead to shifts in vegetation composition. Increases in runoff that increase nutrient levels in basin could also threaten vegetation. Projected sea level rise represents a key climate stressor for tidal salt and brackish marshes, as it could lead to submergence of habitats and declines in vegetation unless they are able to migrate inwards through sediment accretion.

A study of several sites throughout Washington and Oregon, including Padilla Bay, concluded that under a High Emissions scenario, tidal marshes plant communities and available habitat will change in species and composition (Thorne et al 2015). The results indicate that by approximately 2100, sites in the northern portion of the Salish Sea will shift vegetation composition, from containing a mixture of low-, mid- and high-marsh to being comprised largely of unvegetated mudflat (Figure 37).

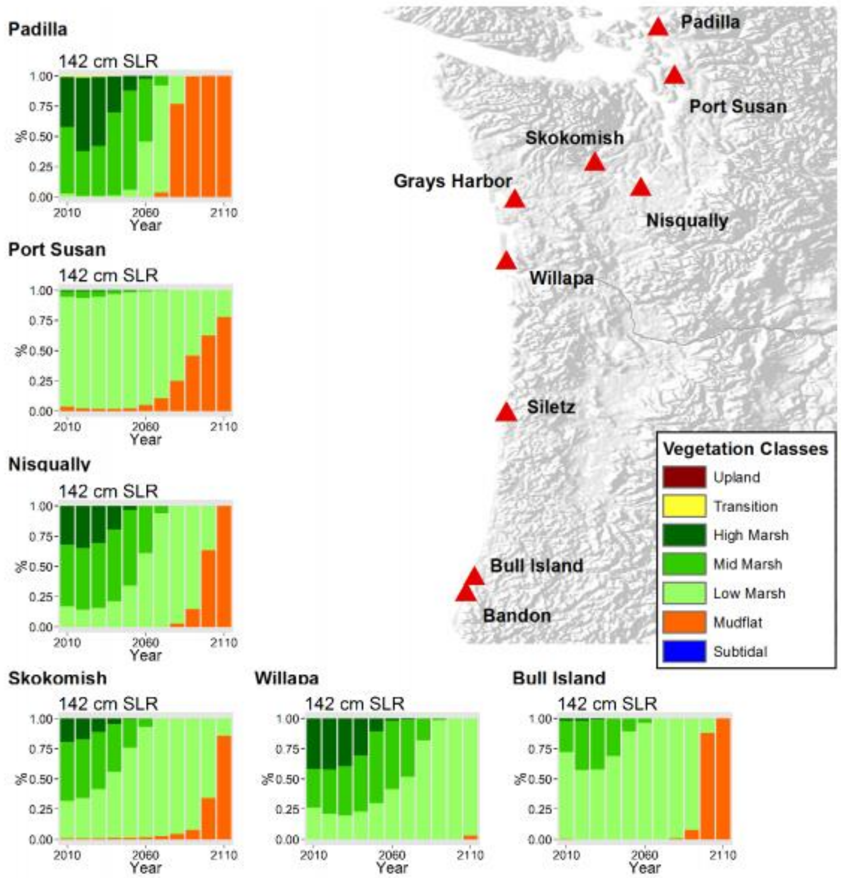


Figure 37: Projected changes to the relative abundance of marsh vegetation zones under a High Emissions scenario (Source: Thorne et al 2015).

Changes in tidal marsh composition may affect various wetland-dependent organisms. For example, loss of middle and high marsh habitat could have negative effects on terrestrial wildlife that less frequently use inundated tidal marsh for cover, foraging, and nesting. However, corresponding gains in low marsh and mudflat may increase habitat available for marine algae, estuarine fish, shellfish species, and foraging areas for migratory shorebirds, and waterfowl.

A preliminary climate assessment of the Puget Sound identified estuaries as being at high risk under changing climate conditions (Siemann and Whitely Binder 2017). This is due to many factors, including higher peak river flows shifting sediment deposition further outward and away from nearshore areas; sea level rise reducing habitat area and function and wave action and erosion (particularly in locations without a good supply of sediment or room to migrate upslope); and increasing water temperatures.

Unconsolidated Shore (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

Unconsolidated shore is a feature found in beaches and rivers with high energy waves, containing silt, sand or gravel and subject to inundation.

Sea-level rise is expected to increase erosion rates and coastal flooding of Washington’s beaches, causing the shoreline to migrate landward as waves break higher on the beach profile. This may in turn cause property owners to install shoreline armoring that may further deprive the beach of needed sediment. As a result, rising sea levels and shoreline armoring that limits the flow of sediment are the major climate change impacts anticipated in this system.

North Pacific Maritime Eelgrass Bed (in Figure 36)

These ecological systems are characterized by submerged vegetated systems dominated by the eelgrass. They are found along all coastal areas, but especially abundant in the northern portion of Puget Sound north of Everett.

Species that may be closely associated with this habitat include the Harlequin Duck and Western High Arctic Brant.

There is some debate about the risk of this system under changing climate conditions. WDFW (2015) identified this ecological system as likely to be at high risk, though it has not been specifically evaluated. However, a preliminary climate assessment of the Puget Sound identified eelgrass areas as being at low risk under changing climate conditions (Siemann and Whitely Binder 2017).

Eelgrass growth may benefit from an increase in CO_2, as it is currently CO_2-limited. Increasing sea levels and additional sediment deposition may benefit eelgrass growth, if turbidity does not become a problem and the eelgrass expansion is not limited by migration barriers such as bulkheads and other shoreline armoring.

However, eelgrass may be adversely impacted by increases in green algae, which may also be able to take advantage of higher water temperatures and more nutrients. Eelgrass could also be adversely impacted by pollutants, in particular nitrogen, which may increase under climate change, but further research is needed. Warmer temperatures could also dry and concentrate mineral salts to levels that are stressful or toxic to eelgrass (Washington Department of Fish and Wildlife, 2011).

Temperate Pacific Intertidal Mudflat (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This ecological system is characterized by sparsely vegetated areas within intertidal zones. Species that may be closely associated with this habitat include the Marbled Godwit and Red Knot. This system may be impacted by rising sea levels, particularly where upland migration of habitats is hindered by bluffs or anthropogenic structures such as bulkheads and other forms of shoreline armoring.

North Pacific Coastal Cliff and Bluff (in Figure 36)

The ecological system is likely to be at high risk, but has not been specifically evaluated.

This ecological system is comprised of un-vegetated or sparsely vegetated rock cliffs and very steep bluffs along Washington's coastline and associated marine and estuarine inlets. Species that are closely associated with this ecological system include the Stellar Sea Lion, Peregrine Falcon, Rock Sandpiper, Island Marble, and Taylor's Checkerspot. Existing stressors include invasive species, habitat degradation, and recreation activities. Sea level rise, increased coastal erosion, and increased storminess and wave action represent significant additional climate stressors.

PLANT AND ANIMAL SPECIES RANGE SHIFTS

Scientists also predict that many species will respond to the impacts of climate change by altering their current geographic distribution. These shifts are likely to occur at the individual species level, with some species experiencing expansion, while others experience contraction or migration. However, these changes may impact important interactions between species, leading to larger changes in the composition of biological communities in the region. Existing stressors (e.g., presence of barriers and fragmented habitat) may also limit the responses of some species.

There are several general predicted changes in the geographic distribution of species (Mauger et al 2015), as follows:

- Reduction in the range of some bird species, including bald eagle, western grebe, and trumpeter swan.
- Increased tree growth and expansion of treed area at high elevations; and
- Prairie expansion in response to contraction of forested areas with species sensitive to drought.

PLANT AND ANIMAL PHENOLOGICAL SHIFTS

Phenology refers to the timing of biological events. Shifts in phenology can affect plant reproduction and/or productivity and animal life histories, survival, reproduction, and growth (WDFW 2015).

Some species may shift timing, while others do not. Because each species will respond differently, climate change may cause important biological interactions to become unsynchronized, such timing of peak predator and prey abundances, altering food web dynamics.

Scientists have indicated that warming water temperatures and changes in streamflow can affect the timing of key life-cycle transitions in species of salmon, including Chinook (WDFW 2015). Changes in water temperatures may create a mismatch between arrival in estuaries and rivers and the timing of ideal ecological conditions. As a result, salmon species may need to shift the timing of a life stage transition to reduce the probability of exposure to changes in temperature or flow (high or low).

In addition, many flood-adapted riparian species exhibit phenology (e.g., seed dispersal) timed with historic streamflow patterns; this may be impacted by shifts in flood timing.

DATA GAPS, RESEARCH AND MONITORING NEEDS

Climate change science is a complex and evolving discipline that is constantly being enriched by additional research studies. As a result, while this document tries to capture the state of the science as it pertains to the Samish Indian Nation, it should be recognized that it is neither comprehensive nor complete. In addition, while this report represents a snapshot of the publicly available research at this time, it is recommended that the Samish Department of Natural Resources continue to monitor new research as it becomes available to keep apprised of the best available science in preparing and maintaining the adaptation plan.

There are many gaps in knowledge that will need additional monitoring and study to advance our understanding of climate impacts and responses. Despite these limitations, it is important to emphasize that scientific uncertainty in some areas is not a reason to delay adaptation planning efforts.

The following is a partial list of gaps that the Samish may want to undertake or partner with academic researchers to advance.

- *Interaction of stressors.* There is still a lack of quantifiable information on the combined effect of multiple climate and non-climate impacts and their synergistic effects.
- *Sea level rise.* Downscaled analysis that can consider information on coastal landforms is needed to better understand the impacts of climate change.
- *Ocean processes.* Major uncertainty still exists in terms of upwelling and outflow patterns, and how these may be impacted by other factors such as coastal winds. Additional monitoring of physical and chemical variables and mixing zones is needed to better determine potential impacts.
- *Ocean Acidification.* Additional
- *Habitat and species impacts.*
    - Samish have indicated their interest in focusing on ecosystems as a coarse filter strategy for understanding impacts to species. Many of the habitat formations identified in Figure 36 are suspected of being highly vulnerable to climate impacts, but have not been specifically evaluated. Additional review of habitat impacts would significantly improve our understanding of how culturally or ecologically important species may be impacted. In addition, improved monitoring is needed at a larger-scale to detect ecosystem shifts, regional implications, and a broad range of potentially important species responses.
    - In addition, there is a significant need for expanded analysis of cultural and ecologically important species and the habitats on which they depend. There are significant gaps in knowledge on the habitat needs and resilience (e.g., the likely

shifts in migration patterns or other adaptive responses) of species, especially reptiles, amphibians, invertebrates, marine and coastal species.
    - Further, understanding of food webs is still limited and is needed to understand how potential shifts in the primary producers that form the base of the food web (e.g., pteropods) may impact salmon and other fish and marine mammal species.

- *Sedimentation*. Sedimentation is a key issue within the Skagit watershed, and continuing research will be needed to build our understanding of how sediment deposition may change over time.
- *Insect, Disease and Invasive Species.* Additional research is needed to accurately quantify the effect of climate change on the complex interactions among hosts, pathogens, and disease vectors.

Please note that this list is not comprehensive; additional research needs have been documented by other reports and studies consulted in preparing this report.

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