DRAFT

Climate Change Impact Assessment and Adaptation Options

Puyallup Tribe of Indians
2016

Acknowledgments

This assessment would not have been possible without the tremendous contributions of many individuals, listed below.

Project Team

Mary Basballe, Air Quality Department

Bill Sullivan, Environmental Department

Special thanks to the following Tribal staff

Paul Arnold, GIS
Mary Brown, Water Quality
Joanne Gutierrez, Housing
Russ Ladley, Fisheries
Rory Laducer, Public Safety
Connie McCloud, Youth & Culture
Barb Moeller, Wildlife
Char Naylor, Water Quality
Michael Polly, GIS
Jeffrey Thomas, Forestry
Brandon Reynon, Historic Preservation
George Stearns, Shellfish
Andrew Strobel, Transportation & Planning
Angela Tate, Realty
Elsie Wescott, Water Quality
David Winfrey, Shellfish

Recommended Citation Format

Puyallup Tribe of Indians. 2016. *Climate Change Impact Assessment and Adaptation Options*. A collaboration of the Puyallup Tribe of Indians and Cascadia Consulting Group.

Prepared for the Puyallup Tribe by

Cascadia Consulting Group

Letter of Introduction

Placeholder for letter from Tribal leader or council.

Table of Contents

Executive Summary

From 2015 to 2016, the Puyallup Tribe worked with Cascadia Consulting Group to conduct a Climate Change Impact Assessment and identify options for adaptation. The assessment aimed to help Tribal staff and members better understand and prepare to proactively manage climate risks to ensure that Tribal customs and the Tribal community can thrive for many generations to come, despite a changing climate.

How is the climate changing?

Changes in the climate have been observed already, including the following:

- **Average annual temperatures for the Pacific Northwest have risen 1.3°F since 1895.** One of the implications has been a longer frost-free season.
- **The cumulative area of Mt. Rainier's glaciers decreased -27% between 1913 and 1994**.
- **Sea level has risen by 7.8 inches** in our region over the last century.
- **Ocean pH has already dropped by about 30%** as the oceans absorb increasing amounts of carbon dioxide.

The climate will continue to change into the future as the concentration of carbon dioxide and other greenhouse gas emissions in the atmosphere continues to rise. Specific anticipated changes include:

- **Average temperatures in Washington State could rise as much as 9.4°F above current levels by 2100.** The most significant temperature increases are anticipated to occur in the summer months.
- Total annual precipitation in the Pacific Northwest is not projected to change substantially, but **heavy rainfall may be more frequent and intense, and summer precipitation may decrease**.
- **More rain and less snow will fall in the winter.**
- **Stream temperatures in the Pacific Northwest are protected to increase** 1°F over 1980 averages by 2020 and 3°F by 2080.
- **Flooding may become more common and more intense** in places like the Puyallup River.
- With warmer, drier summers, **more wildfires** are expected.
- **Landslides are likely to become more frequent in winter and spring** as precipitation rates and soil moisture increase during these months.
- **By 2050, some areas of Washington State could see as much as 19 inches of sea level rise over 2000 levels**; by 2100, the increase could be up to 56 inches.
- Sea level rise combined with storm surge and high tides can cause **more frequent flooding events, coastal erosion, loss or shifting of habitat, and saltwater intrusion** into water sources.
- **Ocean acidification is expected to increase** by 38 to 109% by 2100 relative to 2005 levels.

What impacts might we see locally?

The assessment focused on eight key resources or sectors. Some of the anticipated impacts of climate change in these sectors include the following:

- **Fisheries and hatcheries:** Warmer stream temperatures and summer lower flows can alter salmon migration timing, reduce growth rates, and increase vulnerability to toxins, parasites, and diseases. Increased winter high-flow events can scour the streambed, increasing the risk of egg mortality.
- **Shellfish:** Ocean acidification makes it more difficult for shellfish including oysters, clams, mussels, and crabs to form and maintain their shells. Rising sea levels can reduce the extent of habitats like estuarine beaches; where shorelines are armored, it can be impossible for intertidal zones to shift and adapt, thereby reducing habitat for the species that depend on these zones.
- **Wildlife:** Warming temperatures and precipitation changes will alter the survival, distribution, and seasonality of some wildlife and game species.
- **Restoration sites:** Restoration sites may be affected by rising sea levels and other climate change impacts. They also help to build resilience by protecting important ecosystem functions and habitats.
- **Water quality:** Lower summer precipitation and higher temperatures can concentrate pollutants in waterways.
- **Cultural resources and archaeological sites:** The accessibility and availability of traditional plants, roots, and other resources may change as distributions and habitats of species shift. Cultural sites along the waterfront or near rivers may experience more frequent and more intense flooding, which may temporarily or permanently inundate some places and limit access.
- **Transportation:** Many of the Tribe's important transportation routes lie in areas at risk of flooding or landslides.
- **Public health and safety:** Heat waves, changes in air quality, foodborne illness, and other changes associated with climate change will present new threats to the health and safety of our Tribal members, particularly the young and the elderly and those with existing health conditions.

What can we do to build resilience?

While the Tribe is already undertaking a number of programs that will help to build resilience, even if they weren't designed with climate change in mind, additional action will be needed to protect resources, infrastructure, and people as the climate continues to change. Tribal staff therefore developed a shortlist of potential adaptation measures for further consideration and evaluation. These options are presented at the end of the document, and they fall into five broad categories:

1. Implement protection, restoration, and management practices
2. Provide education and guidance
3. Reevaluate policies, plans, and protocols
4. Gather additional information
5. Leverage partnerships

Introduction

As the climate changes, higher temperatures, rising sea levels, changes in precipitation, and other projected impacts will have far-reaching implications for the resources, livelihoods, and health of the Puyallup Tribal community. The Tribe has nearly 4,000 members today, many of whom live on the reservation. By planning ahead, the Tribe can help ensure that Tribal customs and traditions thrive for many generations to come. This report describes how climate change could affect our people and our resources and how we can take steps to build our resilience.

We already have experience with climate variability, and we can therefore begin to anticipate problems we could face in the future. In 2015, for example, we experienced challenges similar to those anticipated to occur more often in a future changing climate, including hotter temperatures, reduced snowpack, and increased wildfire risk.

Climate change also interacts with other stressors that are already affecting our Tribal resources, including population growth, development, and pollution. Our people have lived in this area for thousands of years. Today, the Puyallup reservation is highly urbanized; the cities of Edgewater, Federal Way, Fife, Milton, Puyallup, and Tacoma have grown around us and overlap, to some degree, with our reservation land. Therefore, through this assessment we also sought to understand how climate change can exacerbate some of these existing issues.

This report provides a picture of where we have been, where we are now, and where we are heading. It combines the latest climate knowledge for the region with input from Tribal staff and members, and it presents key projected impacts as well as actions that will build resilience of our Tribe. The report is organized into the following sections:

- Methodology
- Climate Impacts and Projections
- Sector-Specific Impacts
- Adaptation Options

The appendices include a glossary of climate terms, additional maps, and citations.

Methodology

The Tribe's Environmental Department spearheaded this effort, supported by a team of consultants. We sought to engage program staff from a range of other departments, such as Transportation, Air Quality, Water Quality, Fisheries, Languages, Cultural Resources, Housing, and GIS.

Based on input from program staff who attended the kick-off meeting in April 2015, we focused this assessment on how climate change impacts could affect particular resources and sectors (see text box).

We began with a compilation of climate science and projections for the region to understand how changes in sea level, precipitation, and temperature will affect Tribal people, resources, traditions, and infrastructure. The analysis included a spatial assessment of particular areas that may be most at-risk from sea level rise and storm surge.

We conducted interviews and three workshops with Tribal staff to assess current and potential vulnerabilities to climate variability and change related to the priority resources and sectors. We also consulted scientific literature from local and regional sources to supplement these findings.

This report does not represent the end of this process. Rather, it gives us a foundation from which to begin building our resilience to climate change impacts and to educate our Tribal staff, members, and youth about what the future may hold and what we can do to prepare. We intend to revisit and update this report in the future as new information about climate change becomes available and as we continue to clarify our own needs and priorities. The adaptation options that are listed are a promising starting point. These options will benefit from additional discussion and evaluation to help develop a comprehensive plan that has broad support from across the Tribal community.

Priority Resources and Sectors

- Fisheries and hatcheries
- Shellfish
- Wildlife
- Restoration sites
- Water quality
- Cultural and archaeological sites
- Transportation
- Public health and safety

Climate Impacts and Projections

Defining the Puyallup Tribe's vulnerability to climate impacts begins with understanding how the climate is projected to change in southern Puget Sound. This section summarizes projections of potential climate threats facing the Puyallup Tribe of Indians. To provide broader context and fill gaps in local data, we also provide an overview of impacts affecting Washington State and the Pacific Northwest more broadly.

The climate impacts information and projections discussed below represent the best available information from well-known and trusted datasets, literature, and studies. Conditions for 2050 and beyond will depend upon economic trends, policy decisions, and technological developments in the coming decades. The long-term projections can still be valuable tools for long-range and strategic planning.

Additionally, while the climate is changing, natural climate variability will continue to affect our region and dominate what we observe over the next few decades and, thus, should also be considered when assessing local impacts.

A Changing Climate

Anthropogenic (human-caused) greenhouse gas emissions are expected to increase over the next 100 years. The concentration of carbon dioxide (CO_2) in the atmosphere has almost doubled since before the Industrial Revolution, from 280 parts per million (ppm) to the current concentration of 400 ppm.[*] "Business as usual" global greenhouse gas emissions scenarios, which assume no significant change in current trends, predict that atmospheric CO_2 could reach levels as high as 936 ppm by 2100.[1]

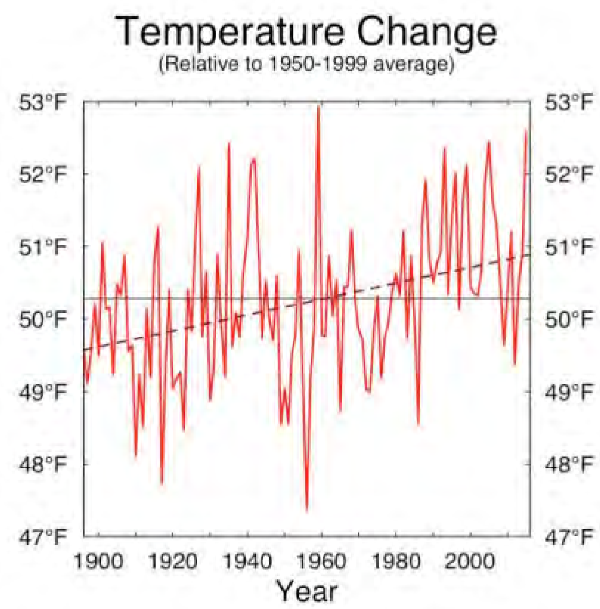
To determine how these projections will manifest at regional scales, researchers use global and regional climate models that reflect future emissions scenarios. Models often take into account changes in population, technology, and other factors that influence anthropogenic emissions rates. This report draws from the conclusions of numerous studies based on the most up-to-date global emissions scenarios referred to as Representative Concentration Pathway (RCP) scenarios, adopted by the Intergovernmental Panel on Climate Change in 2014. This report also includes studies based on the Special Report of Emissions Scenarios (SRES), which preceded the RCP scenarios and were used in climate modeling research conducted between 2000 and 2013. Many of these studies were undertaken by scientists affiliated with the University of Washington Climate Impacts Group.

[*] Monthly average concentrations in carbon dioxide vary due to seasonal and monthly variations in carbon dioxide emissions from human and natural sources (e.g., plant respiration). For example, monthly values in 2014 ranged between 395.26 ppm (Sept 2014) and 401.78 ppm (May 2014). The highest monthly mean value reported to date since measurements began at Mauna Loa in March 1958 is 407.7 ppm (May 2016).

Temperature

Average annual temperatures for the Pacific Northwest have risen 1.3°F since 1895.[2] This change has resulted in a longer frost-free season and increases in nighttime heat waves over the last century, particularly during winter, fall, and summer.[3, 4] Figure 1 below shows the warming trend in average annual temperature in the Pacific Northwest since 1895.

Figure 1. Average annual temperatures (solid red line) since 1895 in the Puget Sound region. Dashed line indicates the warming trend. Source: UW Climate Impacts Group 2015.[5]



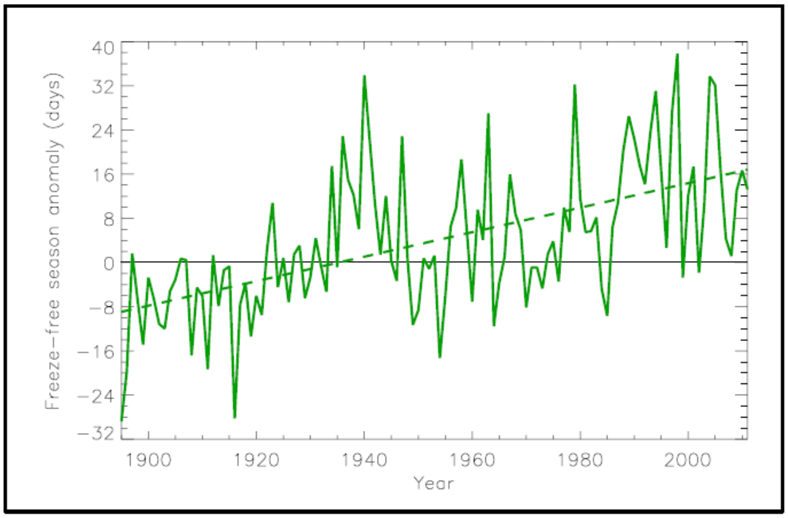
Projections suggest warming will occur across all four seasons in the Pacific Northwest over the 21st century, but the most significant increases are anticipated to occur in the summer months. Temperature projections for Washington State under a high emissions scenario (RCP 8.5) show that average temperatures could rise as much as 9.4°F above current levels by 2100.[6] Table 1 below shows projected increased temperature ranges by the 2050s for the Puyallup area.

Table 1. Projected increase in average annual temperature by 2050 (relative to 1980) for Puyallup under low and high emissions scenarios. Source: UW Climate Impacts Group 2015.[7]

Emissions Scenario	Projected Increase
Low emissions (RCP 4.5)	+4.2°F (range: 2.8 to 5.7°F)
High emissions (RCP 8.5)	+5.5°F (range: 4.3 to 7.3°F)

While summer months are projected to see the largest increases in average temperatures, winter months will see an increase in minimum temperatures and the number of frost-free days.[4] The frost-free season for this region has lengthened steadily since 1895 and is expected to continue increasing throughout the 21st century.[8] Figure 2 shows the increasing trend in the duration of the frost-free season between 1895 and 2010.[2] Meanwhile, the area of Mt. Rainier's glaciers decreased-27% between 1913 and 1994.[9]

Figure 2. Extension in the frost-free season for the Northwest U.S. between 1895 and 2010.
Source: Kunkel et al. 2013.[8]



Precipitation and Streamflow

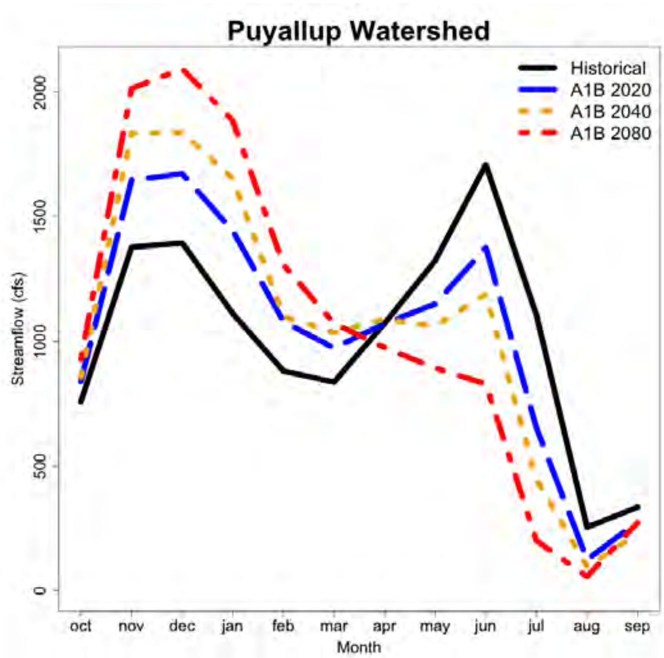
Scientists project slight increases in winter, spring, and fall precipitation and decreases in summer precipitation (see Table 2).[10] Total annual precipitation in the Pacific Northwest is not projected to change substantially, but occurrences of heavy rainfall may be more frequent and intense.[5]

Table 2. Projected decrease in average summer precipitation by 2050 (relative to 1950-1999) under low and high emissions scenarios. Source: Mote et al. 2013.[11]

Emissions Scenario	Projected Decrease in Summer Rainfall
Low emissions (RCP 4.5)	-6%
High emissions (RCP 8.5)	-8%

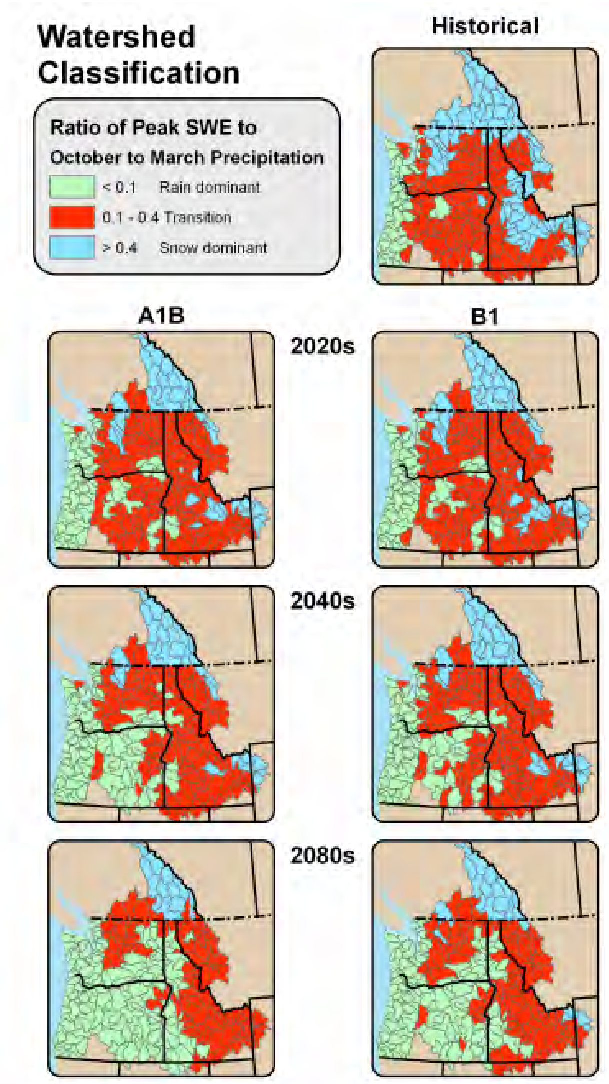
More precipitation will fall as rain during winter months, and snow will melt earlier in the year, resulting in a shorter snow season and earlier peak streamflow.[12] This trend is shown in Figure 3 below, which depicts estimated changes in the magnitude and timing of streamflow for the Puyallup watershed in 2020, 2040, and 2080.

Figure 3. Monthly graph of streamflow estimated for the Puyallup watershed over three time periods (2020, 2040, and 2080). Changes are relative to historical flows over the 1916-2006 time period. Source: UW Columbia Basin Climate Change Scenarios Project.[13]



Records for Washington's Cascade Range show that average snowpack declined throughout the 20th century.[14] Climate projections suggest that snowpack will continue to decline in the Pacific Northwest; Figure 4 below illustrates the projected shift from snow-dominant to rain-dominant watersheds.[15] Note that under the moderate emissions scenario (A1B), there is a total loss of snow-dominant basins in the Cascades by the 2080s.[16

Figure 4. Shifts in watershed classification compared to historical averages for the Pacific Northwest under two future emissions scenarios. (Snow water equivalent, SWE, is a measure of the amount of water contained in snowpack.) Source: Tohver et al. 2014.[16]



Increases in temperature, declining summer precipitation, and reduced snowpack will alter ecosystem composition and health and increase wildfire risk. Extended periods of drought are thought to be among the largest contributing climatic factors in declining forest health observed across the globe.[17] In the Pacific Northwest, research shows that a decline in snowpack is having considerable health impacts on cedars, indicated by stunted growth patterns.[18] Rising winter air temperatures could lead to delayed leaf emergence in Douglas fir due to an inability to meet winter chilling requirements.[5] These changes will likely reduce the area of climatically suitable habitat for Douglas fir in lower elevations of the south Puget Sound region by the end of the 2060s.[5]

Wildfire

According to the Washington State Department of Natural Resources, the declines in forest health noted above can contribute to more frequent and widespread wildfires.[19] Climate change will increase fire activity across the Puget Sound region, including in areas previously unaffected by fire.[5] Past fire records show a strong correlation between warm, dry summers and higher rates of area burned in the Pacific Northwest.[20] Drought and warm temperatures combine to lower moisture content in both live and dead fuels and increase flammability.[20] Scientists attribute the extensive wildfires throughout Washington State in 2015 to the summer drought during that season.[21]

Research suggests that the area burned west of the Cascade crest could more than double by the late 21st century.[5] Further research is needed to fully understand how changing climate conditions may alter wildfire risk and severity in the region.[5]

Flooding

Higher annual temperatures, changes in precipitation, and resulting changes in snowpack and streamflow will alter downstream flood regimes. For example, snowmelt runoff or rain-on-snow events can cause flooding downstream when warmer winter temperatures rapidly melt thick snow cover or increase the amount of precipitation falling as rain instead of snow.[22]

While more research is needed to assess any specific flood-related impacts or risks to the Puyallup Tribe, regional modeling simulations suggest an increasing flood risk for most areas of the Pacific Northwest. The Puyallup River watershed is already among the highest flood risk areas in the state of Washington (see current FEMA-designated flood hazard areas in Figure 5 below and Figure 14 in Appendix B).[23, 24] The Tribe's Public Safety office has noted incidents of repeated flooding in Lower Clear Creek and along the basin near River Road. According to the UW Climate Impacts Group, most models show that the volume of water during the historical 100-year flood event (or a flood with an annual probability of 1%) is expected to increase by the 2040s, suggesting that what are already the most extreme flooding events in the region will become even more intense.[7] Table 3 below shows the increases in water volume of 100-year flood events in the Puyallup watershed based on two emissions scenarios.

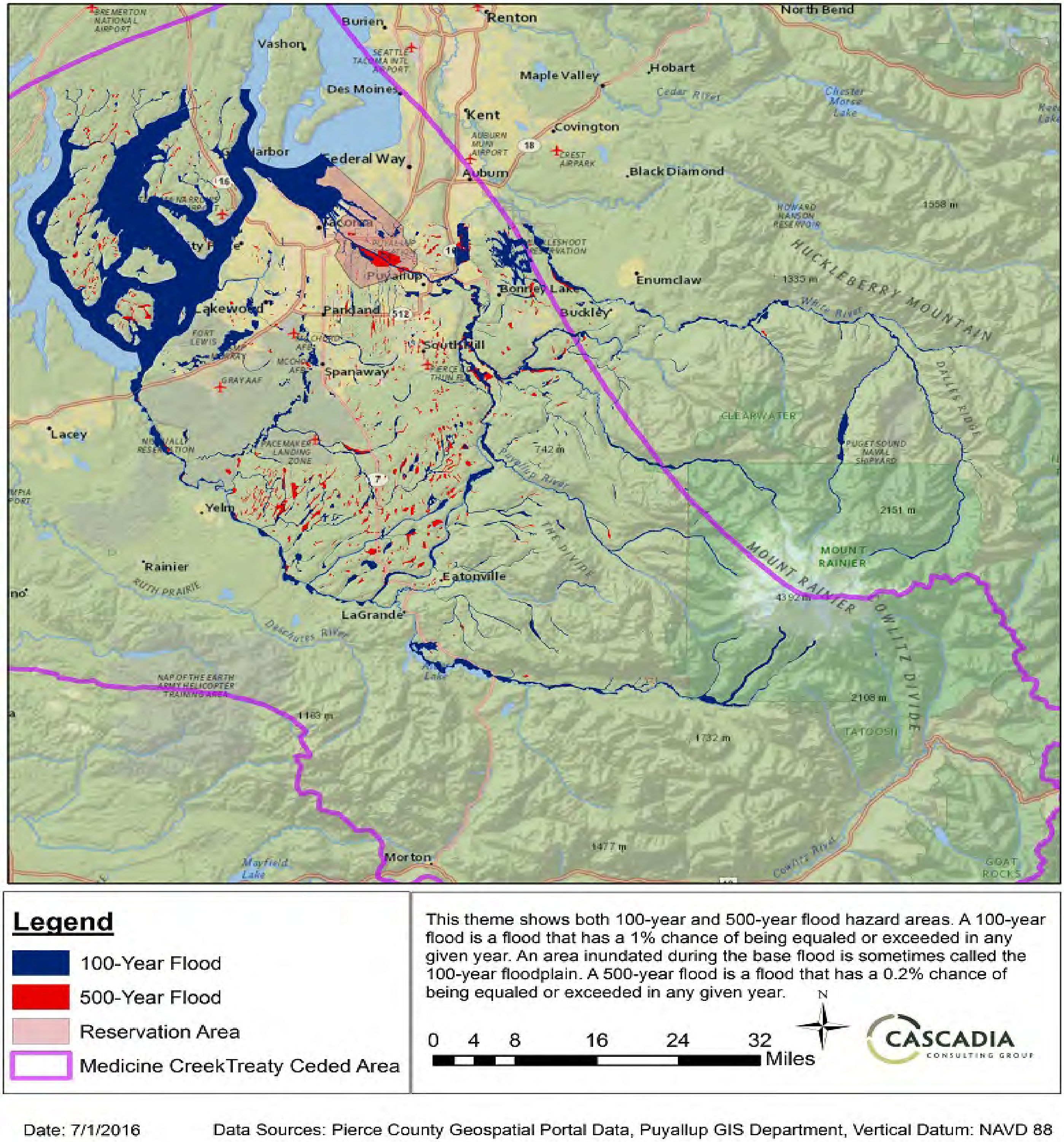
Table 3. Projected increases in water volume associated with 100-year flood events in the Puyallup Watershed by 2040 (relative to 1980) under low and moderate emissions scenarios. Source: UW Climate Impacts Group 2015.[7]

Emissions Scenario	Projected Water Volume
Low emissions (B1)	+39% (range:-14 to +85%)
Moderate emissions (A1B)	+56% (range: +22 to +115%)

The frequency of "atmospheric rivers"—a band of water vapor transport from the tropics and a significant driver of flooding in the Pacific Northwest—will also likely be different with climate change. Climate projections and modeling simulations for the Pacific Northwest indicate that severe precipitation events caused by atmospheric rivers will become more common and severe in the Puget Sound region.[25] Analysis of the flooding event in January 2012 suggests that the extensive flooding was driven by a combination of increased sediment loads in streams and extreme rainfall brought on by an atmospheric river (see the ***Landslides and Sediment Transport*** section below for information on the impacts of increased sediment).[26, 27]

Although heavier winter rainfall is expected, climate models do not project a change in wind speed or strength of low-pressure systems in the Puget Sound region.[28]

Figure 5. Current FEMA flood hazard areas (see Figure 14 in Appendix B for a more detailed map).



Stream Temperature

Stream temperatures will rise in conjunction with rising air temperatures throughout the Puget Sound region, including in the Puyallup watershed.[29] Modeling simulations on the correlation between air and stream temperature show that stream temperature rises approximately 2.8°F for every 3.5°F increase in air temperature.[30] Climate models project that stream temperatures in the Pacific Northwest will increase 1°F over 1980 averages by 2020 and 3°F by 2080.[31] These increases may be more pronounced at lower elevations, where rivers tend to slow and widen and where air temperatures are warmer. Projected mean August stream temperatures projected for the Puyallup watershed region in 2040 range from 7 to 22 °C (45 to 72 °F) as shown in Figure 6. Table 4 below shows projected temperatures for streams in or near the Puyallup reservation. All streams except Canyonfalls Creek are projected to be within the range for increased disease risk in adult salmon (see Table 5 for a list of salmonid temperature thresholds).

Table 4. Projected 2040 average August stream temperatures for selected streams in the Puyallup Tribal region. Source: US Forest Service Regional Database and Modeled Stream Temperatures.[32]

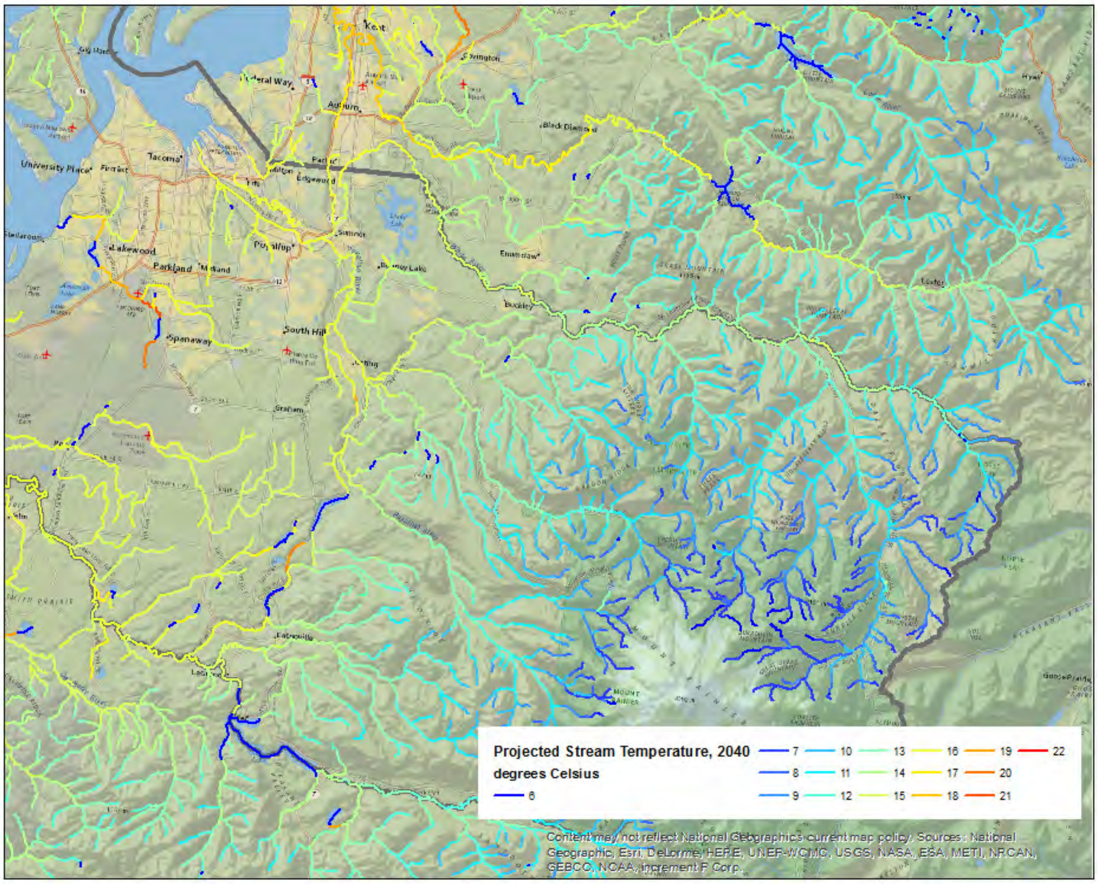
Stream	2040 Projected August Stream Temperature (°C)
North Fork Clover Creek	16.5
Clover Creek	16.5
Puyallup River	16.4
Hylebos Creek	16.3
Clarks Creek	16.2
Wapato Creek	16.2
Carbon River	16.2
White River	16.1
Clear Creek	15.8
West Hylebos Creek	15.8
Swam Creek	15.8
Fennel Creek	15.5
Canyonfalls Creek	15.1*

*All streams except Canyonfalls Creek are projected to be within the range for increased disease risk in adult salmon.

Table 5. Salmonid temperature thresholds. Source: National Wildlife Federation 2011.[33]

Salmonid Temperature Thresholds	
<58.1°F (<14.5°C)	Optimal range for salmon spawning, rearing, and migrating
59.9–67.1°F (15.5–19.5°C)	Range for increased disease risk in adult salmon
68.9–70.7°F (20.5–21.5°C)	Threshold for adult salmon mortality
>70.7°F (21.5°C)	Threshold for juvenile salmon mortality

Figure 6. Projected average August stream temperatures for the Puyallup watershed region in 2040 (A1B moderate emissions scenario). Source: US Forest Service Regional Database and Modeled Stream Temperatures.[32]



Landslides and Sediment Transport

While specific landslide risk projections based on future climate scenarios for the Puyallup Reservation are not currently available, landslides are likely to become more frequent in winter and spring as precipitation rates increase during these months, thereby increasing soil moisture content. Incidence of drought followed by severe rainfall events—a combination that climate projections suggest will become more common[34]—increase landslide risk in communities located in or adjacent to hilly topography, including downstream and downslope areas (see current landslide hazard areas in Figure 7 below). Landslide risk is projected to decline during summer months, however, as summers become drier and hotter.

Puyallup Tribal infrastructure and facilities that are already in or near landslide hazard zones include:

- Diru Creek Hatchery
- Some smokeshops and convenience stores on River Road

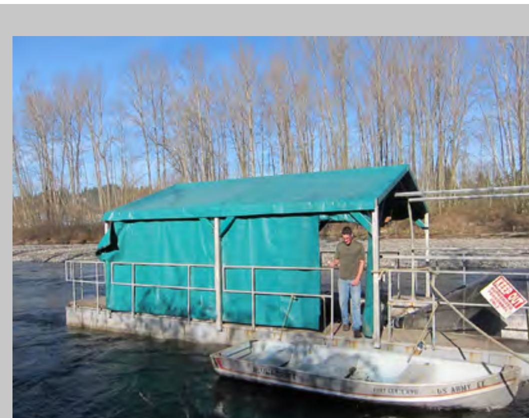
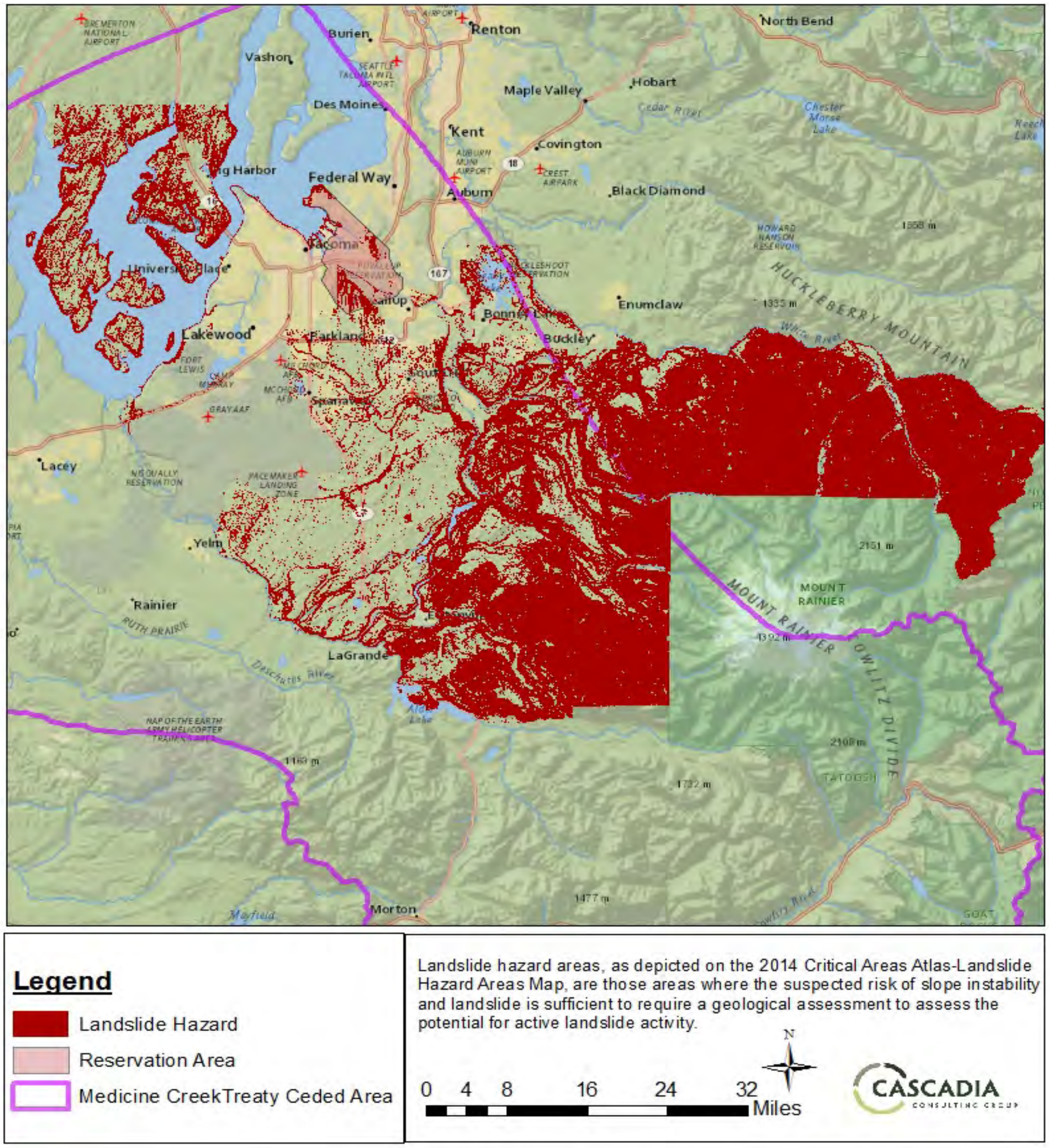


Figure 7. Current landslide hazard areas (see Figure 15 in Appendix B for a more detailed map).



Date: 12/10/2015 Source: Pierce County Geospatial Portal Data, Puyallup GIS Department. Vertical Datum: NAVD 88

Landslides, declining snowpack, receding glaciers, and heavy rainfall events will increase sediment loads in waterways and alter streambank erosion and accretion.[35] Sea level rise and extreme storms will accelerate sediment-driven erosion and accretion along coastlines, affecting wildlife and marine species such as salmon that rely on shoreline sedimentation and habitat.[36, 37] According to a 2015 analysis by the UW Climate Impacts Group, loss of snowpack and glaciers due to warming temperatures will contribute to increased flood flows in the Puyallup watershed and will expedite sediment flow.[7] Increased incidence of wildfires can also lead to greater sediment and debris flow, as root cohesion diminishes and soil composition changes after a fire.[38]

Sea Level Rise

Rates of sea level rise across Washington State are highly dependent on vertical land movement from plate tectonics, thermal expansion of water, seasonal wind patterns, and sedimentation. By 2050, some areas of the state could see as much as 19 inches of sea level rise over 2000 levels; by 2100, the increase could be up to 56 inches.[39] Table 6 below shows projected sea level rise for Washington, Oregon, and northern California by 2030, 2050, and 2100.

Table 6. Sea level rise projections relative to year 2000 for Washington, Oregon, and northern California. Projections (middle column) represent A1B moderate emissions scenario projections, while ranges (right column) represent average B1 (lower emissions) and A1F1 (higher emissions) scenario projections. Source: Department of Ecology 2012.[40]

Year	Projection (in inches)	Range (in inches)
2030	+2.6	-2 to +9
2050	+6.5	-1 to +19
2100	+24	+4 to +56

Sea level rise combined with storm surge and high tides can cause more frequent flooding events, coastal erosion, loss or shifting of habitat, and saltwater intrusion into water sources. Figure 8 and Figure 9 on the following pages show Puyallup Reservation and Tribal facilities that are projected to be exposed to intermittent flooding during extreme high tides in 2050 and 2100 respectively, using the high emissions scenario (RCP 8.5). Note that these illustrations of potential flooding areas are based purely on ground surface elevation and do not account for the presence or absence of water flow pathways. More detailed depictions of these maps are provided in Appendix B (Figure 12 and Figure 13).

Puyallup Tribal infrastructure and facilities that could be at risk of flooding during extreme high tides include:

In 2050:

- Emerald Queen Riverboat (old casino) on Alexander Avenue
- Marine facilities such as Chinook Landing, the 11th Street boat ramp, and Ole & Charlie's Marina
- Some stores on Pacific Highway East

In 2100, those listed above, plus:

- Emerald Queen Ballroom
- Puyallup Tribal Integrative Medicine (PTIM) building
- Several convenience stores and smoke shops on Pacific Highway East, as well as a few on 54th Avenue East and Alexander Avenue

Figure 8. Tribal-owned facilities (green dots) projected to be at risk of flooding during extreme high tides in 2050. Dark blue areas are already below base flood elevation (BFE). Light blue are below BFE with 19 inches of sea level rise (the high-range estimate for 2050).

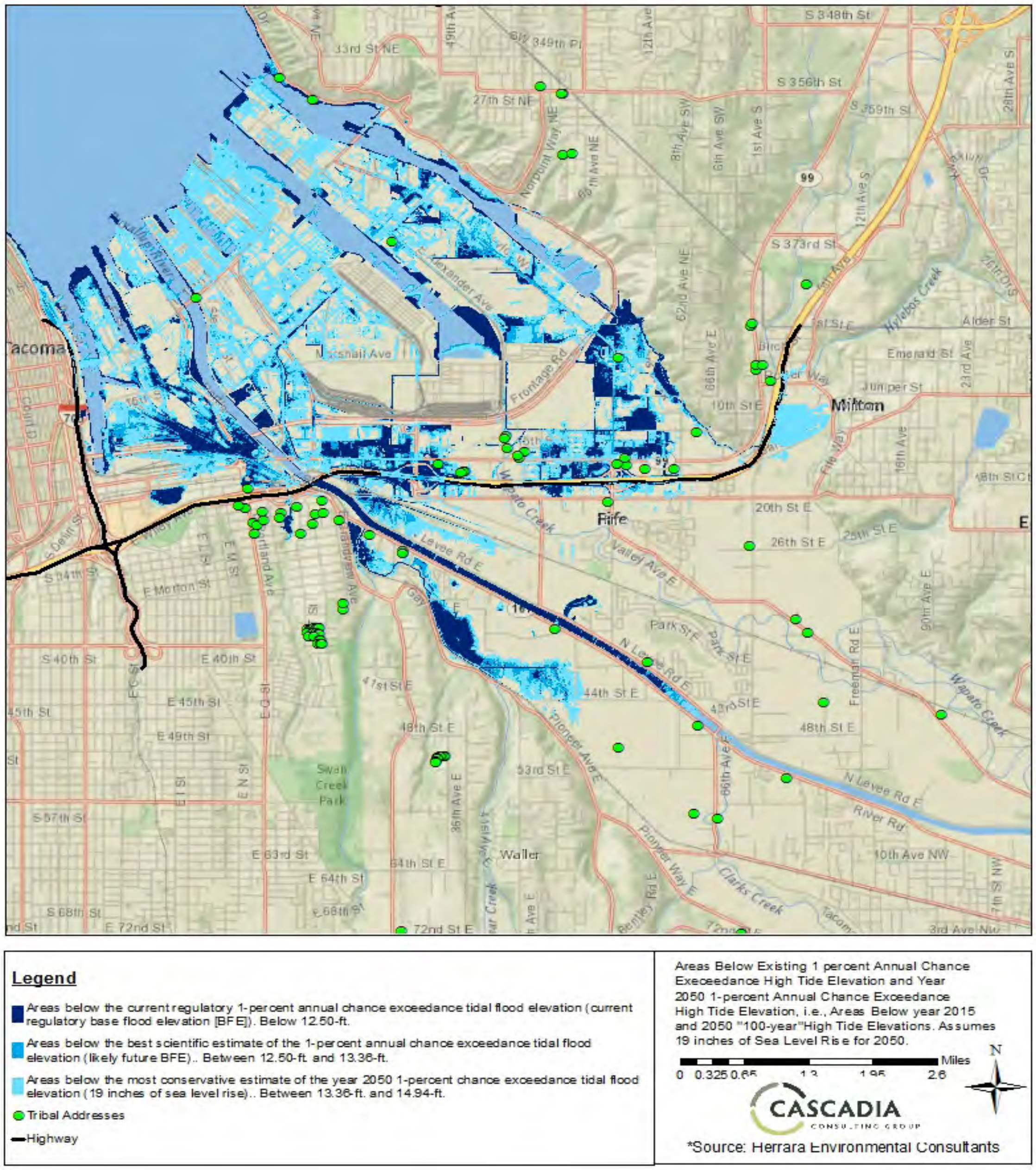
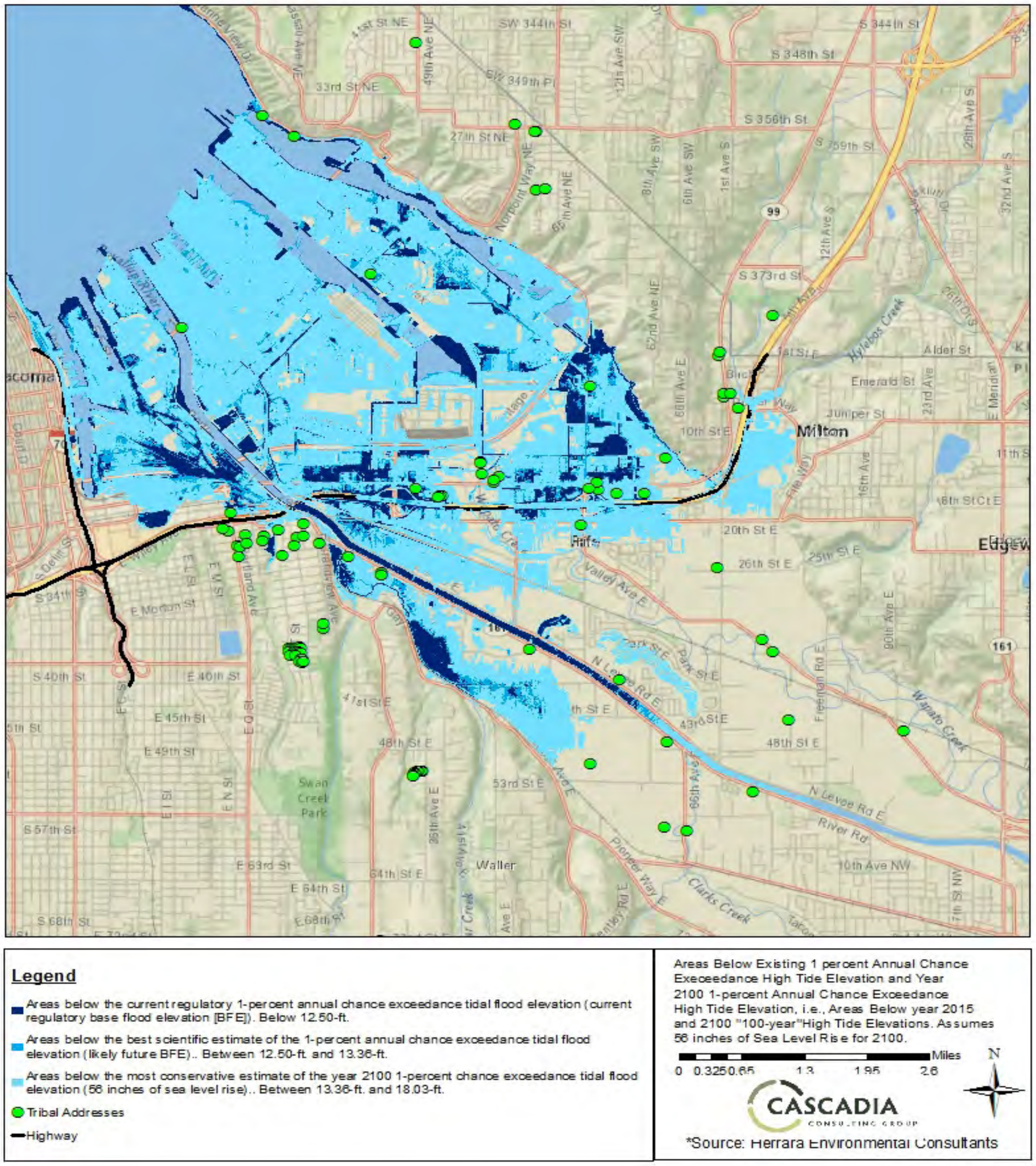


Figure 9. Tribal-owned facilities (green dots) projected to be at risk of flooding during extreme high tides in 2100. Dark blue areas are currently below base flood elevation (BFE). Light blue are below BFE with 56 inches of sea level rise (the high-range estimate for 2100).



Ocean Acidification

As anthropogenic sources of atmospheric greenhouse gases have steadily increased since the Industrial Revolution, the oceans have absorbed more CO_2, effectively raising concentrations of dissolved CO_2 and lowering the pH of the oceans by about 30%.[41] While there are no projections for ocean acidification specifically for Washington State, Table 7 shows projected global increases in ocean acidification by emissions scenario.

Table 7. Projected increases in global ocean acidification by 2100 relative to 2005 levels, by emissions scenario. Source: UW Climate Impacts Group.[7]

Emissions Scenario	Projected Increase in Ocean Acidification
Low emissions (RCP 4.5)	+38 to +41%
High emissions (RCP 8.5)	+100 to +109%

Washington State's marine habitats are particularly at risk of the impacts of ocean acidification due to naturally occurring offshore upwelling processes that transport nutrient-rich yet corrosive water usually found at lower depths to shallower waters along the continental shelf.[42] These corrosive waters reach closer to the surface in the spring, summer, and early fall, limiting the ability of organisms such as clams, oysters, mussels, and pteropods (a key marine food source) to form shells.[43] Recordkeeping of pH levels in Puget Sound, which began in 2008, shows an overall trend of increased corrosive conditions; however, slight variations have occurred year-to-year and in specific locations within the Sound.[43]

Other contributing factors to ocean acidification include hypoxia (low dissolved oxygen) and nutrient runoff from urban and agricultural lands.[44] In hypoxic sections of Hood Canal, for example, eutrophication (excessive nutrients and resulting algal blooms) has increased acidification through the respiration of organic material.[43] Stratification (where water with different properties form layers that impede water mixing) is spatially and temporally variable in Puget Sound, with the most persistent and strong stratification found in Hood Canal, Whidbey Basin, and parts of south Puget Sound.[43]

These effects have already altered the development of shellfish in parts of Puget Sound, and they are projected to inhibit shellfish development more severely into the future.[43, 45]

Sector-Specific Impacts

This section describes the ways in which the changes in climate summarized in the previous chapter could affect sectors and resources of particular importance to the Puyallup Tribe.

Fisheries, Hatcheries, and Forage Fish

Our Tribal members and staff expect that climate change will result in important impacts to local fish habitat and Tribal fisheries infrastructure, including hatcheries. Simultaneous increases in water temperature and decreases in water availability could create conditions that increase diseases and associated fish health risks, affecting hatchery operations and increasing fish kills.[10] A recent study at the Winthrop National Fish Hatchery in eastern Washington found that projected hatchery environmental conditions remained within the general physiological tolerances for Chinook salmon in the 2040s (under the A1B moderate emissions scenario). Still, warmer water temperatures in summer accelerated juvenile salmon growth, increasing the likelihood of physiological stress due to anticipated decreases in water availability during those months.[46]

The Puyallup Tribe's two hatcheries both use groundwater or spring water, which are cooler sources than surface water. These hatcheries are therefore less vulnerable than some others in the region. However, the fish released from the hatcheries still need to swim downstream through sun-exposed river stretches that are projected to present warmer temperatures.

Warmer ocean waters and ocean acidification will also affect fishery production. Scientists have found that a +1.8 °F increase in sea surface temperature—the warming projected for the northeast Pacific Ocean by the 2040s—could reduce salmon species survival from northern California to southeast Alaska by 1 to 4%.[28] Other important fish species will be subject to diminishing food availability as corrosive waters disrupt the ability of some organisms to develop shells and skeletons.

Climate change will also affect habitats and health of a range of aquatic organisms, including those not managed in fisheries or hatcheries. Coastal erosion and inundation from sea level rise, for example, will dramatically alter intertidal ecosystems and landscapes, changing the extent and composition of tidal wetlands, eelgrass beds, and estuaries.[47] One study of Puget Sound found that sea level rise will increase tidal flat area overall but will reduce estuarine beach, brackish marsh, tidal swamp, and tidal freshwater marsh area. Tribal staff have already observed disappearing mudflats resulting from development, pollution, and storms.

Altered streamflows will also bring changes to the landscape, including alterations to sediment delivery and deposition in wetland habitats—processes that are critical for maintaining wetland habitats as sea level rises. Although we anticipate sediment supplied from rivers to increase under future climate conditions, it is not known what proportion of that sediment will reach estuaries and whether it will be sufficient to offset sea level rise inundation.[28]

Dikes and dams within fish-bearing streams can exacerbate climate impacts on fish habitat and survival. After the 1930 flood, the Puyallup River was diked to control future flooding. The dike resulted in a loss of 14 miles of river. Recently, oxbows were reintroduced to improve salmon habitat. Management actions to minimize habitat loss in areas where dikes and dams remain will support climate resilience of instream habitat.

Other non-climate stressors, such as increased development in and around the Puyallup Reservation, will exacerbate climate change impacts on fisheries, hatcheries, and forage fish habitat. Tribal members and staff emphasized that hard beach-armoring infrastructure, such as sea walls, can be detrimental to organisms such as forage fish that rely on the water-land interface. Culverts and other hard stormwater infrastructure components can impede fish migration and degrade habitat quality. Low levels of shading along local waterways, such as from development, further increases instream water temperature. Studies show that the loss of shade from the replacement of forests and agricultural land with urbanization can raise stream temperatures by an additional 4°F.[48]

To address flood risks on local hatcheries, the Tribe's Fisheries and Environmental departments recently worked with Washington State Emergency Management and the Federal Emergency Management Agency (FEMA) to stabilize the riverbank at a fish hatchery near Buckley. In response to the 2009 flood, this $1 million project incorporated natural bank stabilizers such as logs and woody debris instead of cement banks and riprap to slow water flow through the river and provide more habitat for fish. Projects such as these will help ensure that our fish populations can withstand current and future risks from extreme events.

Salmon-specific vulnerabilities

Salmon in Puget Sound are already at risk from a range of different stressors. At the Tribe's 2014 First Fish ceremony, only one fish was caught—highlighting the dire state of our native salmon populations and the need for heightened support and recovery efforts.

Climate change will place additional stress on our salmonid populations, especially for species such as steelhead, sockeye, coho, and stream-type Chinook for which juvenile development occurs in freshwater streams.[5] Even minimal changes in stream temperature can alter salmon migration timing, reduce growth rates, and increase vulnerability to toxins, parasites, and diseases.[49] Warmer stream temperatures also increase salmon metabolism, diminishing critical energy stores for swimming and spawning.[50] Many diseases that affect salmon increase in warmer temperatures, including ***columnaris*** (tail rot) and ***furnuncolosis***, which infects the gills, peritoneal cavity, and liver of salmon.[51] Climate projections indicate that Puget Sound rivers will more frequently exceed thermal tolerances for adult salmon and char by 2080.[5] As drought leads to low streamflows, spawning and rearing habitat will decline, resulting in reduced thermal shelters, increased competition for resources, and perhaps greater vulnerability to predators.[52]

Increased winter high-flow events can scour the streambed, increasing the risk of egg mortality and potentially washing juvenile salmonids downstream prematurely.[5, 53] The Tribe takes coho and spring Chinook to nine acclimation ponds at higher elevation, and releases other species directly from the hatcheries. The Tribe has already seen its facilities affected by flood flows, leading to costly repairs, and is concerned that salmon redds are being scoured by the same flood events.

Shellfish

Anticipated future changes in the ocean's acidity will hinder the growth and survival of calcifying organisms, such as oysters, clams, mussels, pteropods, and crabs. These organisms rely on a non-corrosive environment to form and maintain their skeletons and shells. The Tribe has observed that oyster seed seems to be in short supply and that this may be influenced by ocean acidification. Although limited field studies on ocean acidification have been conducted in Puget Sound, studies elsewhere suggest that ocean acidification will reduce the mussel and oyster shell formation rate by 40%, growth rate by 17%, and survival rate by 34% by the end of the century.[5] These impacts may threaten the Tribe's current reliance on the natural recruitment and reproduction of shellfish stock, bringing considerable consequences for the livelihoods of the approximately 100 geoduckers and 100 to 130 commercial crabbers within the Tribe.

Population growth and development have already caused visible changes in shellfish habitat, and climate change will exacerbate these impacts. Studies suggest that sea level rise will cause a 64 to 91% loss of south Puget Sound's estuaries by 2100.[54] Extreme precipitation events can rapidly change sedimentation, potentially damaging commercial harvesting operations and shellfish populations with little warning.[55]

Armored shorelines impede adaptation of intertidal zones, a critical habitat for shellfish, to sea level rise.[54] Urban development around our Tribal lands and low tree canopy cover along streams can also exacerbate climate-driven temperature increases, heightening the risk of hypoxia and toxic phytoplankton outbreaks (also called harmful algal blooms, or HABs).

Since the 1950s, Puget Sound has seen steady increases in the frequency and geographic scope of HABs that are known to cause paralytic shellfish poisoning (PSP) in humans.[56] Other known health risks associated with shellfish contamination from HABs include amnesic shellfish poisoning and diarrhetic shellfish poisoning.[57, 58] These types of poisoning can bring serious consequences, from gastrointestinal ailments to muscle paralysis and even death in extreme cases.[59] To date, harmful algal blooms have not been a major concern for the Tribe, but the Tribe continues to monitor Washington State's toxin testing results to identify any changes.

Projected changes in water quality resulting from climate change will also favor the growth of the bacteria ***Vibrio***. Excess ***Vibrio*** can contaminate shellfish the same way HABs do and can lead to vibriosis in humans, which also causes gastrointestinal issues.[60]

Wildlife

Warming temperatures and precipitation changes will alter the survival, distribution, and phenology of some wildlife and game species—especially those not able to keep pace with a shifting climate. For many species, non-climate stressors like land use changes will exacerbate these impacts. For example:

- **Wolverine** is a highly snow-dependent species, so changes in snowpack will greatly affect wolverine vulnerability to climate change.[61] Overall, wolverine habitat is projected to shift significantly to higher elevations in western Washington and decline overall.[5] Recently, Puyallup Tribal staff identified a potential new wolverine habitat area near the Goat Rocks wilderness. Staff are currently collecting additional data to determine whether a population of wolverine inhabits the area, or if the sighting was an isolated occurrence.
- **Northern spotted owl** habitat may decline due to wildfire and loss of high-quality habitat.[5]
- **Elk** are less sensitive to climate change relative to other species in the Puyallup region because they are habitat and forage generalists, and they can move long distances and tolerate a large range of climatic conditions.[61] Increased wildfire frequency and intensity may produce more early successional habitat area for herds. Still, climate change as well as non-climate stressors like development put the herds at risk. Pressures like habitat fragmentation and conversion may weaken population resilience and challenge elk survival;[62] when land is converted to agriculture and other uses, it can reduce the herds' critical winter ranges. Introduction of and expansion of existing invasive species, diseases, and parasites could bring new or heightened threats to elk food sources and population health. Canopy closure and meadow disappearance in alpine and subalpine habitats could also limit the quantity and quality of forage in summer ranges for elk as well as for black bear and deer. In particular, there is concern about the continued availability of the subalpine huckleberry.[61] Additional research is needed to fully understand how climate change may affect specific elk populations—like the South Rainier herd in the Upper Cowlitz basin—that are hunted by the Puyallup Tribe.

The Tribe has taken steps to better understand elk population threats and potential management solutions. A recent study of the South Mt. Rainier Elk Herd by Tribal wildlife biologist Barbara Moeller identified critical winter habitat areas along the Cowlitz River valley and found that the elk would benefit from expanded protection and restoration of their winter range.[63] The Tribe has restored more than 300 acres of winter elk habitat in the Cowlitz valley and started an elk reserve with 45 acres of bottom land. The Tribe is also working with Pierce County and landowners to encourage increased riparian buffers.

Habitat Restoration

The Tribe has spearheaded several habitat restoration efforts to improve and preserve important ecosystem functions and services within Tribal areas. These restoration projects will be critical for ensuring continued ecological services and functions in the face of a changing climate. Examples of important restoration sites within the Tribal reservation include the following:

- **Hylebos waterway:** The result of a settlement agreement with the Port of Tacoma, the Hylebos waterway restoration site is an 88-acre conservancy that provides critical protection for juvenile salmon. Shellfish harvesting is restricted within the former Superfund site, which was historically used for log sorting and an auto repair shop.
- **Outer Hylebos:** The Tribe received a second site from the Port of Tacoma in 1986, located near the mouth of the Hylebos waterway that was previously used for aquaculture. The Tribe restored the intertidal mudflat and wetland in 2013.
- **Jordan (West Fork Hylebos Creek):** A joint restoration site with the Port of Tacoma, the Jordan restoration site is a 42-acre stream and floodplain restoration project that includes Wapato Creek. The area used to be filled with invasive reed canarygrass, which forms a thick sod layer that can exclude all other plants.
- **WSDOT and the Port of Seattle** have several mitigation sites within the reservation.

Water Quality

Climate change will likely exacerbate stressors that are already degrading the quality of streams and waterways that the Tribe depends on for recreation, cultural activities, and sustenance. Lower summer precipitation combined with warmer summer temperatures will stress streamside vegetation and worsen summer low flows in urban and rural streams, concentrating pollutants and increasing instream temperatures in the Puget Sound region.[29] These conditions will strain aquatic species and increase the risk of harmful algal blooms, as well as worsen dissolved oxygen levels and other parameters regulated under state surface water quality standards. 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.

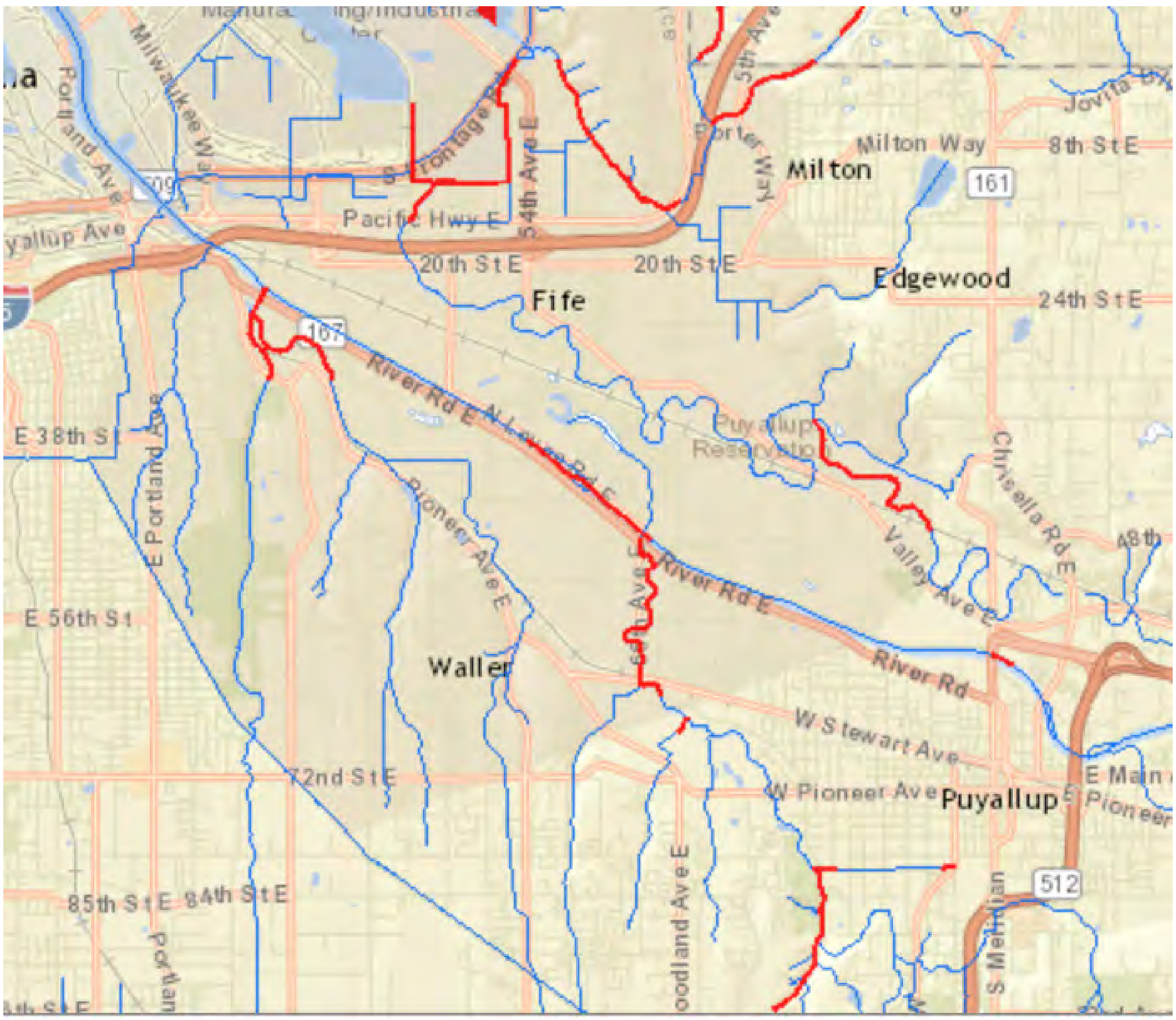
The Tribe's Water Quality department has already observed changes to their monitored streams—many of which have little riparian canopy and have undergone channelization or bank modifications. The department, which has had a water quality monitoring program since 1998, has observed the following trends related to water quality of monitored streams:

- Streams are consistently and increasingly exceeding federal standards for temperature, especially South Prairie Creek—an important stream for salmon migration.
- Heavy rainfall events have resulted in observed impacts to sedimentation and turbidity, and these events are projected to increase in frequency and intensity over the next century. Clarks Creek, a highly urbanized stream, has especially suffered from an influx of stormwater-driven sediment, pollution, and temperature increases during high rainfall events.

- Many of the Tribe's important fish-bearing streams suffer from low dissolved oxygen levels, likely due to a combination of fish density and temperature and nutrient loads.
- Elodea algal blooms have become an increasingly challenging issue that worsens with nutrient loading and temperature increases.
- Other waterways that already suffer from impaired water quality include the Puyallup River, Swan Creek, Wapato Creek, Green Water River, Clear Creek, Clearwater River, and Huckleberry Creek.

Streams that support salmon migration and growth will suffer from higher temperatures and reduced dissolved oxygen levels, in addition to the existing stress of an urbanized environment.

Figure 10. Federally designated impaired streams on the 303(d) list of the Clean Water Act within the Puyallup Tribal region. Impaired streams, noted in red, include Clarks Creek, Puyallup River, Swan Creek, and Wapato Creek. Source: Washington State Department of Ecology.[64]



Population growth and development will also continue to strain water quality and quantity in the region, and saltwater intrusion from rising sea levels may affect instream salinity levels. Actions that preserve base flows and habitat—such as reestablishing meanders, buffering along the floodplain, increasing floodplain and channel connectivity and complexity, and enhancing vegetative cover—will help address these water quality risks. The Tribe has undertaken a number of these types of projects through partnerships with local and federal agencies, including the following:

- The Tribe recently worked with the City of Puyallup to remove elodea from **Clarks Creek,** where a steelhead hatchery is located. The Tribe also purchased property along the streambank and worked with the Pierce County Conservation District to improve vegetation cover along the stream through tree planting.
- The Tribe is also working with the City of Puyallup on two channel stabilization projects to remove sediment and slow down flows to allow infiltration in the incised area of **upper Clarks Creek**. The stabilization projects will reduce (and store) over 90 tons of sediment per year from the upper watershed. This stabilization will benefit downstream uses, including operations of the Tribe's Chinook hatchery.
- The Tribe is also working with the Pierce County Conservation District to reestablish the natural meander of **South Prairie Creek** through land acquisition and river restoration.
- The Tribe's Water Quality department is working with the Tribe's Fisheries department on a feasibility study to reestablish the meander patterns of **Boise Creek** and improve fish passage past the falls.

Continued restoration efforts at these and other threatened streams such as Wapato and First creeks will support climate resilience while protecting important habitat, species, and cultural traditions.

Cultural Resources and Traditions

The Tribe's important archaeological sites, resources, and traditions will also be subject to the hazards of a changing climate. Cultural sites along the waterfront may experience more frequent and more intense flooding and storm surges. Changing precipitation and temperatures may alter the availability of traditional plants for a range of purposes. Diminishing salmon populations will continue to threaten traditional ceremonies and nutrition.

It is critical to consider the exposure of our Tribe's archeological sites and assets to climate impacts such as flooding to ensure their continued protection and preservation. This study did not examine specific sites due to the sensitivity of that information; however, we can anticipate how different sites may be vulnerable based on their locations and characteristics. Assets on a beach or low-lying area near water bodies such as the Puyallup River, for example, may be at risk of flooding or sea level rise impacts, which may temporarily or permanently inundate sites, impede access, and corrode certain materials. More frequent and intense rainfall may inundate areas near rivers and streams that were previously outside flood risk zones.

Shifting distributions of habitat and species may limit the ability to gather materials used to make traditional products.

The accessibility and availability of traditional plants, roots, and other resources may change as species distributions and habitats shift. The abundance of warmer, lower-elevation forests rich in species like Douglas fir are expected to decline by the end of the 2060s due to summer water availability limitations, especially in south Puget Sound and in the southern Olympic Mountains. At the same time, high-elevation species such as western hemlock, cedar, and whitebark pine may experience a longer growing season as snowpack declines.[5] Future drought conditions could threaten traditional ceremonies that require cedar bark, as cedar trees' weakened resilience to pest and disease outbreaks during droughts may outweigh any benefits of a longer growing season.[12] Regardless of type or abundance, all forests in Washington State will be subject to increased risks of wildfire, disease, and pests, which could cause quick, significant loss of forest habitat and the resources therein in some years.

The Tribe has already observed a declining abundance and changing seasonality of traditional cultural resources. Wild berries, including huckleberries, ripened two weeks earlier in 2015 than in previous years, requiring an adjustment in the timing of traditional harvesting activities. High wildfire risk in the summer of 2015 prevented the Tribe from lighting traditional sweat fires.

Development-driven pressures add to these climate-related stresses, putting our resources further at risk. Development-driven vegetation loss and pollution has already compromised the health and abundance of the Tribe's natural areas—many of which had been used for ceremonial and traditional purposes for centuries. Addressing these kinds of non-climate stressors is one way to help build resilience.[1]

Transportation

Many of the Tribe's important transportation routes lie in flood- or landslide-risk areas. The Washington State Department of Transportation's (WSDOT) ***Climate Impacts Vulnerability Assessment*** identified relative vulnerabilities of the State's highway infrastructure to climate change impacts including sea level rise, precipitation change, temperature change, and fire risk. Findings from this study, depicted in Figure 11 below, suggest that the following highways in or near our reservation may be highly vulnerable to climate change impacts, based on the specific potential impacts and the criticality of these routes:

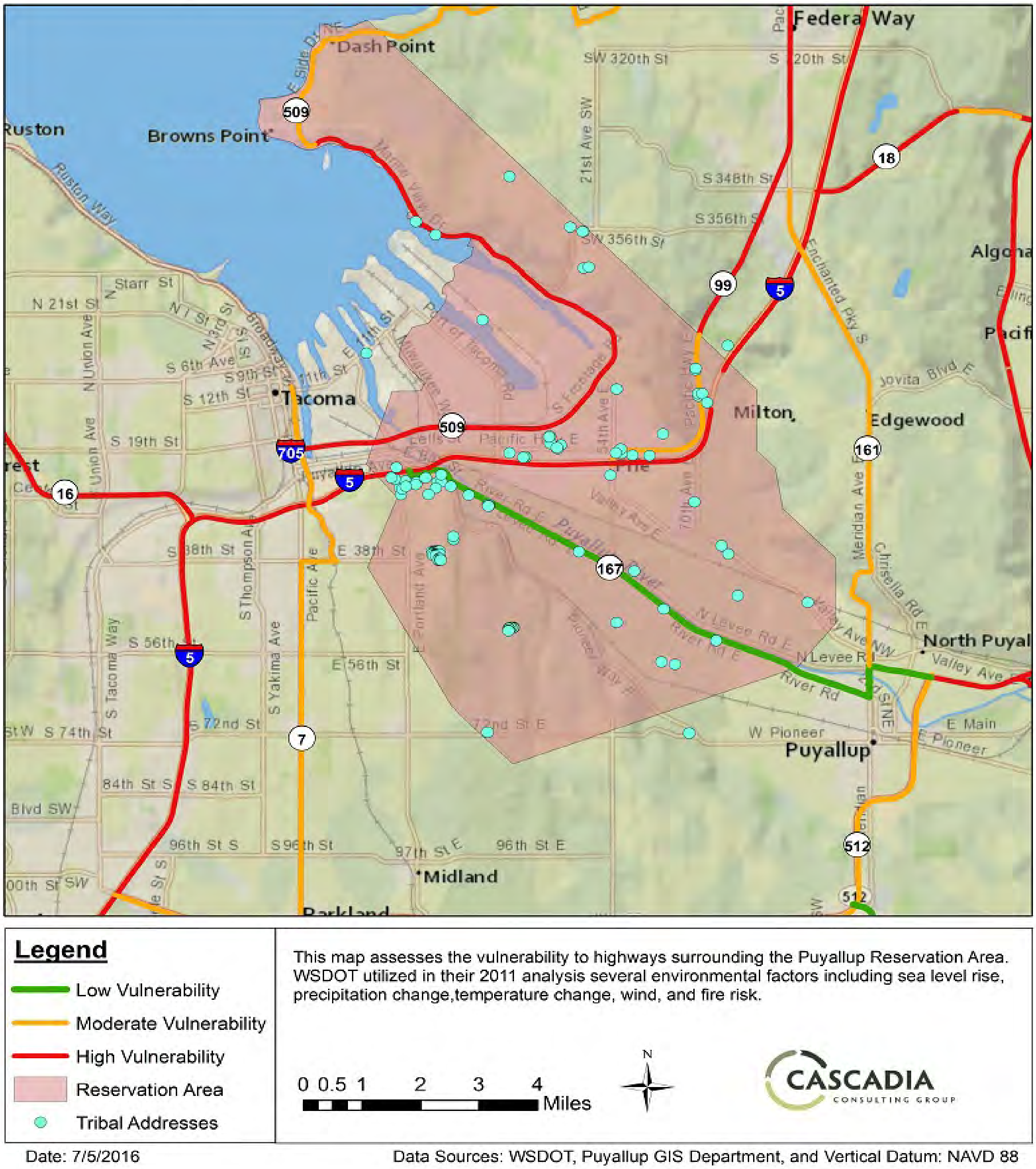
- Highway 509 from downtown Tacoma to Dash Point
- Interstate 5 from Lakewood to Federal Way
- Highway 99 from the edge of the reservation to Federal Way
- Highway 167 from north Puyallup to Auburn

Highway 512 is rated as having medium vulnerability.

It is likely that climate-driven flooding and landslides will also affect other local transportation routes that were not assessed by WSDOT; further study would be required to assess the relative vulnerability of these routes.

Considering climate change in constructing or updating transportation infrastructure will ensure that transportation systems can withstand future impacts. Plans to construct the Puyallup River bridge next year, for example, serve as an opportunity to proactively build in resilience at the onset of major infrastructure projects.

Figure 11. Vulnerability of Puyallup-area highways to one or more climate change impacts. Source: Washington State Department of Transportation 2011.[65]



Public Health and Safety

Changes in air quality, foodborne illness risks, extreme events, and other environmental factors associated with climate change will present increased threats to the health and safety of our Tribal members.[56, 66, 67] Sensitive and vulnerable populations such as the young, elderly, disabled, and homeless are especially at risk.

More frequent and severe extreme heat, flooding, and algal bloom events could increase the risk of respiratory illness, foodborne illness, and physical injury.

In the last decade, more Americans have died from extreme heat than from any other weather-related cause.[68] Heat waves are frequently accompanied by increased ground-level ozone concentrations that can cause respiratory problems for certain vulnerable populations. This threat is especially critical in Pierce County, where asthma is already a concern; studies have shown a 1 to 7% increase in asthma diagnoses between 2002 and 2012, with 30% of children in Pierce County public schools experiencing an asthma attack in 2012.**[69] Indoor mold prevalence is also an air quality-related health concern that Tribal staff fear could be exacerbated by a changing climate. More research is needed to determine how these risks may change under future climate conditions and how those changes may affect health in the Puget Sound region and among Puyallup Tribal members.

Heavy rain and flood events can also jeopardize the health and safety of Puyallup Tribal members. Flooding of structures and roads can limit the ability of residents to move out of harm's way, as well as the ability of first responders to reach those in need. Tribal staff have observed that River Road and Lower Clear Creek are particularly susceptible to flooding; residents had to evacuate the area during previous flooding events. During these disaster events, the Emerald Queen Casino serves as a critical site for emergency shelter and food.

Climate change could also heighten the risk of foodborne illness. Warmer air and water temperatures, ocean acidification, and increased nutrient runoff during heavy precipitation events will likely create favorable conditions for a number of phytoplankton species, many of which produce toxins that accumulate in shellfish.[70] The frequency and severity of harmful algal blooms is projected to increase in Puget Sound; these blooms could lead to beach closures and human health risks if contaminated shellfish are ingested.[66] See the ***Shellfish*** section above for more information.

To respond to these and other public health and safety risks, Tribal staff have recently updated emergency response and preparedness plans, including the Hazard Mitigation Plan, Comprehensive Emergency Management Plan, and the Threat and Hazard Identification and Risk Assessment. The Tribe is currently developing plans to increase public education and engagement in the emergency preparedness process to ensure that Tribal members understand how to prepare for and respond to extreme situations.

The Tribe lacks funds to undertake many other preventative and response measures to address these risks, including building retrofits, cooling centers, redundant emergency shelters, mold remediation, and emergency services. To date, the Tribe has had limited capacity to seek funding through FEMA's Hazard Mitigation Assistance programs, which can help fund restoration projects post-disaster, development of preparedness plans, and retrofits of properties in repetitive flood zones.[71] Currently, the Tribe relies heavily on the response of outside municipalities during emergencies, particularly for fire and paramedic crews. Increasing our internal prevention and response capabilities would help us better protect the health and safety of our Tribe in the face of climate variability and change. It is also important that the Tribe remain engaged in external stakeholder meetings—such as with adjacent localities and owners/operators of critical infrastructure—to ensure emergency response and hazard mitigation plans are aligned and coordinated.

** Includes children between grades 8 and 12.

Adaptation Options

Existing Programs and Plans

The Puyallup Tribe has already undertaken important actions to improve the general resilience of its natural and built systems. As described in the preceding chapters on ***Climate Impacts and Projections*** and ***Sector-Specific Impacts***, Tribal plans, programs, and activities that address climate change threats include the following:

- **Habitat Restoration:** Habitat preservation and restoration is a high priority for the Tribe. The Tribe partners with local jurisdictions such as the Port of Tacoma to acquire, protect, and restore important systems and functions, including coastal intertidal habitat along the Hylebos waterway and floodplain habitat along Clarks, South Prairie, and Boise creeks.
- **Hatchery and Fishery Management:** To address flood risks affecting local hatcheries, the Tribe's Fisheries and Environmental departments recently worked with Washington State Environmental Management and FEMA to stabilize the riverbank at a fish hatchery near Buckley.
- **Monitoring:** The Tribe monitors water quality and other indicators on a regular basis.
- **Emergency Management:** Tribal staff have recently updated emergency response and preparedness plans, including the Hazard Mitigation Plan, the Comprehensive Emergency Management Plan, and the Threat and Hazard Identification and Risk Assessment.
- **Public Education and Outreach Programs:** The Tribe participates in joint presentations about air quality health risks and asthma with the U.S. Environmental Protection Agency at Chief Leschi School. The Tribe is currently developing plans to increase public education and engagement in the emergency preparedness process to ensure that Tribal members understand how to prepare for and respond to crises.

Despite this progress, more work will be needed to adequately prepare for and respond to the risks of climate change. The adaptation approaches below present initial ideas that Tribal staff have developed to build upon successes to date with actions and strategies that protect the health and livelihood of the Tribe's most vulnerable people, places, and resources.

Adaptation Approaches

During the project's third workshop, in April 2016, Tribal staff reviewed adaptation measures adopted by other communities and tribes, brainstormed potential adaptation measures, and used the following criteria to conduct a preliminary screening:

- **Effectiveness:** Likelihood that the action will work to address identified climate vulnerabilities.
- **Affordability:** Overall expense and ease of covering the costs with Tribal budget, grants, or other funds.
- **Feasibility:** Encompasses both technical and political feasibility; includes the likelihood of obtaining support for action and whether the measure is possible to implement.

The adaptation options listed below performed well against these criteria during the screening exercise conducted at the workshop. Additional criteria to include in further evaluation of the proposed adaptation options may include flexibility, consistency with Tribal priorities, urgency, near-term windows of opportunity, and co-benefits.

The adaptation options are presented by sector/resource and categorized under these five main strategies within each sector/resource:

1. Implement protection, restoration, and management practices
2. Provide education and guidance
3. Reevaluate policies, plans, and protocols
4. Gather additional information
5. Leverage partnerships

Fisheries, Hatcheries, and Shellfish

Strategy #1: Implement protection, restoration, and management practices

- **Use hatchery practices (e.g., on-water floating nurseries) to get shellfish larvae past the vulnerable stage**; use out-planting methods.
- **Reduce sources of nutrients that contribute to harmful algal blooms**; in the future, as conditions worsen, this effort could include exploring the use of mussels to filter out excess nutrients.
- To increase stormwater system capacity, **use Low Impact Development (LID) techniques** such as rain gardens for water runoff detention and infiltration.
- **Update the heat exchange system at the Clark Creek Hatchery.**
- **Expand efforts to stabilize headwaters above spawning habitat** (e.g., using large wood, vegetative mattresses). Help seek funding for local jurisdictions to implement such efforts beyond the Puyallup Reservation.

Strategy #2: Provide education and guidance

- **As needed in the future, conduct more outreach to Tribal members** regarding beach closures and response to biotoxin events; information could be shared through the Tribal newspaper, email lists, and at the point of permitting.

Strategy #3: Reevaluate policies, plans, and protocols

- **Lobby for state changes in hatchery management** (e.g., increases in shading, augmenting flows with cooler groundwater when necessary).

Strategy #4: Gather additional information

- **Continue to track data from Washington State** on emerging biotoxins in the region.

Strategy #5: Leverage partnerships

- **Continue to work with the Army Corps of Engineers** to increase shading downstream from Tribal hatcheries.

Public Safety, Air Quality/Health, Transportation, and Infrastructure

Strategy #1: Implement protection, restoration, and management practices

- **Develop redundant services to accommodate system disruptions due to flooding and more frequent storms**, such as by building "rescue roads" and redundant power and communications systems. Ensure that primary and alternate transportation routes can continue to provide everyday access, emergency vehicle access, and evacuation in a safe and effective manner, in the context of a changing climate.
- **Ensure that services provided by critical facilities, including medical and emergency services, are consistently available to at-risk populations.**
- **Increase urban water absorption capacity by minimizing paved surfaces**, using absorptive or permeable construction materials, and increasing public awareness and participation in reducing runoff.
- To extend the life of infrastructure and reduce risks of pollution due to flooding, **locate structures and equipment at higher elevations**. In new construction areas, consider revising ground level requirements to accommodate increased winter flooding.
- Strengthen existing structures and **build protective infrastructure, including slope control structures, to prevent landslides** along elevated and exposed transportation routes.
- **Plant drought- and heat-resistant plant species for erosion control**.
- **Develop natural protective infrastructure** such as embankments, sea walls, beach nourishment, and/or natural infrastructure such as marshes, reefs, beaches, barrier islands, and vegetated shorelines in combination with road construction.
- Work with other agencies and jurisdictions to **consider building new set-back levees** to channel flood waters away from critical roads and abutments of important bridges.
- Consider anticipated increases in peak streamflows when **designing and constructing the new Puyallup River bridge**.

Strategy #2: Provide education and guidance

- **Incorporate climate resilience into current public outreach and education programs**, such as those for air quality.

Strategy #3: Reevaluate policies, plans, and protocols

- **Integrate future climate risk when updating emergency plans and hazard mitigation plans.**
- **Incorporate climate resilience into planning efforts and land use development,** recognizing where new development could be at-risk and adjusting decisions as needed. For example, locate facilities where climate risks are lower.
- **Maintain and periodically update flood contingency and emergency response action plans**, and conduct drills.
- **Consider climate change impacts when planning new assets or rehabilitating existing assets,** especially as part of strategic asset management efforts.
- **Monitor changes in design standards** relating to drainage, and consider applying floodplain-level standards in areas vulnerable to flooding in the life of the project even if they are not located in the current 100-year floodplain.

- **Prohibit road and utility construction in areas subject to excessive erosion and/or accretion.**
- **Consider changing the permitting process** to include sea level rise and other climate change datasets. Review projects not only to consider immediate impacts but also medium- and longer-term anticipated impacts.

Strategy #4: Gather additional information

- **Continue to evaluate risks and devise plans for protecting facilities** that will be exposed to future flood risks during high tides.

Strategy #5: Leverage partnerships

- **Team with other agencies to provide flood mitigation/protection around critical infrastructure** (e.g., repurpose transportation agencies' right-of-way to provide additional flood storage and/or increased conveyance).
- **Coordinate with the City of Tacoma as the city completes its Climate Change Resilience Study** and prepares to make decisions about further studies or adaptation actions.
- **Improve communication with nearby localities (e.g., Tacoma, Fife, Federal Way) to ensure coordinated emergency response and preparedness plans,** especially with regard to services that the Tribe relies on external agencies to provide (e.g., fire and emergency medical services).
- **Increase Tribal participation in road planning projects by strengthening relationships and communication with WSDOT and other stakeholders, and including climate change considerations on meeting agendas.** For example, urge WSDOT to increase scour and erosion protection at bridges and to provide increased river conveyance at bridge crossings (or culverts), such as enlarging culverts or increasing bridge deck elevation to accommodate increased flows.
- **Explore using FEMA funds to implement adaptation projects.** For example, seek funding from FEMA's Hazard Mitigation Assistance grant programs to fund acquisition or elevation of structures in repetitive flood zones.
- Explore joining the National Flood Insurance Program.

Natural Resources (Habitat and Wildlife Restoration and Conservation), Water Quality

Strategy #1: Implement protection, restoration, and management practices

- **Implement on-the-ground habitat and water quality restoration projects** that serve one or more of the following functions:
  - **Enhance floodplain connectivity**, such as by:
    - Improving and reconnecting side channels
    - Setting back levees and dikes
    - Reestablishing stream meanders
    - Daylighting streams (uncovering and restoring buried streams)
    - Focusing on areas within the current 100-year floodplain
  - **Provide refuges for fish** from summer high temperature and winter/spring high-energy flows, such as by:
    - Identifying, protecting, and restoring off-channel habitat
    - Identifying and protecting cool water inflows, undercut banks, and deep stratified pools
    - Increasing shading of streams by planting native trees

  - **Reduce discharge of warm water and stormwater into rivers and streams** (e.g., from irrigation, point source discharges from industry and power plants).
  - **Reduce forest susceptibility** to severe fire, insect outbreaks, and drought by establishing or enhancing planned treatments of forest sites that specifically manage for these impacts.
  - **Restore high-quality freshwater habitat** through the reintroduction of beavers, wetland mitigation and restoration, groundwater recharge, and flow augmentation.
  - **Maintain and increase biological diversity and connectivity** to increase large-scale resilience of vulnerable landscapes to droughts, wildfires, and flooding.
  - **Diversify vegetation and enhance water-retaining areas**, such as by abutting wetland projects to agricultural areas to reduce flood vulnerability.
  - **Provide corridors between conservation areas** to help plants and animals migrate to new locations with suitable habitat.
  - **Protect undeveloped areas that are up-gradient from tidal wetlands** to allow wetland migration and buffer intact ecosystems.
  - **Restore badly eroded streams at coastal outfalls.**
- **Accommodate and facilitate inland/upland migration of tidal freshwater habitats** by creating/restoring wetlands in place with boundary protection (e.g., sill, rock), planned elevation increases, and considering development upstream that could affect species migration.
- **Use vegetation species for restoration that are more flood- and drought-tolerant** and that can withstand higher salinity.

Strategy #2: Provide education and guidance

- **Educate landowners and stakeholder groups about the importance of** conservation and restoration of key corridor habitats, such as buffer areas along riparian systems and critical winter range habitat for elk.
- **Educate Tribal members about existing habitat conditions** and the benefits of building the resilience of those habitats.
- **Use public access points, nature centers, and hunting and fishing regulation guides to inform people of climate change impacts** on wildlife, and what they can do to help.

Strategy #3: Reevaluate policies, plans, and protocols

- **Introduce new policies that encourage or require native and/or drought-tolerant vegetation** in all landscaping and restoration projects.
- **Examine how restoration project maintenance may need to be restructured in drought years**.
- **Incorporate climate change considerations into existing and new management plans** for protecting sensitive and vulnerable species.
- **Update natural resource protection plans, land use plans, and water resources management plans** to address climate change considerations for species and ecosystems.
- Work with partner jurisdictions to evaluate opportunities for improving **current land use permitting processes.**

Strategy #4: Gather additional information

- **Continue examining climate impacts to alpine and subalpine habitats** and associated threats to wildlife such as wolverine, bear, deer, and elk.
- **Work with EPA to initiate research on groundwater influence on stream temperature** within Tribally monitored streams.
- **Continue to monitor and document elk populations** to better understand trends and the impacts of climate change and other stressors, such as effects of increased wildfires on availability of early successional foraging habitat and changes in disease and parasite threats.

Strategy #5: Leverage partnerships

- **Work with partner jurisdictions to leverage seed funding for habitat restoration projects.** For example, fund the design phase internally and partner for the construction phase.
- **Work with conservation groups and nonprofits** to encourage private landowners to protect critical habitat areas through conservation easements.
- **Work with the Army Corps of Engineers to allow more vegetation and shade along levees** through their variance process.
- **Encourage the City of Tacoma and the Port of Tacoma to remove bulkheads and shore defense works** to restore shoreline, preserve natural processes, and help adapt to sea level rise.
- **Work with partner jurisdictions to encourage management of forest density** to reduce susceptibility to severe fire, insect outbreaks, and drought by establishing or enhancing structural prescriptions.

Appendix A. Terms and Definitions

100-year flood	A flood that statistically has a 1-percent chance of occurring in any given year.
Accretion	The gradual accumulation of additional layers or matter.
Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.
Anthropogenic	Originating in human activity.
Adaptive capacity	The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
Atmospheric river	A narrow band of water vapor transport extending from the tropical Pacific to the west coast of North America during the winter months.
Base flood elevation	The 100-year flood elevation used by FEMA.
Climate	The statistics of weather. In other words, the average pattern for weather over a period of months, years, decades, or longer in a specific place.
Emissions	The release of greenhouse gases and/or their precursors and aerosols into the atmosphere over a specified area and period.
Exposure	The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected by climate change.
Extreme weather event	An event that is rare within its statistical reference distribution at a particular place.
Greenhouse gases	The gaseous constituents of the atmosphere, both natural and anthropogenic (including carbon dioxide, methane, and other gases), that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds.
Hypoxia	Low or depleted oxygen in a water body.
Levee	A natural or human-made earthen barrier along the edge of a stream, lake, or river.

Ocean acidification	Increased concentrations of carbon dioxide in sea water causing a measurable increase in acidity (i.e., a reduction in ocean pH). This may lead to reduced calcification rates of calcifying organisms such as corals, mollusks, algae, and crustaceans.
Peak flow	The maximum instantaneous discharge of a stream or river at a given location.
pH	The pH scale measures how acidic or basic a substance is. It ranges from 0 to 14. A pH of 7 is neutral. A pH less than 7 is acidic, and a pH greater than 7 is basic.
Projection	A potential future evolution of a quantity or set of quantities, often computed with the aid of a model. ***Projections*** are distinguished from ***predictions*** to emphasize that projections involve assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.
Redd	A spawning nest that is built by salmon and steelhead in the gravel of streams or the shoreline of lakes.
Resilience	The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.
Scenario	A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships.
Sensitivity	The degree to which a system is affected, either adversely or beneficially, by climate variability or change.
Snow water equivalent	The amount of water contained within the snowpack.
Storm surge	The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds).
Vulnerability	The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.
Weather	The atmospheric conditions at a specific place at a specific point in time.

These definitions are drawn from the Environmental Protection Agency (including its Glossary of Climate Terms), the US Department of Agriculture Forest Service Climate Change Glossary, the Intergovernmental Panel on Climate Change, and the University of Washington Climate Impacts Group website.

Appendix B. Additional Maps

Figure 12. Tribal-owned facilities (green dots) for a portion of Puyallup Reservation north of SR-167, south and east of North Frontage Road, and west of 62nd Avenue East projected to be at risk of flooding during extreme high tides in 2050. Dark blue areas are already below base flood elevation (BFE). Light blue are below BFE with 19 inches of sea level rise (the high-range estimate for 2050).

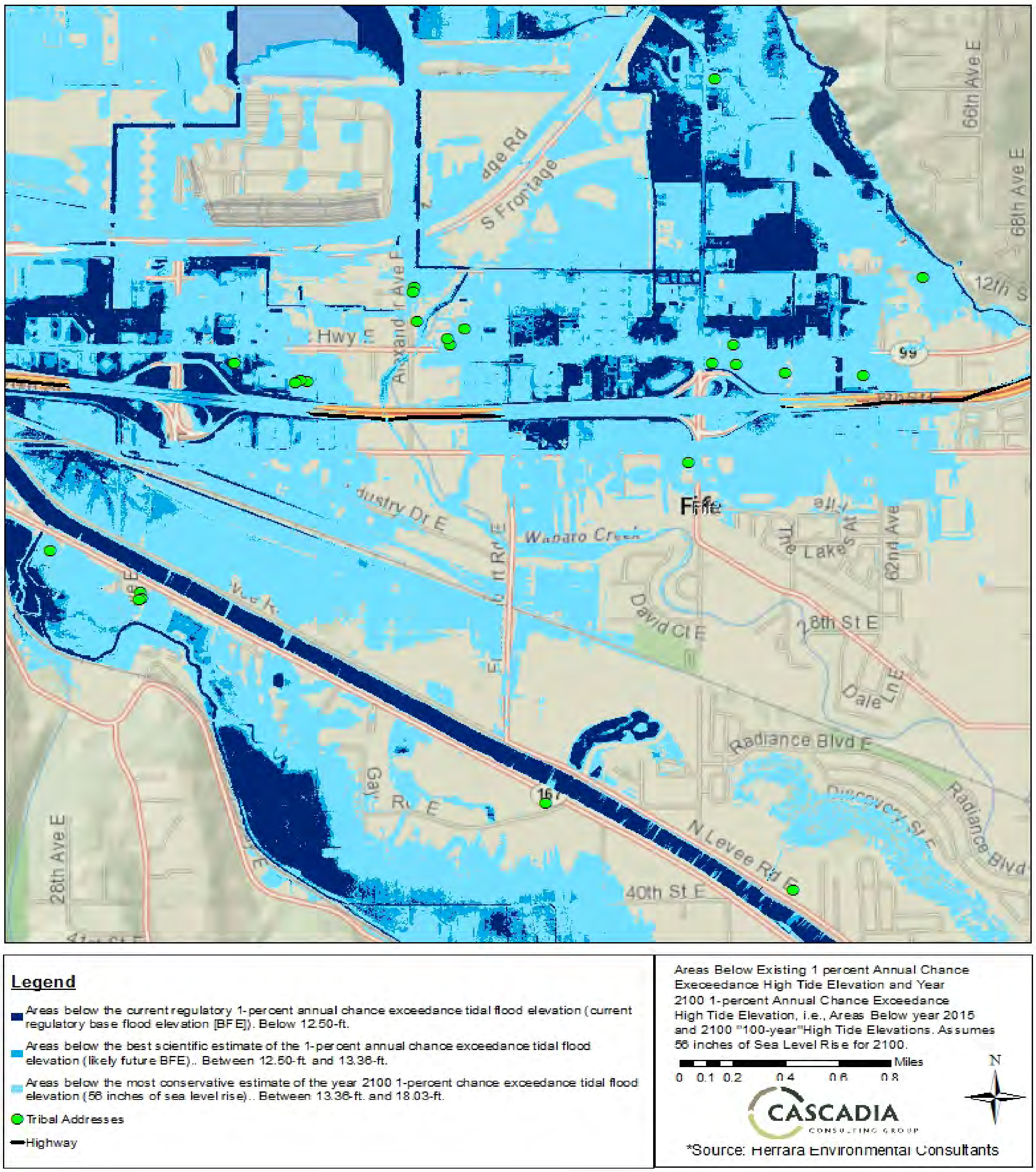


Figure 13. Tribal-owned facilities (green dots) for a portion of Puyallup Tribe Reservation north of SR-167, south and east of North Frontage Road, and west of 62nd Avenue East projected to be at risk of flooding during extreme high tides in 2100. Dark blue areas are already below base flood elevation (BFE). Light blue are below BFE with 56 inches of sea level rise (the high-range estimate for 2100).

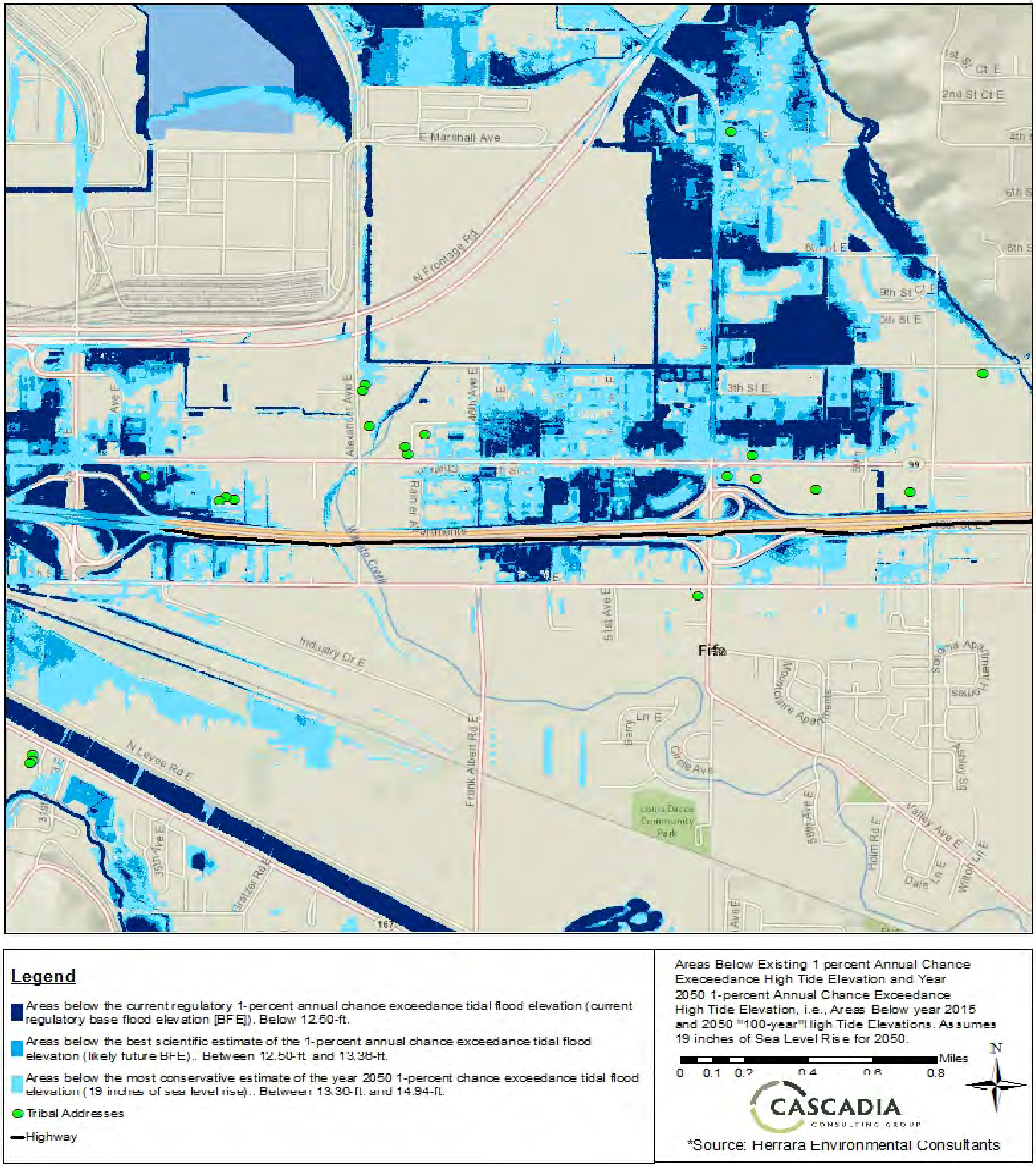


Figure 14. Current FEMA flood hazard areas for a portion of the Puyallup Tribe Reservation. Tribal-owned facilities are marked with green dots.

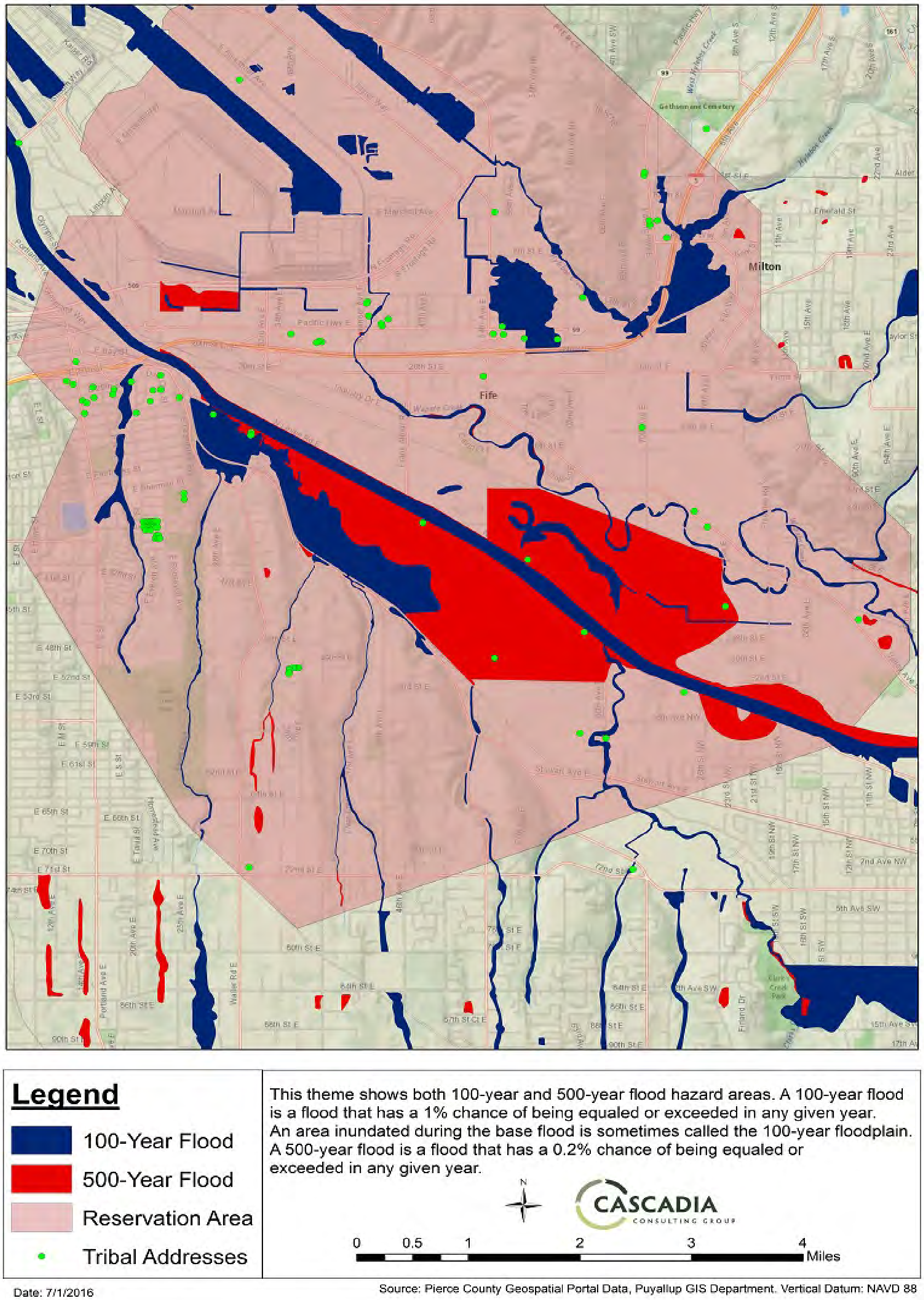
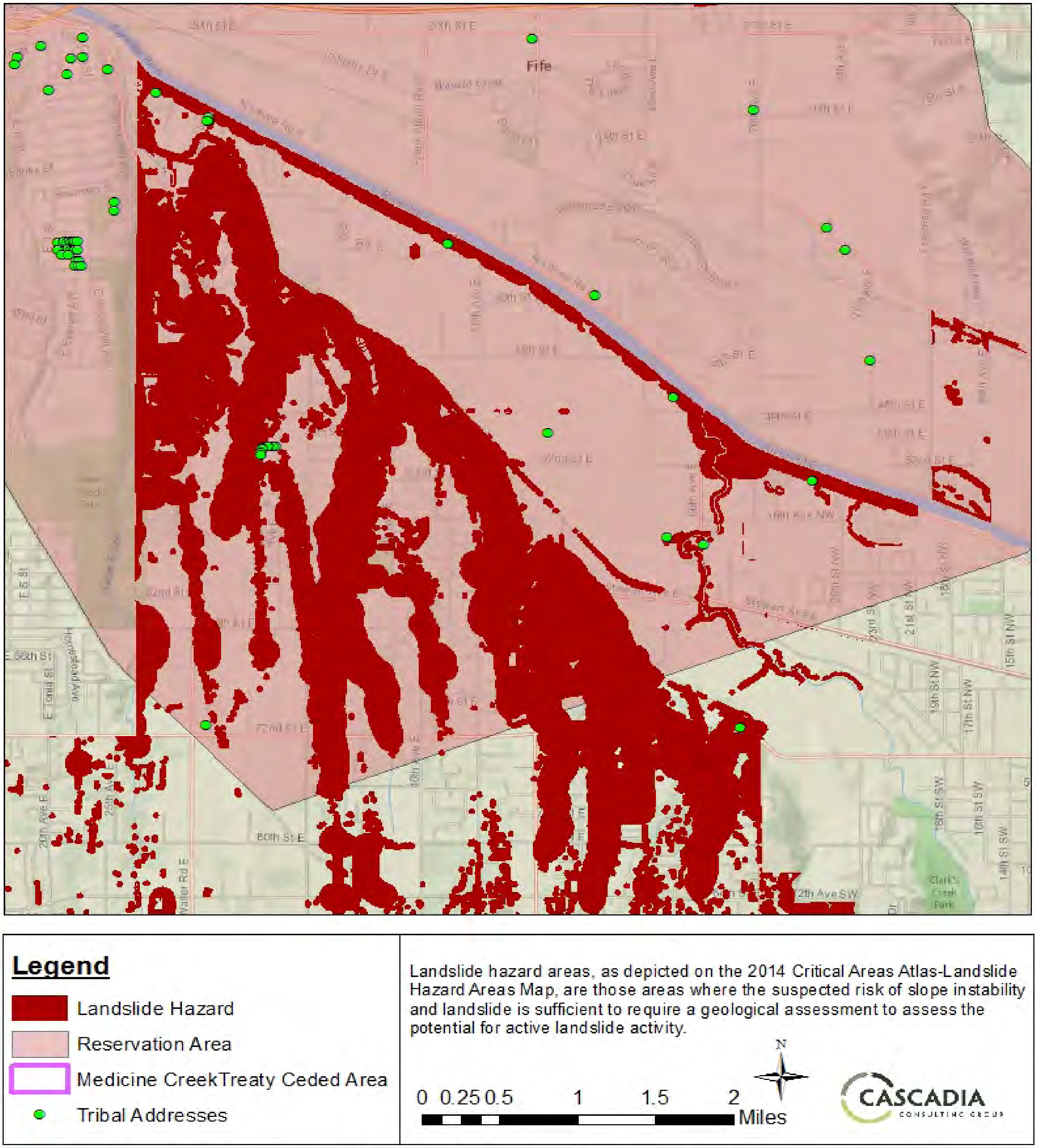


Figure 15.Landslide hazard areas for a portion of the Puyallup Reservation.



Date: 12/10/2015

Source: Pierce County Geospatial Portal Data, Puyallup GIS Department. Vertical Datum: NAVD 88

Appendix C. Bibliography

[1]	M. Meinshausen, "The RCP Greenhouse Gas Concentrations and Their Extensions from 1765 to 2300," Climatic Change, vol. 109, no. 1, pp. 213-241, 2011.
[2]	A. K. Snover, G. S. Mauger and L. C. Whitely Binder, Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision-Makers, Seattle: Climate Impacts Group, University of Washington, 2013.
[3]	K. A. Bumbaco, K. D. Dello and N. A. Bond, "History of Pacific Northwest Heat Waves: Synoptic Pattern and Trends," Journal of Applied Meteorology and Climatology, vol. 52, no. 7, pp. 1618-1631, 2013.
[4]	Climate Central, "Frost-Free Season is Getting Longer," Climate Central , 16 October 2014.[Online]. Available: http://www.climatecentral.org/gallery/maps/frost-free-seasons-are-getting-longer.
[5]	G. S. Mauger, J. H. Casola, H. A. Morgan, R. L. Strauch, B. Jones, B. Curry , T. M. Busch Isaksen, L. Whitely Binder, M. B. Krosby and A. K. Snover, "State of Knowledge: Climate Change in Puget Sound," Climate Impacts Group, University of Washington, 2015.[Online]. Available: http://cses.washington.edu/picea/mauger/ps-sok/PS-SoK_2015.pdf.
[6]	M. M. Dalton, P. W. Mote and A. K. Snover, "Chapter 2, Climate: Variability and Change in the Past and the Future," in Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities, Washington, Island Press, 2013, pp. 25-40.
[7]	Climate Impacts Group, How Will Climate Change Affect the Puyallup Watershed?, Seattle: University of Washington, 2015.
[8]	K. E. Kunkel, L. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, J. Rennells, A. DeGaetano and J. G. Dobson, "Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 1. Climate of the Northeast U.S.," NOAA Technical Report NESDIS 142-1, p. 79, 2013.
[9]	J. Riedel and M. A. Larrabee, "Mount Rainier National Park Glacier Mass Balance Monitoring Annual Report, Water Year 2009: North Coast and Cascades Network," National Park Service, Fort Collins, 2011.
[10]	U.S. Fish and Wildlife Service, "Climate Change in the Pacific Northwest," U.S. Fish and Wildlive Service, 19 October 2011.[Online]. Available: http://www.fws.gov/pacific/Climatechange/changepnw.html#TemperaturePrecipitation.
[11]	P. W. Mote, J. T. Abatzoglou and K. E. Kunkel, "Climate: Variability and Change in the Past and the Future," in Climate Change in the Northwest: Implications for our Landscapes, Waters, and Communities, Washington, D.C., Island Press, 2013, pp. 25-40.
[12]	J. S. Littel, M. McGuire Elsner, L. C. Whitely Binder and A. K. Snover, "Evaluating Washington's Future in a Changing Climate: Executive Summary," in The Washington State Climate Impacts Assessment, 2009, p. 6.
[13]	PI: Alan F. Hamlet, Columbia Basin Climate Change Scenarios Project, University of Washington.
[14]	M. T. Stoelinga, M. D. Albright and C. F. Mass, "A New Look at Snowpack Trends in the Cascade Mountains," Journal of Climate, vol. 23, no. 10, pp. 2473-2491, 2010.

[15]	I. T. Stewart, D. R. Cayan and M. D. Dettinger, "Changes Toward Earlier Streamflow Timing Across Western North America," Journal of Climate, vol. 18, no. 8, pp. 1136-1155, 2005.
[16]	I. M. Tohver, A. F. Hamlet and S.-Y. Lee, "Impacts of 21st-Century Climate Change on Hydrologic Extremes in the Pacific Northwest Region of North America," Journal of the American Water Works Association, vol. 50, no. 6, pp. 1461-1476, 2014.
[17]	C. Allen, A. Macalady, H. Chnchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D. Breshears, E. Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J.-H. Lim, G. Allard, S. Running, A. Semerci and N. Cobb, "A Global Overview of Drought and Heat-Induced Tree Mortality Reveals Emerging Climate Change Risks for Forests," Forest Ecology and Management, vol. 259, no. 4, pp. 660-684, 2010.
[18]	C. Beier, S. Sink, P. Hennon, D. D'Amore and G. Juday, "Twentieth-Century Warming and the Dendroclimatology of Declining Yellow-Cedar Forests in Southeastern Alaska," Canadian Journal of Forest Research, vol. 38, pp. 1319-1334, 2008.
[19]	Washington State Department of Natural Resources, "Forest Health Hazard Warning," 2015.[Online]. Available: http://file.dnr.wa.gov/publications/rp_fh_e_wa_costsharebroch.pdf.[Accessed 2 December 2015].
[20]	J. S. Littell and R. Gwozdz, "Climatic Water Balance and Regional Fire Years in the Pacific Northwest, USA: Linking Regional Climate and Fire at Landscape Scales," in The Landscape Ecology of Fire, Dordrecht, The Netherlands, Ecological Studies, Springer, 2011, pp. 117-139.
[21]	F. Santos, "Dry Days Bring Ferocious Start to Fire Season," The New York Times, 1 August 2015.
[22]	E. C. H. Keskitalo, Climate Change and Flood Risk Management: Adaptation to Extreme Events at the Local Level, Northampton, MA: Edward Elger Publishing Limited, 2013.
[23]	E. P. Salathe Jr. , A. F. Hamlet, C. F. Mass, S.-Y. Lee, M. Stumbaugh and R. Steed, "Estimates of Twenty-First Century Flood Risk in the Pacific Northwest Based on Regional Climate Model Simulations," Journal of Hydrometeorology, vol. 15, no. 5, pp. 1881-1899, 2014.
[24]	Washington State Department of Ecology, "Floodplain Management: Risk Maps," Shorelands and Environmental Assistance, 2015.[Online]. Available: http://www.ecy.wa.gov/programs/sea/floods/riskmap_maps.html.[Accessed 2 December 2015].
[25]	M. D. Warner, C. F. Mass and E. P. Salathe Jr. , "Changes in Winter Atmospheric Rivers along the North American West Coast in CMIP5 Climate Models," Journal of Hydrometeorology, vol. 16, no. 1, pp. 118-128, 2015.
[26]	H. Adelsman, D. Boyd, C. Broom, R. Cakir, J. Franklin, K. Hardin, N. Hoban, C. Hunter, J. Koenings, L. Lampman, E. Minor, J. Mooney, J. Nordstrom, J. Phillips, J. Rahman, S. Ricketts, C. L. Roalkvam, K. Roe, J. Wall and C. Weathers, Summit to Sea Collective: Building Resilience into the Whole System, A proposal for the HUD National Disaster Resilience Competition, 2015.
[27]	A. Freedman, "Climate Central," 3 December 2012.[Online]. Available: http://www.climatecentral.org/news/atmospheric-river-piles-up-record-rain-snow-and-winds-15320.[Accessed 2 December 2015].
[28]	G. S. Mauger, J. H. Casola, H. A. Morgan, R. L. Stauch, B. Jones, B. Curry, T. M. Busch Isaksen, L. Whitley Binder, M. B. Krosby and A. K. Snover, "Section 9: How Will Climate Change Affect Terrestrial Ecosystems?," in State of Knowledge: Climate Change in Puget Sound, Climate Impacts Group, University of Washington, 2015, pp. 9-1- 9-13.
[29]	N. Mantua, I. Tohver and A. Hamlet, "Climate Change Impacts on Streamflow Extremes and Summertime Stream Temperature and Their Possible Consequences for Freshwater Salmon Habitat in Washington State," Climate Change, vol. 102, no. 1-2, pp. 187-223, 2010.

[30]	E. S. Null, J. H. Viers, L. D. Michael, S. K. Tanaka and J. F. Mount, "Stream Temperature Sensitivity to Climate Warming in California's Sierra Nevada: Impacts to Coldwater Habitat," Climatic Change, vol. 116, no. 1, pp. 149-170, 2013.
[31]	H. Wu, J. S. Kimball, M. M. Elsner, N. Mantua, R. F. Adler and J. Stanford, "Projected Climate Change Impacts on the Hydrology and Temperature of Pacific Northwest Rivers," Water Resources Research, vol. 48, no. 11, pp. 1944-7973, 2012.
[32]	U.S. Forest Service, "Regional Database and Modeled Stream Temperatures," 2014.[Online]. Available: http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST/ModeledStreamTemperatureScenarioMaps.shtml.
[33]	National Wildlife Federation, "Climate change effects and adaptation approaches in freshwater aquatic and riparian ecosystems in the North Pacific Landscape Conservation Cooperative Region," 2011.
[34]	D. G. Huber and J. Gulledge, "Extreme Weather and Climate Change: Understanding the Link and Managing the Risk," Center for Climate and Energy Solutions, 2011.
[35]	I. M. Tohver, A. F. Hamlet and S.-Y. Lee, "Impacts of 21st-Century Climate Change on Hydrologic Extremes in the Pacific Northwest Region of North America," JAWRA Journal of the American Water Resources Association, vol. 50, no. 6, pp. 1461-1476, 2014.
[36]	K. D. Splinter, M. A. Davidson, A. Golshani and R. Tomlinson, "Climate Controls on Longshore Sediment Transport," Continental Shelf Research, vol. 48, no. 1, pp. 146-156, 2012.
[37]	J. M. Hardiman and M. G. Mesa, "The Effects of Increased Stream Temperatures on Juvenile Steelhead Growth in the Yakima River Basin Based on Projected Climate Change Scenarios," Climatic Change, vol. 124, no. 1, pp. 413-426, 2014.
[38]	P. Nyman, H. G. Smith, C. B. Sherwin, C. Langhans, P. Lane and G. Sheridan, "Predicting Sediment Delivery from Debris Flows after Wildfire," Geomorphology, vol. 250, pp. 173-186, 2015.
[39]	National Research Council (NRC), Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future, Washington, DC: The National Academies Press, 2012.
[40]	Department of Ecology , "Sea Level Rise and Coastal Hazards," 2012.[Online]. Available: http://www.ecy.wa.gov/climatechange/2012ccrs/coasts.htm.
[41]	R. A. Feely, S. C. Doney and S. R. Cooley, "Ocean acidification: Present Conditions and Future Changes in a High-CO2 World," Oceanography, vol. 22, no. 4, pp. 36-47, 2009.
[42]	H. Adelsman and J. Ekrem, "Preparing for a Changing Climate: Washington State's Integrated Climate Response Strategy," Washington State Department of Ecology, 2012.
[43]	R. A. Feely, T. Klinger, J. A. Newton and M. Chadsey, "Scientific Summary of Ocean Acidification in Washington State Marine Waters," in Washington State Blue Ribbon Planel on Ocean Acidification, 2012.
[44]	National Oceanic and Atmospheric Administration, "What Can We Do About Ocean Acidification?," 2015.[Online]. Available: http://oceanacidification.noaa.gov/Home/Whatcanyoudo.aspx.
[45]	S. Ogburn, "Ocean Acidification Weakens Mussels' Grip," Scientific American , 13 March 2013.[Online]. Available: http://www.scientificamerican.com/article/ocean-acidification-weakens-mussels-grip/.
[46]	K. Hanson and D. Peterson, "Modeling the Potential Impacts of Climate Change on Pacific Salmon Culture Programs: An Example at Winthrop National Fish Hatchery," Environmental Management, vol. 54, no. 3, pp. 433-448, 2014.
[47]	A. J. MacLennan, J. F. Waggoner, J. W. Johannessen and S. A. Williams, Sea Level Rise Vulnerability in San Juan County, Washington, Friday Harbor, Washington: Friends of the San Juans, 2013.

[48]	J. A. Daraio and J. D. Bales, "Effects of Land Use and Climate Change on Stream Temperature I: Daily Flow and Stream Temperature Projections," JAWRA Journal of the American Water Resources Association, vol. 50, no. 5, pp. 1155-1176, 2014.
[49]	J. Martin and P. Glick, A Great Wave Rising, Light in the River and William and Flora Hewlett Foundation, 2008.
[50]	P. J. Katinic, D. A. Patterson and R. C. Ydenberg, "Thermal Regime, Predation Danger and the Early Marine Exit of Sockeye Salmon Onchorhynchus nerka," Journal of Fish Biology, vol. 86, no. 1, pp. 276-287, 2015.
[51]	D. A. McCullough, A Review and Synthesis of Effects of Alteration to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon, Seattle, WA: U.S. Environmental Protection Agency, 1999.
[52]	A. A. Wade, T. J. Beechie, E. Fleishman, N. J. Mantua and H. Wu, "Steelhead Vulnerability to Climate Change in the Pacific Northwest," Journal of Applied Ecology, vol. 50, no. 5, pp. 1093-1104, 2013.
[53]	P. Bisson, Salmon and Trout in the Pacific Northwest and Climate Change, U.S. Deparment of Agriculture, Forest Service, Climate Change Resource Center, 2008.
[54]	P. Glick, J. Clough and B. Nunley, Sea-Level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon, National Wildlife Federation, 2007.
[55]	P. L. Barnard and J. A. Warrick, "Dramatic Beach and Nearshore Morphological Changes Due to Extreme Flooding at a Wave-Dominated River Mouth," Marine Geology, vol. 271, no. 1-2, pp. 131-148, 2010.
[56]	J. Jacobs, S. K. Moore, K. E. Kunkel and L. Sun, "A Framework for Examining Climate-Driven Changes to the Seasonality and Geographical Range of Coastal Pathogens and Harmful Algae," Climate Risk Management, vol. 8, pp. 16-27, 2015.
[57]	Washington State Department of Health, "Amnesic Shellfish Poisoning (ASP) from Domoic Acid," Washington State Department of Health, 2015.[Online]. Available: http://www.doh.wa.gov/CommunityandEnvironment/Shellfish/BiotoxinsIllnessPrevention/Biotoxins/AmnesicShellfishPoisoning. [Accessed 4 December 2015].
[58]	J. K. Lloyd, J. S. Duchin, J. Borchert, H. Flores Quintana and A. Robertson, "Diarrhetic Shellfish Poisoning, Washington, USA, 2011," Emerging Infectious Diseases, vol. 19, no. 8, pp. 1314-1316, 2013.
[59]	D. L. Erdner, J. Dyble, M. L. Parsons, R. C. Stevens, K. A. Hubbard, M. L. Wrabel, S. K. Moore, K. A. Lefebvre, D. M. Anderson, P. Bienfang, R. R. Bidigare, M. S. Parker, P. Moeller, L. E. Brand and V. L. Trainer, "Centers for Oceans and Human Health: A Unified Approach to the Challenge of Harmful Algal Blooms," Environmental Health, vol. 7, no. 2, 2008.
[60]	A. Newton, M. Kendall, D. J. Vugia, O. L. Henao and B. E. Mahon, "Increasing Rates of Vibriosis in the United States, 1996-2010: Review of Suveillance Data from 2 Systems," Clinical Infectious Diseases, vol. 54, no. 5, pp. S391-S395, 2012.
[61]	C. L. Raymond, D. L. Peterson and R. M. Rochefort, "Climate change vulnerability and adaptation in the North Cascades region,," 2014.
[62]	National Wildlife Federation, Nowhere to Run: Big Game Wildlife in a Warming World, 2013.
[63]	Northwest Indian Fisheries Commisson, "Puyallup Tribe Elk Study Points to Need for Protection and Restoration," 2011.[Online]. Available: http://nwtreatytribes.org/puyallup-tribe-elk-study-points-to-need-for-protection-and-restoration/.
[64]	Washington State Department of Ecology, "Water Quality Assessment for Washington,"[Online].

[65]	Washington State Department of Transportation, Climate Impacts Vulnerability Assessment, 2011.
[66]	M. Keim, "Building Human Resilience: The Role of Public Health Preparedness and Response as an Adaptation to Climate Change," American Journal of Preventative Medicine, vol. 35, no. 5, pp. 508-516, 2008.
[67]	S. Moore, V. L. Trainer, N. J. Mantua, M. S. Parker, E. A. Laws, L. C. Backer and L. E. Fleming, "Impacts of Climate Variability and Future Climate Change on Harmful Algal Blooms and Human Health," Environmental Health, vol. 7, no. 2, 2008.
[68]	P. Altman, "Killer Summer Heat: Projected Death Toll from Rising Temperatures in America Due to Climate Change," Natural Resources Defense Council, 2012.
[69]	Washington State Healthy Youth Survey , Healthy Youth Survey Fact Sheet: Asthma for Pierce County, 2014.
[70]	S. K. Moore, N. J. Mantua and E. P. Salathe Jr, "Past Trends and Future Scenarios for Environmental Conditions Favoring the Accumulation of Paralytic Shellfish Toxins in Puget Sound Shellfish," Harmful Algae, vol. 10, no. 5, pp. 521-529, 2011.
[71]	FEMA, "Hazard Mitigation Assistance," Department of Homeland Security, 25 October 2015.[Online]. Available: http://www.fema.gov/hazard-mitigation-assistance.

the PUYALLUP TRIBE of INDIANS
GENEROUS AND WELCOMING TO ALL PEOPLE