LUMMI NATION
CLIMATE CHANGE MITIGATION AND ADAPTATION PLAN: 2016-2026

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EXECUTIVE SUMMARY

The purpose of the Lummi Nation Climate Change Mitigation and Adaptation Plan: 2016-2026 (CCMAP) is to evaluate the potential impacts of anthropogenic climate change on the Lummi Indian Reservation (Reservation), Lummi Usual and Accustomed Grounds and Stations (U&A), and Lummi Traditional Territories and to present both mitigation strategies that may reduce the causes of climate change and adaptation strategies that may minimize climate change impacts that cannot be avoided.

Resolution No. 2014-084 *Guiding Principles to Address Climate Change* was adopted by the Lummi Indian Business Council (LIBC – the governing body of the Lummi Nation) on May 27, 2014 and directed the LIBC administration to undertake efforts to develop goals for addressing the potential effects of climate change, to develop policies and strategies guided by these goals that will enable climate mitigation and adaptation, and to develop and implement programmatic and/or regulatory actions to address the potential effects of climate change and contribute to the reduction of the causes of climate change. An important step toward fulfilling this mandate is this CCMAP, which provides a comprehensive analysis of climate change impacts on and potential mitigation and adaptation strategies for the natural, social, and built systems of the Reservation. Based on the CCMAP, the Lummi Nation finds that the potential impacts of climate change have a direct, serious, and substantial adverse effect on the political integrity, economic security, health, and welfare of the Lummi Nation, its treaty rights, its members, and all persons present on the Reservation.

The goal of the CCMAP is to identify the potential impacts of climate change on the natural, social, and built systems of the Reservation and identify actions to minimize the causes of climate change and damages from climate change impacts that cannot be avoided. This goal will be attained through the achievement of the following objectives:

1. Review existing climate change impacts assessments and scientific literature relevant to the Puget Sound region to evaluate projected climate change impacts on the Reservation.

2. Assess the vulnerability of the natural systems (i.e., water resources, coastal resources, forest resources, and fish, wildlife, and traditional use plants), social systems (i.e., human health, emergency services, and cultural resources), and built systems (i.e., land use, transportation, and utilities) on the Reservation to climate change impacts.

3. Develop a range of mitigation and adaptation strategies that may be implemented to reduce identified vulnerabilities and make the Reservation and the Lummi Nation more resilient to climate change.

Changes in climate affect not only air temperatures (i.e., global warming), but also sea surface temperatures, precipitation patterns, sea level, storm events, and other physical systems. The best available science indicates that climate change impacts on the Reservation over the coming decades-to-centuries are likely to include increasing surface temperature, changes in precipitation (i.e., wetter winters, drier summers), changes in the seasonality and magnitude of streamflow (i.e., higher winter flows, earlier spring snowmelt, lower summer flows), increasing extent, frequency, and/or intensity of extreme weather events (e.g., heat waves, drought, flooding, wildfire), and changes in the coastal ocean (i.e., increasing sea surface temperature, sea level rise, ocean acidification). The extent and severity of future climate change will be inextricably linked to the level of human response to climate change.

To better understand how climate change impacts will affect the natural, social, and built systems of the Reservation, a framework was established for the purpose of the CCMAP in which each system was divided into several sectors and each sector further divided into planning areas. For instance, the natural system (i.e., natural environment) is divided into several sectors, including water resources, coastal resources, forest resources, and fish, wildlife, and traditional use plants; the social system is divided into human health, emergency services, and cultural resources; and the built system is divided into land use, transportation, and utilities. At the subsequent level, the water resources sector is divided into three planning areas (i.e., freshwater, groundwater, and wetlands), the coastal resources sector is divided into three planning areas (i.e., shorelines, tidelands, and seawater), the forest resources sector is divided into three planning areas (i.e., forest type, wildfire, insects and disease), and so on.

Within this framework, the vulnerability (i.e., susceptibility to harm) to climate change of the Reservation's natural, social, and built systems was determined as a function of the sensitivity and adaptive capacity of that system, and was rated using a five-step scale (i.e., low, medium-low, medium, medium-high, high). Findings indicate that the majority of planning areas on the Reservation have a high level of vulnerability to climate change impacts, while some planning areas demonstrated medium-high or medium levels of vulnerability.

Given that anticipated impacts of climate change on the Reservation are significant and diverse, building a climate resilient community in the face of these impacts will require coordinated and comprehensive climate preparedness planning. Climate preparedness should include implementation of both climate mitigation and climate adaptation strategies. Climate mitigation means taking action to reduce greenhouse gas concentrations in the atmosphere, the quantity of which will determine the extent and severity of climate change over the coming decades-to-centuries. Although the Reservation accounts for only a relatively minor contribution to global carbon emissions, achieving emissions reduction goals globally will require universal support and participation. Accordingly, the recommendations of this CCMAP are to undertake action on climate mitigation as soon as practicable. To address climate change impacts that are already occurring and impacts that will unavoidably occur in the future regardless of mitigation efforts, it is also recommended that the Lummi Nation take action on climate adaptation as soon as practicable. Several climate mitigation and adaptation strategies are provided for the natural, social, and built systems on the Reservation.

The key recommendations for implementing climate mitigation and adaption actions on the Reservation that will protect public health and the environment are:

1. Establish and maintain a Climate Preparedness Committee with, at a minimum, one representative from the LIBC, the Natural Resources Department, the Planning and Public Works Department, and the Cultural Resources Department and two representatives from the General Council to provide guidance and oversight in climate mitigation and adaptation planning. Committee membership may be expanded to

include additional tribal institutions as is deemed necessary or desirable, for instance the Police Department, the Lummi Tribal Health Center, the Lummi Tribal Sewer and Water District (LTSWD), the Lummi Commercial Company (LCC), the Lummi Housing Authority (LHA), the Northwest Indian College (NWIC), and others may also be considered.

2. Provide community education and outreach to increase awareness of and preparation for climate change impacts and engender community support for climate mitigation and adaption.

3. Focus initial efforts in climate mitigation and adaptation on the following high priority items as determined from the core concepts for strategy development:

    a. Improve building-, behavior-, and transportation-related energy efficiency.

    b. Improve emergency preparedness planning and response capabilities.

    c. Implement flood risk reduction measures.

    d. Implement wildfire risk reduction measures.

    e. Reduce existing stressors to salmon populations.

    f. Improve water quality in shellfish harvest areas.

    g. Restore and protect instream flow in the Nooksack River basin.

    h. Protect the potable groundwater systems on and adjacent to the Reservation.

4. Further refine and prioritize climate mitigation and adaptation strategies for implementation based on guidance of the Climate Preparedness Planning Committee, community feedback, the recommendations of this report, and other vulnerability assessments as appropriate.

5. Identify and obtain funding to implement selected mitigation and adaptation strategies and determine which tribal entity will be responsible for implementation.

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1. INTRODUCTION

The purpose of this section is to describe the goals of the Lummi Nation Climate Change Mitigation and Adaptation Plan: 2016-2026 (CCMAP) and to summarize the CCMAP organization. This CCMAP has been prepared by the Lummi Nation as a guide to develop and implement effective, integrated environmental programs specific to the needs of the Lummi Nation. This CCMAP was developed by the Water Resources Division of the Lummi Natural Resources Department (LNR).

1.1. Goals and Objectives of the CCMAP

The purpose of the Lummi Nation Climate Change Mitigation and Adaptation Plan: 2016-2026 (CCMAP) is to evaluate the potential impacts of anthropogenic climate change on the Lummi Indian Reservation (Reservation), Lummi Usual and Accustomed Grounds and Stations (U&A), and Lummi Traditional Territories. Additionally, the CCMAP will present both mitigation strategies that may reduce the causes of climate change and climate adaptation strategies that may minimize climate change impacts that cannot be avoided.

Resolution No. 2014-084 *Guiding Principles to Address Climate Change* was adopted by the Lummi Indian Business Council (LIBC) on May 27, 2014 and directed the LIBC administration to undertake efforts to develop goals for addressing the potential effects of climate change, to develop policies and strategies guided by these goals that will enable climate mitigation and adaptation, and to develop and implement programmatic and/or regulatory actions to address the potential effects of climate change and contribute to the reduction of the causes of climate change (Appendix A). An important step toward fulfilling this mandate is this CCMAP, which provides a comprehensive analysis of climate change impacts on and potential mitigation and adaptation strategies for the natural, social, and built systems of the Reservation. Based on the CCMAP, the Lummi Nation finds that the potential impacts of climate change have a direct, serious, and substantial adverse effect on the political integrity, economic security, health, and welfare of the Lummi Nation, its members, its treaty rights and all persons present on the Reservation.

The goal of the CCMAP is to identify the potential impacts of climate change on the natural, social, and built systems of the Reservation and to identify actions to minimize the causes of climate change and damages from impacts that cannot be avoided. This goal will be attained through the achievement of the following objectives:

1. Review existing climate change impacts assessments and scientific literature relevant to the Puget Sound region to evaluate projected climate change impacts on the Reservation.

2. Assess the vulnerability of the natural systems (i.e., water resources, coastal resources, forest resources, and fish, wildlife, and traditional use plants), social systems (i.e., human health, emergency services, and cultural resources), and built systems (i.e., land use, transportation, and utilities) on the Reservation to climate change impacts.

3. Develop a range of mitigation and adaptation strategies that may be implemented to reduce identified vulnerabilities that will make the Reservation and the Lummi Nation more resilient to climate change.

1.2. Why the Lummi Nation is Planning for Climate Change

The Lummi Nation is planning for climate change because preparedness is more effective than disaster response. This is a principle that has long been recognized by the Lummi Nation and is evidenced by adoption of the original Lummi Nation Multi-Hazard Mitigation Plan in 2004, the first state-level plan approved by the Federal Emergency Management Agency (FEMA) nationwide. The impacts of climate change are likely to exacerbate some existing natural hazards on the Reservation (e.g., riverine and coastal flooding, coastal erosion, drought, and wildfire) and introduce new hazards (e.g., spread of diseases and pests, ocean acidification). Climate change mitigation, which addresses the causes of climate change, requires taking action to reduce greenhouse gases emissions and greenhouse gas concentrations in the atmosphere and is necessary to limit the damage of future climate change. For Reservation residents, this means reducing energy use from energy sources (e.g., gasoline, diesel, propane, electricity generated at coal-fired power plants) that result in emissions of greenhouse gases such as carbon dioxide (CO_2). Although climate change mitigation is necessary to limit the extent of future warming and other impacts, many climate change impacts are already occurring and some future impacts are unavoidable even with extensive mitigation efforts. Given these circumstances, it is imperative that the Lummi Nation take action to minimize the impacts of climate change on the Reservation by developing and implementing climate change adaptation strategies.

If adaptation actions are not taken, climate change may lead to irreversible or unacceptable losses to the Lummi Nation. As such, the Lummi Nation has a responsibility to be proactive in preparing for climate change. In many cases, planning for the future will benefit the present and build upon existing programs designed to protect human health, environmental and cultural resources, and infrastructure. For example, the Lummi Nation Wetland and Habitat Mitigation Bank that is currently being developed by the Lummi Natural Resources Department has tangible benefits that are already being observed, such as restoring and enhancing wetland areas that provide critical habitat for culturally and economically important fish species (e.g., salmon). Preservation of open space in the floodplain also protects future generations by preventing development and retaining flood storage capacity in an area that is projected to experience an increase in the frequency and intensity of flood events as a result of climate change. This type of "win-win" strategy simultaneously reduces the impacts of climate change on the Reservation and provides environmental and economic benefits to the Lummi Nation that serves both current and future generations.

Additionally, American Indian and Alaska Native tribes and nations are expected to be disproportionally impacted by changes in climate (Dalton 2013). As stated by the LIBC: "The Lummi Nation, like other place-based American Indian and Alaska Native peoples, lives on the frontlines of a changing world where the disruption to our natural resources caused by changes in the climate are having real and measurable effects on the livelihoods of our people (LIBC Resolution No. 2014-084)." In recognition of the fact that climate change poses unique threats to tribal cultural resources, traditional practices, ways of life, and treaty-protected rights, the U.S. Global Change Research Program's Third National Climate Assessment (NCA 2014b) for the first time included a chapter addressing Indigenous Peoples, land, and resources; drawing attention to this important issue.

1.3. Adoption of the CCMAP

The Lummi Indian Business Council passed Resolution No. 2016-040 on February 16, 2016 to formally adopt the Lummi Nation Climate Change Mitigation and Adaptation Plan: 2016-2026 (Appendix B). In adopting the plan, the LIBC considered not only the merits of the plan, but also the recommendation of the Lummi Natural Resources Department Director and Deputy Director (meeting held on December 1, 2015), the Lummi Fisheries and Natural Resources Commission (meeting held December 3, 2015), and the Lummi Planning Commission (meeting held on December 8, 2015) that the plan be adopted by the LIBC.

1.4. Planning in a Regional Context

Planning for climate change is an increasingly evident priority for federal, state, local, and tribal governments and agencies. At the national level, the U.S. Global Change Research Program (USGCRP), which was mandated by the Global Change Research Act (1990), is charged with "building a knowledge base that informs human responses to climate and global change through coordinated and integrated federal programs of research, education, communication, and decision support (USGCRP 2014)." Among the responsibilities of the USGCRP is to publish assessments that provide analyses of current and future climate change impacts across the nation; the Third National Climate Assessment (NCA) was published in May 2014. Along with the release of President Barak Obama's Climate Action Plan (June 2013) and Executive Order No. 13653 – Preparing the United States for the Impacts of Climate Change (November 2013), circulation of the NCA has bolstered awareness of climate change impacts nationwide. The key messages of these federal efforts are clear: (1) climate change is occurring now, (2) we need to cut carbon pollution, and (3) we need to prepare for the impacts of climate change.

Washington State is also taking action on climate change, an effort that started in earnest in February 2007 when then Governor Christine Gregoire directed state agencies to work toward reducing greenhouse gas emissions in the state (Executive Order No. 07-02 – Washington Climate Change Challenge). As a result, statutory limits on carbon emissions were signed into law in 2008 (Revised Code of Washington [RCW] 70.235.020), which required a reduction of greenhouse gas emissions to 1990 levels by 2020. Climate change planning continued to grow under the governor's leadership and resulted in the release of two seminal reports in 2012, *Preparing for a Changing Climate: Washington State's Integrated Climate Response Strategy* (Publication No. 12-01-004) by the Washington State Department of Ecology (Ecology) and *Ocean Acidification: From Knowledge to Action* by the Washington State Blue Ribbon Panel on Ocean Acidification (Publication No. 12-01-015). Building on this framework, Governor Jay Inslee recently signed Executive Order No. 14-04 – Washington Carbon Pollution Reduction and Clean Energy Action, which is aimed at reducing carbon emissions and developing and implementing renewable energy and energy efficiency technologies. A Carbon Emissions Reduction Taskforce (CERT) considered market-based mechanisms for reaching the carbon emission reduction goals established in RCW 70.235.020, including a carbon tax, carbon cap-and-trade, or a hybrid system, that were introduced to the state legislature in 2015. The efforts of Washington State to prepare for climate change continue to provide a model for state-level planning that is just beginning in some other areas of the country.

Indian Tribes are also providing leadership on climate change action. Among the 20 member tribes of the Northwest Indian Fisheries Commission (NWIFC) there are already several climate change programs underway. The Swinomish Indian Tribe has a well-developed climate change program, called the Swinomish Climate Change Initiative. Through the initiative, the tribe has published a climate change impact assessment and a climate change adaptation plan, and has started implementing action items recommended in the reports. The Jamestown S'Klallam Tribe has also completed a climate change impacts assessment, and several other tribes are in the process of developing their own assessments. Likewise, adaptation planning is in progress at the Quileute Reservation in La Push, Washington, which is subject to coastal and riverine flooding and tsunamis. In 2012, nearly 800 acres of Olympic National Park forestlands adjacent to the Quileute Reservation were transferred from the National Park Service to the Quileute Nation for the purpose of providing higher ground for community relocation. There is also a diverse range of climate change research being piloted by tribal governments. For instance, the Nooksack Indian Tribe is conducting research on glacier ablation rates in the Nooksack River watershed and the subsequent effect of glacier melt on stream temperature and flow. Meanwhile, the Tulalip Tribes recently commissioned a study to develop baseline carbon budgets in the Snohomish River basin. These are but a few of the many examples of the tribal commitment to climate change planning in the Pacific Northwest.

Some local governments have also taken steps to plan for climate change. Notably, Whatcom County and the City of Bellingham have each adopted climate protection plans that recognize the need for action.

1.5. CCMAP Organization

This CCMAP is organized into the following sections:

- Section 1 is this introductory section.
- Section 2 describes the climate, land use, and socioeconomic conditions of the Reservation and the government of the Lummi Nation.
- Section 3 summarizes the observed and projected impacts of climate change in the Pacific Northwest.
- Section 4 presents a vulnerability assessment of the natural, social, and built systems of the Reservation to climate change impacts.
- Section 5 presents climate mitigation and adaptation recommendations for reducing greenhouse gas emissions from the Reservation and increasing the resilience of the Reservation to climate change impacts.
- Section 6 presents a summary and conclusion.
- Section 7 is the list of references cited in this CCMAP.

The glossary, acronyms, and abbreviations used in this CCMAP and appendices follow Section 7.

2. DESCRIPTION OF THE LUMMI INDIAN RESERVATION

The Lummi Indian Reservation (Reservation) is located in northwest Washington State, approximately eight miles west of Bellingham, Washington (Figure 2.1). The Reservation is located along the western border of Whatcom County and at the southern extent of Georgia Strait and the northern extent of Puget Sound. Approximately 38 miles of highly productive marine shoreline surround the Reservation uplands on all but the north and northeast borders. The Reservation includes approximately 12,500 acres of uplands and 7,000 acres of tidelands. The Nooksack River drains a watershed of approximately 786 square miles, flows through the Reservation near the mouth of the river, and discharges to Bellingham Bay (and partially to Lummi Bay during high flows). The Reservation is comprised of a five-mile long peninsula (Lummi Peninsula), which separates Lummi Bay on the west and Bellingham Bay on the east; a northern upland area (Northwest Uplands) and the smaller Sandy Point peninsula that separates Georgia Strait on the west and Lummi Bay on the east; the floodplains and deltas of the Lummi River and the Nooksack River; Portage Island; and associated tidelands (Figure 2.2). The remainder of this section briefly describes the climate, land use, and socioeconomic conditions of the Reservation, as well as the Lummi Nation's government structure.

2.1. Climate

The Pacific Northwest climate and ecology are largely shaped by the interactions that occur between seasonally varying precipitation patterns and the region's mountain ranges. Approximately 75 percent of the regions precipitation occurs in just half the year (October – April) when the Pacific Northwest is on the receiving end of the Pacific storm track. Based on climate data collected at the nearby Bellingham International Airport, the average annual precipitation on the Reservation is approximately 36 inches. On average, November, December, and January are the wettest months; June, July, and August are the driest months.

Temperature on the Reservation is relatively mild year round. Temperature data collected at the Bellingham Airport from 1949 – 2005 indicate that the warmest months are July and August. During these months the average maximum daily temperature is approximately 71 degrees Fahrenheit (^{o}F). December and January are the coldest months when the average minimum daily temperatures are about 32^{o}F. The growing season is "the portion of the year when soil temperature (measured 20 inches below the surface) is above biological zero (5°Celsius [C] or 41°F)". May through September is the approximate growing season for agricultural crops in the area (Gillies 1998).

Wind data for Bellingham indicate that the prevailing wind direction on the Reservation is from the south and southeast with gusts upward of 80 miles per hour. Winds from the west are not as common and generally not as strong (ACOE 1997). Wind roses developed from meteorological data collected at two locations on the Reservation as part of a wind energy development feasibility assessment over the January 2011 through January 2012 period indicate that the wind direction is from the south-southeast or south about 50 percent of the time and from the north or northeast about 15 percent of the time (DNV KEMA 2012).

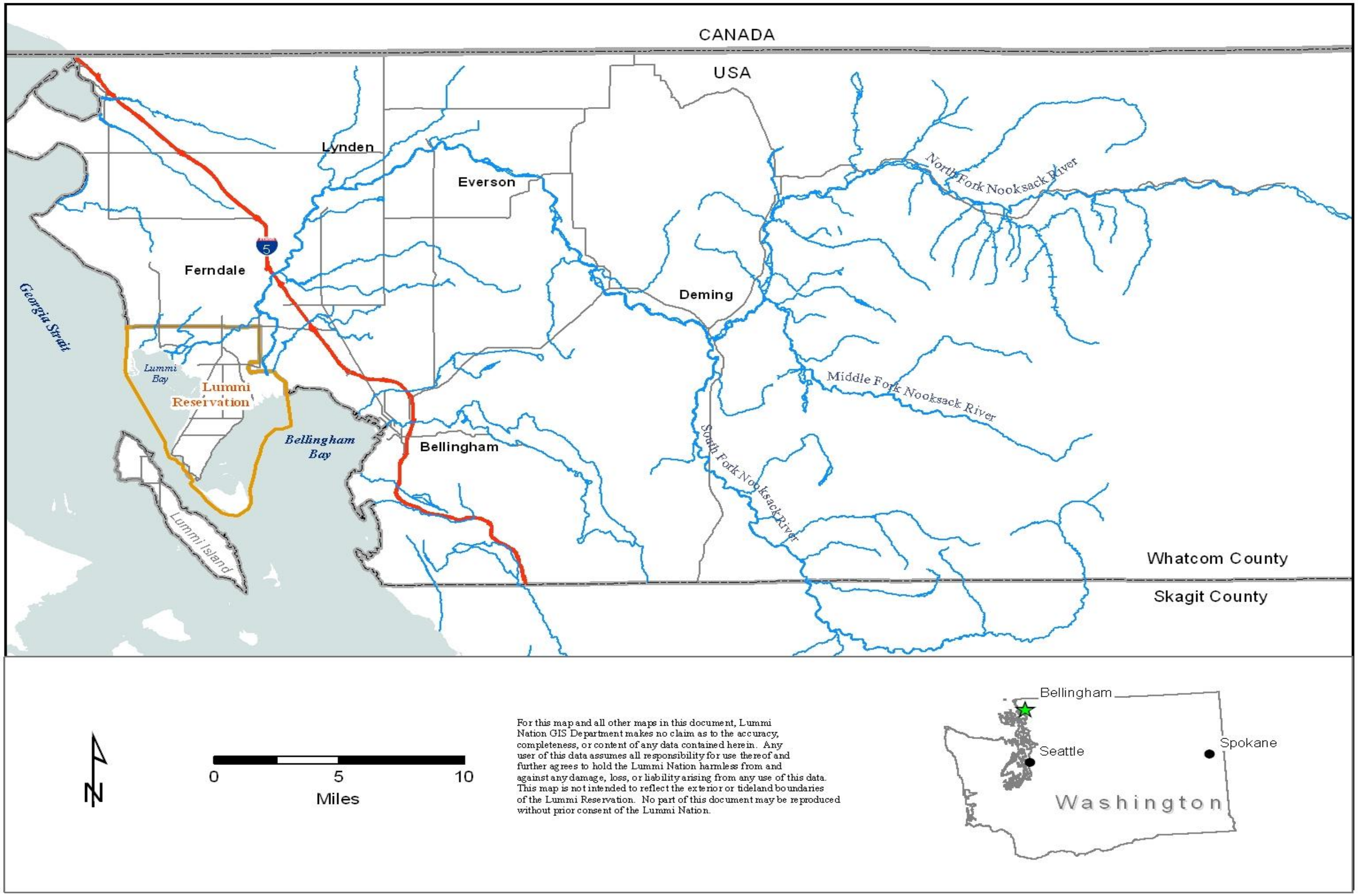

Figure 2.1 Regional Location of the Lummi Indian Reservation

The Reservation experiences a variety of infrequent weather patterns. A typical but infrequent weather pattern is generated from the northeast by cold air masses moving down the Fraser River valley. Strong winds from this pattern, blowing across the Fraser and Nooksack river basins, have caused damage to the residents and businesses of the Reservation (USDA 1992). Another typical but infrequent weather pattern involves continental air masses from the east that bring unusually dry weather that can last a few days or weeks (USDA 1992). During the summer, these air masses bring unusually warm temperatures (mid to upper 90s Fahrenheit). During the winter, these air masses bring unusually cold temperatures (0°F and colder).

2.2. Land Use and Socioeconomic Conditions

Like most places, land use changes on the Reservation have been associated with changes in vegetation types, decreases in the areas covered by vegetation, changes in natural drainage patterns, and increases in impervious surfaces. With the arrival of Euro-Americans, forested land was logged, cleared, and drained for agriculture development, homes, municipal development, and commercial enterprises. Historic and current land uses in the Reservation watersheds and socioeconomic conditions on the Reservation are described below. Much of the information about historic land uses and socioeconomic conditions comes from the *Lummi Nation Comprehensive Environmental Land Use Plan: Background Document* (LIBC 1996).

2.2.1. Historical Land Use

Before the arrival of Euro-Americans, the Lummi People were a fishing, hunting, and gathering society. Based on the accounts of Lummi Elders, early European explorers, and early photographs of the region, before 1850 old-growth forests of massive Douglas fir, western hemlock, Sitka spruce, and western red cedar dominated what was to become the Lummi Indian Reservation. Deciduous trees such as western big leaf maple, black cottonwood, red alder, and western paper birch were also likely present along the rivers, streams, and open areas. Understory vegetation probably included vine maple, Oregon grape, several different willows, ocean spray, salmon berry, thimbleberry, soapberry, and many others. Wetlands, streams, and rivers supported a unique array of plants adapted to wet environments. The marine shoreline was also a unique environment, where only plants adapted to a saltwater-influenced environment thrived.

The forces that shaped vegetation patterns in the Northwest before the arrival of Euro-Americans were forest succession, fires, windstorms, ice storms, floods, and traditional use of natural vegetation by the indigenous peoples. Native American uses of vegetation included the gathering of medicinal plants, the use of willows and other shrubs for fishing, and the extensive use of western red cedar trees for many things, including clothing, baskets, buildings, and canoes. Many plants were also sources of food to complement the traditional diet of fish, shellfish, elk, and deer. Native Americans cultivated some of these plants, such as ferns, camas, and wapato, in prairies along the Nooksack River.

Figure 2.2 Lummi Indian Reservation Overview

Similar to most areas in the lower Nooksack River watershed downstream from Everson, conversion of forestland to agricultural land occurred on the Lummi Indian Reservation following the arrival of Euro-Americans. In 1896, approximately 1,222 acres were reportedly under cultivation on the Reservation. Along with clearing the forested land for agriculture, Euro-Americans constructed ditches, drained wetland areas, cleared logjams, diverted the Nooksack River to drain into Bellingham Bay, built a levee that cut off the Lummi River delta from the Nooksack River, and built a seawall along Lummi Bay. These changes in the natural hydrology of the Lummi Reservation changed the distribution and patterns of watercourses and of wetland- and riparian-associated plant communities.

Much of the cedar on the Reservation was cut into shingle bolts and shipped to local shingle mills. The old-growth trees on Portage Island were cut down to fuel steamboats traveling the Nooksack River. One or more large fires swept through the Reservation area between 1850 and 1900. These fires destroyed nearly all of the remaining old-growth forests. Since reforestation was not practiced during the early logging period and did not begin until approximately 1980, pioneer tree species, such as alder, willows, and cottonwood, soon replaced the conifer forests and dominated the landscape (Leckman 1990).

Historically, the Nooksack River flowed (alternately or simultaneously) to both Lummi and Bellingham bays (effectively making the Lummi Peninsula an "island"). Before 1860, the Nooksack River discharged primarily into Lummi Bay by way of the present Lummi River channel, with smaller distributaries flowing into Bellingham Bay (WSDC 1960; Deardorff 1992). In 1860, the mainstem of the river was diverted into what was then a small stream flowing into Bellingham Bay (WSDC 1960). Since that time, considerable effort has been expended to keep the Nooksack River discharging into Bellingham Bay because of the increased commercial value of the river that resulted from its proximity to sawmills along Bellingham Bay (Deardorff 1992). Until the early 1900s, the Nooksack River was also the primary transportation corridor to as far upstream as present day Lynden. The water body remaining in the old channel of the Nooksack River has been called the Lummi River or the Red River (WSDC 1960).

In the 1920s, a reclamation project was initiated both to construct a dike/seawall to keep back the saltwater along the shore of Lummi Bay and to construct a levee along the west side of the Nooksack River (Deardorff 1992). This project, which was started in 1926 and completed in 1934, initially resulted in the nearly complete separation of the Lummi River from the Nooksack River. However, when saltwater intrusion onto the newly reclaimed farmlands and damage to the dam at the head of the Lummi River occurred during flooding, the dam was replaced with a dam and spillway structure (Deardorff 1992). This spillway structure was also damaged over the years during high-flow conditions and was replaced in 1951 by a five-foot-diameter culvert that allowed flow from the Nooksack River into the Lummi River (FEMA 2004). Currently a partially collapsed four-foot diameter culvert allows flow to the Lummi River only during relatively high-flow conditions (approximately 9,600 cfs) (Deardorff 1992). Levees were also constructed along the Lummi River to prevent saltwater from Lummi Bay from flowing onto adjacent farmlands during higher tides. The dike and levee construction activities were accompanied by agricultural ditching to drain fields and wetland areas. Based on 1887-88 topographic surveys, Bortleson et al. (1980) estimated that wetlands located landward of the general saltwater shoreline in the lower Lummi River watershed have decreased from approximately 2.0 square miles to 0.1 square miles (approximately 95 percent) over the 1888-1973 period.

Between 1920 and 1960 several new public roads providing access to Ferndale and Bellingham as well as a toll ferry to Lummi Island were constructed and led to an increase in development on the Reservation. Since 1960 there has been a significant increase in the total population on the Reservation and the number of tribal members living on the Reservation. The increase in the number of enrolled Lummi tribal members living on the Reservation has been attributed to a number of factors including improved economic conditions within the community, the beginning of tribal self-governance, the increased rate of house construction, the development of a water distribution and a wastewater collection and treatment system, and a renewed sense of Lummi cultural identity.

2.2.2. Current Land Use

Over the last century, the increase in population, the construction of extensive road networks, development of wastewater collection and treatment systems, the construction of the Sandy Point Marina, and several tribal housing projects have fostered a trend towards higher density neighborhoods throughout the Reservation. Several distinct residential neighborhoods now exist, mainly along the shores of the Reservation including Sandy Point, Neptune Beach, Sandy Point Heights, and Gooseberry Point. Higher density residential neighborhoods can also be accessed from the numerous spur roads along Haxton Way and Lummi Shore Road, which are the primary roads along the perimeter of the Lummi Peninsula. A Lummi Nation Geographic Information Systems (GIS) analysis identified 1,975 addressed structures on the Reservation in 2009. Although increased residential and commercial development has occurred on the Reservation in the last few decades, the majority of the Reservation remains rural.

An approximation of the current land cover and land use in the Reservation watersheds is shown in Figure 2.3. This map was derived from the 2006 National Oceanic and Atmospheric Administration (NOAA) database, Classification of Coastal Washington, which is part of the Coastal Change Analysis Program (C-CAP) of the NOAA Coastal Services Center (NOAA 2006). The map gives an overview of the extent of forest and agricultural lands, residential areas, and wetlands in these watersheds. The estimated distribution of land cover/land use types within the Reservation boundaries is summarized in Table 2.1.

The majority of the forested areas are on the Lummi Peninsula, Portage Island, and the Northwest Uplands. Although there are some conifer groves and Douglas fir plantations, the 2007 inventory of Reservation forests showed that present day forests are largely comprised of deciduous trees, with some mixed deciduous/conifer stands (International Forestry Consultants, Inc. 2007). Wetlands are underrepresented on the C-CAP map, as the remote sensing analysis did not recognize big swathes of forested and scrub-shrub wetlands, but counted them towards forests and scrub-shrub. Based on the 1999 Reservation-wide wetland inventory (LWRD 2000), the percentage of the Reservation land base that is wetland is closer to 40 percent than the 3.46 percent listed in Table 2.1.

Table 2.1 Current Land Cover/Land Use Types on the Lummi Indian Reservation

Land Cover/Land Use	Percent of Area[1]
Residential	2.59
Forest	20.88
Scrub-Shrub	47.79
Wetlands	3.46
Cultivated Land/Grassland	25.28

[1] Does not include the off-Reservation portions of the Lummi Watersheds or tribal tidelands

The floodplains of the Lummi and Nooksack Rivers are sparsely developed. The most important commercial enterprise in the floodplains is the Silver Reef Hotel, Casino & Spa and the adjacent gas station and mini-mart. This commercial center is located at the intersection of Haxton Way and Slater Road. The floodplains are dominated by agricultural lands and wetlands, both freshwater and estuarine. The tribal governmental offices are mostly located along Kwina Road; the Northwest Indian College (NWIC) is also located along Kwina Road.

Based on estimates of land cover in Whatcom County, land cover/use in the Nooksack River watershed is generally dominated by forested areas upstream from the town of Deming and agricultural lands downstream from Deming (Whatcom County 2005). The agricultural lands in the lowlands were largely forested before the arrival of Euro-Americans and had been largely denuded of trees by 1925 (Pierson 1953, as cited in Smelser 1970). Population centers such as Ferndale, Lynden, Everson, and Deming are located adjacent to the Nooksack River.

2.2.3. Future Land Use

Future development on the Reservation is guided by a number of tribal laws (Lummi Nation Code of Laws [LCL]) and associated regulations including:

- LCL Title 15: Land Use, Development, and Zoning Code
- LCL Title 15A: Flood Damage Prevention Code
- LCL Title 16: Sewer and Water District Code
- LCL Title 17: Water Resources Protection Code
- LCL Title 22: Building Code
- LCL Title 40: Cultural Resources Preservation Code

Figure 2.4 shows the current official zoning map of the Lummi Reservation. This zoning map was revised and adopted by the LIBC in 2004 as part of the comprehensive planning effort currently underway by the Planning and Public Works Department. The zoning update incorporated comments from tribal departments and commissions and from public comments received during four community meetings.

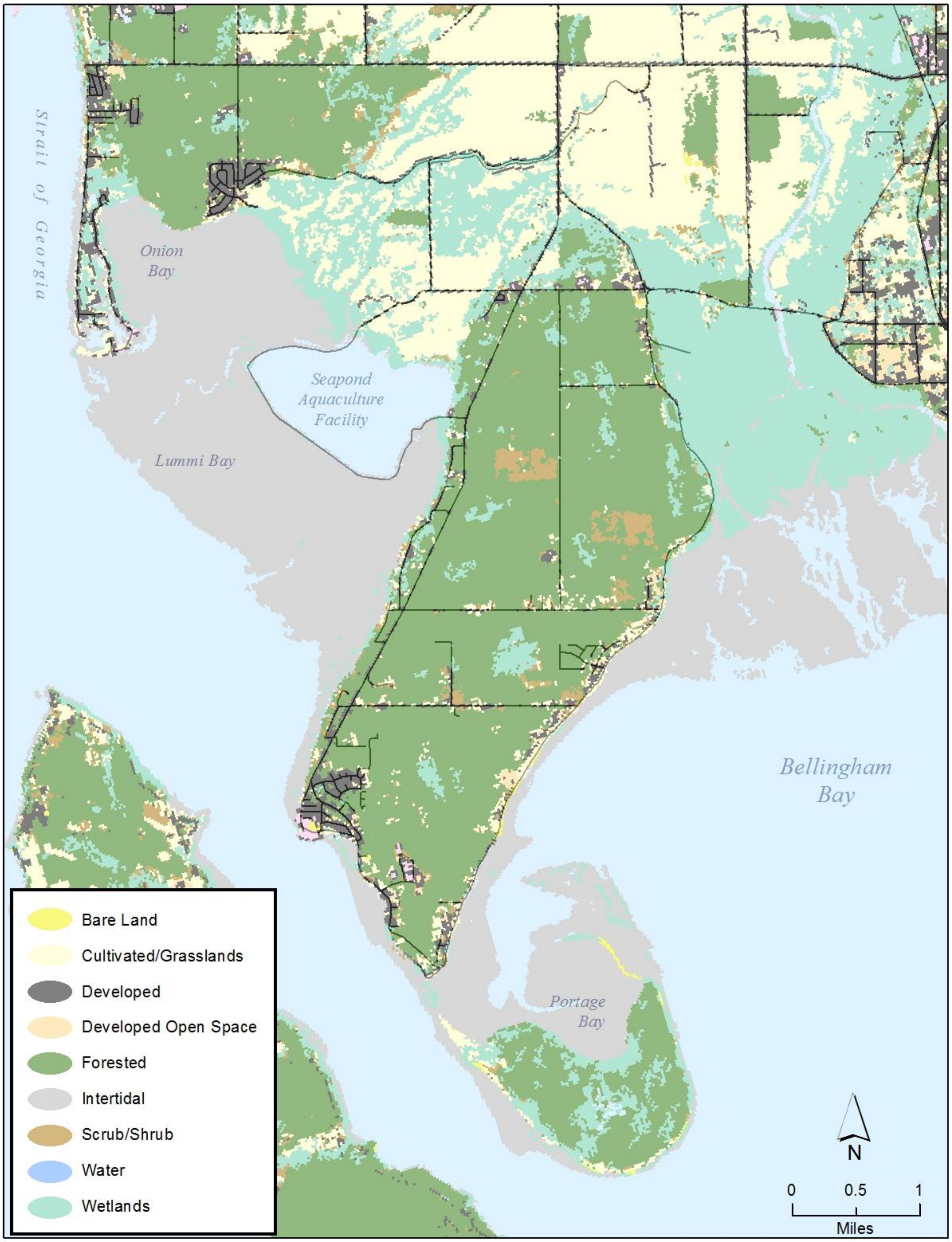

Figure 2.3 Upland Use/Land Cover of the Lummi Indian Reservation Watersheds

The Lummi Planning and Public Works Department is developing a Comprehensive Plan for the Lummi Reservation. The plan will show, in general, how land on the Reservation will be used over the next 20 years. The Comprehensive Plan will identify areas that will be developed for residential, commercial, mixed uses, industrial, and agricultural purposes, as well as show areas that require protection (e.g., Special Flood Hazard Areas, wetlands, and aquifer recharge zones). To date, a technical background document (LIBC 1996) has been developed, public opinion surveys conducted, drafts of the Comprehensive Plan and maps developed, and focused planning workshops and meetings with commissions and community groups have occurred. The Comprehensive Plan is codified in LCL Title 15 (Land Use, Development, and Zoning Code). Title 15 also formalized an environmental review process that had been already largely in place since 1997 pursuant to LIBC resolutions.

2.2.4. Population

According to the 2010 Census, a total of 4,706 people lived on the Reservation during 2010, which is an 11 percent increase from the 2000 Census population of 4,193. In the 2010 Census, 2,643 people (56.2 percent) identified themselves as American Indian and Alaska Native (Indian) alone or in combination with other races. Corrected by the 2010 undercount rate (4.9 percent), approximately 2,772 American Indians or Alaska Natives are currently living on the Reservation. Population projections from a 2003 study by Northwest Economic Associates suggest that the number of American Indians living on the Reservation would increase from 2,346 persons in 2000 to 3,767 persons in 2020 and to 15,451 persons in 2100. Including the non-Indian population, which was predicted to grow at a slower rate, the Reservation population is estimated to reach 5,800-6,800 persons by 2020. In 2011, the Lummi Enrollment Office reported that there were approximately 4,650 enrolled Lummi tribal members living on- and off-Reservation (Kamkoff 2011).

2.2.5. Socioeconomic Conditions

Fishing, logging, farming, and other natural resource related work have historically provided most of the jobs for Lummi tribal members. Until the 1974 Boldt Decision, Lummi tribal members were systematically precluded from the profitable salmon fishery in Puget Sound. Once the treaty fishing right was upheld by the U.S. Supreme Court, commercial fishing and fish processing began to expand on the Reservation resulting in increasing numbers of fishermen, fish processing, and increased overall tribal revenue from the salmon fisheries.

The Lummi Nation is the largest fishing tribe in the Puget Sound in terms of pounds of fish landed and number of species fished (NWIFC 2012). However, the recent declines in salmon stocks have dramatically altered the tribal reliance on salmon fishing as an economic mainstay. In 1985, the average Lummi fisherman made $22,796 ($49,000 in 2011 dollars). In 1993, the average income from fishing was only $5,555 ($8,500 in 2011 dollars). During this period, about 30 percent of the tribal work force relied on fishing for their sole source of income (LIBC 1996). In the 10 year period between 1995 and 2005, there was an average of 592 fishing registrations and 126 crabbing registrations each year. During the 2012-2013 harvest management year (July 1 – June 30) there were 404 vessels registered with the Lummi Nation.

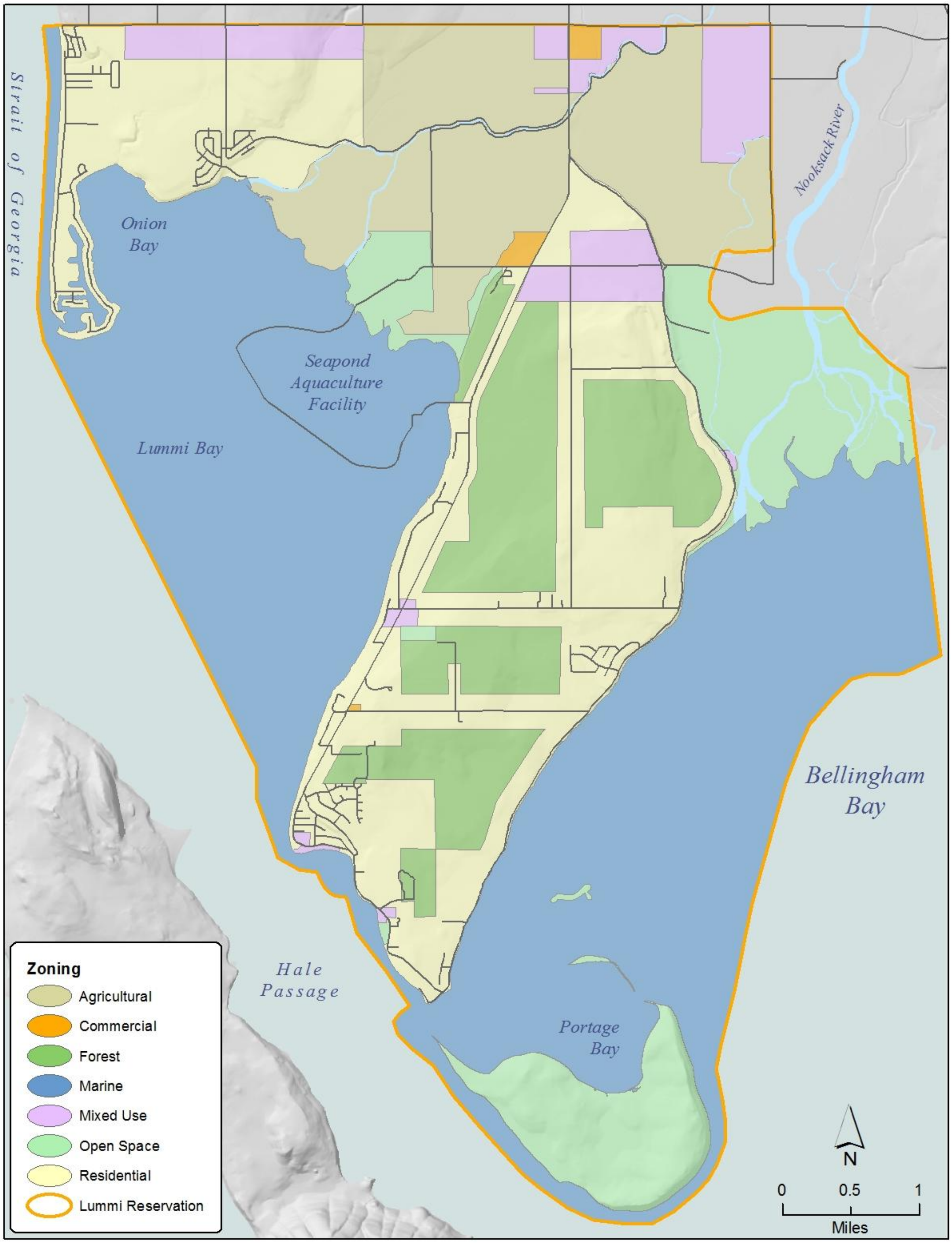

Figure 2.4 Current Land Use Zones on the Reservation

Over the last 15 years, the crab fishery has provided the largest percentage of the yearly fishery revenue followed by sockeye salmon and manila clams. Since 1993, further reductions in salmon stocks have resulted in closure of some fisheries and a further reduction in tribal fishery incomes (LIBC 1996). During 1999, 2007, 2009, and 2013 the sockeye salmon fishery was closed entirely due to low fish runs. The loss or reduction of a fishery increases the importance of the other fisheries to the Lummi economy. Although there are annual variations, 2001 is representative of the most recent 10 years. In 1985, the Lummi Fishing Fleet landed about 15.3 million pounds of finfish and shellfish. In 2001, the combined harvest was about 3.9 million pounds of finfish and shellfish.

In addition to catching fish and harvesting shellfish, the Lummi Nation owns and operates three salmon hatchery facilities. These facilities produce millions of young salmon each year and help offset the decline of fish stocks due to loss of natural habitat and historic over-fishing. The tribe also owns an on-Reservation shellfish hatchery, producing approximately 23 million Pacific oyster and manila clam seed for enhancing tribal tidelands and 2.5 million geoduck seed for sale annually. The tribe owns 7,000 acres of tidelands, much of which is suitable for productive shellfish beds (LIBC 1996). All of these tidelands are held in trust by the United States for the exclusive use of the Lummi Nation.

The tribal commercial shellfish enterprise and the commercial, subsistence, and ceremonial harvest of shellfish by the Lummi Nation and individual tribal members was severely impacted by the closure of 60 acres of tidelands in 1996 and 120 additional acres in 1997. These closures occurred in Portage Bay and were largely attributed to poor dairy waste management practices in the Nooksack River watershed (DOH 1997). Not considering the multiplier effects on the economy, the lost value of the shellfish products alone was estimated to be approximately $825,000 per year. In response to the 1996 closure, the EPA conducted compliance enforcement inspections of dairy operations in the Nooksack River watershed starting in 1997, the State of Washington passed the 1998 Dairy Nutrient Management Act (RCW 90.64), and dairy farmers developed and implemented nutrient management plans (a.k.a. farm plans). As a result of these reactions and additional compliance inspections by the Washington State Department of Ecology, water quality in the Nooksack River improved. In November 2003, approximately 75 percent of the previously closed shellfish beds in Portage Bay were reopened to commercial harvest. In May 2006, the remaining closed shellfish growing areas were reclassified as "approved" for harvest.

Although Nooksack River water quality improved dramatically during the 1997 through 2004 period and resulted in the re-opening of the shellfish beds in 2006, deteriorating water quality trends started to become apparent again in 2005. Despite efforts to proactively prevent another shellfish bed closure due to poor water quality, portions of the Portage Bay shellfish beds no longer achieved the National Shellfish Sanitation Program (NSSP) standards during 2014. In order to protect public health, the Lummi Nation voluntarily closed 335 acres of shellfish growing areas to harvest in September 2014. Continuing poor water quality over the growing area resulted in nearly 500 acres of shellfish bed being closed to harvest by the end of December 2014.

A Lummi Casino project began in 1983 in an effort to diversify the Reservation economy. The casino operation was upgraded significantly in 1994 with the opening of the Lummi Casino at

Fisherman's Cove. The casino flourished initially, employing approximately 400 people, 65 percent of whom were Native American (LIBC 1996). However, competition and changing economic conditions resulted in the closure of the casino on August 26, 1997. With 238 workers losing their jobs, the Lummi unemployment rate grew to approximately 50 percent.

A new casino opened in April 2002 at a new location (the corner of Haxton Way and Slater Road) closer to the Interstate 5 highway. The new casino (the Silver Reef Casino) initially was 28,000 square feet and employed approximately 200 people. The casino was expanded in 2004 (Phase II) to a total of 55,000 square feet with the addition of additional gaming space, a restaurant, and a 400 seat pavilion. The casino was expanded again in 2006 (Phase III) to 135,000 square feet with the addition of a restaurant, additional gaming space, a spa and fitness room, and a six floor, 109 room hotel (NEI 2005). Following this expansion, the Silver Reef Casino was renamed the Silver Reef Hotel, Casino & Spa. A smaller expansion (Phase IV) of approximately 9,000 square feet occurred in 2008 to add gaming space and an additional restaurant. The Phase V expansion was additional parking only. The most recent expansion was completed in 2013 (Phase VI) and included the addition of 50,000 square feet of additional gaming area, a new restaurant, theater, and event center. A second hotel tower (Phase VII) was completed in November 2015. In 2005, after the first expansion, the casino employed 382 workers of which 274 were full-time employees and 108 were part-time employees (NEI 2005). In 2007, after the addition of the hotel and spa, the casino employed 500 people (Werner 2007). By 2010, the Silver Reef Hotel, Casino & Spa employed 550 people; following the opening of the Phase VI expansion in 2013 there were 675 employees. The LIBC operates a gas station and mini-mart adjacent to the Silver Reef Hotel, Casino & Spa.

Other employment opportunities for Reservation residents exist at the two oil refineries and the aluminum smelter just north of the Reservation and nearby in the communities of Ferndale and Bellingham. In 2004, 40.8 percent (131) of the 321 businesses licensed to operate on the Reservation were owned by enrolled tribal members (NEI 2005). These businesses included fireworks sales, food preparation and retail, wholesale, and trade businesses. In 2009, 249 businesses were licensed to operate on the Reservation according to the LIBC Accounting Department. These businesses range from large employers (Silver Reef Hotel, Casino & Spa) to long established fish buying and processing enterprises, trades, native arts, and food catering.

In 2013, the LIBC was the 9th largest employer in Whatcom County and the Silver Reef Hotel, Casino & Spa was the 14th largest employer; with all tribal institutions combined, the tribe is the 3rd largest employer in the county (WWU 2011). Most of the LIBC and Northwest Indian College (NWIC) employees are tribal members. In 2003, native employees made up 70 percent of LIBC staff (55 percent enrolled Lummi tribal members) and 61 percent of NWIC staff (33 percent enrolled Lummi tribal members) (Valz 2003). The LIBC provides community, administrative, education, natural and cultural resources protection, and health services to the tribal population in order to help achieve the tribal economic and social development goals. These goals include job creation for tribal members, income generation to fund community development programs, and diversification and stabilization of the local economy by creating alternatives to fishing. Revenue generation is needed in order for the Lummi Nation to develop economic self-sufficiency.

In 1993, 56 percent of the 2,500 working-age Lummi tribal members were unemployed, under employed, full-time students, or no longer seeking work (LIBC 1996). Since 1993, the combined effect of the decline in the fishery and the closure of the original casino have had a substantial negative impact on the Lummi economy. The BIA reported that the unemployment rate on the Reservation in 1999 was 21 percent (BIA 1999). Table 2.2 presents the results of a survey of 2,054, over the age of 18, enrolled tribal members conducted by the LIBC Statistics Office in 2003. This survey indicates that 28 percent of adult tribal members were unemployed and up to 14 percent may have been underemployed (part-time, seasonally employed) (LIBC 2003). In 2004, 74.6 percent of enrolled Lummi tribal members in Whatcom County ages 18 through 64 were employed and 15.9 percent were unemployed (NEI 2005).

Table 2.2 Employment Status of Lummi Tribal Members, 2003

Employment Status	Number in Status[1]	Percentage of Survey Individuals
Employed full-time	825	40.2
Employed part-time	156	7.6
Employed seasonally	133	6.5
Self-employed	84	4.1
Retired	127	6.2
Unemployed	567	28.0
Not available for employment	153	7.4

[1]LIBC 2003

2.3. Lummi Nation Government

The United States government has a unique legal relationship with tribal governments based on the U.S. Constitution, treaties, statutes, executive orders, and court decisions. Indian tribes have sovereign powers separate and independent from federal and state governments. Tribal sovereignty refers to the inherent authority of indigenous tribes to govern themselves, thus tribal governments have the same power as the federal and state governments to regulate their internal affairs, with a few exceptions. For example, tribes have the inherent power to form a government, to decide their own membership, the right to regulate property, the right to maintain law and order, and the right to regulate commerce. As a result of tribal sovereignty, specific federal legislation, and the trust responsibility of the United States that resulted from treaties, various federal government agencies are involved in assisting Indian tribal governments.

The Lummi Nation is a signatory of the 1855 Treaty of Point Elliot, and is a federally recognized sovereign Indian Tribe organized pursuant to an order approved on November 13, 1947 by the Acting Commissioner of Indian Affairs. The Lummi Nation is governed by an elected 11-member council, the Lummi Indian Business Council (LIBC), and the General Council which consists of all enrolled Lummi tribal members of voting age (18 years old). The LIBC is supported by several administrative departments including Planning and Public Works, Economic Development, Police, Office of the Reservation Attorney, Cultural Resources, and Natural Resources. The LIBC is responsible for the protection, restoration, enhancement, and management of the natural resources within the boundaries of the Lummi Indian Reservation (Reservation) and throughout the Lummi Nation's usual and accustomed (U&A) hunting, fishing, and gathering grounds and stations. The Lummi Natural Resources Department (LNR) is the caretaker of the Lummi Nation natural resources and is responsible for developing and implementing LIBC policies related to Lummi resources.

2.3.1. The 1855 Treaty of Point Elliott

The 1855 Treaty of Point Elliott (Treaty) promulgated articles of agreement between the United States and the Lummi Tribe (now the "Lummi Nation" pursuant to Lummi Indian Business Council [LIBC] Resolution No. 90-13). The Treaty is superior to any conflicting state laws or state constitutional provisions under the Supremacy Clause of the U.S. Constitution. Under the articles of the Treaty, the Lummi Nation ceded certain areas of its aboriginal lands to the United States and reserved for its use and occupation certain lands, rights, and privileges; the United States assumed fiduciary obligations, including, but not limited to, legal and fiscal responsibilities to the Lummi Nation.

An aboriginal right retained under the Treaty includes the immemorial custom and practice to hunt, fish, and gather within all usual and accustomed (U&A) grounds and stations. These customs and practices are the basis of the Tribe's source of food and culture. This reserved right is found under Article 5 of the Treaty, which states that the Tribe has "the right of taking fish at all usual and accustomed grounds and stations … and of erecting temporary houses for the purpose of curing, together with the privilege of hunting and gathering roots and berries on open and unclaimed lands." Treaty-reserved resources situated on- and off-Reservation ("Lummi resources") include, but are not limited to, fishery resources situated within the Lummi Nation's adjudicated U&A fishing area. The Lummi Nation U&A includes the marine areas of northern Puget Sound from the Fraser River south to the present environs of Seattle, particularly Bellingham Bay. Freshwater fisheries include the river drainage systems, especially the Nooksack, emptying into the bays from Boundary Bay south to Fidalgo Bay.

3. CLIMATE CHANGE IMPACTS

There is near scientific consensus and broad international support for the assertion that current changes in climate observed globally are the result of human activities (NCA 2014a, IPCC 2013). This section provides a technical analysis of the evidence of anthropogenic climate change, including a brief overview of the earth's climate system, as well as observed and projected impacts of climate change in the Pacific Northwest (PNW).

3.1. Climate 101

Climate and weather are distinct, but often confused, concepts. While weather describes the day-to-day state of the atmosphere at a given place and time, climate describes the average weather conditions over a period of at least 30 years. As such, weather is inherently chaotic (i.e., it may or may not rain today), whereas climate is inherently predictable (i.e., winters in the Puget Sound region are rainy). However, changes in the earth's climate can and do occur naturally over long periods of time (centuries to millennia). Changes in climate affect not only air temperatures (i.e., global warming), but also sea surface temperatures, sea level, precipitation patterns, storm events, and other physical systems. One reason for the anomalous nature of the current changes in Earth's climate is that these changes are largely the result of anthropogenic emissions of long-lived, heat-trapping gasses, called greenhouse gasses (GHGs) into the atmosphere. Examples of GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chloroflurocarbons (CFCs). Fossil fuel burning, land use change (e.g., biomass burning from deforestation), and industrial processes (e.g., cement and fertilizer production) are a few of the many sources of human-generated greenhouse gas emissions. Increasing atmospheric concentrations of GHGs since the industrial era (mid-17th century) has enhanced the greenhouse effect, the process that mediates the Earth's energy budget. Greenhouse gasses serve as the Earth's blanket, without which the Earth would be too cold to be habitable by humans. Increasing the concentration of GHGs in the atmosphere is like using a thicker blanket; the greenhouse effect is enhanced and additional warming occurs.

The positive correlation between increasing atmospheric GHG concentrations, specifically CO_2, and increasing surface temperatures over the period of the instrumental record is depicted in Figure 3.1. This figure is taken from the U.S. Global Change Research Program's (USGCRP) Third National Climate Assessment (NCA), which was published in May 2014, with a caption reading as follows:

> Global annual average temperature (as measured over both land and oceans) has increased by more than 1.5°F since 1880 (through 2012). Red bars show temperatures above the long-term average, and blue bars indicate temperatures below the long-term average. The black line shows atmospheric carbon dioxide (CO_2) concentration in parts per million (ppm). While there is a clear long-term global warming trend, some years do not show a temperature increase relative to the previous year, and some years show greater changes than others. These year-to-year fluctuations in temperature are due to natural processes, such as the effects of El Niños, La Niñas, and volcanic eruptions.

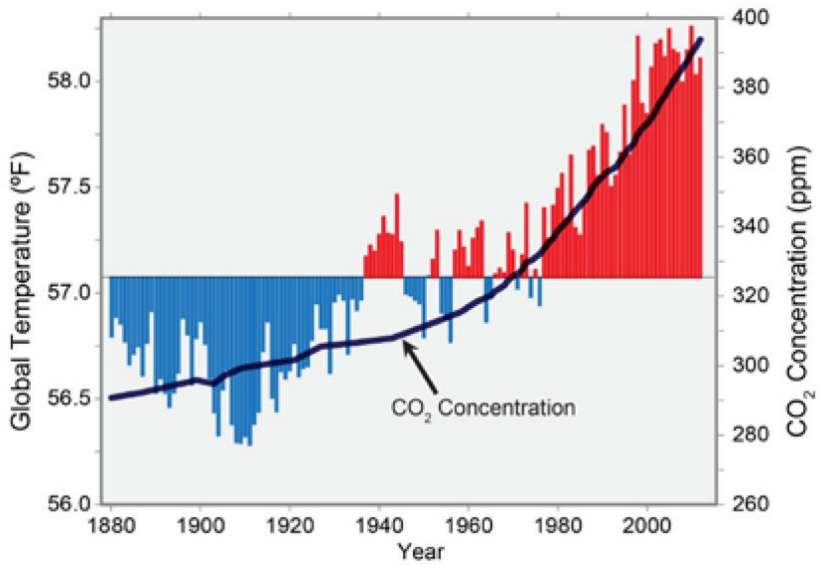

Figure 3.1 Global Annual Average Temperature and Atmospheric Carbon Dioxide Concentration

Other key findings reported in the 2014 NCA provide a clear summary of the current understanding of global climate change. These findings include: (1) "human-induced climate change has moved firmly into the present;" (2) "Americans are already feeling the effects of increases in some types of extreme weather and sea level rise;" (3) "impacts are apparent in every region and in important sectors including health, water, agriculture, energy, and more;" and (4) "there are many actions we can take to reduce future climate change and its impacts and to prepare for the impacts we can't avoid."

3.2. Climate Projections

Future climate change depends on the quantity of GHG emissions over the coming decades. Scientists use complex climate models (e.g., General Circulation Models/Global Climate Models [GCMs], Regional Climate Models [RCMs]) that are built and calibrated using current and past climate data to simulate future climatic conditions under a range of different greenhouse gas emissions scenarios. Emissions scenarios are determined by the Intergovernmental Panel on Climate Change (IPCC), an international consortium of hundreds of experts who analyze and synthesize climate change research. In 2013-2014 the IPCC released its Fifth Assessment Report (AR5), which is actually a series of reports that summarize the current state of scientific knowledge relevant to climate change. The IPCC designs emissions scenarios based around different storylines, called Representative Concentration Pathways (RCPs), that describe how humans might respond to a changing climate. The "high" emissions scenario (RCP 8.5; a.k.a., "business as usual") reflects continued increases in GHG emissions over the next century, the "medium" emissions scenario (RCP 6.0) reflects gradually increasing GHG concentrations that stabilize near the end of the century, the "low" emissions scenario (RCP 4.5) reflects GHG emissions stabilizing mid-century and then falling thereafter, and the "very low" emissions scenario (RCP 2.5; a.k.a., "best case scenario") reflects aggressive GHG reduction and carbon sequestration efforts. Because each scenario accounts for different amounts of GHG emissions, they result in different projected increases in the Earth's surface temperature over time (Figure 3.2). It is impossible to know which emissions scenario is most likely to occur, so modeling multiple scenarios is important to capture a broad range of potential future conditions. Emission scenarios are periodically updated and some figures in this report contain scenarios from an earlier IPCC report Special Report on Emissions Scenarios (SRES; i.e., from high to low emissions A2, A1B, B1).

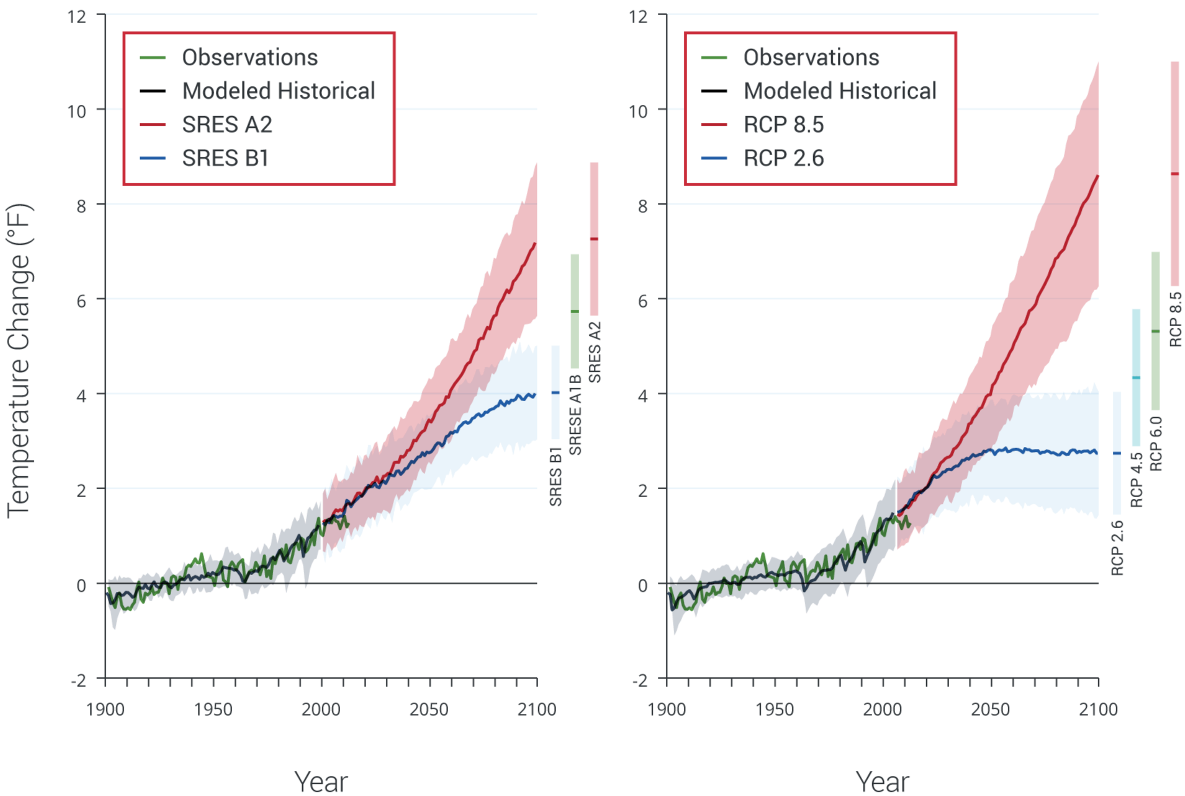

Figure 3.2 Different Amounts of Greenhouse Gases Released into the Atmosphere by Human Activities Produce Different Projected Increases in the Earth's Temperature

[1] Figure on the left shows the IPCC's older scenarios from the Special Report on Emissions Scenarios (SRES), the figure on the right shows the IPCC's newer scenarios (Representative Concentration Pathways [RCPs]) from the Fifth Assessment Report

[2] Figure downloaded from the 2014 National Climate Assessment website at http://nca2014.globalchange.gov/

3.3. Climate Change in the Pacific Northwest

Climate change is occurring globally, but the impacts of climate change will vary regionally. For example, rising temperatures are not evenly distributed across the globe or over time. Climate change adaptation activities require an understanding of regional trends, so the remainder of this chapter provides a brief overview of observed and projected climate change impacts that will affect the Pacific Northwest (PNW) region in the coming century. It is important to note that even within the Pacific Northwest (PNW) region, which encompasses Washington, Oregon, and Idaho, there is significant local variability in climate and anticipated climate changes (e.g., western Washington versus eastern Washington). Although this report presents the best available science, all research has inherent limitations and uncertainties. One of the primary limitations of climate change science is that although there is generally high confidence in course-scale regional predictions, predictions specific to relatively small areas such as Whatcom County or the Lummi Indian Reservation (Reservation) are not feasible given the coarse spatial resolution of climate models, model uncertainties (e.g., generally higher level of confidence in temperature simulations than in precipitation simulations), degree of agreement between models, methods used to statistically downscale GCM output, natural climate variability (e.g., PDO, ENSO, anomalous events), and other factors. It should be understood that actual changes on the Reservation may or may not conform to the regional averages presented here.

3.3.1. Temperature

Between 1895 and 2011, average annual surface temperatures in the Pacific Northwest (PNW) warmed by approximately 1.3°F (CIG 2013). There was some seasonal variability in the extent of warming, with the largest changes occurring during the winter months. Higher temperatures over this time period were associated with lengthening of the frost-free season and an increased frequency of nighttime heat events. Based on the IPCC's "low" and "high" GHG emission scenarios, warming in the PNW in the 2050s is projected to increase between 4.3°F and 5.8°F relative to the 1950-1999 period (CIG 2013). Coincident with continued warming, extreme heat events during the summer months are expected to occur more frequently and extreme cold events during the winter months are expected to occur less frequently.

3.3.2. Precipitation

No detectable change in annual precipitation was evident in the PNW over the 1895-2011 time period (Dalton et al. 2013, CIG 2013). What was visible during this time period were natural fluctuations in precipitation patterns, which change on a scale of years-to-decades and are affected by natural climate patterns such as the Pacific Decadal Oscillation (PDO) and El Niño Southern Oscillation (ENSO). Given this high degree of natural variability, model projections of precipitation under future climate scenarios suggest that the PNW will experience only relatively small changes in the amount of annual precipitation. However, significant changes in the seasonality of precipitation (drier summers and wetter winters) and an increased frequency of heavy rainfall events (>1 inch/day) are expected; the magnitude of these changes remains uncertain (CIG 2013).

3.3.3. Hydrology

With warmer, wetter winters and warmer, drier summers anticipated under future climate scenarios, there will be significant impacts to the hydrology of the Pacific Northwest. For example, as more precipitation occurs during the winter and this precipitation occurs as rain rather than snow, there will be changes in natural water storage (e.g., snowpack, glaciers) and the seasonality and magnitude of streamflow.

3.3.3.1. Snowpack and Glaciers

Consistent with warming air temperatures and resultant reduced natural water storage, spring snowpack in the Washington Cascades has decreased by approximately 25% since the mid-20th century (CIG 2013). Similarly, most of Washington's glaciers are in decline, with the greatest losses in average glacier area observed in the south (49% glacier loss at Mt. Adams) and more moderate losses in the north (7% loss in the North Cascades) (CIG 2013). It is understood that glacier area and glacier volume are distinct variables; however, lost area is indicative of lost storage volume. Continued losses in spring snowpack and glacier area are projected under future climate scenarios. For example, spring snowpack across Washington is expected to decline approximately 60 percent by the 2080s compared to the 20th century average (Ecology 2012). The timing of spring snowmelt is also changing, now occurring earlier in the season. By 2050, spring snowmelt is projected to occur up to 30 days earlier than the 20th century average (NCA 2014c).

3.3.3.2. Streamflow

The Nooksack River, which flows through the Reservation, is considered a transitional or mixed rain-snow watershed, as compared to a rainfall dominant or snowmelt dominant watershed (Hamlet et al. 2013). This is evident in the bimodal trend in monthly stream discharge, where two distinct peaks in streamflow are observed each year (Figure 3.3). The first peak (November – January) coincides with runoff from fall/winter storm events, while the second peak (March – May) coincides with spring snowmelt discharged to the Nooksack River's headwaters in the Cascades. Over time, reductions in spring snowpack, earlier snowmelt, and increased winter rainfall are expected to shift transitional hydrologic regimes toward rainfall dominated hydrologic regimes characterized by a "single-peak" hydrograph. In the Nooksack River, this shift is projected to increase winter discharge, decrease summer discharge, and shift the timing of spring peak melt earlier, exacerbating existing problems with winter flood events, summer low flows, and warming water temperatures (Figure 3.3).

3.3.4. Extreme Weather Events

Another serious consequence of global climate change is observed and expected future increases in the extent, frequency, and/or intensity of extreme weather events. In the Pacific Northwest these events include, but are not limited to, heat waves, drought, and heavy rain events. For example, as the atmosphere warms, so too does its capacity to hold water vapor. With more moisture in the atmosphere, precipitation events are more likely to be larger. Supporting evidence is provided by the 2014 NCA, which reported that the amount of precipitation falling in very heavy events (heaviest 1 percent of all daily events) increased by 12 percent in the PNW between 1958 and 2012. While no single extreme weather event can be directly attributed to climate change, the increasing frequency and intensity of these events can be expected as the climate changes in response increasing atmospheric GHG concentrations.

3.3.5. Coastal Ocean

Ocean temperature, volume, and acidity are changing in response to climate change. These changes have significant implications for the Reservation, given its location along the Puget Sound and the reliance of the Lummi People on coastal and marine resources.

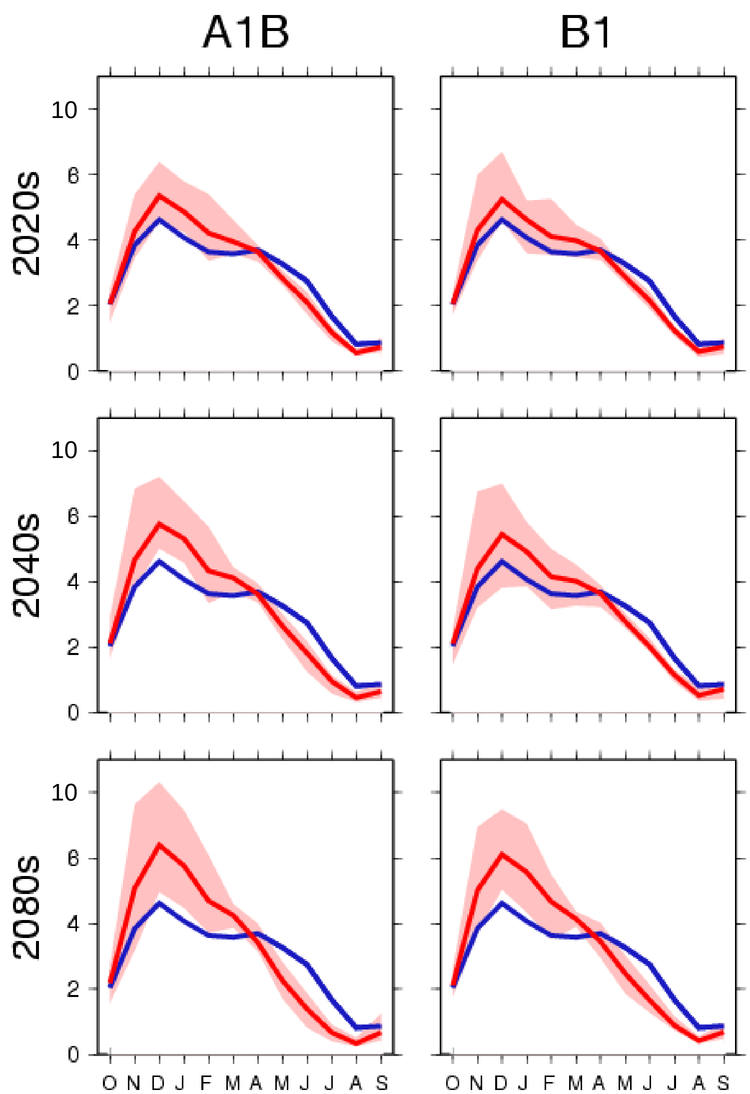

Figure 3.3 Historical (Blue) and Projected Future (Red) Combined Flow (Inches) in the Nooksack River Watershed at Ferndale

[1] Combined flow is the average total runoff and baseflow over the entire basin expressed as an average depth. This variable is a primary component of the simulated water balance, and is one of the primary determinants of streamflow

[2] Figures were downloaded from the Columbia Basin Climate Change Scenarios Project website at http://warm.atmos.washington.edu/2860/

3.3.5.1. Ocean Temperature

The ocean has absorbed and stored a significant portion of the heat energy that has accumulated in the Earth's climate system over recent decades. As a result, ocean surface temperatures in the upper 250 ft of the water column across the globe increased an average of 0.2°F over the 1979-2010 period (CIG 2013). Measurements of ocean temperature in the upper 330 ft of waters in the Strait of Georgia exceed the global average, increasing by 0.4°F per decade between 1970 and 2005 (CIG 2013). Although it is expected that continued heat absorption will result in increasing ocean temperatures globally, with warming extending into deeper waters, it is unclear how ocean temperatures will change locally due to a limited understanding of how climate change will affect coastal upwelling and natural climate patterns (e.g., ENSO).

3.3.5.2. Sea Level Rise

Warmer global temperatures have accelerated the rate of global sea level rise (i.e., eustatic sea level rise), due to the combined effects of increased land ice melt and thermal expansion of the world's oceans, which both contribute to increased ocean volume. Throughout the 20th century, sea level rose at a rate of approximately 1.7 mm/yr, but in recent decades (1993-2010) has accelerated to approximately 3.2 mm/yr (IPCC 2013) or nearly double the rate of the earlier period. Continued acceleration of the rate of sea level rise is expected. Based on recent IPCC estimates, global mean sea level by 2100 (relative to the 1986-2005 period) is projected to increase approximately 1.3 ft (likely range 0.9 ft to 1.8 ft) under the "very low" emissions scenario (RCP 2.6) and approximately 2.1 ft (likely range 1.5 ft to 2.7 ft) under the "high" emissions scenario (RCP 8.5) (Figure 3.4; IPCC 2013). A wider range and generally higher estimates of regional sea level rise are reported by the National Research Council, whose research suggests that mean sea level along the outer coasts of Washington, Oregon, and California may increase between 0.3 and 4.7 ft by 2100 (NRC 2012).

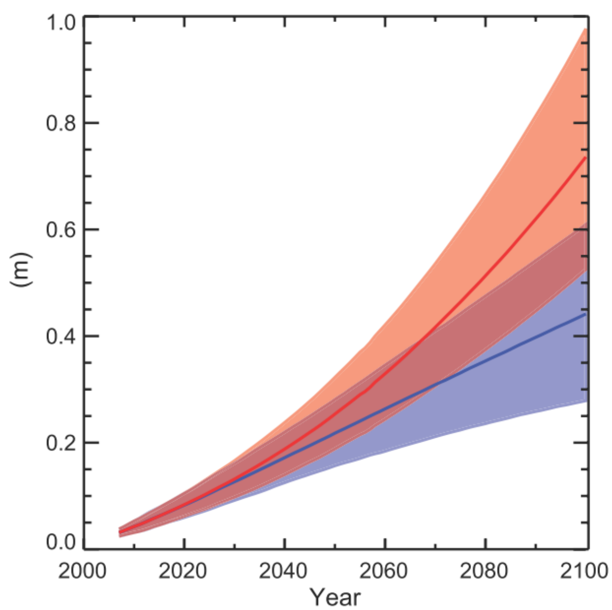

Figure 3.4 Projected Global Mean Sea Level Rise Over the 21st Century for RCP 2.6 (Blue) and RCP 8.5 (Red)

Although sea level rise occurs globally, changes are not evenly distributed across the world's oceans. Additionally, regional differences in vertical land movement (e.g., tectonic uplift or subsidence) and surface sediment dynamics (e.g., sediment accretion, shallow subsidence, and erosion) are expected to generate regional variability in realized sea level change. As a result, local change in mean sea level (i.e., relative sea level rise) may significantly depart from changes in global mean sea level. Estimates of vertical land movement near the Lummi Indian Reservation (Reservation) are conflicting, with some research reporting uplift up to 2.0 mm/yr (CIG 2008) and other research reporting subsidence of roughly 2.0 mm/yr (PANGA 2014; Station P440, Station DEA2), suggesting that the impacts of sea level rise may be either ameliorated or exacerbated at the local scale. However, it would be inappropriate to draw any conclusions without also considering surface sediment dynamics, of which there is unfortunately insufficient data to assess the magnitude and direction of these potential changes in the coastal areas on and near the Reservation. It should also be noted that significant changes in sea level result from natural climate patterns (e.g., ENSO may temporarily elevate wintertime sea level by approximately 1 ft) or earthquakes (e.g., 8.0 magnitude earthquakes along the Cascadia subduction zone have resulted in sudden land subsidence of ≥3.3 ft) (CIG 2013, 2008). Despite these uncertainties, there is a high level of confidence among the scientific community that increases in mean sea level in the Puget Sound will threaten to inundate coastal habitats, increase coastal flooding, accelerate coastal erosion, and increase saltwater intrusion into coastal groundwater systems.

3.3.5.3. Ocean Acidification

Ocean acidification (OA) is one consequence of elevated atmospheric carbon dioxide (CO_2) concentrations. When absorbed by the ocean, CO_2 reacts with water to form carbonic acid (H_2CO_3), which then undergoes a series of chemical reactions that reduce pH (i.e., increase hydrogen ion [H^+] concentration) and the availability of carbonate ions (CO_3^{2-}) (NOAA 2012). As a result, some calcifying organisms (a.k.a., "calcifiers"; e.g., oysters, clams, crabs, pteropods, some copepods) are experiencing difficulty forming and increased corrosion of their shells, skeletons, or other hard body parts, which are composed of calcium carbonate ($CaCO_3$). Not only do higher levels of acidity reduce the growth and survivorship of some calcifiers, but increasing corrosive waters are also expected to reduce food availability for animals that feed on calcifiers and may increase the toxicity of harmful algal blooms (HABs).

Since the mid-17th century, the world's oceans have absorbed approximately 25 percent of human-generated CO_2 emissions (Blue Ribbon Panel 2012). Consequently, ocean pH has declined from 8.2 to 8.1 (pH is measured on a log scale), which equates to an increase in ocean acidity of nearly 30 percent (Blue Ribbon Panel 2012). This is particularly startling considering that the current rate of acidification is occurring nearly 10 times faster than any time in the past 50 million years (Blue Ribbon Panel 2012). By 2100, ocean pH is projected to decline by another 0.1-0.3 pH units (IPCC 2013). Waters of the Washington coast and Puget Sound have and are projected to continue acidifying at a rate consistent with the global average, although locally variable conditions will make some areas prone to higher levels of acidification (CIG 2013). Local conditions that may exacerbate the acidification process include seasonal upwelling of low pH, CO_2-rich waters along the continental shelf, land-based runoff and discharge of nutrients (e.g., nitrogen, phosphorous) and organic carbon, low pH freshwater inputs, and absorption of other acidifying gasses (e.g., nitrogen oxides, sulfur oxides) (Blue Ribbon Panel 2012, NOAA 2012).

4. VULNERABILITY ASSESSMENT

This section provides an assessment of the vulnerability of the natural, human, and built systems of the Lummi Indian Reservation (Reservation) to climate change. For the purposes of this assessment, the natural system (i.e., natural environment) is divided into several sectors, including water resources, coastal resources, forest resources, and fish, wildlife, and traditional use plants, which constitute key areas of concern. Sectors of the social environment included in this analysis are human health, emergency services, and cultural resources. Land use, transportation, and utilities are the components of the built environment that are addressed. Each sector is divided into planning areas. For instance, the water resources sector includes three planning areas: freshwater, groundwater, and wetlands.

4.1. Description of Assessment Process

Vulnerability is defined as the susceptibility of a system to harm. Accordingly, the purpose of this vulnerability assessment is to evaluate the susceptibility the natural, human, and built systems of the Reservation to climate change. The methodology used in this report loosely follows the assessment process outlined in *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* (Snover et al. 2007), a joint publication of the University of Washington Climate Impacts Group (CIG), King County, Washington, and ICLEI – Local Governments for Sustainability.

In the framework developed by Snover et al. (2007), there are two variables that affect vulnerability: (1) the sensitivity of a system and (2) the capacity of a system to adapt. These variables are defined as follows:

> **Sensitivity** is the degree to which a natural, human, or built system is directly or indirectly affected by changes in climate conditions (e.g., temperature and precipitation) or specific climate change impacts (e.g., sea level rise, increased water temperature). If systems in a planning area are likely to be affected as a result of a projected climate change, then that system should be considered sensitive to climate change. For instance, a community of coldwater fish at the southern edge of its range is highly sensitive to changes in climate, because even a slight warming may make its habitat unsuitable. In turn, regional economies based on fisheries solely targeting those fish would also be highly sensitive to changes in climate.
>
> **Adaptive capacity** describes the ability of natural, human, or built systems to accommodate changes in climate (including climate variability and climate extremes) with minimal potential damage or cost. As a general rule, systems that have high adaptive capacity are better able to deal with climate change impacts. For instance, agriculture in a given region will have greater adaptive capacity if the farms of that region have a choice of water sources for irrigation (i.e., in the face of water shortage) and the financial ability and training to switch crop types (i.e., if another crop were proven to grow better based on new climate characteristics).

Figure 4.1, which is adapted from Snover et al. (2007), depicts the relationship between sensitivity and adaptive capacity. If a system has a high sensitivity to climate and a low capacity to adapt to climate change, then this system is considered to have a high level of vulnerability to climate change. Conversely, a system with low sensitivity to climate and a high capacity to adapt to climate change will have a much lower vulnerability to projected climate change impacts. In this analysis, each sector of the natural, human, and built systems of the Reservation was rated for sensitivity and adaptive capacity and then assigned a vulnerability ranking according to the definitions above and the vulnerability matrix below. Ratings were made using the best available science when scientific data were appropriate. However, some key areas of concern, such as cultural resources, cannot be quantified scientifically. As such, some of the vulnerability rankings reflect not only the physical climate change impacts, but also the mission of the Lummi Indian Business Council (LIBC) to preserve, promote, and protect the Lummi *Schelangen* ("way of life") and the cultural and social values of the Lummi Nation. As a result, the vulnerabilities reported here are specific to the Lummi Indian Reservation.

Also, the information presented in this analysis is cumulative by design. For example, sea level rise is described in detail in Section 4.2 – Water Resources and Section 4.3 – Coastal Resources. In subsequent sections, it is assumed that the reader possesses the requisite understanding of potential sea level rise impacts and further discussion on the topic is minimized.

	Adaptive Capacity		
Sensitivity	High	Medium	Low
High	Medium	Medium-High	High
Medium	Medium-Low	Medium	Medium-High
Low	Low	Medium-Low	Medium

Figure 4.1 Vulnerability Matrix

4.2. Water Resources

The Lummi Nation is the largest fishing tribe in the Salish Sea in terms of pounds of fish landed and number of species fished (NWIFC 2012), and has relied on water resources since time immemorial for ceremonial, subsistence, and commercial purposes. Surface waters of the Reservation include the Nooksack River, the Lummi River, sloughs, small streams, roadside and agricultural ditches, springs, wetlands, estuaries, and marine waters (Figure 2.2). Groundwater resources of the Reservation are located in underlying aquifers.

For the purposes of this vulnerability assessment, the water resources sector is divided into three planning areas: freshwater, groundwater, and wetlands. It is acknowledged that groundwater can also be considered "freshwater" – for the purposes of this assessment, freshwater refers to non-marine surface waters. Marine waters are also an important water resource to the Lummi Nation and are address in the subsequent sector on coastal resources. Vulnerability rankings developed for potential climate change impacts to each of these planning areas are provided in Table 4.1.

Table 4.1 Water Resources Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Freshwater	Increasing volume of winter streamflow, more frequent and higher magnitude flood events	High	Low	High
	Decreasing volume of summer streamflow	High	Low	High
	Increasing stream temperature	High	Low	High
	Increasing sediment loads from glacial and snowfield retreat, bank erosion, mass wasting events (e.g., landslides), wildfire activity	Medium	Low	Medium-High
Groundwater	Increasing salinization from saltwater intrusion	High	Low	High
	Possible changes in aquifer recharge[1]	-	-	-
Wetlands	Increasing inundation of estuarine wetlands from relative sea level rise and storm surge	High	Low	High
	Possible degradation of upland wetlands from hydrologic changes	Medium	Medium	Medium

[1] Insufficient data for assessment

4.2.1. Freshwater

The Nooksack River watershed (786 square miles) drains most of western Whatcom County and currently flows through the Reservation and discharges into the marine waters of Bellingham Bay near the eastern extent of the Reservation. Historically, the Nooksack River flowed (alternately or simultaneously) to both Lummi and Bellingham bays (effectively making the Lummi Peninsula an "island"). Before 1860, the Nooksack River discharged primarily into Lummi Bay by way of the present Lummi River channel (the Lummi River is sometimes called the Red River). By 1860, dike and levee construction, damming, and large woody debris removal effectively diverted the mainstem of the river into what was then a small stream near present day Ferndale that flowed into Bellingham Bay (PSNERP 2012). Since that time, considerable effort has been expended to keep the Nooksack River discharging into Bellingham Bay. These efforts have included constructing levees along the west bank of the Nooksack River and restricting inputs to the Lummi River to relatively high-flow conditions (greater than approximately 9,600 cubic feet per second [cfs]) (Deardorff 1992). Without freshwater input from the Nooksack River, the Lummi River carries storm water runoff from the Ferndale upland, as well as the drainage from a complex network of agricultural ditches in the floodplain.

This assessment focuses largely on the impacts of climate change to the Nooksack and Lummi rivers, including changes in streamflow and degraded water quality. The other 15 watersheds that drain the Reservation uplands into Lummi and Bellingham bays, Hale Passage, and the Strait of Georgia will also be affected, though not necessarily to the same extent. For example, these lowland watersheds are relatively small (between approximately 135 – 4,100 acres) and rarely generate snowmelt runoff.

To begin, future reductions in spring snowpack, earlier snowmelt, and increased winter rainfall are projected to increase winter flows in the Nooksack River, as well as the frequency and magnitude of winter flood events. Results from a hydrologic model simulating future streamflow in the Nooksack River suggest that the magnitude of a historical 10-year flood will have a return interval of 3 years by 2050 (Dickerson-Lange et al. 2013). Similarly, Mantua et al. (2010) report that a historical 20-year flood event on the Nooksack River may occur up to 30 percent more frequently by mid-century. Figure 4.2 was developed by the University of Washington Climate Impacts Group (CIG) as part of the Columbia Basin Climate Change Scenarios Project and also indicates an increasing magnitude and frequency of flooding on the Nooksack River at Ferndale; note that future flood statistics (red and yellow circles in Figure 4.2) are significantly higher than historical flood statistics (blue circles). It goes without saying that larger, more frequent flooding in the future poses significant risk in Special Flood Hazard Areas (SFHAs) and adjacent areas of the Reservation that are already vulnerable to flooding.

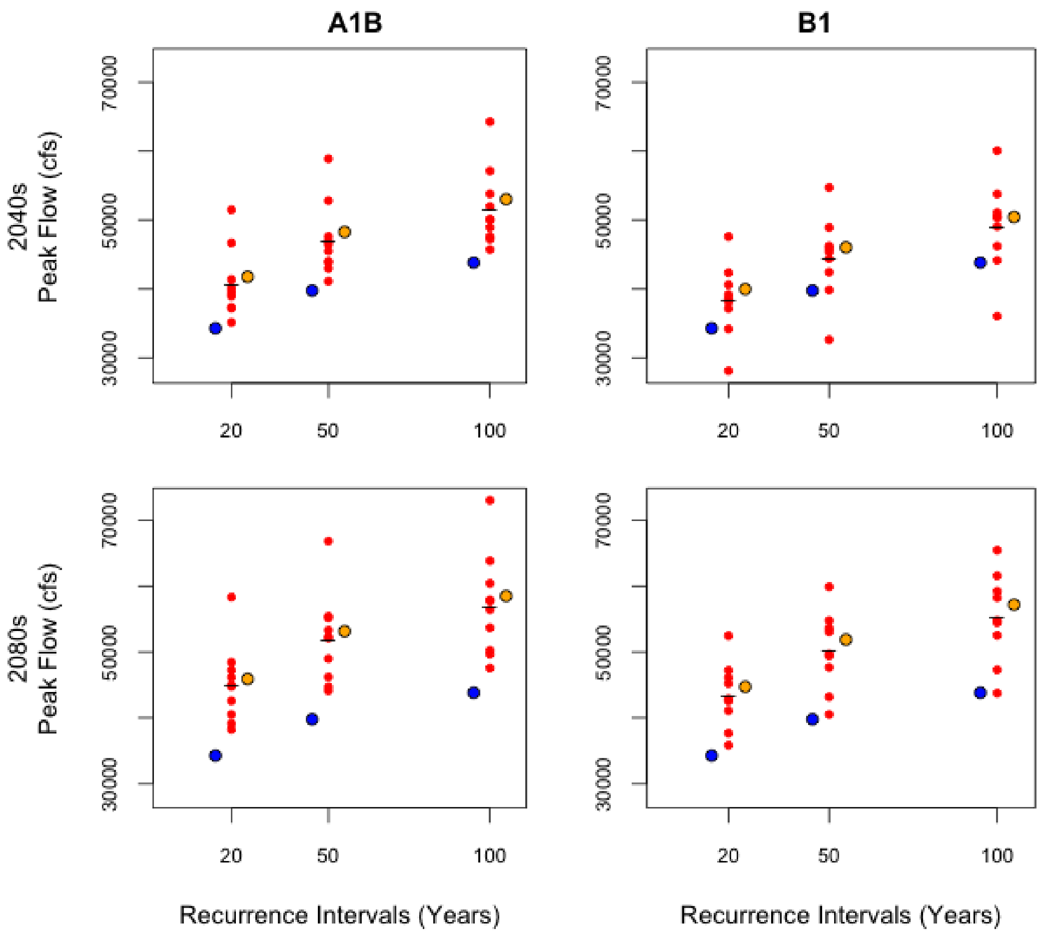

Figure 4.2 Simulated Flood Statistics in the Nooksack River at Ferndale

[1] Blue circles show simulated historical value, red and yellow circles show simulated future values derived from different modeling techniques (i.e., hybrid delta and composite delta methods of statistical downscaling, respectively)

During the summer months, decreasing seasonal precipitation is anticipated to cause a reduction in instream flow. Simulations of future summer streamflow indicate that the magnitude of streamflow in the Nooksack River may decline by approximately 25 percent by 2050 (Dickerson-Lange et al. 2013; Mantua et al. 2010). Figure 4.3 was published in the Third National Climate Assessment (2014) and illustrates projected changes across the Pacific Northwest in local runoff and streamflow for the 2040s under the A1B emissions scenario. As depicted in this figure, natural surface water availability during the already dry late summer period is projected to decrease across most of the Northwest; a trend that also holds true in the Nooksack River basin. Lower instream flows can reasonably be expected to exacerbate existing problems in an already over allocated basin where water of adequate quantity is currently not available to the Lummi Nation, the most senior water rights holder in Whatcom County, to support the purposes of the Reservation as a permanent, economically viable homeland or to support a sustainable, harvestable surplus of salmon and shellfish sufficient to support the Lummi *Schelangen* ("way of life"). Furthermore, excessive groundwater withdrawals (discussed in Section 4.2.2 – Groundwater) could further reduce streamflow in this hydraulically connected aquifer-stream system.

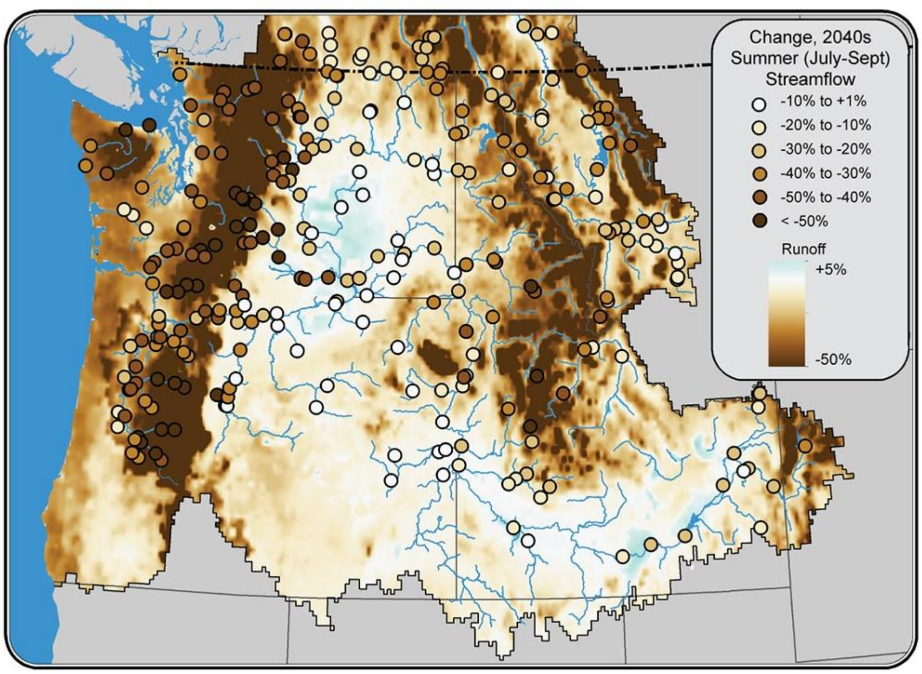

Figure 4.3 Projected Changes in Summer Runoff (Shading) and Streamflow (Colored Circles) for the 2040s Under the A1B Emissions Scenario

Commensurate with low flow conditions, stream temperatures during the summer months are also projected to increase. This is illustrated in Figure 4.4 and Figure 4.5 (Mantua et al. 2010), which depict historic versus projected August maximum stream temperature (shaded circles) in Washington State. It is important to note that although stream temperatures in the Nooksack River watershed are likely to increase and become stressful for salmon under certain climate scenarios (e.g., A1B 2080s), simulated stream temperatures are not projected to reach lethal limits by the end of the century. However, it is also important to understand that projected future changes will exacerbate existing problems with elevated stream temperatures in certain reaches (e.g., the South Fork Nooksack River); a factor that may not be well captured in the hydrologic modeling. As a step to restore and maintain the beneficial uses of currently impaired reaches, the Environmental Protection Agency (EPA), Washington State, Nooksack Indian Tribe, and the Lummi Nation are developing a Total Maximum Daily Load (TMDL) pursuant to the federal Clean Water Act (CWA) to address elevated stream temperature in the South Fork Nooksack River. This assessment is part of the EPA's Climate Change Pilot Project and is laying the framework for inclusion of climate change impacts into TMDL guidelines. One product of the TMDL will be fine-scale projections of future stream temperature in the South Fork, which will help refine our understanding of future stream temperature impacts on salmon and contribute to the development of salmon restoration strategies.

In addition, glacier recession may significantly impact stream temperature and hydrology, especially in areas where relatively large proportions of summer instream flows are derived from glacial melt. The timing and severity of these impacts depend on the current contribution of glacial melt to temperature and streamflow, as well as the hydrologic response of glaciers to global warming. As part of the Nooksack Climate Change Project organized by the Nooksack Indian Tribe, research is underway to quantify current conditions of glacier melt and model future changes. Theoretically, there are four phases of glacier recession: (1) enhanced melt and increased discharge to streams (2) peak melt and peak discharge to streams, (3) decreased glacial area and volume and reduced discharge to streams, and (4) complete glacier loss and zero discharge to streams (Frans 2014). Determining where the glaciers that drain into the Nooksack River basin fall on this spectrum will be one outcome of the Nooksack Climate Change Project and will help refine future projections of temperature and streamflow impacts.

Finally, flooding and water quality issues may be expected if sediment loads (i.e., suspended and bedload) in the Nooksack River increase significantly. High sediment production and delivery is likely to result from glacial and snowfield retreat, which exposes additional bare ground to erosion, from higher peak streamflows, which enhances bank erosion, and from other sources of climate induced sediment production (e.g., wildfire, landslides). First, increasing bedload sediment deposition (sediment aggradation) decreases flood conveyance (carrying capacity) of river channels and may result in higher flood hazards. Second, higher turbidity degrades water quality and may also increase stream temperature and the transport of absorbed contaminants and nutrients. Projections of future sediment load have not been developed for the Nooksack River. Given the paucity of local data, looking to the Skagit River may help illustrate the scale of potential changes. The Skagit River has the highest mean annual discharge (18,000 cfs) and the highest annual sediment load (2.8 million tons/yr) of all the rivers draining into the Puget Sound (Czuba et al. 2011). It should be noted that there are three hydroelectric dams that trap sediment in the upper Skagit River watershed and that without these impoundments sediment production would likely be higher. Regardless, the annual sediment load in the Skagit River is projected to double by 2080 (Lee et al. *in press*). The Nooksack River has the second highest annual sediment load in the Puget Sound (1.4 million tons/yr), despite the fact that the river has only the fourth highest mean annual discharge (3,200 cfs) (Czuba et al. 2011). Naturally high sediment production is expected because the Nooksack watershed drains the glaciers on the northern slopes of Mt. Baker. Land use changes (e.g., agriculture, forestry, urbanization) in the watershed over the past 150 years are likely to have altered historical sediment loads. Over the coming

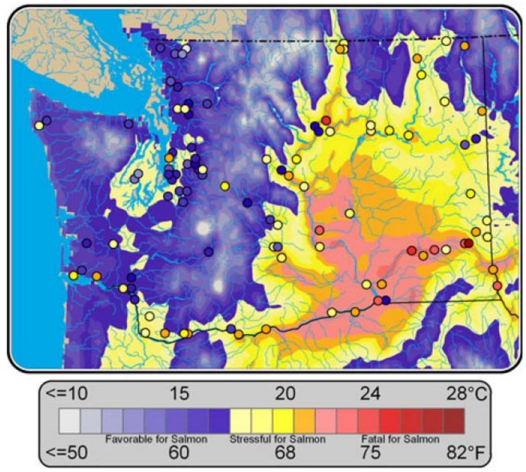

Figure 4.4 Historical (1970-1999) August Mean Surface Air Temperatures (Shading) and Simulated Maximum Stream Temperature (Colored Circles) in Washington State

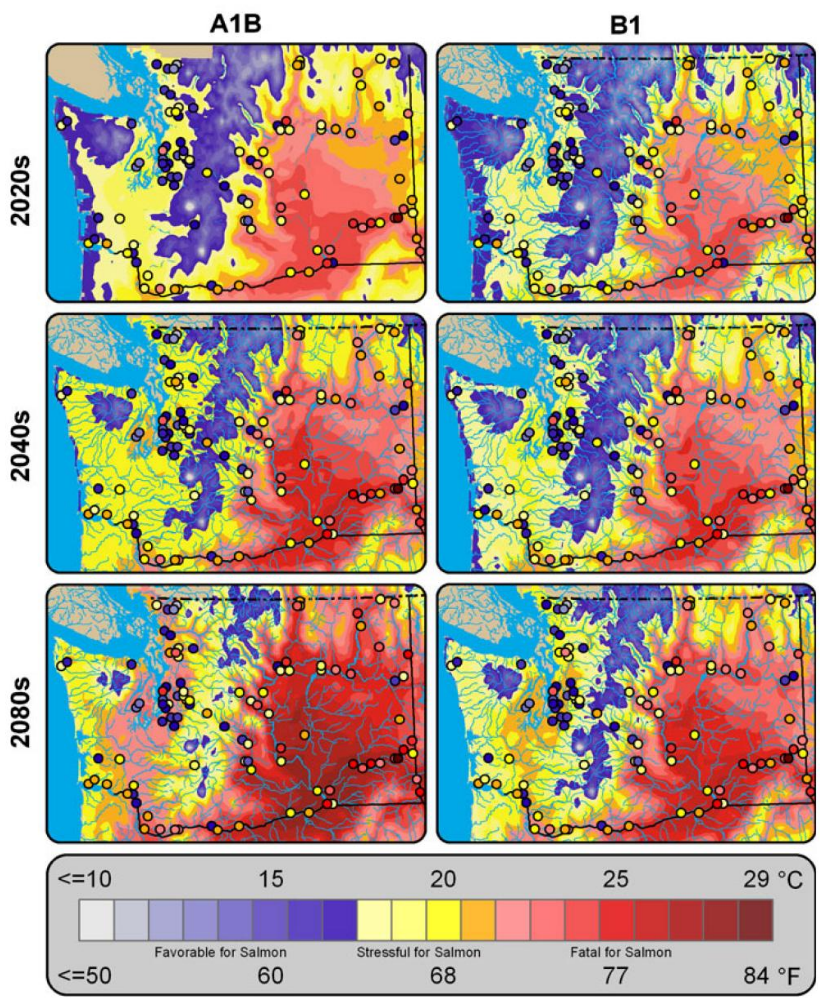

Figure 4.5 Projected August Mean Surface Air Temperature (Shading) and Maximum Stream Temperature (Colored Circles) in Washington State

decades, it is reasonable to expect an increasing sediment load in the Nooksack River as a result of climate change.

4.2.2. Groundwater

Two (apparently separate) potable groundwater systems occur on the Reservation. One system is located in the northern upland area and is recharged both on-Reservation and from off-Reservation areas to the north; the other system is located in the southern upland area of the Reservation (Lummi Peninsula) and is completely contained within the Reservation boundaries (Figure 4.6) (LWRD 2011b). The floodplain of the Lummi and Nooksack rivers, which contains a surface aquifer that is saline, separates the two potable water systems (Cline 1974). A third potable water system may exist on Portage Island, but information on the water quality and the potential yield of this system is limited and inconclusive (LWRD 2011b).

As a finite resource, groundwater is one of the most important and critical of the Lummi Nation's resources. Over 95 percent of the residential water supply for the Reservation is pumped from local groundwater wells. Most of the existing water supply wells on the Reservation are located within a half mile of marine waters. Progressive saltwater intrusion has already led to the closure of several public water supply wells, and continued vertical and lateral intrusion along some shoreline areas can be expected as sea levels rise. Excessive drawdown due to over pumping of fresh groundwater aquifers may also increase the rate and extent of salinization. Additionally, changes in precipitation patterns and surface water hydrology may alter groundwater recharge (Alexander et al. 2007); however, there is insufficient data available to assess potential climate change impacts to groundwater recharge locally. Because the hydrogeologic conditions on the Reservation vary considerably over short horizontal and vertical distances, the precise locations of the aquifer recharge zones are not definitively known at this time. It is likely that aquifer recharge areas are distributed over the upland areas. However, given the low infiltration potential of the glaciomarine drift that covers much of the Reservation upland, it is also possible that aquifer recharge areas are of limited areal extent and are located primarily in only a few locations around and north of the Reservation.

In addition to climate change impacts, groundwater resources are vulnerable to contamination by pollutants introduced on or near the ground surface by human activities (e.g., illegal solid or hazardous waste dumping). Agricultural, residential, municipal, commercial, and industrial land uses increase the potential for groundwater contamination. Future population growth, economic growth, and residential and municipal development on and near the Reservation could further threaten the Lummi Nation's groundwater resources if such activities are not managed effectively. Contamination, saltwater intrusion, and other sources of groundwater degradation could lead to the loss of the primary water supply source for the Reservation because water supply wells are difficult to replace, groundwater contamination is very expensive to treat, and some damages to groundwater caused by contamination may be unmitigable.

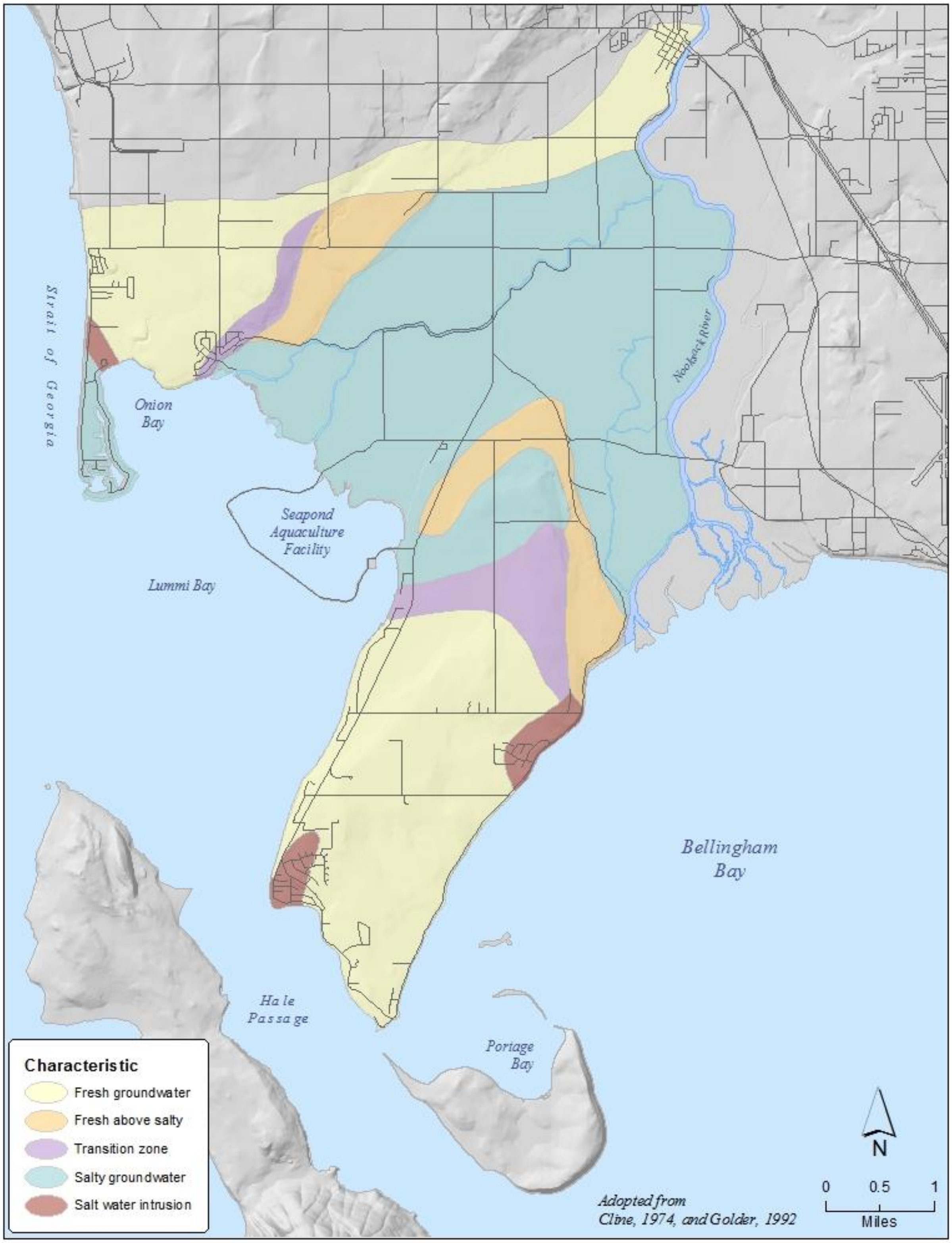

Figure 4.6 Lummi Indian Reservation Groundwater Characteristics

4.2.3. Wetlands

The Lummi Nation conducted a Reservation-wide wetland inventory in 1999. The inventory indicated that about 43 percent of the Reservation land area is either wetlands or wetland complexes and that approximately 60 percent of these wetland areas are located in the Nooksack and Lummi river floodplains (Harper 1999; LWRD 2000). Ongoing, GPS-based wetland delineations are further refining the wetland boundaries determined in 1999 (Figure 4.7). Prior to human alteration by Euro-American settlers, the wetlands of the Reservation were likely much more extensive. Beginning in the late 1800s, floodplain and estuarine wetlands were diked, drained, and filled for the purpose of cultivation. Concurrent with agricultural reclamation, some palustrine wetlands found in the Reservation's forested uplands were degraded by hydrologic alterations associated with logging, draining, impounding, and/or road construction. The wetlands of the Reservation provide vital ecosystem goods and services, including storm water attenuation, floodwater storage, water quality enhancement, fish habitat, wildlife habitat, and plants with traditional cultural importance. Protecting and enhancing wetlands is essential to preserving and restoring interdependent fish, shellfish, and wildlife habitats in addition to reducing flood damage. In this section, the potential impacts of climate change on the Reservation's coastal wetlands will be presented first, followed by a discussion of impacts to palustrine wetlands.

The Reservation's coastal wetlands (estuaries/deltas) form where fresh water rivers and streams meet the sea and include habitat types such as eelgrass meadows, tidelands, salt marshes, scrub-shrub wetlands, and forested wetlands. Coastal wetland losses resulting from relative sea level rise are due to submergence of estuarine habitats and their permanent conversion to open water, as well as subsequent shifts in habitat types as vegetation communities migrate shoreward to keep within optimum depth and salinity tolerances. For example, *Zostera marina*, an eelgrass species found in Lummi and Portage bays, is adapted to specific elevations within the intertidal range; limited shoreward by desiccation and seaward by light attenuation (Boese et al. 2005, Thom et al. 2008). Accordingly, as sea level rises and light availability falls below *Z. marina* tolerances, habitats in the lower tidal range will be converted to open water and the persistence of eelgrass communities will require shoreward migration. However, where shoreline dikes/seawalls, natural bluffs, or other barriers exist, such landward movement will be prevented. When biological communities reach barriers to migration, they may be extirpated from the bottom-up, which is termed "coastal squeeze".

Fortunately, large tracts of estuarine and floodplain wetlands of the Lummi and Nooksack rivers will be protected and functionally improved in the future through the implementation of the Lummi Nation Wetland and Habitat Mitigation Bank and other nearby restoration projects (Figure 4.8). In 2009, the Lummi Nation approved the acquisition of approximately 2,770 acres of wetland habitat for mitigation banking and restoration purposes, these areas will be protected into perpetuity through conservation easements (LIBC Resolution No. 2009-094). The mitigation bank will be developed in phases. The first phase, which encompasses most of the Nooksack River estuary, became operational during 2012. Enhancement activities underway in this area include removing invasive species and planting native species (e.g., willows, conifers). At the Lummi River estuary sites, which have not been developed yet, rehabilitation will focus largely on restoring direct tidal input to areas that have been isolated from tidal hydrology by shoreline dikes and levees. Restoration at these sites will include removing existing tide gates or replacing them with self-regulating tide gates, removing portions of existing dikes, and opening remnant sloughs and distributary channels. By implementing this extensive wetland protection and enhancement project, the Lummi Nation has taken an important step to guard against coastal wetland losses due to coastal squeeze.

The National Wildlife Federation (NWF) modeled wetland habitat transitions in the Nooksack delta, Lummi Bay, and Bellingham Bay using the Sea Level Affecting Marshes Model (SLAMM), which integrates sea level rise data, tidal data, elevation data, and National Wetland Inventory (NWI) data to simulate future changes in habitat composition (Glick 2007). In one model scenario, all existing shoreline dikes were removed. Under such conditions, some wetland habitat types expanded in area (e.g., transitional marsh, salt marsh, tideflats), while other habitats were projected to decrease in area (e.g., tidal swamp, estuarine beach). Although the NWF did not directly simulate habitat transitions following full implementation of the Lummi Nation wetland and habitat mitigation bank, these model results serve as an indicator of the significant shifts in wetland composition that may be expected as a result of sea level rise.

Another important consideration is that some estuaries may be capable of surviving sea level rise if the rate of vertical accretion is sufficient to keep pace with the rate of relative sea level rise. This may be feasible in the Nooksack River delta, which was identified as the fastest growing delta relative to its basin size in Puget Sound, with a progradation of approximately one mile over the 1888-1973 period (Bortleson et al. 1980). Consequently, a large area that was once intertidal is now supratidal and new wetlands have formed. However, without a detailed study of sediment dynamics in the Nooksack River delta, it is difficult to accurately project future habitat gains and/or losses. Furthermore, in areas where sedimentation has likely been reduced below historical levels, such as Lummi Bay, sediment elevation loss resulting from shallow sediment subsidence and/or erosion may exacerbate the impacts of eustatic sea level rise. Again, site-specific research is required to better understand estuarine surface elevation dynamics.

The potential impacts of climate change on upland wetlands (e.g., palustrine wetlands on the Lummi Peninsula) are varied and will depend on changes in precipitation, evapotranspiration, surface and/or ground water inflow, and other hydrologic factors that are difficult to accurately forecast. However, if wetland hydroperiods are significantly altered, changes in structure, function, and provision of certain ecosystem goods and services may be anticipated.

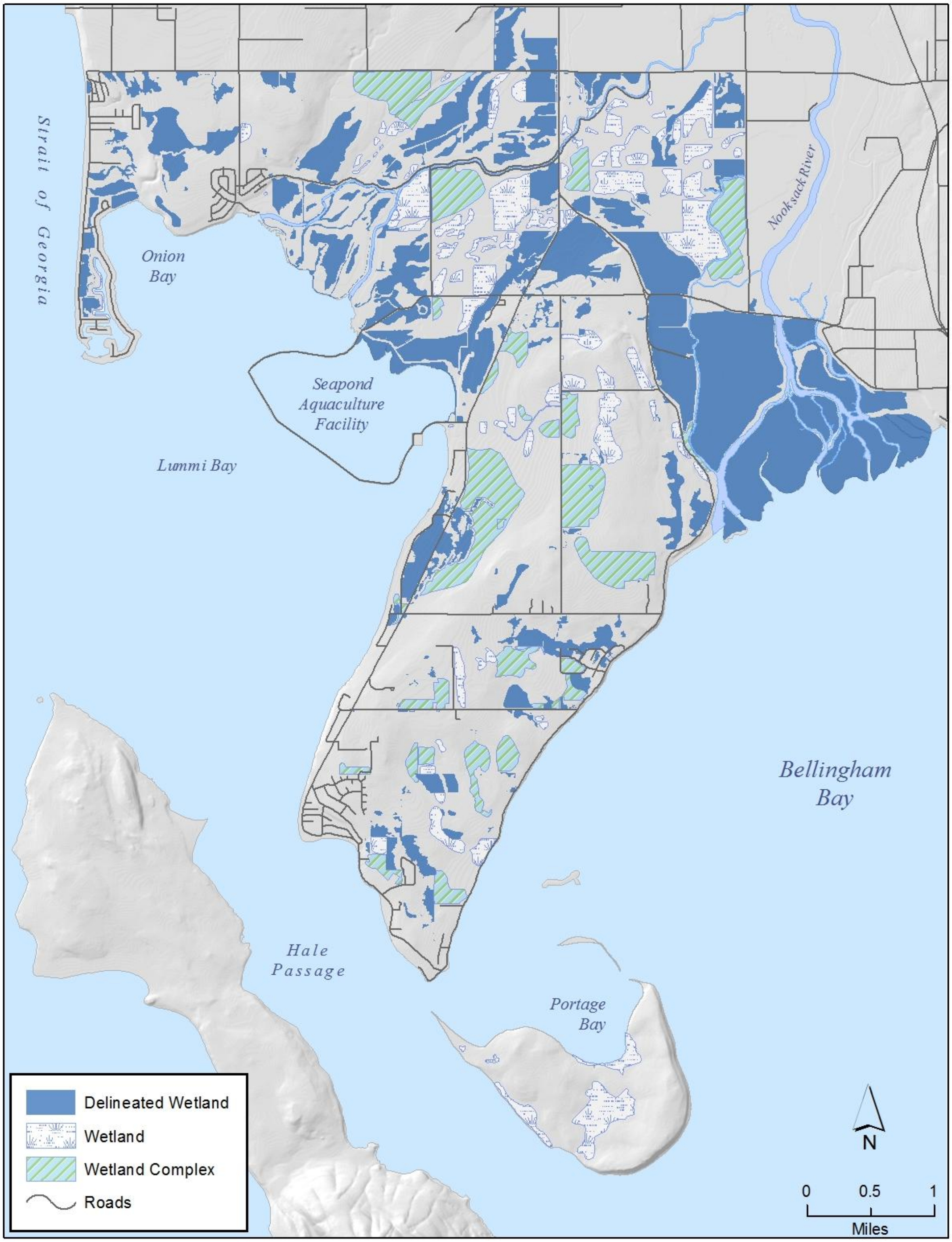

Figure 4.7 Lummi Indian Reservation Wetlands

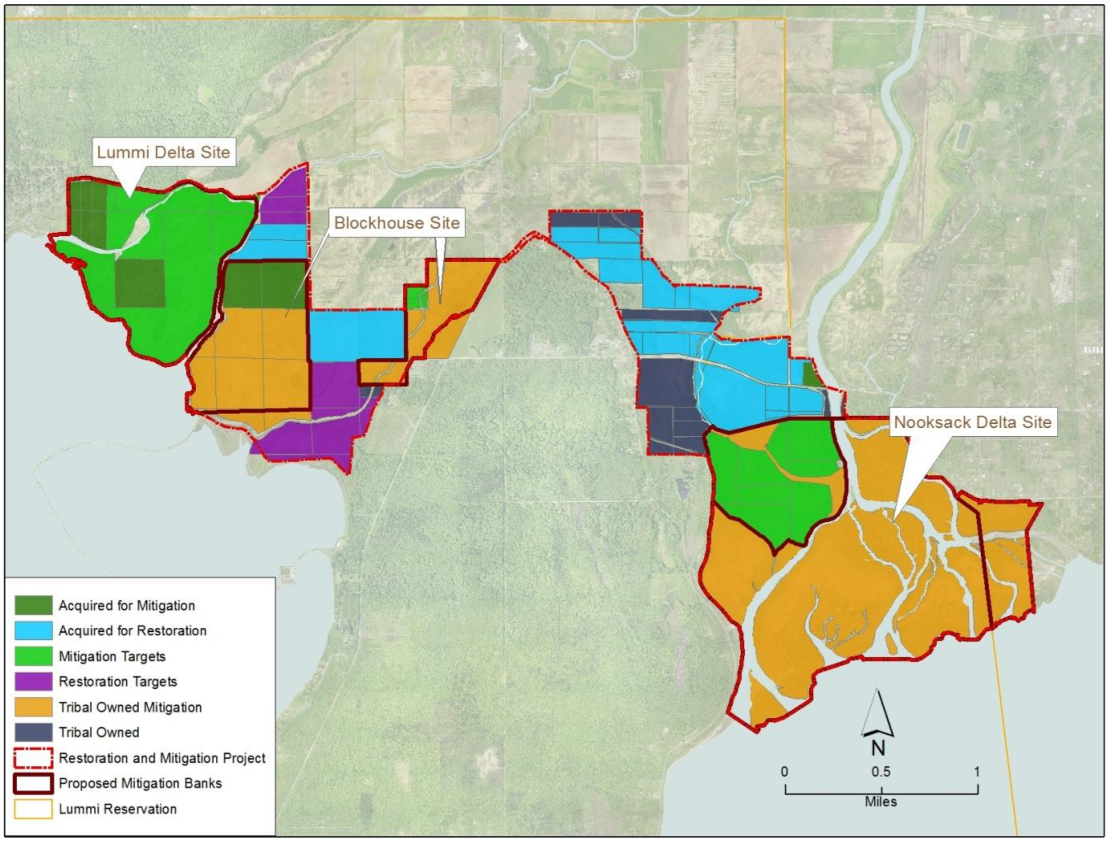

Figure 4.8 Acquisition and Use Plan for Reservation Lands in the Floodplain

4.3. Coastal Resources

The coastal resources of the Reservation are characterized by the estuaries of the Nooksack and Lummi rivers, which form the interface between marine and freshwater. These coastal areas are important habitat for juvenile and adult salmon as they acclimate to either saline or freshwaters during their seaward and landward/spawning grounds migrations, respectively. Estuaries also serve as habitat for juvenile and adult individuals of many other important aquatic species (LNR 2010). The complex and rich aquatic resources that provide feeding grounds for fish also attract a large variety of wildlife. The estuaries of the Lummi and Nooksack rivers are a part of the Pacific Coast flyway for ducks, geese, swans, and shorebirds. These estuaries are also habitat for peregrine falcon and bald eagle, both formerly listed species under the Endangered Species Act (ESA). Additionally, the estuarine tidelands (tideflats) located in or near Lummi Bay, Gooseberry Point, the Stommish Grounds, and Portage Bay are rich in resources for tribal ceremonial, subsistence, and commercial shellfish harvest and are integral to the Lummi *Schelangen* ("way of life"). In order to document the existing diversity, abundance, distribution, and habitats of the biological resources that are found on the Reservation tidelands, the Lummi Natural Resources Department (LNR) conducted the Lummi Intertidal Baseline Inventory (LIBI), which documented over 242 separate taxa present on the Reservation tidelands (LNR 2010).

The coastal resources sector is divided into three planning areas: shorelines, tidelands, and seawater. Vulnerability rankings developed for potential climate change impacts to each of these planning areas are provided in Table 4.2.

Table 4.2 Coastal Resources Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Shorelines	Increasing to permanent inundation from relative sea level rise	High	Low	High
	Increasing frequency and intensity of coastal flooding from sea level rise and storm surge	High	Low	High
	Increasing coastal erosion from sea level rise and storm events (depending on shoreline type)	High	Low	High
Tidelands	Increasing to permanent inundation from relative sea level rise	High	Low	High
Seawater	Increasing seawater acidity (i.e., decreasing pH)	High	Low	High
	Increasing sea surface temperature	High	Medium	Medium-High

4.3.1. Shorelines

There are approximately 38 miles of marine shoreline surrounding the Reservation (except along portions of the east boundary and the northern boundary). As sea levels rise, these shorelines and adjacent low-lying areas will become increasingly vulnerable to permanent inundation or inundation during high tide, more frequent and intense coastal flooding (from storm surge) and river flooding (from the "backwater effect"), and/or accelerated coastal erosion (Figure 4.9).

The Lummi Nation is taking steps to better understand the potential effects of accelerated sea level rise along Reservation shorelines. The Lummi Natural Resources Department, Planning and Public Works Department, and Police Department are currently working in partnership with the Federal Emergency Management Agency (FEMA) Region X, a FEMA contractor (Strategic Alliance for Risk Reduction [STARR]), and Washington State (Department of Ecology [Ecology], Department of Natural Resources [DNR], and Emergency Management Division [EMD]) on the coastal Risk MAP project, which will develop regulatory and non-regulatory tools that the Lummi Nation can use to plan for and reduce the risk of coastal hazards. Risk MAP products will include an updated Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) for the entire Reservation coastline that may alter the existing floodplain boundaries, as well as a base flood elevation (BFE) "plus" grid (i.e., BFE +1, 2, and 3 ft) to be used for sea level rise planning. Coastal hydrology (e.g., storm surge) and coastal hydraulics (e.g., overland wave height analysis) will be included in the flood hazard analysis. Project completion is planned in 2016.

Recently, several sea level rise modeling tools have become available online, including The Nature Conservancy's (TNC) Coastal Resilience Tool (available at http://coastalresilience.org/), the National Oceanic and Atmospheric Administration's (NOAA) Digital Coast Sea Level Rise Viewer (available at http://coast.noaa.gov/digitalcoast/), and the Climate Central's Surging Seas Risk Finder (available at http://sealevel.climatecentral.org). These tools are very useful for illustrating the potential scale of future flooding on the Reservation and through the Lummi Nation's Usual and Accustomed (U&A) areas.

At this time, the Lummi Nation is using the Coastal Resilience Tool, Sea Level Rise Viewer, and Surging Seas Risk Finder as planning reference tools, but is awaiting completion of the Risk MAP project to adopt an official sea level rise map for regulatory purposes. That being said, areas that already impacted by coastal flooding can be reasonably expected to become more vulnerable under future sea level rise scenarios; as identified in the Lummi Nation Multi-Hazard Mitigation Plan (2010) these areas include, but are not limited to, portions of the Sandy Point peninsula, Gooseberry Point, the Nooksack and Lummi river floodplains, and portions of Portage Island. As sea level continues to increase, adjacent upland areas will be at an increased risk of exposure to flooding.

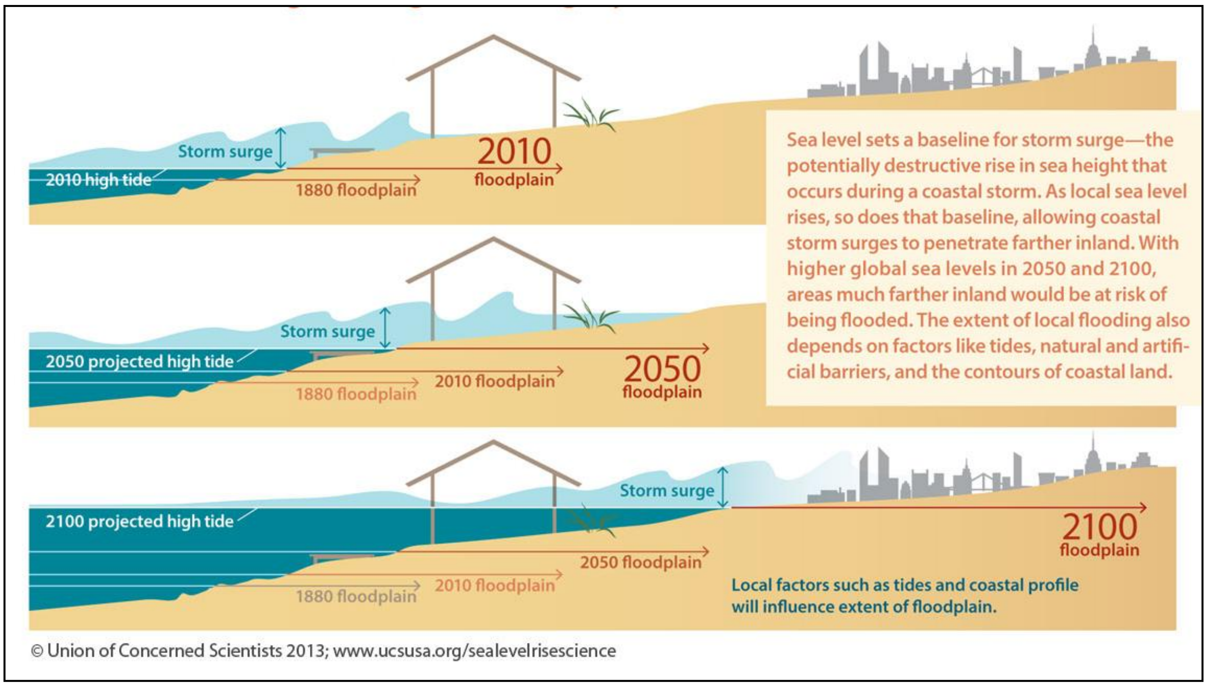

Figure 4.9 Inundation and Flood Risk from Sea Level Rise, Storm Surge, and High Tide

Concurrent with inundation and coastal flooding, sea level rise will also accelerate bluff and beach erosion. Although erosion is an important natural process that allows shorelines, which are not fixed physical features, to migrate over time, erosion management may be necessary where accelerated erosion threatens to destabilize important infrastructure. In 2007, the Lummi Nation contracted Coastal Geologic Services, Inc. (CGS) to assess the condition of Reservation shorelines (e.g., accretion shoreforms, feeder bluffs, and modified shorelines) and provide recommendations for coastal protection considering existing conditions and future sea level rise. Several areas with high erosion potential (eroding at a minimum of -0.6 ft/yr) or moderate erosion potential (eroding -0.3 to -0.6 ft/yr) were identified and include Neptune Beach, the western shore of Sandy Point, shores along the Lummi Peninsula between West Beach and Portage Point (i.e., along Lummi View Drive), and portions of Portage Island (CGS 2007). To protect valuable nearshore habitats and associated marine resources and provide protection for coastal infrastructure from erosion, CGS made recommendations (e.g., managed retreat, beach nourishment, rockery wall, revetment) for managing each of 22 distinct shore units on the Reservation.

Where the Reservation's coastlines are developed (e.g., Sandy Point, Gooseberry Point) or contain important infrastructure (e.g., Lummi Shore Rd., Lummi View Dr.) or cultural resources, difficult decisions about future land use need to be made. In some areas, managed retreat, wherein inland migration is facilitated, is likely to be the most viable long-term option to protect human life and reduce property damages. An example of managed retreat on the Reservation is the setback of Lummi View Dr. (approximately 400-500 ft) landward of the bluff crest in 2006 after erosion damages. In other areas, it may be appropriate to fortify the existing shoreline. As discussed previously (Section 4.3.1–Wetlands), flora and fauna will also require space for shoreward migration, otherwise progressive inundation can result in habitat loss as some areas are permanently converted to open water. Along undeveloped shorelines of Lummi and Bellingham bays that are part of the Lummi Nation Wetland and Habitat Mitigation Bank, shoreward migration of coastal biota will be allowed or actively managed for (e.g., breaching the Lummi Bay seawall).

4.3.2. Tidelands

There are approximately 7,000 acres of tribally-owned tidelands on the Reservation. Similar to shoreline impacts, relative sea level rise will progressively inundate areas in the lower tidal range and force the shoreward migration of tideland flora and fauna, including some shellfish species. Because ceremonial, subsistence, and commercial shellfish harvest are integral to the Lummi *Schelangen* ("way of life"), this section is included to highlight the importance of taking steps to protect and preserve tideland resources. As a first step, it would be beneficial to quantify the potential changes in suitable shellfish habitat under future sea level rise scenarios. By taking into account the current abundance and distribution of shellfish species of concern, tideland surface elevation (e.g., digital elevation model [DEM]), tideland sediment characteristics (substrate coarseness affects habitat suitability), and other important determinates of shellfish habitat, areas of potential habitat loss and/or gain could be identified and actions taken. For example, shoreline armoring can enhance scour, leading to seaward beach erosion and substrate coarsening (CIG 2009). As such, it may be feasible to remove shoreline armoring in certain areas to increase the viability of current or future shellfish habitat.

4.3.3. Seawater

This section addresses two of the primary impacts of climate change on seawater: (1) increasing acidity (decreasing pH) and (2) increasing surface temperatures. Thermal expansion of the oceans and resultant sea level rise was previously discussed in the context of shoreline impacts and is not included here.

Ocean acidification (OA) directly reduces the growth and survival of some calcifying organisms ("calcifiers"), such as oysters, clams, mussels, geoduck, crabs, sea urchins, and sea cucumbers, with indirect affects transmitted throughout the marine food web. Figure 4.10 depicts the dissolution of a pteropod (swimming snail) shell over 45 days in seawater at pH and carbonate levels projected for 2100 (Blue Ribbon Panel 2012). Under these conditions, calcifiers must expend more energy to build and maintain their shells, skeletons, or other hard body parts, resulting in reduced energy allocation for growth, reproduction, and coping with other environmental stressors (Feely et al. 2014). Although species vary in their sensitivity to OA, organisms with more soluble forms of calcium carbonate in their shells or skeletons (e.g., aragonite), including many juvenile shellfish, are more sensitive than those with less soluble mineral forms of calcium carbonate (Kroeker et al. 2010). Additionally, shellfish larva exposed to OA can exhibit "carry-over" effects (e.g., reduced growth rates) into adulthood (Feely et al. 2014). Some shellfish hatcheries (e.g., Whiskey Creek Shellfish Hatchery, Oregon coast; Taylor Shellfish, Puget Sound's Hood Canal) and shellfish growing areas (e.g., Willapa Bay, Washington coast) in the Pacific Northwest have already experienced oyster larvae die-offs as a result of corrosive seawater. As corrosive events in surface waters become more frequent and longer duration, shellfish on tribally-owned tidelands and throughout the Lummi Nation's Usual and Accustomed (U&A) areas will become increasingly vulnerable to OA, placing the Lummi *Schelangen* and treaty-protected resources at risk.

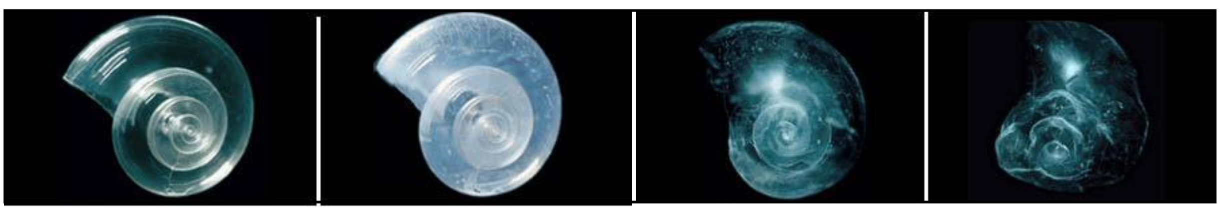

Figure 4.10 Pteropod Shell Dissolution Over 45 days in Seawater at pH and Carbonate Levels Projected for 2100

The impacts of OA will be observed across the entire marine food web. For example, decreasing abundance of species at the base of the food web, like the pteropod pictured in Figure 4.10, will have implications for species at higher trophic levels. Similarly, decreasing abundance of predatory and/or keystone species, such as sea urchins (OA disrupts egg fertilization), may significantly impact community structure and function.

Furthermore, it bears mention that toxin production in some algal species associated with harmful algal blooms (HABs) is positively correlated with increasing OA (Moore 2008). Ingestion or contact with these toxins can result in paralytic shellfish poisoning, amnesic shellfish poisoning, diarrheic shellfish poisoning, and other poisoning syndromes in humans and other animals. Shellfish harvest areas in Lummi Bay, Portage Bay, and some of the Lummi Nation's U&A areas (e.g., Semiahmoo, Birch Bay, Squalicum Harbor) already face temporary closures during the spring and summer due to toxicity levels that are unsafe for human consumption. Additional or prolonged closure of shellfish beds could further restrict commercial, ceremonial, and subsistence harvests.

The consequences of increasing sea surface temperature are also far reaching. Warmer waters may alternatively enhance or reduce the growth, reproduction, and survival of marine organisms depending on their location and physiological tolerances. Similar to the process of shoreward migration in response to relative sea level rise, some marine species are capable of migrating to new areas to stay within their preferred thermal range. This is evidenced by periods of higher than average ocean temperature along the coast of the Pacific Northwest, when warm-water species (e.g., anchovies, sardines) become more abundant (Dalton 2013). It follows that cold-water species will also need to migrate to higher latitudes as temperatures rise. For species that cannot migrate, species abundance and distribution may decline in response to thermal stress.

Additionally, warmer waters have been linked with the increasing frequency, duration, and distribution of harmful algal blooms (HABs) (Moore et al. 2008). For example, *Alexandrium catenella* is a dinoflagellate associated with paralytic shellfish poisoning (PSP) in the Puget Sound that grows best at temperatures above 13 °C. As sea surface temperatures increases by 2 °C, 4 °C, and 6 °C, the annual window of opportunity for *A. catenella* growth is expected to expand beyond the historical average (68 days, shaded region), by 69 days, 127 days, and 191 days respectively (Moore et al. 2008; Figure 4.11). As a result, the closure of shellfish beds may not be restricted to the late summer months (July-August), but may begin sooner and end later depending on toxicity levels.

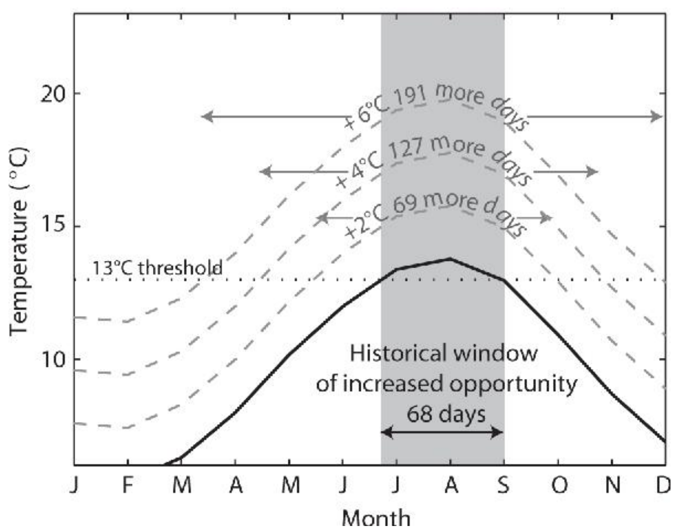

Figure 4.11 Potential Impact of Increasing Sea Surface Temperature on Harmful Algal Bloom (HAB) Growth

4.4. Forest Resources

Nearly 50 percent of the Reservation land base (excluding tidelands) is forested, including 5,360 acres on the Reservation mainland (distributed across the Lummi Peninsula and Northwest Uplands) and 703 acres on Portage Island (Figure 2.3; LNR 2011). Many of the forested parcels on the Reservation are held in individual Native trust status. Parcels on the Lummi Peninsula are largely zoned for forestry or residential purposes, while parcels in the Northwest Uplands are mostly in the residential zone. Additionally, the Lummi Nation owns two forested conservation areas located off-Reservation, including 1,771 acres in the Arlecho Creek watershed (South Fork Nooksack River basin) and 26 acres on Madrona Point (Orcas Island). As discussed previously, nearly all the Reservation's old-growth forests were either harvested by Euro-American settlers or destroyed by wildfire by the early 1900s. After these disturbances, forests that were allowed to regenerate did so naturally. As a result, many of the second and third-growth stands on the Reservation are dominated by deciduous species, particularly red alder, although there are some mixed deciduous/conifer stands. In 2007, an inventory of mainland Reservation forests (excluding Portage Island) indicated that the net volume of red alder is approximately 18,000 million board feet (MBF) (LNR 2011). Other species, in descending order by volume, are western red cedar, black cottonwood, western big leaf maple, Douglas fir, and western paper birch. Sitka spruce, western hemlock, and grand fir are also present in low volumes. The majority of forested lands on the Reservation are now 55 years or older (55 percent), while 35 percent of forested lands are under 25 years of age (LNR 2011).

Forests provide valuable ecosystem goods and services including fish and wildlife habitat, soil stabilization, carbon sequestration, and provision of clean air and clean water. Traditional uses of forest ecosystems by the Lummi People include activities such as gathering cedar (wood and bark), berries, and medicinal plants and hunting large and small game. As the climate changes, the provision of these ecosystem goods and services may be at risk. Warmer and drier summers in the Puget Sound region are generally expected to increase water demand deficits and subsequently alter forest type, increase wildfire activity, and increase the incidence of insect infestation and disease. The potential effects of climate change on the Lummi Nations forest resources, both on and off-Reservation, are discussed below.

The forest resources sector is divided into three planning areas: forest type, wildfire, and insects and disease. Vulnerability rankings developed for potential climate change impacts to each of these planning areas are provided in Table 4.3.

Table 4.3 Forest Resources Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Forest Type	Increasing water-deficits that decrease drought-sensitive species survival and increase drought-tolerant species survival	High	Medium	Medium-High
Wildfire	Increasing area burned by wildfire annually	High	Low	High
Landslides	Increasing risk of landslide activity	High	Low	High
Insects and Disease	Greater pest infestations or disease outbreaks	Medium	Medium	Medium

4.4.1. Forest Type

Water demand deficits occur when water demand (relative humidity) exceeds water supply (soil moisture) and are expected to increase during summer months in the Puget Sound region under future climate conditions. In the short-term, vegetation that is “water-limited” may experience decreased growth and reproduction and increased disease and mortality (Dalton et al. 2013). For example, decreasing growth is expected for Douglas fir, western red cedar, western hemlock, and Sitka spruce in low elevation forests west of the Cascade Range crest (“west-side”) as the climate warms (Peterson 2014). Conversely, high elevation west-side forests are typically energy-limited rather than water-limited, and the growth of species such as subalpine fir, mountain hemlock, and lodgepole pine may increase as the growing season lengthens.

In the long-term, species that are drought-sensitive, such as western red cedar and Sitka spruce, may be forced to migrate to more climatically suitable areas. In the Pacific Northwest, this species migration typically means moving to higher latitudes, higher elevations, or protected microclimates (i.e., refugial habitats). Conversely, drought-tolerant species may become more abundant and widely distributed. Species range shifts are of particular concern to the Lummi Nation because the Reservation and Usual and Accustomed (U&A) grounds and stations are legally defined geographic areas reserved by the 1855 Treaty of Point Elliot. If species ranges shift outside of the Reservation or U&A areas, the tribe may experience difficulty maintaining viable populations of culturally important species such as western red cedar.

4.4.2. Wildfire

Wildfire has been and will continue to be an important factor in shaping forest ecosystems in the Pacific Northwest. Historically, fire regimes in Washington State west of the Cascade Range crest (“west-side”) are characterized by low frequency (200-500 year return interval) but high severity fires (e.g., stand-replacing fires), although high frequency/low severity fires do still occur (e.g., understory fires) (Rogers et al. 2011). The Reservation has not experienced a stand-replacing fire, which occur under rare conditions of drought and high winds, in the past 100 years, but does experience between 1 and 4 small wildfires each year that are typically caused by fireworks or abandoned fire pits (LNR 2011). In this region, warmer and drier summers are expected to decrease fuel moisture, while warmer and wetter winters are expected to promote vegetation growth and consequently increase fuel availability. With more abundant and highly flammable fuels, an increasing annual burn area is anticipated (Dalton et al. 2013). Meanwhile, the earlier onset of spring snowmelt is expected to increase the length of the fire season (Dalton et al. 2013). Although it is difficult to forecast future wildfire activity, the results of one model simulating the response of wildfire in west-side forests under a high greenhouse gas emissions scenario suggest that the area burned annually may increase by 150 to 1,000 percent by the 2080s when compared to the 1970-2000 average (Rogers et al. 2011). It should be noted that because of the low annual area burned in west-side forests, the statistical relationships between climate and fire have a high level of uncertainty and less explanatory power compared to east-side models where frequent fire activity provides sufficient data to build predictive relationships (Littell et al. 2010). Regardless, significant consequences will result from changes in wildfire activity.

The primary concerns with wildfire activity on the Reservation are protecting human health and safety and preventing property damage. This is of particular concern where residences and workplaces are located in forested areas or along the urban-wildland interface. Fire protection services on the Reservation are provided by Whatcom County Fire District #8 (Marietta Fire District), Fire District #17 (Sandy Point District), and Fire District #7 (Ferndale District). For wildland fire suppression, the Lummi Nation has a cooperative agreement with the Washington State Department of Natural Resources (DNR), which allows the state agency to respond to wildfires on the Reservation. The Lummi Natural Resources Department (LNR) also maintains firefighting equipment and current training so that certified staff members are available to respond to and/or assist other first responders with wildfire suppression. If wildfire occurs as the result of timber harvest operations on the Reservation, the purchaser or logging operator is financially and legally responsible for all fire suppression actions necessary to contain wildfires caused by their own activities. To protect the Reservation from wildfires, a burn ban is implemented most years that is usually consistent with the Whatcom County burn ban. The implications of degraded air quality from smoke and particulate pollution that results from wildfires on human health will be discussed in Section 4.6 – Human Health. Finally, other impacts to Reservation residents include property damages and diminished economic opportunity (e.g., harvestable timber units burned).

The ecological consequences of climate-driven changes in wildfire activity are also of concern to the Lummi Nation. Unfortunately, the lack of available information on how climate change will affect west-side fire regimes, which includes not only area burned but also fire intensity and impact severity, makes it difficult to accurately forecast how forest ecosystems will respond to changing conditions (e.g., changing structure, function, composition, distribution). If fire regimes change significantly, it is reasonable to expect that impacts from wildfire may overwhelm the gradual shifts in forest structure and function discussed above. As forests change, so too will habitat availability and suitability. Increased wildfire activity will likely favor species that are adapted to post-burn conditions ("fire-specialists"; e.g., woodpecker species), while population declines may be expected in species associated with late successional or old-growth forests (e.g., spotted owl, marbled murrelet) (Dalton et al. 2013). This may result in a loss of biodiversity and/or local species extinction. A significant negative consequence of increased burn area is the increased potential for sediment erosion and runoff into freshwater systems. The impacts of increased sedimentation in the Nooksack River watershed are discussed in Section 4.2.1 – Freshwater.

4.4.3. Landslides

Climate change may increase the risk of landslides by affecting several of the factors that influence slope stability (e.g., precipitation, soil moisture, erosion, vegetation coverage). Although most of the Reservation is at no or minimal risk of slope failure (LWRD 2010), there are some areas, particularly along coastal bluffs, that are at significant risk of damage due to landslides. In areas where past landslides occurred along the Lummi Peninsula shoreline (e.g., Lummi Shore Road, West Beach), wave-caused erosion along the base of the bluff, saturated soils from periods of heavy or prolonged rainfall, and/or poor storm water drainage associated with development at the top of the bluff contributed to slope failure. Bluff erosion was previously discussed in the context of sea level rise impacts on coastal resources, but it also bears mention that climate change induced variations in precipitation patterns are also likely to increase landslide risk in already vulnerable areas of the Reservation. In the upper reaches of the Nooksack River watershed where there is more topographic relief, increasing landslide activity due to climate change is also a large concern. Slope stability in these areas will not only be affected by wetter winters, an increasing frequency of heavy rainfall events, and more precipitation falling as rain rather that snow, but also bank undercutting associated with more severe winter flooding and reduced vegetation coverage resulting from wildfire, insect damage, and/or disease.

4.4.4. Insects and Diseases

Climate is an important driver of insect infestation and disease outbreak in forested ecosystems of the Pacific Northwest. Drought stress typically increases host vulnerability by decreasing a tree's capacity to repel attack, while warmer temperatures increase the survival and geographic distribution of some forest insects and diseases. Forest insects and diseases of concern in the western United States include mountain pine beetle, spruce budworm, and Swiss needle cast (Dalton et al. 2013). While most insect and disease problems in Washington State are occurring on the east side of the Cascade Range crest, west-side forests may become increasingly vulnerable over time. Currently, fungus rots and root rots are commonly observed in Reservation forests, but no other significant disease or insect problems have been detected (LNR 2011). If climate-induced insect and disease problems do arise on the Reservation, increased tree mortality can be expected to increase wildfire vulnerability.

4.5. Fish, Wildlife, and Traditional Use Plants

The 1855 Treaty of Point Elliot reserves the right of the Lummi People to take fish at the tribe's Usual and Accustomed (U&A) grounds and stations and to hunt and gather on all open and unclaimed lands. Access to a sufficient quantity and quality of these treaty-protected resources is vital to the Lummi *Schelangen* ("way of life"). Commercial, ceremonial, and subsistence finfish and shellfish harvest supports tribal member's livelihoods, preserves cultural practices, and provides sustenance for individuals and families. In fact, the Lummi Nation is the largest fishing tribe in the Salish Sea in terms of pounds of fish landed and number of species fished (NWIFC 2012). The Lummi are known as the "salmon people" and, as found by the U.S. Supreme Court in *United States v. Winans* (1905) which ruled on another "Stevens Treaty" (an Indian Treaty that is essentially the same as the Treaty of Point Elliot), fishing to Indians is "not much more necessary than air they breathe."

Hunting and gathering also support individual and community health and wellness. As Lynn et al. (2013) adeptly describe: "The indigenous relationship between food and people is intimately tied to the cultural, physical, emotional, psychological, and spiritual health of tribal communities. Traditional foods […] provide not only sustenance, but also cultural connections through storytelling, ceremonies, harvesting, processing, and sharing of food resources." This section provides an overview of potential climate change impacts to fish, wildlife, and plant species (food and non-food) that hold significant social, cultural, and economic value to the Lummi Nation.

The fish, wildlife, and traditional use plants sector is divided into five planning areas: salmon, forage fish, shellfish, upland wildlife, and plants (terrestrial and aquatic). Vulnerability rankings developed for potential climate change impacts to each of these planning areas are provided in Table 4.4.

Table 4.4 Fish, Wildlife, and Traditional Use Plants Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Salmon	Combined impacts of increasing winter high flows, decreasing summer low flows, increasing stream temperatures, increasing sediment loads, sea level rise, and ocean acidification	High	Low	High
Forage Fish	Inundation of spawning habitat	High	Low	High
Shellfish	Combined impacts of sea level rise, ocean acidification, and increasing sea surface temperatures	High	Low	High
Upland Wildlife	Species specific[1]	-	-	-
Plants	Species specific[1]	-	-	-

[1] Taxa and/or species specific data required for assessment

4.5.1. Salmon

All five species of Pacific salmon (Chinook, sockeye, coho, pink, and chum) and three other salmonid species (steelhead trout, cutthroat trout, and bull trout) are found in the Nooksack River. However, salmon runs today are estimated to be less than ten percent of what they were in the 1850s. Furthermore, the North Fork/Middle Fork Nooksack River spring Chinook salmon and the South Fork Nooksack River spring Chinook salmon have been listed as threatened under the federal Endangered Species Act (ESA) since 1999. The National Marine Fisheries Service (NMFS) identified Puget Sound/Strait of Georgia coho salmon as a species of concern in 1997. Existing stressors to salmon populations include habitat loss, fragmentation, and degradation; water of insufficient quantity and quality; alteration of historical disturbance regimes (e.g., flood regime, sediment regime); and historical overharvest. Cumulatively, these stressors have caused significant declines in salmon populations (e.g., abundance, productivity, genetic diversity, life history diversity) and reduced the resilience of salmon to future disturbances. Many of stressors that are negatively affecting salmon today will be exacerbated under future climate scenarios.

Given salmon and steelhead's anadromous lifecycle and population-specific life histories, climate change impacts will vary depending on which species, population, and life stage is under consideration (Figure 4.12, Beechie et al. 2012). For example, "stream-type" Chinook salmon rear in freshwater habitats for one to two years before migrating to the sea, whereas "ocean-type" Chinook migrate to estuarine habitats within a few months of hatching. As a result, stream-type and ocean-type Chinook will be distinctively vulnerable to climate change impacts on freshwater and estuarine habitats given the particulars of their life history strategies (Beechie et al. 2012). A brief introduction to climate change impacts in freshwater, estuarine, and marine environments and the probable consequences to salmon are presented below.

Climate change is expected to increase stream temperatures, decrease summer low flows, and increase winter high flows in watersheds like the Nooksack River basin. Warmer stream temperatures can decrease the survival of salmon and other cold-water fish species by increasing thermal stress and the probability of fish kills, creating barriers to migration, altering the timing of migration, reducing habitat connectivity and the availability of cold water refugia, increasing the spread of disease, and favoring native or non-native warm-water fish that may compete with or prey on salmon (Mantua et al. 2010, Beechie et al. 2012). Generally, prolonged exposure to temperatures above approximately 21°C is lethal to salmon. More precise temperature thresholds that are specific to each species at different life stages are presented in Table 4.5 (Beechie et al. 2012). Some studies have suggested that higher stream productivity resulting from warmer waters may benefit salmon; however, this potential benefit is likely outweighed by the aforementioned negative consequences. Low instream flows during the summer months can create physical barriers to migration, decrease habitat availability, and contribute to increasing stream temperatures. Finally, high stream flows during the winter months can scour redds or clog them with fine sediments and prematurely displace fry downstream (especially in areas without off-channel habitat).

In marine and estuarine habitats, salmon may be affected by habitat loss resulting from sea level rise and coastal erosion, increasing sea surface temperatures, and changes in food web structure as a consequence of ocean acidification. Unlike the freshwater life stages, there is relatively scarce information available to assess the marine survival of salmon under current and future climate conditions. One way to try to better understand some of these future climate change impacts is to look at how salmon respond to anomalous conditions that occur from time to time as result of natural variability inherent in the earth's climate system. For example, an unusually warm area of water (a.k.a., "the Warm Blob") that was about 2-4 °C warmer than normal formed and persisted in the northeast Pacific Ocean in 2013-2014 (Bond 2015, OWSC 2015). Although there was no evidence of a direct connection between the Warm Blob and climate change, the Warm Blob did provide some insight as to how a warmer ocean might impact fisheries. The warm waters of the Warm Blob may have been the reason why most of the Fraser River sockeye returned through the Johnstone Strait rather than going around the outside of Vancouver Island and passing through the Strait of Juan de Fuca in the summer of 2014. In a typical run year, sockeye migrate through the Johnstone Strait and the Strait of Juan de Fuca in roughly similar proportions, giving Lummi fishers better access to the migrating salmon. In addition to potential effects on salmon migration routes, there were also concerns about how the Warm Blob might impact zooplankton communities, which could have an impact the diets of salmon. However, as stated by the NOAA Northwest Fisheries Science Center (NWFSC): "Major impacts [of the Warm Blob] on commercially important salmonid fisheries will not be known for a year or two but early signs suggest that for some salmon stocks, the warm water was not harmful (NOAA 2015)."

It is also important to note that production at the Lummi Nation's three salmon hatcheries, the Skookum Creek Hatchery, Lummi Bay Hatchery, and Sandy Point Hatchery, which are necessary to maintain a harvestable surplus of salmon for the Lummi People, are likely to be negatively affected by climate change impacts, particularly those related to water quantity and water quality. Hatchery operations require a reliable supply of high quality water to maximize salmon production, and when problems of insufficient water quantity and/or quality arise there can be lasting effects on hatchery programs. For example, Skookum Creek Hatchery staff were forced to develop and implement a contingency plan to reduce juvenile coho salmon production at the facility by 20 percent in 2015 due to a lack of water availability (i.e., low instream flows in Skookum Creek; Washington State Governor declared drought in the Nooksack River basin

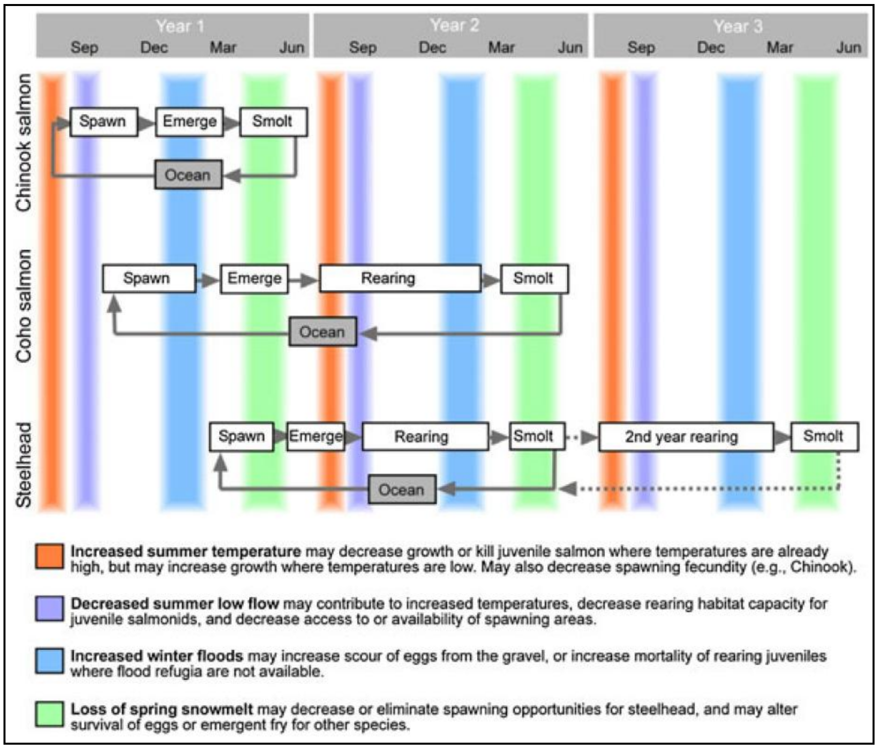

Figure 4.12 Timing of Climate Change Effects on Streamflow and Temperature by Life History Stages of Chinook Salmon (Ocean-Type), Coho Salmon, and Steelhead

[1]Note that the riverine/estuarine life history phases (white boxes) are shown to scale, but the ocean life history phase (grey box) is not to scale (e.g., Chinook salmon typically spend 2-4 years in the ocean, coho salmon typically spend 1.5 years in the ocean)

Table 4.5 Temperature Thresholds (°C) for Critical Parts of the Salmonid Life Cycle

Life stage	Chinook (*O. tshawytscha*)	Chum (*O. keta*)	Coho (*O. kisutch*)	Pink (*O. gorbuscha*)	Sockeye (*O. nerka*)	Steelhead (*O. mykiss*)
Adult migration						
Optimal threshold			15.6			
Lethal threshold	22	21	21			
Thermal blockage						22
Adult holding and spawning						
Optimal threshold	14.5	12.8	15.6			12.8
Detrimental to internally held gametes			20			
Incubation and early fry development						
Upper threshold	14.5	10	12	12	12.5	12
Juvenile rearing						
Optimal threshold	14.8[a]	15	17			19
Lethal threshold		21	23		20	
UZNG[b]	24	19.8	23.4	21		24
Smoltification						
Impairment threshold	12–17		15			13

Temperatures cited are for constant exposure, unless otherwise noted. Data compiled from Bjornn and Reiser (1991), Eaton and Scheller (1996), McCullough *et al.* (2001), and Richter and Kolmes (2005).
[a]Natural rations level
[b]Upper zero net growth (UZNG) temperature: maximum weekly temperature at which fish can live for several days but at which they do not ingest enough food to gain weight

on April 17, 2015) and associated poor water quality (i.e., high temperature, low dissolved oxygen). As this example demonstrates, the water supply at the Skookum Creek Hatchery is already vulnerable during drought and/or low summer streamflow, both of which are expected to become more frequent with climate change. Similarly, production at the Lummi Bay hatchery would be jeopardized if the water supply and/or water intake system from the Nooksack River at the Marine Drive Bridge were rendered inadequate. It also bears mention that hatcheries are particularly vulnerable to water quality degradation, climate-induced or otherwise, because of the high density rearing conditions under which salmon are raised to meet production goals.

4.5.2. Forage Fish

Forage fish are relatively small fish species that are the prey base for a wide variety of other marine organisms (e.g., salmon, mammals, birds). Forage fish are also harvested for ceremonial, subsistence, and commercial purposes. The primary forage fish species that occur on or near the Reservation include Pacific herring, sandlance, surf smelt, longfin smelt (a.k.a., "hooligans"), and anchovy. Accelerated sea level rise may inundate forage fish spawning habitat (herring use eelgrass meadows in Lummi Bay and Portage Bay; sandlance and surf smelt use estuarine beaches along Bellingham Bay, Portage Bay, Hale Passage, and the Strait of Georgia) unless vertical accretion keeps pace with rising sea levels or shoreward migration preserves habitat area.

4.5.3. Shellfish

Commercial, ceremonial, and subsistence shellfish harvest are essential to the Lummi *Schelangen* ("way of life"). Due to the decline in salmon availability, commercial Dungeness crab harvest has provided the largest percentage of annual fishery revenue in the Lummi Nation for at least the past 15 years despite year-to-year variability in catch. Even in 2010 when there was a record Fraser River sockeye run, the landed value of all salmon species combined was $6.3 million while the landed value of Dungeness crab was $4.3 million. Other important commercial shellfish species include sea cucumber, geoduck, spot shrimp, and manila clam. Ceremonial and subsistence harvests often include Dungeness crab, spot shrimp, manila clam, butter clam, and Pacific oyster. To support shellfish harvests, the Lummi Bay Shellfish Hatchery produces Pacific oyster spat and manila clam seed for tribal tideland enhancement, while also producing and selling geoduck seed to partially support operation costs. Climate change impacts on shellfish include decreased growth and survival as a result of ocean acidification, habitat loss as a result of inundation from sea level rise, and thermal stress as a result of warmer sea surface temperatures. Furthermore, the expected increasing incidence and toxicity of harmful algal blooms (HABs) may limit or eliminate the opportunity for harvest of some filter feeding shellfish species.

Given the severity of potential climate change impacts, the Pacific Shellfish Institute has instituted a water chemistry monitoring program at the Lummi Bay Shellfish Hatchery. Monitoring equipment is located at one site in the Seapond aquaculture facility and one site within the hatchery. Over the period of record (2011 to present), there has been no detectable change in pH or temperature in waters tested in the Seapond that could be attributed to anthropogenic climate change or that were outside of the range of natural variability (e.g., seasonal change, tidal change) (Suhrbier 2014). Continued monitoring is necessary to further refine the range of current conditions and ensure early detection of potential future problems.

4.5.4. Upland Wildlife

Upland wildlife species on the Reservation and in the Lummi Nation's Usual and Accustomed (U&A) areas that are hunted for ceremonial and subsistence purposes include deer, elk, mountain goat, bear, bobcat, cougar, and coyote. Hunting areas off Reservation are located on Washington State Department of Natural Resources (DNR) and United States Forest Service (USFS) public lands. Waterfowl are the only species that the tribe permits to be hunted on the Reservation. The vulnerability of these game species to a changing climate will depend on how sensitive each species is to the impacts discussed in Section 4.4 – Forest Resources, which include changes in forest type and wildfire activity.

4.5.5. Traditional Use Plants

As discussed in Section 4.4 – Forest Resources, changes in temperature and precipitation over the coming decades will likely lead to species range shifts and, in some cases, local extirpation. Similarly, aquatic plant species may migrate or become less abundant as a result of changes in hydrology discussed in Section 4.2 – Water Resources and Section 4.3 – Coastal Resources. As species are lost from their historical range, the Lummi People may lose access to plants with significant cultural value. Additionally, the timing of important life history events (a.k.a., phenology; e.g., spring bud burst, start of migration) is changing with the climate. For example, a Jamestown S'Klallam tribal member has reported that, in her experience, the optimal time to harvest cedar bark for weaving traditional baskets has shifted to earlier in the spring (Jamestown S'Klallam Tribe 2013). As the window of opportunity for harvest changes, so too will the timing of human activities surrounding the harvest.

4.6. Human Health

Climate change impacts to human health stem from a wide range of sources (e.g., heat waves, flooding, wildfire, infectious disease) that affect the social and environmental determinants of health common to all humans, including clean air, safe drinking water, sufficient food, and secure shelter (WHO 2014). This section discusses how climate change may affect morbidity (i.e., illness) and mortality (i.e., death) in the Pacific Northwest. It is important to note that the Pacific Northwest is expected to remain a relatively safe place to live, especially when compared to some other regions of the United States and the world. Also, some populations will be more vulnerable to these health impacts than others; at-risk populations generally include the young, the elderly, the sick, and the poor.

The human health sector is divided into seven planning areas: heat-related illness, health effects related to extreme weather events, respiratory disease, infectious disease, harmful algal blooms (HABs), food insecurity, and mental health. Vulnerability rankings developed for potential climate change impacts to each of these planning areas are provided in Table 4.6.

4.6.1. Heat-Related Illness

As summer temperatures and the frequency of extreme heat events (above 90 °F) increase in the near- and long-term, so too will the incidence of heat-related illness. Heat-related illness includes, from low to high severity, heat rash, heat syncope (fainting), heat cramps, heat exhaustion, and heat stroke (Dalton et al. 2013). Heat stroke can be life-threatening. Extreme heat events are also associated with increases in heart attacks and strokes and may worsen existing health conditions in individuals with respiratory disease, cardiovascular disease, or kidney failure (Dalton et al. 2013). In addition to the vulnerable populations described in the previous section, outdoor workers (e.g., construction workers, fishermen) are particularly susceptible to heat-related illness.

4.6.2. Health Effects Related to Extreme Weather Events

Projected increases in the extent, frequency, and/or intensity of extreme weather events such as storms, floods, and wildfires, will have severe direct and indirect consequences for human health. For example, more intense winter flooding will directly increase the likelihood of injury and drowning, while drinking water contamination, hazardous materials spills, and reduced indoor air quality from mold growth may also affect human health. As another example, larger wildfires pose immediate threats to human safety; meanwhile, exposure to wildfire-generated particulate matter can increase the incidence of respiratory problems such as asthma, bronchitis, and pneumonia.

Table 4.6 Human Health Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Heat-Related Illness	Increasing incidence of heat rash, heat syncope (fainting), heat cramps, heat exhaustion, and heat stroke	High	Medium	Medium-High
Extreme Weather Events	Increasing incidence of injury, death, and/or an array of indirect impacts	High	Low	High
Respiratory Disease	Increasing incidence of asthma, allergies, bronchitis, emphysema, and pneumonia	High	Medium	Medium-High
Infectious Disease	Increasing incidence of infection from vector-borne, water-borne, and fungal diseases	Medium	Medium	Medium
Harmful Algal Blooms	Increasing incidence of poisoning from consuming toxin-laden shellfish	High	Low	High
Food Insecurity	Increasing incidence of hunger and malnutrition	High	Low	High
Mental Health	Increasing incidence of anxiety, depression, and post-traumatic stress disorder	High	Low	High

4.6.3. Respiratory Disease

Respiratory diseases such as allergies, asthma, bronchitis, emphysema, and pneumonia are affected by outdoor and indoor air quality. Currently, the primary outdoor air quality concerns on the Reservation are related to combustion byproducts (i.e., particulate matter) from the use of wood burning stoves, trash burning, and nearby off-Reservation industrial sources (e.g., Phillips 66's Ferndale Refinery, BP's Cherry Point Refinery, Shell's Puget Sound Refinery, Tesoro's Anacortes Refinery, Alcoa Intalco Works) (LNR 2011). It is expected that continued installation of EPA-certified wood burning stoves and implementation of the recently updated Lummi

Nation Integrated Solid Waste Management Plan (2014) will reduce pollution from stoves and trash burning. The current and future contributions of heavy industry to air quality on the Reservation cannot be readily assessed, but should not be discounted without implementation of an ambient air quality monitoring program. As introduced previously, wildfire-generated particulate matter is expected to reduce air quality in the future if the area burned by wildfire in the vicinity of the Reservation increases. Another air quality concern has to do with pollen and seasonal allergies. Under future climate conditions, plants are expected to increase pollen production and the growing season is expected to lengthen, both of which may contribute to more severe and longer lasting allergy symptoms (Dalton et al. 2013). In other regions of the United States, ground-level ozone production (i.e., smog) is expected to increase during the summer months as a result of warmer air temperatures and air stagnation; however, this is not anticipated to be a significant problem in the Pacific Northwest, particularly in rural areas such as the Reservation (Dalton et al. 2013).

4.6.4. Infectious Disease

Climate influences the type, distribution, and transmission of vector-borne, water-borne, and fungal diseases and a changing climate may increase the potential for illness and death resulting from some infectious diseases (CIG 2013). Although not an exhaustive list, several examples are provided below. It is important to note that the risk of a major epidemic in the United States is unlikely given continued maintenance and improvement of existing public health infrastructure (Dalton et al. 2013).

First, it is hypothesized that the spread of West Nile virus, a vector-borne disease transmitted by mosquitoes, from New York State in 1999 to Washington State in 2002 was facilitated by warmer than average temperatures over that time period (Dalton et al. 2013). Although the West Nile virus is a potentially dangerous threat to public health, it is important to keep the threat of West Nile virus in perspective: only 47 cases of infection were reported in Washington between 2002 and 2014 and disease activity in the state has been in decline since it peaked in 2009 (DOH 2014). The incidence of other vector-borne disease (e.g., Lyme disease, hantavirus, malaria, dengue) are typically low in the PNW and are not currently considered a high risk (Dalton et al. 2013). Second, the risk of infection from *Vibrio parahaemolyticus,* a water-borne disease that causes gastrointestinal illness when consumed in raw oysters and other shellfish, is expected to increase with warming sea surface temperatures. A recent outbreak of *V. parahaemolyticus* from shellfish harvested in Washington State and British Columbia resulted in 55 confirmed and 23 probable cases of infection in Washington State between May-July 2006 (Dalton et al. 2013). Lastly, *Cryptococcus gattii* is a fungus historically restricted to tropical and subtropical climates that has now expanded its range into the Pacific Northwest, possibly as a result of climate change. From 2006-2011, there were 21 cases of *C. gattii* reported to the Washington State Department of Health (DOH), 4 of the infected individuals died as a result of the disease (DOH 2012). Similar to West Nile virus, the emergence of *C. gattii* suggests that other diseases may move into the Pacific Northwest region as the climate changes.

4.6.5. Harmful Algal Blooms

As discussed in Section 4.3 – Coastal Resources, changes in ocean chemistry and temperature are likely to cause increased toxicity, frequency, duration, and distribution of harmful algal blooms (HABs). The toxins produced by HABs are concentrated in filter feeding shellfish and ingestion of contaminated shellfish can result in paralytic shellfish poisoning, amnesic shellfish poisoning, diarrheic shellfish poisoning, and other poisoning syndromes. When toxin concentrations reach levels that are unsafe for human consumption, shellfish beds are closed to harvest until the risk abates. As such, HABs not only affect individuals that are poisoned, but also individuals and families who rely on commercial, ceremonial, and subsistence shellfish harvests for their livelihood, cultural practices, or sustenance.

4.6.6. Food Insecurity

Food security requires that families have continuous and reliable access to a sufficient quantity of healthy food; food insecurity arises when an adequate quantity or quality food is not available. Subsistence harvest of salmon, shellfish, and other foods is vital to the Lummi *Schelangen* ("way of life") and is imperative to tribal members who could not otherwise meet their daily nutritional needs. Any reduction in the availability of these foods, whether from climate change (e.g., habitat loss, species range shifts, environmental disturbance) or from other anthropogenic impacts, places the health of Lummi tribal members at risk. The most obvious consequences of food insecurity are the physical and mental symptoms of malnutrition. Sometimes more difficult to trace are the social and cultural impacts, which are important aspects of community health. Furthermore, food prices across the nation are expected to rise in response to climate change (e.g., drought-induced crop failure), which will disproportionately affect the poor (Dalton et al. 2013).

4.6.7. Mental Health

Climate change will impact not only physical health, but also mental health. Mental health impacts can occur in response to a sudden, traumatic stressor or a persistent, chronic stressor. Regardless of the cause, the consequences to mental health may include anxiety, depression, and post-traumatic stress disorder (PTSD). It is also recognized that poor mental health can have physical repercussions. As described by Dalton et al. (2013): "Living in a state of long-term stress can manifest as negative physical health outcomes, such as system-wide inflammation, high blood pressure, and unhealthy coping mechanisms such as smoking, excessive alcohol use, and poor dietary habits."

4.7. Emergency Services

An increasing demand for emergency services in response to environmental and civil emergencies that arise from or are exacerbated by climate change impacts, such as extreme weather events, coastal and riverine flooding, and wildfire, is anticipated. The emergency services sector is divided into two planning areas: fire and police. Vulnerability rankings developed for potential climate change impacts to each of these planning areas are provided in Table 4.7.

Table 4.7 Emergency Services Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Fire	Increasing demand for service	Medium	Medium	Medium
Police	Increasing demand for service	Medium	Medium	Medium

4.7.1. Police

The Lummi Nation Police Department provides public safety protection on the Reservation. The Police Department is responsible for enforcement of the Lummi Nation Code of Laws, is the first responder to all emergency calls on the Reservation, and is responsible for emergency services on the Reservation in the case of flood, earthquake, or other natural disasters. The Police Department also works with the Federal Bureau of Investigation (FBI), the Washington State Patrol, the Whatcom County Sheriff's Department, and other law enforcement agencies as appropriate. For instance, the Police Department has jurisdiction over all members of federally recognized tribes on the Reservation, while the Whatcom County Sheriff's Department has jurisdiction when an offense is committed on the Reservation by a person who is not a member of a federally recognized tribe or if the offense is committed on non-member owned fee land. The FBI investigates major crimes that are committed on trust land or member-owned fee land by members of federally recognized tribes. Although the scale of required emergency services is event-dependent, the Lummi Nation Police Department and other law enforcement agencies may be overburdened by the demand for services in the event of climate-induced environmental and/or civil emergencies.

4.7.2. Fire

Three fire districts with primarily volunteer staff provide fire protection and medical aid services on the Reservation. Whatcom County Fire District No. 8 covers the Reservation south of the Lummi River, including the Lummi Peninsula, and has one station (Station No. 5) located at Gooseberry Point. Whatcom County Fire District No. 17 provides fire protection and emergency medical services to the Sandy Point Peninsula and Sandy Point Heights/Lake Terrell Road areas in the northwest portion of the Reservation. District No. 17 has two stations on the Reservation, one on the Sandy Point Peninsula (Station No. 1) and one at Sandy Point Heights (Station No. 2). Station No. 1 lies within the coastal shallow flooding zone and has had to be protected by sand bags during previous coastal flooding. Finally, Whatcom County Fire District No. 7 provides services to the Slater Road area along the northern boundary of the Reservation, including the Silver Reef Hotel, Casino & Spa and the Lummi Mini Mart. Similar to law enforcement agencies, local fire districts may be overtaxed by the required response to the array of potential environmental and/or civil emergencies that may arise as a result of climate change.

4.8. Cultural Resources

Out of respect for individuals and families and to protect the integrity of the Lummi Nation's tangible and intangible cultural resources, the content of this section is kept brief and nonspecific. Although there are many aspects of cultural resources that are appropriate to share publicly, such as the importance of salmon and shellfish harvest to the Lummi *Schelangen* ("way of life"), there is some information that needs to be kept confidential, such as the location of recorded historical cultural sites. Confidentiality is partly due to traditional Lummi values towards sacred and otherwise meaningful sites, and partly to prevent looting or other disturbance. Where it was appropriate to do so, potential climate change impacts to the Lummi Nation's cultural resources were introduced in previous sections. The purpose of reiterating this information here is to draw attention to the importance of the Lummi Nation's cultural resources and Traditional Cultural Properties (TCPs) and to consolidate this information into a clear and succinct summary of potential climate change impacts; more detailed information can be found in Section 4.2 – Water Resources, Section 4.3 – Coastal Resources, Section 4.4 – Forest Resources, and Section 4.5 – Fish, Wildlife, and Traditional Use Plants.

The cultural resources of the Lummi Nation are administered and protected by the Cultural Resources Department in accordance with the Cultural Resources Preservation Code (LCL Title 40). The term "Cultural Resources" under LCL Title 40 includes culturally significant sites and is defined as follows: "Cultural Resources in the traditional view of Lummi includes, but is not limited to, four major category types: language, including traditional named places and Oral History or Tradition; traditional cultural properties; historic sites; and archeological resources. 'Cultural Resources' also means any material remains of past, present, or future human life or activities which are of historic significance, and/or cultural or archeological interest. Such material includes, but is not to be limited to: pottery, basketry, weapons, weapon projectiles; tools, structures or portions of structures, pit houses, rock paintings, rock carvings, intaglios, talus slide depressions, cairns, sea caves, inland caves, graves, human skeletal remains, or any portion or piece thereof, whether or not found in a cultural resource context."

There are several potential climate change impacts to the cultural resources of the Lummi Nation. To begin, accelerated sea level rise and coastal erosion may lead to the loss of or damage to coastal burial sites and human remains, loss of or damage to other coastal archaeological sites and artifacts, and a decreased accessibility to or availability of traditional use plants and animals (e.g., shellfish harvest areas). Shoreline erosion is already a key concern of the Cultural Resources Department, which currently invests significant staff time to inventory and monitor cultural resources that are degraded or exposed by wave action. In upland areas, an increased area burned by wildfire may lead to the loss of or damage to upland archaeological sites, artifacts, and traditional use plants and animals. Changes in climate are also expected to induce species range shifts, which may lead to the loss of traditional use plants and animals either by local extinction or migration outside of the Lummi Nation's Traditional Territories. Meanwhile, changes in the timing of life history events (i.e., phenology) may subsequently affect the timing of some traditional practices (e.g., western red cedar bark harvest). Salmon and shellfish harvest, which are vital to the Lummi *Schelangen* ("way of life"), will be affected by a range of climate change impacts. In particular, salmon species will be affected by decreasing food and habitat availability (e.g., from ocean acidification and sea level rise, respectively), increasing stream temperatures, and altered streamflow, among others. While impacts to shellfish species will largely stem from ocean acidification, sea level rise, and increasing sea surface temperatures. It is reasonable to expect that unforeseen and/or synergetic climate change impacts can and probably will occur in the future. Additionally, in Lummi culture, everything is interconnected. Impacts on salmon are not independent of impacts on forest resources or impacts on coastal resources or impacts on human health or any other aspect of life; if salmon are impacted by climate change, so too will be everything else.

It should also be recognized that cultural resources are irreplaceable and the integrity of cultural resources is extremely delicate. When cultural resources are damaged or destroyed, they cannot be renewed, replanted, relocated, or replicated; when they are gone, they are gone forever.

Due to the sensitive nature of cultural resources, specific planning areas are not presented in this report. Generally, the vulnerability ranking for potential climate change impacts to cultural resources is high (Table 4.8).

Table 4.8 Cultural Resources Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Undisclosed	Irretrievable harm to Lummi Nation cultural resources	High	Low	High

4.9. Land Use

Current and future land use on the Reservation is guided by the comprehensive planning efforts currently underway in the Planning and Public Works Department. These efforts include the classification and regulation of land use districts to ensure orderly growth and protection of the political, economic, social, cultural, and physical integrity of the Lummi Nation. Several aspects of land use management were discussed in Section 4.2 – Water Resources, Section 4.3 – Coastal Resources, and Section 4.4 – Forest Resources and will not be reiterated here. Instead, this section provides a brief overview of potential climate change impacts to designated land uses (e.g., residential development, commercial development, mixed use development, agriculture) and land management concerns (e.g., floodplain infrastructure, hazardous materials sites) that have been outside of the scope of previous sections.

The land use sector is divided into five planning areas: floodplain infrastructure, residential development, commercial and mixed use development, agriculture, and hazardous materials sites. Vulnerability rankings developed for potential climate change impacts to each of these planning areas are provided in Table 4.9.

Table 4.9 Land Use Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Floodplain Infrastructure	Reduced effectiveness of existing floodplain infrastructure given the increasing frequency and intensity of riverine flood events and relative sea level rise	High	Low	High
Residential Development	Increasing property damages in high impacts areas, particularly those susceptible to flooding, erosion, and wildfire	High	Medium	Medium-High
Commercial and Mixed Use Development	Increasing property damages and/or economic consequences in high impacts areas, particularly those susceptible to flooding, erosion, and wildfire	High	Medium	Medium-High
Agriculture	Decreasing viability of farming with sea level rise	High	Low	High
Hazardous Materials Sites	Increasing risk of hazardous materials spills	High	Low	High

4.9.1. Floodplain Infrastructure

One of the prevailing challenges to future land use management on the Reservation will likely stem from the projected increase in the frequency and intensity of coastal and riverine flooding. Flooding in riverine systems is a natural occurrence that results when runoff from rain or snowmelt exceeds the carrying capacity of river channels, ditches, drains, reservoirs, and other water bodies. Flooding in coastal areas is a natural occurrence that results when high tides and/or storm-driven waves overtop naturally created storm berms or man-made shore defense works.

In order to discuss residential development, commercial development, mixed use development, agriculture, and hazardous materials sites, it is necessary to first understand the condition of existing floodplain infrastructure and basic characteristics of the current flood regime. Of the approximately 12,500 acres of Reservation uplands, nearly 5,400 acres are designated special flood hazard areas (SFHAs) as determined by the U.S. Federal Emergency Management Agency (FEMA). The SFHA is the area expected to be covered by floodwaters during the 100-year flood event. The 100-year flood event is the magnitude of flood that has a 1 percent probability of occurrence during any one year. Similarly, a 50-year flood has a 2 percent probability of occurrence during any year and a 5-year event has a probability of 20 percent.

The floodplain infrastructure (e.g., dikes, levees, tide gates) on the Reservation was originally intended to protect agricultural lands against frequent, low magnitude floods. In 1988, the U.S. Army Corps of Engineers (ACOE) inventoried the lower Nooksack River levee system and determined that the levees of Diking District No. 1 (south of Ferndale) along the west bank of the Nooksack River provided from less than 5-year to up to 10-year flood protection. Since that time, and in particular following large flood events in the 1990s, significant levee improvements along the west bank of this reach have been made. Preliminary model data provided by Whatcom County indicate the majority of levees along the west bank of this reach now provide greater than 100-year protection; however, there are still segments of this reach with lower levels of protection, ranging from less than 5-year protection up to less than 100-year protection. Additional flood control structures on the Reservation include levees along the banks of the Lummi River (less than 5-year protection), bank protection made of rip-rap, seawalls along Lummi Bay (less than 5-year protection), tide gates in the Lummi Bay seawall, and floodgates along Lummi Bay and floodplain sloughs. Flooding under future climate scenarios is expected to reduce the effectiveness of the existing flood protection infrastructure on and near the Reservation.

When the levee along the western side of the lower Nooksack River fails or is overtopped, floodwaters discharge to both Lummi and Bellingham bays. During major flood events that close access roads in the Nooksack and Lummi river floodplains, the Lummi Peninsula can be completely isolated from surrounding mainland areas. Additionally, several low-lying coastal areas of the Reservation are susceptible to flooding. Areas with the greatest probability of coastal flooding are the Sandy Point Peninsula and Neptune Beach and, to a lesser degree, Gooseberry Point, Hermosa Beach, and other portions of the southeastern shoreline of the Lummi Peninsula. The main physical effects of floods on the Reservation are damage to flood control structures and residences, erosion of agricultural areas and roads, deposition of sediment and pollutants, and road closures.

4.9.2. Residential Development

Residential development on the Reservation over the 1910 through 2013 period is illustrated in Figure 4.13. Along with population growth over the last century, construction of an extensive road network, a potable water distribution and wastewater collection and treatment system, the Sandy Point Marina, and several tribal housing projects have fostered a trend towards higher density residential development throughout the Reservation. Several distinct residential neighborhoods now exist, mainly along the shorelines of the Reservation including Sandy Point, Neptune Beach, Sandy Point Heights, and Gooseberry Point. Higher density residential neighborhoods can also be accessed from the numerous spur roads along Haxton Way and Lummi Shore Road. The Sandy Point neighborhoods, as well as the numerous waterfront parcels along the west shore of the Lummi Peninsula, consist of a combination of trust and fee lands but are predominantly owned by non-tribal members. The east shore of the Lummi Peninsula, and the numerous scattered subdivisions in the interior of the Reservation, are almost exclusively tribal member owned properties. The 2010 Census found 1,989 housing units on the Reservation, of which 1,632 (82.1 percent) were occupied year-round and 221 (12.6 percent) were for seasonal or occasional use. The remaining 73 (4.2 percent) housing units were vacant.

Some residential areas will be particularly vulnerable to climate change impacts, including inundation from sea level rise, coastal flooding, coastal erosion, riverine flooding, and wildfire, which may result in increasing property damage or loss over the coming decades. Homes located along the Sandy Point Peninsula, Neptune Beach, Gooseberry Point, and Hermosa Beach shorelines are within currently designated coastal flood zones and will become increasingly vulnerable to flood damages with time. There are relatively few homes located in the Nooksack River floodplain; many of these are on agricultural properties and were constructed before 1950. Homes located among forested areas on the Lummi Peninsula or other areas along the urban/wildland interface may become increasingly vulnerable to damages from wildfire.

4.9.3. Commercial and Mixed Use Development

Similar to residential development, potential climate change impacts to existing and planned commercial and mixed use development on the Reservation include, but are not limited to, flooding and wildfire. The Silver Reef Hotel, Casino & Spa and adjacent Lummi Mini Mart are the primary commercial enterprise on the Reservation and are located on a tribal trust parcel in the floodplain at the intersection of Slater Road and Haxton Way. These structures comply with the Flood Damage Prevention Code (Title 15A) of the Lummi Nation Code of Laws (LCL) and are constructed so that the elevation of the lowest floor is at least one foot above the base flood elevation, which will theoretically only be reached in a historical 100-year flood event. Irrespective of physical flood damages, the potential economic losses resulting from closure of Slater Road, which serves as the primary access route to the site, would significantly reduce customer attendance and negatively impact commercial revenues. In the Gooseberry Point area of the Lummi Peninsula, the Fisherman's Cove gas station and mini mart, two boat launch facilities, and the Lummi Island ferry terminal are also located in areas subject to flooding.

Mixed use development on the Reservation is intended for important community centers where planned multiple uses are allowed and desirable. For instance, the corridor of mixed use development along Kwina Road between Lummi Shore Drive and Haxton Way contains the Lummi Nation Tribal Administrative Center, Lummi Head Start, Lummi Clinic and Fitness

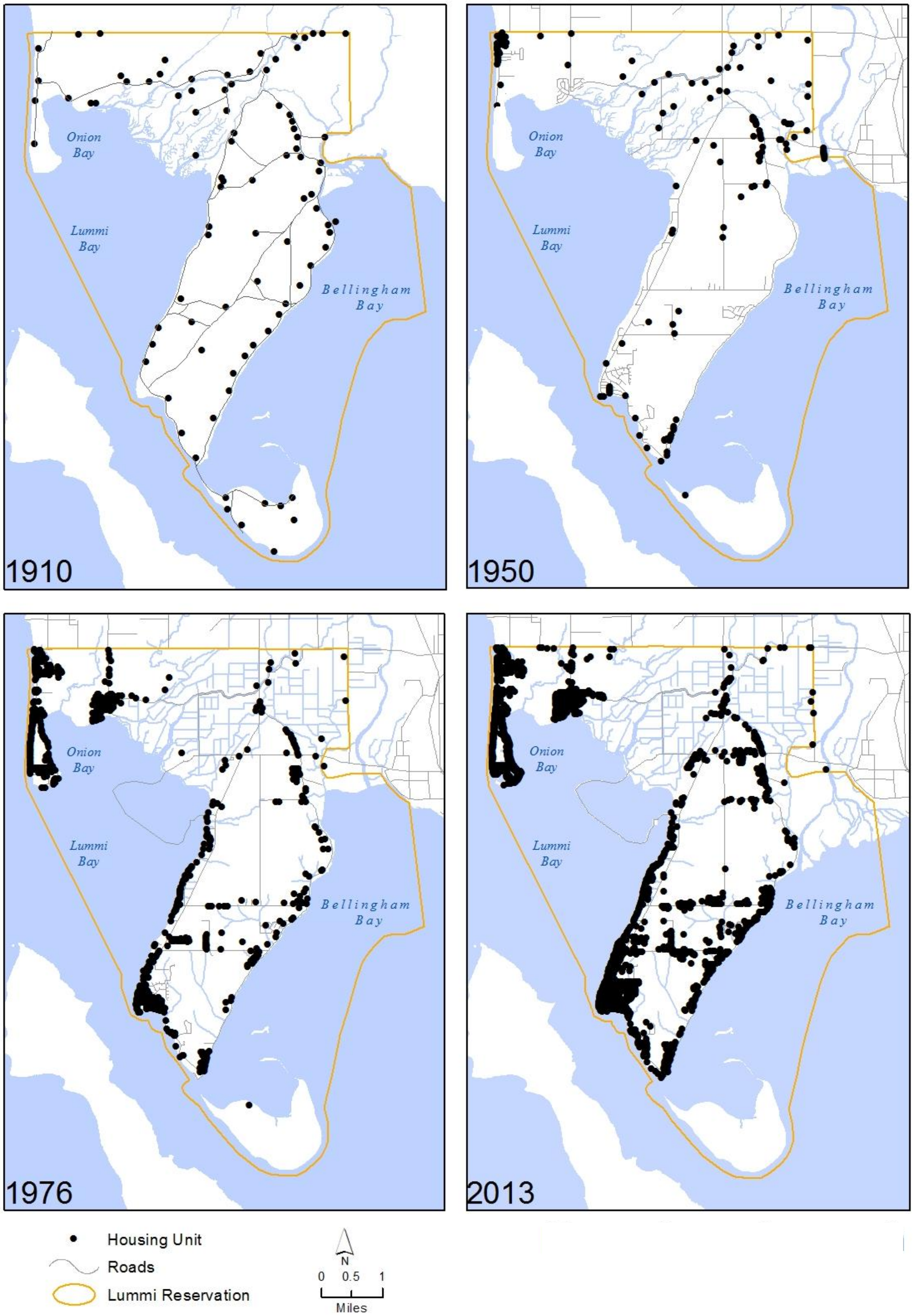

Figure 4.13 Lummi Indian Reservation Households (1910-2013)

Center, former LIBC administrative offices (i.e., east, central, and west campuses), Kwina Apartments, Turkeyshoot Development (under construction), and Northwest Indian College (NWIC) campus. The Kwina corridor and other areas zoned for commercial or mixed use development are located adjacent to densely forested areas, which are wildfire risk zones. The annual area burned by wildfire is projected to increase under future climate conditions, which may place current and future development at risk of damages.

4.9.4. Agriculture

This section does not address potential climate change impacts to crop yields, but instead focuses more broadly on the long-term viability of farming in low-land coastal areas that may be negatively impacted by accelerated sea level rise. On the Reservation, there are approximately 2,885 acres of land zoned for agricultural use in the Nooksack and Lummi river floodplains, though the area currently under cultivation is less. Existing floodplain infrastructure provides a moderate level of protection to agricultural lands that would otherwise be subject to more frequent coastal flooding. However, as sea levels continue to rise, this infrastructure may be rendered ineffective and maintaining adequate drainage may become increasingly difficult (e.g., storm water runoff historically discharged through tide gates may need to be pumped over dikes). This may be further exacerbated by subsidence of farmland soils as a result of sediment compaction and organic matter decomposition. Although agricultural production on the Reservation is not a regionally significant source of foodstuffs, lost revenue from agricultural leases may be important for individual tribal members.

4.9.5. Hazardous Materials Sites

Hazardous materials are substances that are toxic, corrosive, flammable, and/or explosive. In many instances, hazardous materials have the potential to cause injury to life and/or damage to water and other environmental resources. Potential sources of hazardous pollutants in the immediate vicinity of the Reservation include oil refineries, an aluminum smelter, electrical generation plants, chemical factories, and other facilities. There are numerous industrial facilities in very close proximity to the Lummi Reservation (e.g., Phillips 66 Ferndale refinery, Alcoa-Intalco Works aluminum smelter, BP Cherry Point refinery), as well as three wastewater treatment facilities (i.e., Ferndale, Lynden, and Everson) with outfalls that discharge to the Nooksack River. Transportation of hazardous materials to and from these facilities via the freeway, major roads (e.g., Slater Road), railroads, and oil and fuel pipelines near the Reservation also poses a risk of spills. Many small businesses, such as dry cleaners or auto body paint shops, are also potential sources of contamination. There are also several facilities that store pollutants within the Reservation (e.g., the three Lummi Tribal Sewer and Water District [LTSWD] wastewater treatment plants, in-line chlorinators associated with water supply wells, the Lummi Mini Mart gas station, the Fisherman's Cove gas station, the Sandy Point Marina). The risk of a hazardous material emergency on the Reservation is already expected to increase given the future residential and economic growth on the Reservation, in the Cherry Point Heavy Impact Industrial Zone, and in the area upstream from the Reservation; climate change will heighten this risk. There are a host of climate change impacts that increase the probability of a hazardous material spill, including an increasing frequency and intensity of extreme weather events, sea level rise and storm surge, and an increasing frequency and intensity of riverine flooding, among others.

4.10. Transportation

Transportation to and from the Reservation is dependent on a few key routes. Slater Road and Marine Drive are the two primary east-west corridors, while Haxton Way, Ferndale Road, and Lake Terrell Road provide north-south access. The Reservation can also be reached by water at public and private marine facilities.

The transportation sector is divided into three planning areas: road system integrity, access and circulation, and marine facilities. Vulnerability rankings developed for potential climate change impacts to each of these planning areas are provided in Table 4.10.

Table 4.10 Transportation Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Road System Integrity	Accelerated weathering of and damage to roads and bridges from various climate change impacts, particularly extreme heat events and flooding	Medium	Medium	Medium
Access and Circulation	Increasing frequency of road closures due to coastal and riverine flooding, possible isolation of the Lummi Peninsula during flooding	High	Low	High
Marine Facilities	Increasing damage sustained during storm events	High	Medium	Medium-High

4.10.1. Road System Integrity

Although Whatcom County is responsible for the maintenance of most of the roads and bridges on and near the Reservation, potential climate change impacts to the road system bear mention. Increased damage to and accelerated weathering (e.g., buckling, cracking, bleeding) of roads can be expected to reduce pavement longevity and increase maintenance and repair costs with the coming changes in temperature, precipitation, flooding, erosion, and wildfire. The potential positive impacts of climate change are relatively insignificant by comparison; nonetheless, winter driving conditions are expected to improve as snow and ice becomes less of a problem and a longer construction season for necessary road repairs may be observed. Potential damages to bridges (e.g., Marine Drive bridge, Slater Road bridge), which are critical for maintaining adequate access to the Reservation, include erosion of bridge footings and deterioration of bridge joints from thermal expansion and contraction.

4.10.2. Access and Circulation

Road closures during flood events can significantly delay or prevent travel and transportation of goods and services to and from some areas of the Reservation. For instance, when the levee along the western side of the lower Nooksack River fails or is overtopped and floodwaters discharge to both Lummi and Bellingham bays, the Lummi Peninsula can be completely isolated from surrounding mainland areas. This isolation can have a large impact on public health and safety since the only remaining transportation is by boat or helicopter. Although the Lummi

Nation Police Department and Fire District No. 8 stations are on the Lummi Peninsula, extra support for emergency situations is not available in a timely manner. The road closures also have a large economic impact on the community. Because many employees cannot get to work, this isolation affects tribal government offices, the health clinic, tribal schools, the Northwest Indian College, and other businesses located on the Lummi Peninsula. In addition, many residents of the Lummi Peninsula lose income because they cannot get to work off-Reservation. Residents of other areas on the Reservation, such as the Northwest Uplands, are inconvenienced by road closures due to flooding in the floodplain, but are typically still able to access their homes by road. Under future climate conditions, which are projected to increase the frequency and intensity of riverine and coastal flooding, it is prudent to expect an increasing frequency of road closures in the coming decades unless significant infrastructure improvements (e.g., elevating access roads, constructing 100-year setback levee) are undertaken.

4.10.3. Marine Facilities

The primary marine facilities on the Reservation are located at Gooseberry Point, including the Fisherman's Cove public boat launch and the Whatcom County operated ferry terminal that serves Lummi Island, and the privately-owned Sandy Point Marina located along the Sandy Point peninsula. There are also several boat access points along the shorelines of the Reservation or nearby trust lands that may be used for launching and landing small craft at higher tides. These marine facilities may be damaged during flooding, particularly when storm surges coincide with high tides, and can be expected to worsen under conditions of sea level rise.

4.11. Utilities

Public utilities provided on the Reservation include treatment and distribution of potable water supplies, wastewater collection and treatment, storm water management, and energy supplies. The University of Washington (UW) Climate Impacts Group (CIG) sufficiently summarizes the broad array of potential climate change impacts to infrastructure in Washington State, many of which are relevant to utilities on the Reservation (CIG 2013):

> Climate change is expected to increase the potential for infrastructure damage and service disruptions, and may also lead to higher operating costs and reduced asset life. […] Impacts that can increase risks to infrastructure include more frequent or more severe flooding, extreme heat, extreme precipitation, storm surge, saltwater intrusion, mudslides, erosion, wildfire, and inundation of low-lying areas. Projected changes in extreme events are more likely to damage infrastructure than are changes in average conditions.

The utilities sector is divided into four planning areas: water supply, wastewater collection and treatment, storm water management, and energy supply. Vulnerability rankings developed for potential climate change impacts to each of these planning areas are provided in Table 4.11.

4.11.1. Water Supply

The potable water supply on the Reservation is provided by the Lummi Tribal Sewer and Water District (LTSWD), non-tribal water associations, and individual or small group domestic wells (Figure 4.14). The LTSWD is the largest and most geographically comprehensive water purveyor, serving approximately 1,100 Reservation residences, as well as municipal and commercial operations, using a network of production wells and supplemental water purchased from the City of Bellingham (LSTWD 2014). There are currently eight non-tribal water associations serving predominantly non-tribal members in densely developed residential areas along the Reservation shorelines. These systems are entirely dependent on wells adjacent to or within the association boundaries and provide service to approximately 850 residences. The non-tribal water associations refused the Lummi Nation's offer in 1990 to become integrated into the LTSWD, which would consist of system upgrades and management for aquifer protections. There are currently about 160 domestic wells that supply water to one or more residential units on the Reservation. Non-potable water systems supply untreated surface water (from the Nooksack River or Skookum Creek) or groundwater to the Lummi Bay Salmon Hatchery, the Skookum Creek Salmon Hatchery (located off-Reservation), and the Sandy Point Salmon Hatchery, respectively.

Table 4.11 Utilities Vulnerability Rankings

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
Water Supply	Saltwater intrusion into aquifers and/or altered aquifer recharge	High	Low	High
Wastewater Collection and Treatment	Increasing saltwater inflow at low-lying pump stations and/or increasing hydraulic head at outflows (resulting from relative sea level rise)	High	Medium	Medium-High
Storm water Management	Increasing inundation and/or backup of drainage network from heavy precipitation events and/or storm surge	Medium	Medium	Medium
Energy Supply	Service disruption during and following extreme weather events	Medium	Low	Medium-High

As discussed in Section 4.2.2 – Groundwater, over 95 percent of the residential water supply for the Reservation is pumped from local groundwater wells and contamination of wellheads carries the risk of adversely affecting the health of persons drinking or using water from these supplies. Potential climate change impacts to groundwater include saltwater intrusion and altered aquifer recharge, which may be further exacerbated by stressors unrelated to climate (e.g., over-pumping, land use change, hazardous materials contamination). If a sufficient quantity of high quality groundwater is not available, water purchased from the City of Bellingham or other alternative water sources will become increasingly important to serve the needs of the Reservation. In addition to concerns over cost, it is also reasonable to expect that future climate changes may also reduce the availability or quality of alternative water sources. For example, the City of Bellingham, which obtains water from Lake Whatcom has indicated that climate change impacts to the water supply may include an increase in storm water runoff that can flush contaminants and sediments into the lake and an increase in algal blooms that can increase the cost of treatment and the concentration of disinfection byproducts (e.g., trihalomethanes [THMs], haloacetic acids [HAAs]) (COB 2014).

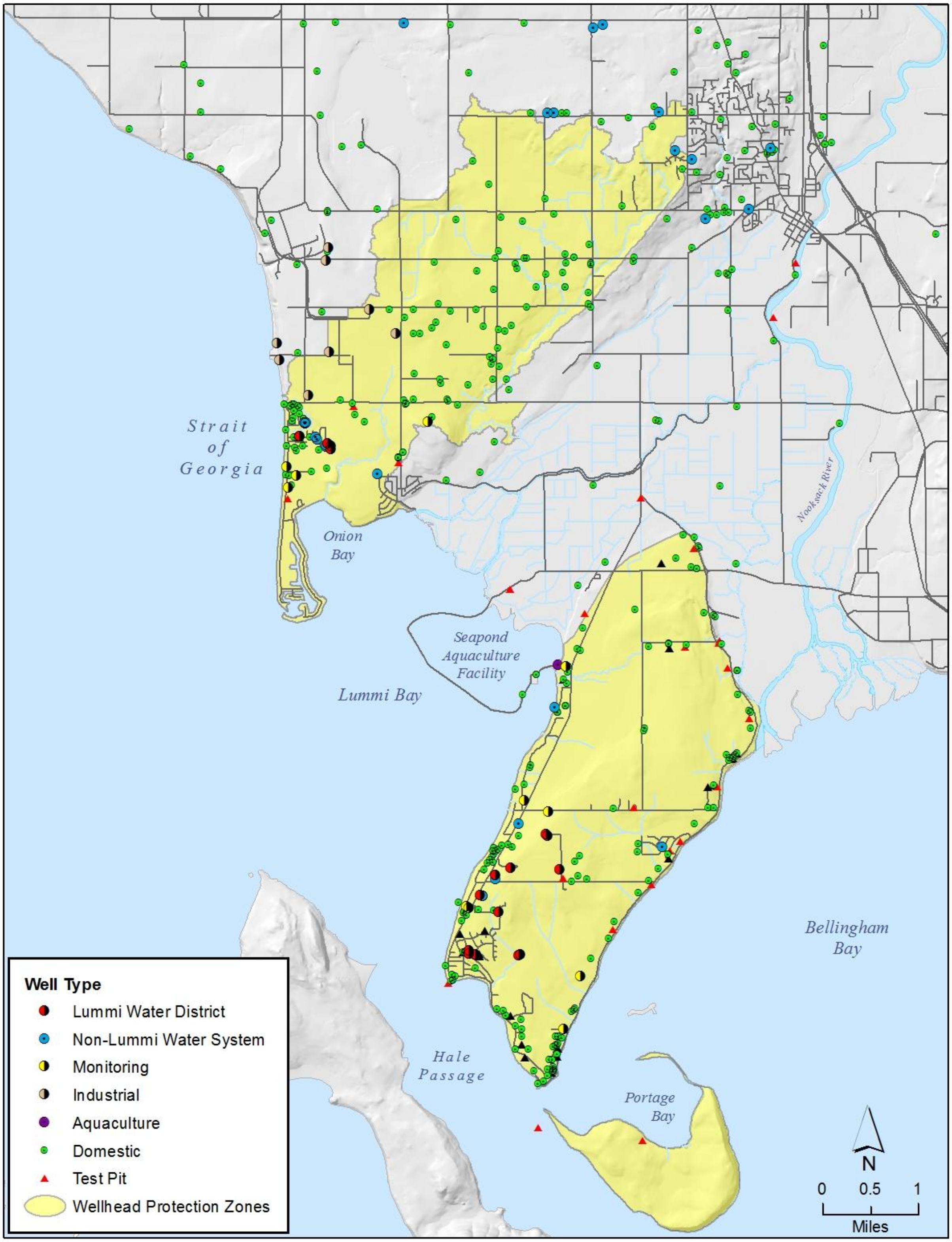

Figure 4.14 Wells and Wellhead Protection Areas on the Reservation

It is also important to note that the non-potable water supply to the Lummi Nation's salmon hatchery programs, which are culturally and economically significant to the Lummi Nation and its members, is dependent on both groundwater and surface water. Climate change impacts to surface waters include changes in the quantity and timing of streamflow and increases in stream temperature. There are currently no suitable alternative water sources on or near the Reservation that could be used to support hatchery operations.

4.11.2. Wastewater Collection and Treatment

The Lummi Tribal Sewer and Water District (LTSWD) currently operates and maintains three wastewater treatment plants (WWTPs) and a forested Biosolids Application Site (Figure 4.15). The Gooseberry Point WWTP and the Sandy Point WWTP produce secondary treated effluent that is discharged to Hale Passage and the Strait of Georgia, respectively. The Kwina Road WWTP (a.k.a. the Membrane Bioreactor [MBR] WWTP) produces "Class A" reclaimed water that is discharged into the ground through a series of underground injection wells or into adjacent wetlands. There are 30 wastewater pump stations across the Reservation as part of the wastewater collection system, 9 of these sewer pump stations are located the Lummi and Nooksack river floodplains or areas susceptible to coastal flooding. These pump stations have been flood-proofed to minimize their susceptibility to flood damage and have been equipped with backup diesel generators to prevent spills in case of power outages (e.g., in the event of windstorms).

The most significant climate change impact to wastewater collection and treatment on the Reservation is sea level rise, which may (1) allow saltwater inflow into the conveyance/collection system at pump stations (through the overflow chambers) located in low-lying coastal areas (e.g., Sandy Point area) and (2) increase hydraulic head at the sewage outflows into the Strait of Georgia and Hale Passage. More frequent heavy rain events over the winter months may also increase rainwater inflow and infiltration entering the system seasonally (e.g., seepage into manholes). Additional inflow into the wastewater conveyance system increases the volume of wastewater that must be transported and treated, increases energy use and subsequent treatments cost, and increases maintenance necessary to replace worn or corroded equipment (King County 2012). The LTSWD recently completed several pump station upgrades that accounted for historical high tide levels and then added elevation to provide a margin of safety above historical conditions; however, these stations will not accommodate the 50- to 100-year projections of sea level rise (Anderson 2014). Finally, although flooding or inundation of WWTPs is a concern at many other coastal communities in the Puget Sound, it is not a pressing concern on the Reservation because the LTSWD WWTPs are sited at relatively high elevations (75-160 feet NGVD29) that are outside of the adjacent Federal Emergency Management Agency (FEMA) delineated special flood hazard areas (SFHA) identified on the current Flood Insurance Rate Maps (FIRMs).

A few of the homes on the Reservation have not yet been connected to the LTSWD sewer system and rely on on-site septic systems for wastewater management. Improperly designed or maintained septic systems may allow floodwater infiltration into the systems or discharge from the systems into floodwaters. These problems exist under current conditions and can be reasonably expected to increase under future climate scenarios that projected increasing coastal and riverine flooding.

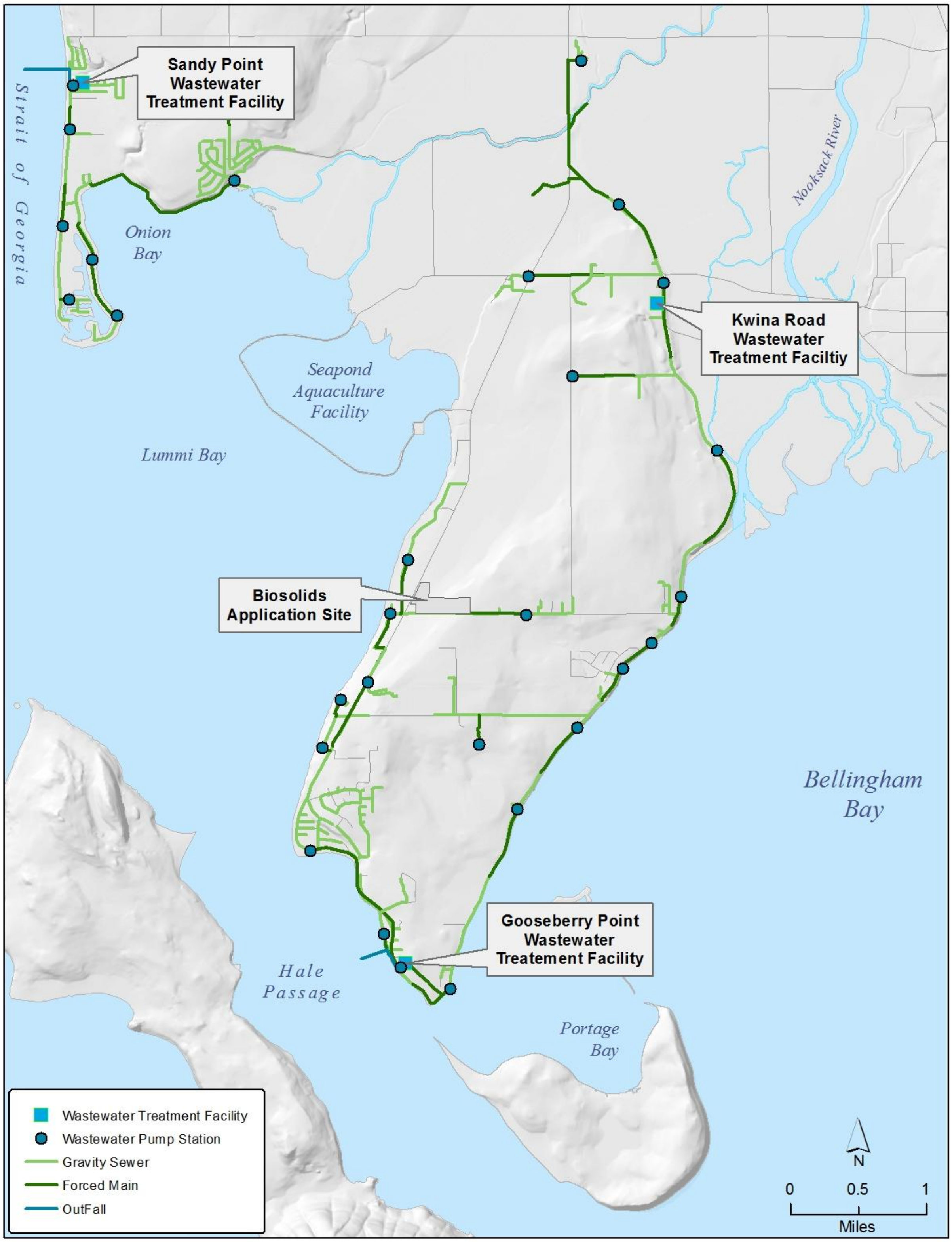

Figure 4.15 Reservation Wastewater Collection Systems and Treatment Facilities

4.11.3. Storm Water Management

With the exception of water discharged into Washington State aquatic lands from two wastewater treatment plants, all water that falls onto or passes through the Reservation discharges to resource rich tidelands and/or estuaries of the Lummi Nation or infiltrates into the underlying aquifer system. Under future climate scenarios, storm water infrastructure on the Reservation, including culverts, bridges, tide gates, catch basins, roadside ditches, and agricultural ditches, will be affected by projected changes in the seasonality of precipitation (i.e., drier summers and wetter winters) and an increasing frequency of heavy rainfall events (i.e., >1 inch/day) (CIG 2013). Heavy rainfall during the winter months may generate peak conditions that exceed the designed capacity of storm water infrastructure. If storm water systems are overwhelmed, local flooding, erosion and scour, and debris accumulation can be expected. Storm surge also threatens to overwhelm storm water infrastructure in low-lying coastal areas, a condition that will worsen over time with relative sea level rise.

As discussed previously, Whatcom County is responsible for the maintenance of most of the roads and associated storm water drainage systems on the Reservation. Other storm water infrastructure is managed by Whatcom County Diking District No. 1 (e.g., Lummi Bay Seawall tide gates), the Lummi Natural Resources Department (e.g., Seapond Aquaculture Facility tide gates), or parties undertaking large development projects. Large development projects are defined as any new development or redevelopment exceeding 5,000 square feet of impermeable surface and/or land disturbing activities of one acre or more. Pursuant to the Water Resources Protection Code (Title 17) of the Lummi Nation Code of Laws (LCL), developers of large projects are required to comply with Storm Water Pollution Prevention Plans (SWPPPs) subject to Lummi Natural Resources Department review and approval.

4.11.4. Energy Supply

There are several sources of electrical and thermal energy on the Reservation. Puget Sound Energy (PSE) provides electricity to the Reservation through a traditional system of aboveground transmission lines (i.e., the “grid”). There are also some small solar energy installations (e.g., photovoltaic) that capture and convert the energy contained in sunlight directly into electricity. For instance, the Environmental Science Building at the Northwest Indian College (NWIC) has a 7.8 kilowatt (KW) photovoltaic system, which not only provides electricity for on-site use but also feeds surplus electricity (i.e., high generation, low demand) back into the grid. Space heating in homes and other buildings on the Reservation typically uses electricity, propane gas (Vander Yacht Propane Inc., Propane Gas Industries), or wood. Natural gas is provided by Cascade Natural Gas (CNG), but utility service is only available to the Silver Reef Hotel, Casino & Spa and the Lummi Mini Mart. The new Tribal Administration Building located along Kwina Road uses a geothermal heat pump to minimize energy use for space heating and cooling.

Climate change has the potential to impact energy supply and energy demand, often stemming from extreme weather events. For example, intense storm events may cause power outages or service disruptions when PSE transmission lines are downed or damaged. Backup energy sources (e.g., diesel generators) are available for some, but not all, emergency electricity needs. Another consequence of downed trees and power lines may be delays in propane gas delivery until roads can be cleared and reopened. At the regional scale, changes in the timing and magnitude of streamflow are projected to alter hydropower generation at the federally owned and operated dams on the Colombia and Snake rivers, which are the predominant source of electricity used in the Pacific Northwest. By the 2080s, hydropower production is expected to increase 7-10 percent during the winter months and decrease 18-21 percent during the summer months, resulting in a net reduction of approximately 3 percent (Hamlet et al. 2010). Although global warming is expected to reduce the demand for heating during the winter months, rising air temperatures will also increase the demand for air conditioning during the summer months. With warmer average temperatures and an increasing frequency and intensity of heat waves coinciding with low electricity production, regional "brownouts" (i.e., an intentional decrease in electricity supply), subsystem failures, and heat-related illness may become more frequent events.

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5. CLIMATE MITIGATION AND ADAPTATION

The impacts of climate change on the Lummi Indian Reservation (Reservation), Lummi Usual and Accustomed Grounds and Stations (U&A), and Lummi Traditional Territories are significant and diverse. When these impacts emerge and to what extent projected damages are realized is highly variable and will be shaped by current and future human activities (e.g., greenhouse gas emissions, land use change). Despite these uncertainties, it is important to begin developing climate mitigation and adaptation strategies now, so that efforts to reduce the causes of climate change can be initiated while also preparing for the changes that are likely to occur in the future.

5.1. Guiding Principles

As discussed in Section 1.2 – Why the Lummi Nation is Planning for Climate Change, it is necessary that the Lummi Nation take action to minimize the impacts of climate change on the Reservation by developing and implementing climate mitigation and adaptation strategies. The primary purpose of climate preparedness is to make the Lummi Nation resilient to climate change. The UW Climate Impacts Group (CIG 2007) defines a climate resilient community as: "[…] one that takes proactive steps to prepare for (i.e., reduce the vulnerabilities and risks associated with) projected climate change impacts." Preparing for climate change will be an ongoing and dynamic process. As such, it is important to establish a suite of guiding principles that will help direct efforts to build a climate resilient community. The following five guiding principles are recommended based on the Lummi Indian Business Council (LIBC) mission to preserve, protect, and promote the Lummi *Schelangen* ("way of life") and LIBC Resolution No. 2014-084: Guiding Principles to Address Climate Change, as well as suggestions of the CIG and the Institute for Tribal Environmental Professionals (ITEP):

1. Increase public awareness of global climate change and projected regional impacts.
2. Contribute to a reduction of the causes of climate change (i.e., reduce greenhouse gas emissions).
3. Increase the technical capacity of the Lummi Nation to prepare for climate change impacts.
4. Increase the adaptive capacity of the natural, social, and built systems of the Reservation.
5. Strengthen intergovernmental and community partnerships that reduce the vulnerability of the Lummi Nation to climate change impacts.

Each of these guiding principles is described further in Section 5.3 – General Mitigation and Adaptation Recommendations, where practical approaches for utilizing these principles are discussed.

5.2. Tools and Selection Criteria

There are a wide variety of tools that are available to communities undertaking climate mitigation and adaptation. Often cited are regulatory tools, non-regulatory tools, and engineered solutions. For instance, regulatory bodies may set limits on carbon emissions, develop zoning restrictions (e.g., inundation risk zone, wildfire risk zone) and setback requirements, update building code standards, and/or adopt low-impact development standards. Non-regulatory tools include incentives for reducing carbon emissions, land acquisition and open space preservation, incentives for relocation or risk avoidance, penalties (disincentives) for high risk activities, and/or financial assistance (e.g., grants, loans) for at-risk community members. Engineered solutions typically refer to development of renewable energy sources, energy efficiency retrofitting, armoring or fortification of existing structures, retrofitting existing structures (e.g., floodproofing), performing preventative maintenance (e.g., culvert replacement), and/or loss-prevention design for new construction. Other tools range from enhanced hazard mitigation planning and emergency preparedness to continued or improved ecological monitoring.

There are certain criteria that should be used when selecting a particular mitigation or adaptation tool. Proponents of any given action may ask: Will this be viable under a range of possible future climate scenarios, or is it limited in application? Will this be sustainable over the long-term, or is it a short-term fix? Does this allow flexibility to adjust for changing circumstances, or is it rigid and inflexible? Can this be successfully implemented, or is implementation infeasible (e.g., cost-benefit analysis [includes economic and non-economic costs], time to completion)? Is this action equitable, or does it make impacts worse for certain members of the community, vulnerable populations, or future generations? Will this increase greenhouse gas emissions, thus contributing to the causes of climate change, or will this reduce or prevent emissions? These criteria were adapted from the Institute for Tribal Environmental Professionals (ITEP) Climate Change Adaptation Planning workshop materials, the UW Climate Impacts Group's (CIG) publication *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* (Snover 2007), and the *Swinomish Climate Change Initiative Climate Adaptation Action Plan* (Swinomish 2010). Other criteria may be developed as planning efforts move forward.

5.3. General Mitigation and Adaptation Recommendations

The purpose of this section is to present general climate mitigation and adaptation recommendations that directly address the guiding principles outlined above and may be applied to a broad range of activities undertaken by the Lummi Nation to address the impacts of climate change.

1. **Provide Community Outreach and Education** – It is the duty of the Lummi Nation to provide for the well-being of the community. An integral part of this responsibility is to inform the Lummi People about the projected impacts of climate change on the Reservation and the Lummi *Schelangen* ("way of life"), as well as what the Lummi Nation is planning to do or is already doing to reduce emissions and increase the resilience of the community. Community education and outreach holds multiple benefits for individuals and the community alike. Raising awareness will give the public the opportunity to make preparations for impacts (e.g., extreme weather events) and may

encourage individuals and families to consider what they can do to reduce greenhouse gas emissions (e.g., using the results of a household carbon footprint calculator). Secondly, education should also help engender community support for the actions taken by the Lummi Nation to build a climate resilient community.

2. **Develop and Update Vulnerability Assessments** – Chapter 4 – Vulnerability Assessment serves as the starting point for the ongoing process of identifying and assessing the sensitivity and adaptive capacity of projected climate change impacts on the Lummi Nation's natural, social, and built systems. As more precise information becomes available, impacts are felt, new concerns emerge, or actions are taken, it will be necessary to update the identified vulnerabilities to reflect the current state of conditions. Additionally, it will be beneficial to develop more detailed vulnerability assessments specific to certain sectors (e.g., water resources), areas of concern (e.g., for each species of salmon and shellfish), or entities (e.g., the Lummi Tribal Sewer and Water District). As these efforts evolve and policy makers become more aware of climate impacts, climate change may be incorporated into other plans (a.k.a., "mainstreaming") as appropriate. Together, these actions can serves as a significant step toward increasing the technical capacity of the Lummi Nation to prepare for climate change impacts.

3. **Designate Priority Planning Areas** – Using the information provided by the vulnerability assessment(s), planning areas may be refined and prioritized. There are many ways to determine priorities. One recommended method is to prioritize areas that have both high vulnerability and high risk. Risk is typically assessed based on the consequence of an impact and the probabilities (i.e., likelihood) that an impact will occur. A high risk area would be one of high consequence and high probability of occurrence. Because risk perception and risk tolerance may vary between and among communities, it is important to engage a wide audience of community members, facility managers, scientific experts, and government leaders to determine what level of risk is acceptable. Another recommended method is to find planning areas where multiple objectives can be achieved with a single action. For instance, promoting alternative transportation such as walking or biking to work would both reduce carbon emissions and improve individual health. Once the priority planning areas have been designated, officials can set goals for what they hope to accomplish in each planning area. Goals should be specific and achievable and include methods for measuring program success.

4. **Take Action** – Priority planning area goals will drive the mitigation and adaptation actions that are undertaken to build a climate resilient community. Options for sector specific actions are provided in the next sections.

5. **Build Partnerships** – Building partnerships, both within the Lummi community and between the Lummi Nation and federal, state, local, and other tribal governments and agencies, non-profit organizations, and the private sector can help to enhance climate preparedness. For instance, the LIBC has mandated that the Lummi Nation collaborate with the Affiliated Tribes of Northwest Indians (ATNI) and the National Congress of American Indians (NCAI) to develop an action plan that addresses the impacts of climate change on tribal governments, cultures, and lifeways (Resolution No. 2014-084).

5.4. Mitigation Strategies

Climate mitigation means taking action to reduce greenhouse gas (GHG) concentrations in the atmosphere, the quantity of which will determine the extent and severity of climate change over the coming decades-to-centuries. Although methane (CH_4), nitrous oxide (N_2O), and chloroflurocarbons (CFCs) are also important GHGs, this section focus specifically on carbon dioxide (CO_2) because this gas has lead to the largest uptake of energy in the earth's climate system to date (i.e., largest positive radiative forcing; IPCC 2013) and is most relevant to the activities that occur on the Reservation.

The atmospheric concentration of carbon dioxide is determined by the balance between carbon sources, such as carbon emissions from fossil fuel burning and land use change (e.g., deforestation), and carbon sinks, such as carbon captured and stored (i.e., sequestered) by the oceans, forests, and wetlands. Therefore, effective climate mitigation requires not only reducing emissions from energy production and use, but also maintaining or increasing the capacity of carbon sinks. As part of the Lummi Nation Strategic Energy Plan: 2016-2026, the tribe is exploring options for implementing energy efficiency measures and switching to renewable energy sources where practicable with the goal of reducing carbon emissions from the Reservation. The Lummi Nation has also undertaken actions to preserve and enhance known carbon sinks on and near the Reservation. These actions and other opportunities for action are summarized in Table 5.1 and discussed in the following sections.

Table 5.1 Climate Mitigation Recommendations

Target Area	Mitigation Strategy
Transportation Alternatives	Walk, bike, or carpool to your destination
	Provide and promote utilization of public transportation
	Invest in pedestrian-friendly infrastructure
	Drive an electric, hybrid, or high fuel economy vehicle
	Use fuel efficient driving habits
Building-Related Energy Efficiency	Conduct an energy audit
	Perform energy efficiency retrofitting and weatherization
	Promote green building standards for new construction
Behavior-Related Energy Efficiency	Provide recycling services, promote reuse of materials, and reduce consumption
	Encourage building occupants to perform energy saving measures
	Promote water conservation
Renewable Energy	Continue installation of photovoltaic (solar) arrays for electricity production
	Continue installation of geothermal heat pumps in new construction
Carbon Storage	Continue forest and wetland conservation and restoration

5.4.1. Transportation Alternatives

An analysis of baseline energy use conducted as part of the Lummi Nation Strategic Energy Plan: 2016-2026 indicates that transportation accounted for the largest share of carbon emissions from the Reservation in 2010; an outcome that has not likely changed over the past five years. There are many options for reducing the relatively high carbon footprint associated with transportation. The best way to reduce emissions is to leave the car/truck at home and walk or ride a bike to a destination instead. Although desirable, walking and/or biking will not be a viable option for all individuals and activities and/or for the entire year due to poor weather conditions and short day lengths during the winter months. Another good option that is accessible to most Reservation residents is to use public transportation (e.g., Lummi Transit, Whatcom Transportation Authority [WTA]) or carpooling. The Lummi Nation may choose to further promote alternative transportation through incentives and infrastructure. For instance, employer incentives could take the form of the LIBC encouraging employees to participate in the wellness/fitness program (30 minutes of paid exercise time 3 days per week) to walk or bike to work, allowing employees to telecommute to work, providing reduced health insurance premiums for walking or biking to work, providing a free WTA bus pass, or developing a bike share program (i.e., public bicycle system) on the Reservation.

Utilizing non-motorized transportation has many benefits for the environment and human health, but there are also risks associated with a lack of pedestrian-friendly infrastructure. Like many rural areas, more sidewalks, bike lanes, and other transportation system upgrades (e.g., roundabouts) can significantly improve pedestrian safety. The LIBC has invested in such infrastructure improvements in recent years, with projects including the 1.8 mile Haxton Way pedestrian path (completed in 2010), the Kwina Road and Blackhawk Way sidewalks (2011), the Haxton Way/Kwina Road roundabout (2013), and the Haxton Way/Smokehouse Road roundabout (2014). There are plans to install several additional miles of sidewalk in the coming years including projects along Lummi Shore Road (between Scott Road and Kwina Road), along Lummi View Drive/Haxton Way (between Gooseberry Point and Balch Road), and a pedestrian pathway to connect the McKenzie Housing Development to the Lummi Nation School.

Even when driving is necessary, there are still ways to limit emissions. For example, the type of vehicle and how it is driven can make a big difference. Individuals planning to buy a new or used car may choose an electric, hybrid, or high fuel economy vehicle to maximize their potential reduction of carbon emissions and fuel cost savings. The LIBC already owns at least one hybrid car and has installed two electric car charging stations at the new Tribal Administration Building. A commitment to purchase hybrid and/or electric vehicles by the LIBC could have a significant impact on transportation sector carbon emissions from the Reservation. Reducing emissions from boats can be achieved by replacing or retrofitting older, inefficient motors with newer and more energy efficient models or parts. In 2013, the Harvest Management Division of the Lummi Natural Resources Department obtained nearly $275,000 in grant funding from the Environmental Protection Agency (EPA) as part of the Diesel Emissions Reduction Act (2005) to retrofit diesel engines on commercial fishing vessels. Six Lummi-owned vessels were retrofitted in 2013. During 2014, nearly $80,000 in additional funding was awarded by the EPA in support of a similar effort. Other ways to reduce emissions while driving include using fuel efficient driving habits (e.g., slow and smooth starts and stops, maintain a steady speed) and keeping the car well maintained (e.g., replace filters as needs, keep tires properly inflated).

5.4.2. Building-Related Energy Efficiency

In the homes and businesses on the Reservation, carbon emissions result largely from building-related energy use such as space heating, air conditioning, lighting, appliances, and electronics. While energy used for these purposes is necessary to create a comfortable indoor environment, many buildings use energy inefficiently, which leads to higher energy consumption, higher carbon emissions, and associated higher costs. There are many energy saving measures (e.g., energy efficiency retrofitting, weatherization) that can be applied to existing buildings on the Reservation. These may include adding insulation; preventing air leaks in the building envelope (e.g., weather stripping, caulking) and ducts; replacing heating, ventilation, and air conditioning (HVAC) systems (e.g., with heat exchange/heat pump furnaces or more efficient furnaces); properly maintaining appliances and electronics and/or buying Energy Star appliances and electronics; installing controls (e.g., programmable thermostats to regulate temperature according to building occupancy and/or time of day, light switches triggered by sensors); and replacing incandescent light bulbs with compact fluorescent lights (CFLs) or light emitting diodes (LEDs). In new construction, energy efficiency can be incorporated throughout building design, construction, and use. For instance, the U.S. Green Building Council has established a set of building standards that are intended to promote environmentally-minded development; this program is called Leadership in Energy and Environmental Design (LEED). Buildings that meet credited performance levels may be LEED Certified (e.g., the Lummi Gateway Center is LEED Silver-Certified).

An effective way to determine what can be done to save energy in the home or workplace is to get an energy audit. An energy audit performed by qualified professionals will identify energy saving measures that may be taken and can help owners prioritize energy efficiency projects based on potential carbon emissions reductions, energy and cost savings, and/or project costs. For instance, the Lummi Shellfish Hatchery underwent an energy audit in 2012 through the Whatcom Opportunity Council's Community Energy Challenge. The Opportunity Council is a local non-profit organization that conducts energy audits, vets contractors qualified to complete energy efficiency retrofitting and weatherization, and leverages utility rebates, cash incentives, and other funding sources to subsidize the cost of some energy efficiency projects and lower the costs paid by owners. Assessment results at the hatchery led facility managers to have a new roof and an electric heat pump installed. The new roof has significantly improved building insulation and helped to ensure the maintenance of consistent and appropriate temperature in shellfish rearing tanks. Meanwhile, the electric heat pump, which replaced a propane broiler, cost $50,000 for purchase and installation, but is expected to reduce annual energy costs by $40,000 (Point 2014).

One of primary recommendations of the Lummi Nation Strategic Energy Plan: 2016-2026 is to conduct energy audits of tribal facilities and Reservation residences and prioritize the implementation of energy efficiency practices based on the findings of these energy audits. With grant funding received from the Bureau of Indian Affairs (BIA) Rights Protection Implementation (RPI) Climate Change Fund, the Lummi Natural Resources Department (LNR) has recently developed the Residential Energy Efficiency Pilot Program in pursuit of this recommendation. The LNR has contracted the Opportunity Council to complete at least 14 energy audits and upgrades in income-qualified, tribal member owned homes on the Reservation by the end of 2016. Not only will this pilot project create energy savings and carbon emissions reductions for homes on the Reservation, which has clear benefits for climate mitigation, but will also increase community awareness about climate change and local actions that can be taken to minimize the carbon footprint of the Reservation and to create a healthier (e.g., improved indoor air quality) and more comfortable home environment. A future goal of the pilot program is to expand to include commercial and municipal facilities identified in the Strategic Energy Plan as high energy users, including the Silver Reef Hotel, Casino & Spa and the Lummi Nation School.

5.4.3. Behavior-Related Energy Efficiency

Not all climate mitigation activities require a large financial investment; at heart, many mitigation actions are really about personal choices. What we buy, how we manage our waste, and the habits of building occupants can significantly affect our carbon footprint. Simple actions like reducing, reusing, and recycling can help reduce carbon emissions from resource extraction, manufacturing, and disposal. Everyone can likely find ways to reduce consumption and reuse certain products. Recognizing the need to better serve the community, the Lummi Nation has recently adopted the Lummi Indian Reservation Integrated Solid Waste Management Plan (2014). Some key recommendations of this plan are to re-establish a Solid Waste Management Division within the Lummi Nation Planning and Public Works Department and to fully subsidize weekly curbside solid waste and every other week recyclable collection or its equivalent. If this program is fully implemented, individuals will be afforded ample opportunity to recycle.

Other important behaviors are the habits of building occupants. Changing the way occupants operate lights, electronics, appliances, heaters, and air conditioning can add up to measurable energy savings. Targeted behaviors for reducing energy consumption include turning off lights in unoccupied rooms or when daylight is sufficient; using energy-saver settings on computers that power down the screen when not in use; connecting electronics to power strips that can be switched off when not in use (some electronics use power even in standby mode, i.e., "phantom power"); turning off heating or air conditioning when leaving the building; ensuring that windows are not open when heaters or air conditioning are running; and promoting water conservation. Some of these actions can be automated by installing occupancy-detection sensors for lights and programmable thermostats.

There are many individuals on the Reservation who already practice energy efficient behaviors. There are also some opportunities for individuals who are not aware of the actions that may be undertaken to conserve energy to learn more about energy saving measures, a recent opportunity was the Energy Workshop lead by the Opportunity Council on July 31, 2014 in combination with registration for their Energy Assistance Program. Additional opportunities will arise over the course of the Residential Energy Efficiency Pilot Program implementation, when homeowners will be provided information about building-related and behavior-related energy efficiency practices. In the Tribal Administration Building and other recently constructed buildings on the Reservation, occupancy-detection sensors and programmable thermostats are used to automate actions that increase energy conservation. Widespread use of behavior-related energy efficiency practices in the workplace could result in people using them at home.

5.4.4. Renewable Energy

Achieving tribal goals of energy self-sufficiency and reduced emissions requires two complementary components; energy efficiency, which will reduce energy demand, and energy development from renewable energy sources, which will provide energy for use on the Reservation. Currently, the Reservation does not contain any single renewable energy source with the capacity to provide enough energy to meet all community needs. However, attaining a portfolio of different renewable energy sources will make progress towards energy self-sufficiency. In the meantime, energy purchased from renewable sources located off-Reservation could be utilized to reduce greenhouse gas emissions.

Renewable energy is generated from sources that can be naturally replenished, including hydropower, wind power, solar power, biomass energy, and geothermal energy. Not only does renewable energy production result in little to no carbon emissions (biomass is considered carbon neutral), but the cost of conventional, hydrocarbon-based energy is expected to increase in the future. Under the proper environmental conditions, shifting to renewable energy sources can be both an environmentally sound decision, as well as a cost effective one. For example, the analysis of renewable energy production potential given current clean energy technologies in the Lummi Nation Strategic Energy Plan: 2016-2026 determined that the continued pursuit of photovoltaic (solar) electricity production and geothermal heating and cooling are two viable options for renewable energy production on the Reservation.

The Strategic Energy Plan does not recommend further pursuit of wind energy development at this time, unless new technologies or new incentives become available that result in economic and environmental costs that are less than the economic and environmental benefits. This recommendation is based on the results of a two year wind energy development feasibility assessment conducted by the Lummi Natural Resources Department with funding provided by the U.S. Department of Energy. The feasibility study evaluated wind energy potential on the Reservation and the wildlife and noise impacts of wind turbines on the Reservation. The assessment included an analysis of over one year of wind speed and direction data collected from two anemometer towers (each equipped with anemometers at different heights to allow for the calculation of wind shear) located where regional wind maps indicated would be most favorable for wind energy. The final report, *Wind Resource and Feasibility Assessment Report for the Lummi Reservation* (DNV KEMA 2012) concluded that a wind energy project at all three scales of commonly used turbines (i.e., utility, community, and residential scale) were all not economically viable projects on the Reservation. Recommendations for solar and geothermal energy development are discussed below.

Solar energy, the energy contained in sunlight, can be captured by photovoltaic (PV) cells (a.k.a., solar panels) and converted into electricity or captured by a medium contained in solar thermal panels and used for water heating. Although the Pacific Northwest has not been developed for utility-scale solar installations, distributed systems (i.e., systems that are installed on commercial or residential buildings and generate electricity for consumption in those buildings) have proven effective. Indeed, the photovoltaic arrays on the Northwest Indian College's (NWIC) Environmental Science Building and along the Haxton Way pedestrian path (for outdoor lighting) have been operating successfully since 2010. There is a significant opportunity to expand the use of solar energy on the Reservation, particularly at tribal facilities with high demand for electricity and/or water heating that are located in appropriate areas and have available roof space for solar installations. These facilities may include the Silver Reef Hotel, Casino & Spa, the Lummi Nation School, the Tribal Administration Building, the Lummi Bay Salmon Hatchery, the Shellfish Hatchery, the Skookum Creek Hatchery, Lummi Housing Authority residential developments, and the Gateway Center. If grants, incentives, and subsidies are utilized to reduce the initial investment of installation, solar systems offer a viable option to replace or supplement the use of electricity from conventional energy sources.

Geothermal energy refers to heat generated from the earth and in the Pacific Northwest is typically captured using geothermal heat pumps (GHPs), which take advantage of the relatively stable year-round ground temperature (approximately 50° F) found at depths of 6-10 feet below the ground surface. Geothermal heat pumps (GHPs) consist of a heat exchanger, which is a system of underground pipes (“loops”) filled with water, and a heat pump. In the winter, when the ground temperature is higher than the air temperature, the ground operates as a heat source and the heat pump circulates warm air for space heating. When the air temperature is higher than the ground temperature during the summer, the ground operates as a heat sink and the heat pump removes heat from the building and provides for space cooling. In addition to space heating and cooling, GHPs can be equipped to supply hot water. The new Tribal Administration Building and the nearby Early Child Learning Center (both completed in 2013) use a geothermal heat pump to support the need for space heating and cooling and has realized significant energy savings per square foot of conditioned indoor space compared to the previous LIBC offices at the West, Central, and East campuses. With continued development on the Reservation, there is a valuable opportunity to utilize geothermal energy in tribal facilities and in new residential developments. Although there substantial upfront cost associated with installing a geothermal heat pump, the payback period is generally 5-10 years.

Another option to reduce carbon emissions from energy production and support the development of renewable energy throughout the Pacific Northwest is to purchase “Green Power.” Pursuant to Washington State Law (RCW 19.29A.090) electric utilities are mandated to provide customers with the option to voluntarily participate in Green Power programs. In these programs, customers pay additional costs that the utility directs to renewable energy facilities that then supply additional electricity into the grid. Puget Sound Energy (PSE) is the electricity provider on the Reservation and provides Green Power at a rate of $0.0125 per kilowatt-hour (kWh). At this rate, the average household, which uses around 800 kWh monthly, can offset 100 percent of their usage through PSE’s Green Power Program for approximately ten additional dollars ($10) each month (PSE 2014). The LIBC may opt to lead by example and commit to purchasing a designated amount of Green Power. For example, the nearby City of Bellingham purchases enough Green Power to offset 100 percent of electricity use in municipal facilities and has been recognized as a leading EPA-certified Green Power Community nationwide (COB 2014). The LIBC used approximately 4,670 MWh of electricity for municipal operations in 2010 at a cost of about $38,000 per month. To offset 100 percent of this electricity use through the purchase of Green Power at current rates would cost an additional $4,900 per month, or about 13 percent more per month.

5.4.5. Carbon Storage

The Lummi Nation promotes biological carbon sequestration through the conservation and/or restoration of forests and wetlands, wherein atmospheric carbon dioxide is captured via photosynthesis and stored as organic matter in vegetation, soils, and sediments. Though carbon storage was not necessarily the primary goal of habitat conservation and restoration, the benefits for climate mitigation are the same nonetheless. Two of the Lummi Nation's largest projects, the Arlecho Creek Conservation Area and the Lummi Nation Wetland and Habitat Mitigation Bank are discussed below; it should also be noted that there are many smaller reforestation and salmon habitat restoration projects (e.g., riparian plantings) that create and maintain terrestrial carbon sinks that will not be addressed here.

The Arlecho Creek watershed consists of approximately 2,126 acres of forestland and is located in the headwaters of the South Fork Nooksack River. The forest is comprised of a mix of previously logged forestland, some tracts were harvested as recently as the early 1990s, and intact mid-elevation old-growth forest. The tribe purchased 1,771 acres of the watershed from the Crown Pacific Holding Company in 2002 as a part of efforts to recover lands that hold historical, cultural, and environmental significance to the Lummi people (LNR 2011). Additionally, Arlecho Creek is the main tributary to Skookum Creek, which is the primary water source for the Lummi Nation's Skookum Creek Hatchery and the largest tributary to the South Fork of the Nooksack River. In 2007, the Lummi Nation finalized the sale of a 100-year conservation easement to the Climate Trust of Portland, Oregon for all the carbon offsets available on 1,297 acres of the 1,771 acres held by the tribe. The Climate Trust anticipates that this property will sequester 350,000 metric tons of carbon over the next century. Permitted activities in the Arlecho Creek Conservation Area include low-impact cultural and educational use by Lummi tribal members; forest management practices are limited to those deemed necessary to protect the historical, cultural, and environmental values of the property from threats such as wildfire, insects and disease, and invasive species.

Forestlands are not the only habitats that capture and store carbon; wetlands also serve as significant carbon sinks by sequestering carbon in plant biomass and organic-rich soils. A recent study in the Snohomish estuary analyzed the climate benefits of coastal wetland restoration by quantifying the carbon storage potential of restored wetlands and concluded that historically altered Puget Sound estuaries have a high capacity to serve as significant carbon sinks (Crooks et al. 2014). As introduced in Section 4.2.3 – Wetlands, large tracts of estuarine and floodplain wetlands of the Lummi and Nooksack rivers will be protected and functionally improved through the implementation of the Lummi Nation Wetland and Habitat Mitigation Bank and other nearby restoration projects (Figure 4.8). In 2009, the Lummi Nation approved the acquisition of approximately 2,770 acres of wetland habitat for mitigation banking and restoration purposes. Wetland enhancement activities will include replacing or removing tide gates, removing portions of dikes, invasive weed control, and opening remnant sloughs and distributary channels. Restoring direct tidal input to areas that have been isolated from tidal hydrology will reestablish the conditions that allow for accretion of the wetland sediment surface. Accretion, or the vertical accumulation of organic and mineral matter, is the mechanism by which vast stores of carbon may be sequestered in wetland soils. As plant biomass is buried, the persistent low-oxygen (i.e., hydric) soil conditions reduces the decomposition of organic matter, resulting in long-term carbon storage. Alternatively, when wetlands are drained and soils become aerobic, microbial respiration can release stored carbon back into the atmosphere. Therefore, implementation of the wetland and habitat mitigation bank will likely reactivate carbon sequestration in soils that were drained in the early 1900s for agricultural reclamation. As carbon markets develop, there may be future opportunities to bank so-called "Blue Carbon" credits associated with coastal wetland restoration.

In summary, land use management has a direct and significant effect on biological carbon sequestration. It is the recommendation of this report that the Lummi Nation continue to promote land use practices such as forest and wetland conservation and restoration that improve carbon storage.

5.5. Adaptation Strategies

Coincident with actions to ensure climate mitigation, the Lummi Nation is also committed to undertake climate adaptation. The primary purpose of climate adaptation is to make the Lummi Nation resilient to climate change. This will require taking proactive steps to prepare for future climate change impacts, a planning process that will be dynamic and ongoing. Some preparedness actions are already underway on the Reservation; others will need to be developed. In this section, adaption goals and strategies for each sector of the Reservation's natural, social, and built systems will be identified.

There are three caveats that must be understood to properly interpret the information presented in the remainder of this chapter. First, it should be noted that there is no "one-size-fits-all" approach to climate adaptation. A given adaptation option may be the best available strategy in one situation and entirely inappropriate in another. The reader is urged to assess the efficacy of different adaptation options on a case-by-case basis. For this reason, adaptation goals and strategies are not ranked or prioritized. Second, the goals and strategies identified in this assessment are intended to provide a broad range of possible options for climate adaptation, but not every possible option. Key goals were identified based on vulnerability rankings and the specific concerns of the Lummi Nation. It is recognized that new and additional goals and strategies will be required to realize a higher level of climate-preparedness on the Reservation. Lastly, the ideas presented here mark a starting point, not an endpoint. These adaption goals and strategies should be revisited and revised as necessary to reflect new data, changing community concerns, or other factors.

There are several instances where similar or overlapping adaptation goals and strategies exist between sectors. In these cases, the reader may be directed to the section where similar information is presented.

5.5.1. Water Resources

As discussed in Section 4.2 – Water Resources, some of the primary impacts of climate change on water resources are an increased risk of severe flooding during the winter months and reduced instream flows and increased stream temperature during the summer months. Several adaptation goals and strategies addressing these climate change impacts are presented in this section (Table 5.2). Climate-related wetland and groundwater impacts are discussed in Section 5.5.2 and Section 5.5.10 respectively.

Adaptation Goal A-1: Reduce the risk of property damage from riverine flooding.

Adaptation Strategies:

1. *Strengthen regulatory flood risk reduction measures*. Continued enforcement of the Lummi Flood Damage Prevention Code (LCL Title 15A) in special flood hazard areas (SFHA) and participation in the National Flood Insurance Program (NFIP) and the NFIP's Community Rating System (CRS) are necessary for effective floodplain management on the Reservation. However, as the flood regime changes, regulatory measures will need to be strengthened and augmented to reflect the increased risk. Examples of more protective regulations include: (1) increasing building elevation requirements from a 1 foot freeboard to a 3 foot freeboard, (2) adopting a more protective building code such as the International Building Code rather than the currently adopted Uniform Building Code, (3) requiring relocation of critical facilities outside of the SFHA, and (4) prohibiting new development in some high hazard areas and restricting development in other flood-prone areas to flood-compatible land uses unless there is no practicable alternative.

2. *Upgrade infrastructure to accommodate or protect against flooding*. Breaches of the 5-year to 10-year levees along the Nooksack River downstream of Ferndale and subsequent discharge of floodwaters into Lummi Bay can completely isolate the Lummi Peninsula from the surrounding mainland. The Lummi Nation Multi-Hazard Mitigation Plan (MHMP 2010) has identified several flood mitigation priorities to protect people and reduce property damage during these flood events, including: (1) constructing a 100-year setback levee along Ferndale Road, (2) raising Slater Road and Haxton Way and providing for underflow, and (3) monitoring the condition of culverts, tide gates, and Lummi Bay seawall for potential maintenance or repairs. So long as climate change impacts are integrated into infrastructure redevelopment projects, the recommendations of the MHMP are consistent with the findings of this report.

3. *Continue to pursue land acquisition, building relocation or demolition, and open space preservation in special flood hazard areas (SFHA).* In some high hazard areas, the best way to protect people and property is to relocate them to a safer area. The Lummi Nation has applied for and received FEMA Pre-Disaster Mitigation (PDM) and Hazard Mitigation Grant Program (HMGP) funding to buyout and demolish vulnerable existing structures on the Reservation in the past. Funding for and resident participation in the buyout program will likely expand in response to future damaging floods. Conservation easements on buyout properties should prohibit new buildings into perpetuity, thereby preventing the recurrence of structural damages and preserving open space for natural floodwater storage.

4. *Protect existing development in flood-prone areas*. There are options available to reduce flood risks to structures in the SFHA. These include elevating or floodproofing the structure to at least one foot above the published base flood elevation (BFE) and/or constructing local flood control structures to protect properties. Residents may also be encouraged to obtain an elevation certificate and purchase flood insurance through the National Flood Insurance Program (NFIP); although this does nothing to reduce flood risk, it can help homeowners better understand their flood risk and protect against some financial losses in the event of flood damage.

Adaptation Goal A-2: Restore instream flow and maintain suitable stream temperature in the Nooksack River basin.

Adaptation Strategies:

1. *Continue to pursue a negotiated or litigated settlement to resolve conflicts over water rights allocations in the Nooksack River basin*. From 1998-2010 the Lummi Nation engaged in water rights negotiations through participation in the Water Resources Inventory Area (WRIA 1) Watershed Management Project. After efforts to reach a settlement were unsuccessful, the Lummi Nation suspended negotiations on December 1, 2010 and soon thereafter filed a litigation request with the United States seeking quantification of the tribal instream flow right. As work to resolve this conflict continues, it is important that all involved parties understand how climate change will impact water resources. For instance, the fact that past hydrological data may no longer provide an accurate representation of future streamflow should be incorporated into the decision-making process.

2. *Undertake climate-conscious riparian and floodplain restoration to decrease existing stressors and ameliorate climate change effects on summer instream flow and temperature.* Historic and current human activities that contribute to low instream flow and high stream temperature include deforestation, alterations to channel morphology and geometry, agricultural drainage practices and irrigation, municipal and industrial water uses, and removal of riparian vegetation. Beechie et al. (2012) identify several restoration actions that begin to address existing problems and are likely to remain effective under future climate conditions, including: (1) improving lateral connectivity (e.g., levee removal, reconnection of floodplain features, creation of new floodplain habitats), (2) improving riparian function (e.g., planting trees and other vegetation), and (3) improving vertical connectivity (e.g., reintroducing beaver, removing cattle). Pending legal action to reduce water withdrawals, restoration provides an opportunity to begin making positive change.

Table 5.2 Water Resources Adaptation Goals and Strategies

Goal	Strategy
A-1: Reduce the risk of property damage from riverine flooding.	1. Strengthen regulatory flood risk reduction measures.
	2. Upgrade infrastructure to accommodate or protect against flooding.
	3. Continue to pursue land acquisition, building relocation or demolition, and open space preservation in special flood hazard areas.
	4. Protect existing development in flood-prone areas.
A-2: Restore instream flow and maintain suitable stream temperature in the Nooksack River basin.	1. Continue to pursue a negotiated or litigated settlement to resolve conflicts over water rights allocations in the Nooksack River basin.
	2. Undertake climate-conscious riparian and floodplain restoration to decrease existing stressors and ameliorate climate change effects on summer instream flow and temperature.

5.5.2. Coastal Resources

As discussed in Section 4.3 – Coastal Resources, some of the primary impacts of climate change on coastal resources are inundation from sea level rise and storm surge, accelerated shoreline erosion, and ocean acidification. Several adaptation goals and strategies addressing these climate change impacts are presented in this section (Table 5.3). Potential adaptation strategies to ameliorate the impact of ocean acidification on shellfish are discussed in Section 5.5.4 – Fish, Wildlife, and Traditional Use Plants.

Adaptation Goal B-1: Reduce the risk of property damage from coastal flooding and shoreline erosion.

Adaptation Strategies:

1. *Continue to assess coastal areas for flooding and erosion risks*. There are two basic approaches to shoreline management in the face of climate change: managed retreat or protect in place. Determining which option is appropriate will require an understanding of local risk, as well as a site-specific assessment of the benefits and drawbacks of each approach. There are several tools that are already available and others that are in development to help assess coastal flooding and erosion risks. Existing resources include the current FEMA Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) for the Reservation, the *Lummi Reservation Coastal Protection Guidelines* (CGS 2007), the Lummi Nation Multi-Hazard Mitigation Plan (2010), the Nature Conservancy's Coastal Resilience Tool, and NOAA's Digital Coast. Studies that are in progress include the coastal Risk MAP project, which will provide regulatory and non-regulatory products, and other, simultaneous FIS and FIRM updates. Additional research should be encouraged as appropriate.

2. *Facilitate managed retreat through land acquisition, zoning changes, development restrictions, and/or other regulatory tools as appropriate.* Planning to retreat from hazardous areas will require deliberate, long-range planning and the use of several planning tools. For instance, increasing setback requirements could reduce risks to new development. An assessment of the Lummi Coastal Zone Management Program and update to the Coastal Lummi Nation Coastal Zone Management Plan (1988) are currently underway, providing an excellent opportunity to plan for climate change. Other programmatic updates should also include consideration of potential climate change impacts on the Reservation.

3. *Protect coastal buildings and infrastructure through shoreline hardening and/or building elevation and floodproofing.* Shoreline hardening (e.g., bulkheads, dikes, riprap, and other engineered shore defense structures) can be damaging to intertidal habitats, erode unarmored shorelines downdrift, and may provide only a short-term option for coastal protection depending on the future rate of sea level rise. However, in some circumstances it may be appropriate to construct or fortify shoreline armoring, such as when there are significant tribal assets at stake that will require time to relocate, when setback levees are constructed to allow the removal of existing shoreline levees, or when approved water-dependant uses are at risk. Buildings may also be elevated or otherwise designed to reduce flood damage.

4. *Encourage soft bank protection, rather than traditional shoreline armoring.* Soft coastal engineering (e.g., beach nourishment, planting vegetation, anchoring large woody debris, natural breakwaters) mimics natural shoreline features and can be used to minimize erosion while still maintaining wetland habitat and sediment transport. Soft bank protection can be a viable alternative to shoreline hardening along reaches with low to moderate erosion potential. One successful model for encouraging the use of soft bank protection is the Stewardship Centre for British Colombia's Green Shores Program. Green Shores is a coastal development rating system (similar to the LEED rating system) that provides certification to developers and landowners who utilize planning and design principles credited for maintaining shoreline structure and function.

Adaptation Goal B-2: Maintain and enhance coastal wetland habitats.

Adaptation Strategies:

1. *Facilitate shoreward migration of coastal wetlands though land acquisition and removal of hard shore protection (e.g., bulkheads, dikes, sea walls) or other barriers to tidal flow*. Preserving open space for shoreward migration and restoring tidal hydrology are two major goals of the Lummi Nation Wetland and Habitat Mitigation Bank and other current and planned restoration projects. By accommodating for sea level rise and facilitating the inland migration of wetland plants and animals, the Lummi Nation has adopted what is arguably the best adaptation strategy for preserving coastal wetlands in the face of climate change. Continuation and expansion of these programs and other actions that prevent coastal squeeze is highly recommended.

2. *Preserve and restore structural complexity and biological diversity when undertaking wetland enhancement activities*. Ecological diversity is widely recognized as making habitats more resilient to climate change. By managing for diversity and incorporating climate change projections into restoration planning, land managers will be better able to protect critical estuarine habitats, such as nursery and spawning grounds. A diverse Puget Sound estuary contains a mosaic of wetland habitat types, including eelgrass meadows, tidelands, salt marshes, scrub-shrub wetlands, and forested wetlands, such as were present before Euro-American settlement and subsequent wetland destruction beginning in the late 1800s.

3. *Promote and maintain mechanisms for sediment transport and deposition.* The goals of this sediment management strategy are twofold. First, if coastal wetlands are to survive in the face of accelerated sea level rise, vertical accretion must be sufficient to pace with increasing sea level. Restoring direct tidal and riverine input to areas that have been isolated from tidal hydrology or are otherwise sediment-starved can reestablish the conditions that promote mineral sediment deposition and organic matter accumulation, thereby enhancing vertical accretion. Second, shoreline sediment transport, also called shoreline drift, has been disrupted in some areas by bluff armoring and the excavation of the entrance channel to the Sandy Point Marina. Bulkheads are installed in efforts to protect upland development from erosion, but effectively starve downdrift beaches of needed feeder bluff sediment and induce alternative patterns in erosion that adversely affect seaward and downdrift habitats. Where identified as appropriate, removing bulkheads

entirely or replacing them with soft bank protection may successfully restore and maintain natural sediment transport processes.

Adaptation Goal B-3: Reduce local land-based contributions to ocean acidification.

Adaptation Strategy:

1. *Strengthen pollution reduction actions to reduce nutrient and organic carbon discharge into fresh and marine waters*. Sources of excess nutrients and organic carbon include farms and livestock operations (e.g., dairies and beef cattle), urban storm water runoff, wastewater treatment outfalls, and on-site septic systems. Although the magnitude of nutrient and organic carbon impacts to local acidification has not been quantified in this area, the implications of these pollutants are clear (i.e., decreased pH resulting from decomposition of excessive plant and algal biomass) and improved pollution reduction measures need to begin now. There will be multiple benefits to controlling sources of pollution that reduce pH, including a reduction in bacterial contamination and prevention of potential low dissolved oxygen conditions.

Table 5.3 Coastal Resources Adaptation Goals and Strategies

Goal	Strategy
B-1: Reduce the risk of property damage from coastal flooding and shoreline erosion.	1. Continue to assess coastal areas for flooding and erosion risks.
	2. Facilitate managed retreat through land acquisition, zoning changes, development restrictions, and/or other regulatory tools as appropriate.
	3. Protect coastal buildings and infrastructure through shoreline hardening and/or building elevation and floodproofing.
	4. Encourage soft bank protection, rather than traditional shoreline armoring.
B-2: Maintain and enhance coastal wetland habitats.	1. Facilitate shoreward migration of coastal wetlands though land acquisition and removal of hard shore protection (e.g., bulkheads, dikes, seawalls) or other barriers to tidal flow.
	2. Preserve and restore structural complexity and biological diversity when undertaking wetland enhancement activities.
	3. Promote and maintain mechanisms for sediment transport and deposition.
B-3: Reduce local land-based contributions to ocean acidification.	1. Strengthen pollution reduction actions to reduce nutrient and organic carbon discharge into fresh and marine waters.

5.5.3. Forest Resources

As discussed in Section 4.4 – Forest Resources, one of the primary impacts of climate change on forest resources is an increasing area burned by wildfire. One adaptation goal and several adaptation strategies addressing this climate change impact are presented in this section (Table 5.4).

Adaptation Goal C-1: Reduce the risk of property damage from wildfire on the Reservation.

Adaptation Strategies:

1. *Implement "firewise" standards in high-risk residential and commercial areas.* Homes and businesses along the urban-wildland interface (i.e., adjacent to or surrounded by forestlands) of the Lummi Peninsula and Northwest Upland are at an elevated risk of wildfire damages. As outlined in the Lummi Nation Multi-Hazard Mitigation Plan (MHMP 2010), there are several preventative measures (a.k.a., firewise measures) that can be taken to reduce this risk, such as maintaining a defensible space around buildings, minimizing fuel hazards near buildings, using fire-resistant building materials, providing routes for emergency access, and others. An important component of firewise development is providing community outreach and education to help individuals identify hazards, develop fire plans, and implement risk reduction measures. There are an array of resources pertaining to fire prevention measures and educational materials available from the National Fire Protection Association's (NFPA) Firewise Communities/USA and FireSmart Canada that may be utilized for this purpose.

2. *Continue to support wildfire prevention and response capabilities within the Lummi Natural Resources Department (LNR).* The LNR Forestry Division is responsible for wildfire prevention (e.g., issues burn bans and burn permits) on the Reservation and shares the responsibility of wildland firefighting with the Washington State Department of Natural Resources (DNR) and local Whatcom County Fire Districts. It is important that the LNR maintain and improve fire response capabilities not only by continuing with firefighter training and equipment maintenance, but also by obtaining additional funding to address identified program needs. For instance, the MHMP (2010) suggested inventorying alternative firefighting water sources and encouraging the development of additional sources, such as water storage facilities with fire-resistant electrical pump systems in developments outside of fire protection districts that are not connected to community water or hydrant system.

3. *Implement forest practices that minimize wildfire risk.* Although standard fire prevention measures such as mechanical thinning and prescribed burning are typically ineffective in west-side forests when applied across large geographic areas, targeted application of these measures may be used to reduce the risk of severe wildfire disturbance at finer scales (Dalton et al. 2013). If these forest practices are employed, they should be undertaken in a manner consistent with the goals of promoting climate-resilient ecological management.

Table 5.4 Forest Resources Adaptation Goal and Strategies

Goal	Strategy
C-1: Reduce the risk of property damage from wildfire on the Reservation.	1. Implement "firewise" standards in high-risk residential and commercial areas.
	2. Continue to support wildfire prevention and response capabilities within the Lummi Natural Resources Department.
	3. Implement forest practices that minimize wildfire risk.

5.5.4. Fish, Wildlife, and Traditional Use Plants

As discussed in Section 4.5 – Fish, Wildlife, and Traditional Use Plants, climate change impacts on salmon, shellfish, and upland plants and wildlife are of particular concern to the Lummi Nation. Several adaptation goals and strategies addressing climate change impacts on these species are presented in this section (Table 5.6).

Adaptation Goal D-1: Protect and restore a harvestable surplus of salmon for the Lummi People.

Adaptation Strategies:

1. *Reduce existing stressors to salmon populations*. Existing stressors to salmon populations include habitat loss, fragmentation, and degradation; water of insufficient quantity and quality; alteration of historical disturbance regimes (e.g., flood regime, sediment regime); and historical overharvest. Cumulatively, these stressors have caused significant declines in salmon populations and reduced the resilience of salmon to future disturbances, including climate change. It is widely recognized that reducing existing stressors (e.g., preventing and reversing habitat destruction, replacing undersized culverts and other barriers to migration, preventing pollution, restoring instream flows) is necessary for the recovery of Pacific salmon.

2. *Incorporate climate change into salmon recovery and habitat restoration/conservation plans*. The anticipated effects of climate change on salmon should be integrated into existing and new management plans. Beechie et al. (2012) outline potential decision-making processes for adapting salmon recovery plans to climate change based on four guiding questions: What habitats limit salmon recovery? Do climate change scenarios alter salmon restoration plans or priorities? Does the plan or action ameliorate a predicted climate effect? Does the plan or action increase habitat diversity and salmon population resilience? Finding the answers to these questions must be guided by the best available science. Unfortunately, although there are several regional assessments of the vulnerabilities of salmon to climate change, there is a paucity of fine-scale analyses necessary for local planning efforts. As such, conducting species and habitat vulnerability assessments should go hand-in-hand with updates to management plans. Additional information can be found in *Restoring Salmon Habitat for a Changing Climate* (Beechie et al. 2012).

3. *Restore habitat diversity and riparian ecosystem function throughout the Nooksack River watershed using methods demonstrated to ameliorate the negative impacts of climate change on salmon*. Beechie et al. (2012) also evaluated the efficacy of different restoration actions to ameliorate the impacts of climate change and increase salmon resilience in the face of these changes. Their findings indicate that some restoration methods are more likely than others to achieve and sustain multiple benefits for salmon over the long-term, these methods include restoring longitudinal, lateral, and vertical connectivity and restoring stream flow regimes. Table 5.5 identifies restoration actions and their ability to ameliorate climate change effects (Beechie et al. 2012). One of the core principles behind these findings is that increasing habitat diversity serves to increase diversity in salmon, which may increase the resilience of salmon populations to climate change. This conclusion is supported by other researchers, including Wade et al. (2013) who state: "Steelhead and salmon have evolved for millions of years and have long thrived under changing climatic conditions when provided access to a connected array of varied habitats that support genetic and life history diversity."

   It should be noted that some restoration actions evaluated by Beechie et al. (2012), such as instream rehabilitation (e.g., adding large woody debris, adding spawning gravel, recreating meanders), were determined to have context-dependent effects pertaining to climate change; this does not negate the positive outcomes of such actions on improving ecological conditions (e.g., increasing salmon habitat and production) over the near-term.

Adaptation Goal D-2: Protect and restore a harvestable surplus of shellfish for the Lummi People.

Adaptation Strategies:

1. *Improve water quality in shellfish harvest areas.* Degraded water quality can negatively impact shellfish population health and/or make shellfish unsafe for human consumption. For instance, Lummi shellfish beds in portions of Portage Bay were closed to ceremonial, subsistence, and commercial harvest from 1996-2006 (735 total acres affected, includes intertidal and subtidal) and again from September 2014 to the present (496 total acres affected, includes intertidal and subtidal, as of December 31, 2014) after concentrations of *fecal coliform* bacteria were measured in excess of federal National Shellfish Sanitation Program (NSSP) standards. The 1996-2006 closure was largely attributed to poor dairy waste management practices in the Nooksack River watershed. In response to this closure, federal and state agencies increased compliance inspections and a new state law was enacted that required the development and implementation of nutrient management plans (a.k.a., farm plans) throughout Whatcom County. As a result of these actions, additional water quality monitoring, and improved inter-agency coordination, water quality improved in the Nooksack River and over the shellfish growing area which led to the eventual reopening of the shellfish harvest areas. The current shellfish area downgrade illustrates that increased enforcement and other actions will again be necessary to achieve and sustain federal, state, and Lummi Nation water quality standards.

Table 5.5 Restoration Action Types and Their Ability to Ameliorate Climate Change Effects

Category	Common techniques	Ameliorates temperature increase	Ameliorates base flow decrease	Ameliorates peak flow increase	Increases salmon resilience
Longitudinal connectivity (barrier removal)					
	Removal or breaching of dam	●	●	○	●
	Barrier or culvert replacement/removal	○	○	○	●
Lateral connectivity (floodplain reconnection)					
	Levee removal	●	○	●	●
	Reconnection of floodplain features (e.g. channels, ponds)	●	○	●	●
	Creation of new floodplain habitats	●	○	●	●
Vertical connectivity (incised channel restoration)					
	Reintroduce beaver (dams increase sediment storage)	●	●	●	●
	Remove cattle (restored vegetation stores sediment)	●	●	●	○
	Install grade controls	●	●	●	○
Stream flow regimes					
	Restoration of natural flood regime	●	●	○	◒
	Reduce water withdrawals, restore summer baseflow	●	●	○	○
	Reduce upland grazing	○	◒	◒	○
	Disconnect road drainage from streams	○	○	●	○
	Natural drainage systems, retention ponds, other urban stormwater techniques	○	◒	●	○
Erosion and sediment delivery					
	Road resurfacing	○	○	○	○
	Landslide hazard reduction (sidecast removal, fill removal)	○	○	○	○
	Reduced cropland erosion (e.g. no-till seeding)	○	○	○	○
	Reduced grazing (e.g. fencing livestock away from streams)	◒	○	○	○
Riparian functions					
	Grazing removal, fencing, controlled grazing	●	○	○	○
	Planting (trees, other vegetation)	●	○	○	○
	Thinning or removal of understory	○	○	○	○
	Remove non-native plants	◒	◒	○	○
Instream rehabilitation					
	Re-meandering of straightened stream, channel realignment	◒	○	○	◒
	Addition of log structures, log jams	◒	○	○	○
	Boulder weirs and boulders	◒			
	Brush bundles, cover structures	○	○	○	○
	Gravel addition	○	○	○	○
Nutrient enrichment					
	Addition of organic and inorganic nutrients	○	○	○	○

Actions are grouped by major processes or functions they attempt to restore: connectivity (longitudinal, lateral and vertical), watershed-scale processes (stream flow and erosion regimes), riparian processes, instream rehabilitation, and nutrient enrichment. Filled circles indicate positive effect, empty circles indicate no effect, and partially filled circles indicate context-dependent effects. See text for supporting citations.

2. *Ensure continued water quality monitoring.* The Pacific Shellfish Institute has established a water chemistry monitoring program at the Lummi Bay Shellfish Hatchery. Monitoring equipment is located at one site in the Seapond Aquaculture Facility and one site within the hatchery. This equipment operates continuously and makes real-time data available to hatchery staff. Although there has been no detectable change in pH or temperate in waters tested in the Seapond facility that could be attributed to anthropogenic climate change or that were outside of the range of natural variability over the period of record (2011-present), continued monitoring is necessary to further refine the range of current conditions and ensure early detection of potential future problems. Additionally, the Lummi Water

Resources Division (LWRD) implements an ambient water quality monitoring program that samples fresh and marine waters on the Reservation. Continued monitoring and additional monitoring of nutrients will enhance our understanding of local water quality status and trends.

3. *Maintain and expand shellfish enhancement on tribal tidelands*. The Lummi Bay Shellfish Hatchery is responsible for propagating and restocking tribal tidelands with manila clam seed (20 million seed) and oyster spat (3,000 cultch bags) annually. The hatchery also produces and sells geoduck seed to offset operation costs. These enhancement activities should be continued to support tribal harvest and may be expanded in response to climate change. For example, seeding or transplanting oysters and clams into new areas that are more likely to be successful as sea levels rise (i.e., assisted migration) may maintain opportunities for tribal harvest. Other actions such as enhancing the substrate of shellfish beds may also help maintain tribal shellfish harvesting opportunities.

4. *Explore options for seawater chemistry remediation*. The Washington State Blue Ribbon Panel on Ocean Acidification (2012) identified two novel actions, phytoremediation and pH buffering, that may be effective in remediating local seawater conditions. Phytoremediation involves using vegetation to remove carbon dioxide from the water column (via photosynthesis), thus locally reducing the impacts of ocean acidification. Phytoremediation techniques suggested by the Blue Ribbon Panel include "[…] using seaweeds or seagrasses within shellfish hatcheries for better larval survival and growth, co-culturing eelgrass and shellfish, using seaweed farming to capture and remove carbon, and harvesting algae from shellfish-growing gear for onshore use as fertilizer." The second suggested approach involves spreading properly seasoned shells in shallow waters to buffer corrosive conditions within and atop the seafloor. Although these techniques are still in the exploratory phase, these and other potential methods of remediation may be tested by the Lummi Nation should water quality monitoring indicate sufficient need.

Adaptation Goal D-3: Conserve forestland and other upland habitats throughout the Lummi Nation's Traditional Territories.

Adaptation Strategies:

1. *Advocate for the expansion of protected areas.* Safeguarding upland plant and wildlife populations may be accomplished, in part, by expanding protected areas to encompass greater landscape diversity, include climate-resilient refugial habitat, and enhance habitat connectivity. Not only does advocating for conservation help protect the treaty-reserved rights of the Lummi Nation, which include the right to hunt and gather throughout the tribe's Usual and Accustomed (U&A) grounds and stations and traditional territories, but it also helps protect ecosystem function, sustain vulnerable populations, and facilitate species range shifts in the face of climate change.

2. *Continue to monitor forest practices and encourage better forest management.* The Lummi Natural Resources Department (LNR) works to ensure proper implementation of federal and state laws and agreements (e.g., Washington State's Forests and Fish Law) in forestlands and other upland habitats through review of Forest Practices Application (FPA),

Hydraulic Project Approval (HPA), Road Management and Abandonment Plans (RMAPs), and other permitting documents. While monitoring compliance is important, the Lummi Nation also has a role to play in ensuring that regulations and standards are modified as necessary to provide adequate levels of protection under future climate scenarios.

Table 5.6 Fish, Wildlife, and Traditional Use Plants Adaptation Goals and Strategies

Goal	Strategy
D-1: Protect and restore a harvestable surplus of salmon for the Lummi People.	1. Reduce existing stressors to salmon populations.
	2. Incorporate climate change into salmon recovery and habitat restoration/conservation plans.
	3. Restore habitat diversity and riparian ecosystem function throughout the Nooksack River watershed using methods demonstrated to ameliorate the negative impacts of climate change on salmon.
D-2: Protect and restore a harvestable surplus of shellfish for the Lummi People.	1. Improve water quality in shellfish harvest areas.
	2. Ensure continued water quality monitoring.
	3. Maintain and expand shellfish enhancement on tribal tidelands.
	4. Explore options for seawater chemistry remediation.
D-3: Conserve forestland and other upland habitats throughout the Lummi Nation's Traditional Territories.	1. Advocate for the expansion of protected areas.
	2. Continue to monitor forest practices and encourage better forest management.

5.5.5. Human Health

As discussed in Section 4.6 – Human Health, some of the primary impacts of climate change on human health are an increasing incidence of heat-related illness, injury from extreme weather events, respiratory disease, infectious disease, poisoning from harmful algal blooms, food insecurity, and mental health problems. One adaptation goal and several adaptation strategies addressing these climate change impacts are presented in this section (Table 5.7).

Adaptation Goal E-1: Improve community health.

Adaptation Strategies:

1. *Develop a comprehensive assessment of community health risks, including assessment of Indigenous health indicators.* Understanding the risks of climate change to human health and prioritizing actions to reduce these risks requires a comprehensive assessment of current and potential future community health risks on the Reservation. Community health assessments typically include local health data, local environmental data, and community concerns. The Swinomish Indian Tribe has recently developed a model for integrating Indigenous health indicators, which they identify as community connection, natural

resources security, cultural use, education, self determination, and well-being (Donatuto et al. 2014; Swinomish 2010), into community health assessments. The intent of this approach is to broaden the scope of a standard assessment, which is usually focused on "individual, physiological health," to include aspects of "community-scale, social, cultural, and mental health" that are also important to individual and tribal wellbeing (Donatuto et al. 2014).

2. *Improve and expand healthcare services to meet anticipated increased demand.* The aforementioned climate-induced health risks are expected to increase demand for healthcare services, adding additional stress to already overburdened providers. The Lummi Health Clinic provides many health services to Lummi tribal members and other American Indians and Alaska Natives, including medical, dental, mental, and public health services. There is a recognized need to improve and expand these services and the clinic is currently developing or planning several projects to strengthen patient care services for community members (e.g., establishing a Community Medicine Department, increasing the number of exam rooms, increasing the number of providers, providing physical therapy, expanding preventative healthcare services). These and similar improvements are recommended to increase the capacity of the clinic to serve the Lummi People and improve the provision of essential healthcare services.

3. *Help individuals prepare for potential climate-related health risks by providing public outreach and education.* Increasing public awareness of and preparation for climate-related health risks is an important step toward reducing the negative health outcomes that may result from climate change. Because climate change is expected to exacerbate existing health problems, targeting already vulnerable populations, such as the sick or elderly, may be particularly effective initial approach.

Table 5.7 Human Health Adaptation Goal and Strategies

Goal	Strategy
E-1: Improve community health.	1. Develop a comprehensive assessment of community health risks, including assessment of Indigenous health indicators.
	2. Improve and expand healthcare services to meet anticipated increased demand.
	3. Help individuals prepare for potential climate-related health risks by providing public outreach and education

5.5.6. Emergency Services

As discussed in Section 4.7 – Emergency Services, the primary impact of climate change on emergency services is an increasing demand for services in response to environmental and civil emergencies that arise from or are exacerbated by climate change impacts, including extreme weather events, coastal and riverine flooding, and wildfire. One adaptation goal and several adaptation strategies addressing these climate change impacts are presented in this section (Table 5.8).

Adaptation Goal F-1: Improve emergency planning and preparedness.

Adaptation Strategies:

1. *Increase the capacity of the Lummi Nation to respond to climate-related emergencies.* The recommendations of this report in regards to emergency services are consistent with those identified in the Lummi Nation Multi-Hazard Mitigation Plan (2010). These recommendations include: (1) establish a Lummi Nation Division of Emergency Management within the Lummi Nation Police Department and hire an Emergency Manager, (2) continue to update and implement the Lummi Nation Comprehensive Emergency Management Plan, (3) maintain the Multi-Hazard Mitigation Team, and (4) coordinate hazard planning and emergency response efforts with other appropriate jurisdictions and agencies. Emergency management planners can effectively integrate anticipated climate change impacts into programs designed to address current hazards.

2. *Provide public education and outreach to inform residents of potential climate change impacts and ways to prepare for these impacts.* Increasing public awareness of climate change impacts empowers individuals to take steps toward protecting themselves and their families in the event of climate-related emergencies. Outreach activities may build on efforts already underway as part of the Multi-Hazard Mitigation Plan (2010), such as promoting the establishment and maintenance of 72 hour emergency survival kits, sponsoring Safe Streets Walks to promote community disaster awareness, and providing informational brochures and online resources.

Table 5.8 Emergency Services Adaptation Goal and Strategies

Goal	Strategy
F-1: Improve emergency planning and preparedness.	1. Increase the capacity of the Lummi Nation to respond to climate-related emergencies.
	2. Provide public education and outreach to inform residents of potential climate change impacts and ways to prepare for these impacts

5.5.7. Cultural Resources

As discussed in Section 4.8 – Cultural Resources, some of the potential impacts of climate change on cultural resources are damage or loss due to accelerated sea level rise, coastal erosion, wildfire, and/or species range shifts, as well as potential decreases in the abundance and survival of salmon and shellfish. One adaptation goal and two adaptation strategies addressing these climate change impacts are presented in this section (Table 5.8).

Adaptation Goal G-1: Preserve and protect the Lummi Nation's cultural resources.

Adaptation Strategies:

1. *Continue implementing the Cultural Resources Protection Code (LCL Title 40).* The cultural resources of the Lummi Nation are administered and protected by the Cultural

Resources Department in accordance with the Cultural Resources Preservation Code (LCL Title 40). Department actions include managing the Lummi Cultural Resource Register, issuing Cultural Resource Permits, and monitoring implementation of federal laws (e.g., the Native American Graves Protection and Repatriation Act [NAGPRA], the National Historic Preservation Act [NHPA]). Cultural Resources Department staff members are aware of potential climate change impacts and are already taking steps to begin addressing these impacts and ensure the continued protection of cultural resources under future climate scenarios.

2. *Explore the use of Traditional Knowledge (TK) in the context of climate change.* One definition of Traditional Knowledge (TK) is that TK is "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment (NCA 2014)." The potential use of TK to inform climate change assessments and adaption planning has recently received significant attention nationally and internationally. Although the potential benefits of applied TK are widely recognized, it is important that any use of TK be managed to ensure proper protection of tribal cultural resources. As summarized by Dalton et al. (2013), "traditional knowledge can inform tribal and non-tribal understanding of how climate change may impact tribal resources and traditional ways of life. However, its use in climate change initiatives should ensure respect for the values associated with these knowledge systems and protection of sacred knowledge and wisdom, and give tribes decision-making authority over how traditional knowledge is used." A recent publication, *Guidelines for Considering Traditional Knowledges in Climate Change Initiatives* (2014), was developed by tribal and non-tribal participants in the Climate and Traditional Knowledges Workgroup (CTKW) as a framework to guide appropriate use of TK in the context of climate change. This resource may be useful to the Lummi Nation as climate change planning efforts advance.

Table 5.9 Cultural Resources Adaptation Goal and Strategies

Goal	Strategy
G-1: Preserve and protect the Lummi Nation's cultural resources.	1. Continue implementing the Cultural Resources Protection Code.
	2. Explore the use of Traditional Knowledge (TK) in the context of climate change.

5.5.8. Land Use

As discussed in Section 4.9 – Land Use, some of the primary impacts of climate change on land use are reduced effectiveness of existing floodplain infrastructure and increasing property damages to due to flooding, erosion, and wildfire. Adaptation goals and strategies that specifically address flooding were discussed previously in Section 5.5.1 – Water Resources and Section 5.5.2 – Coastal Resources; likewise, wildfire was addressed in Section 5.5.3 – Forest Resources. Because these topics were already covered, this section focuses more broadly on land use planning. One adaptation goal and two strategies addressing land use planning are presented in this section (Table 5.10).

Adaptation Goal H-1: Promote climate-conscious land use planning.

Adaptation Strategies:

1. *Complete a Comprehensive Land Use Plan for the Lummi Nation, taking into account climate change impacts*. The Lummi Planning and Public Works Department (Planning) is developing a Comprehensive Land Use Plan for the Lummi Nation. The purpose of the plan is to guide land use development on the Reservation for the next 20 years in accordance with the community's goal of attaining sustained prosperity and wellness. In addition to guiding policy and actions regarding land use and development, identifying and allocating land for specific uses, prioritizing capital facilities needs, and ensuring protection of critical areas (e.g., wetlands, sensitive habitats, frequently flooded areas, geologically hazard areas), it is recommended that the plan also focus on building a climate resilient community.

2. *Adopt a better, more protective building code*. The Building Code (LCL Title 22) approved by the LIBC in 2004 adopted the 1997 Uniform Building Code (UBC) by reference. However, after publication of the 1997 edition, the regionally-specific Uniform Building Code was replaced by the more widely used International Building Code (IBC). As such, the Lummi Nation is using a model building code that is now nearly 20 years out-of-date. The Lummi Planning and Public Works Department recognizes that a better, more protective building code should be adopted to ensure higher development standards and improved public safety. It is recommended that Planning undertake revision of LCL Title 22 to adopt the most recent version of the IBC, along with supplements and amendments thereto.

Table 5.10 Land Use Adaptation Goal and Strategies

Goal	Strategy
H-1: Promote climate-conscious land use planning.	1. Complete a Comprehensive Land Use Plan for the Lummi Nation, taking into account climate change impacts.
	2. Adopt a better, more protective building code.

5.5.9. Transportation

As discussed in Section 4.10 – Transportation, some of the primary impacts of climate change on transportation are reduced road system integrity and impaired access and circulation. In particular, coastal and riverine flooding may significantly impact roads and bridges on and near the Reservation. One adaptation goal and two strategies addressing transportation are presented in this section (Table 5.11).

Adaptation Goal I-1: Support transportation infrastructure improvements.

Adaptation Strategies:

1. *Continue making transportation infrastructure improvements on the Reservation*. Although Whatcom County is responsible for the maintenance of most of the roads and bridges on and near the Reservation, the tribe has completed several transportation

infrastructure improvements in recent years. For example, a section of Marine Drive prone to flooding was elevated and a self-regulating tide gate installed to provide underflow as part of the Smuggler's Slough Restoration project. This project was completed in 2011 under the direction of the Lummi Natural Resources Department and was the first step in a long-term strategy to alleviate flooding on all flood-prone stretches of Marine Drive. More information on recommended infrastructure upgrades, such as elevating Slater Road and Haxton Way, can be found in the Lummi Nation Multi-Hazard Mitigation Plan.

2. *Collaborate with Washington State and Whatcom County on public works projects*. As described above, both the Lummi Nation and Whatcom County have invested significant resources in road improvements. When opportunities arise and goals align, it may be mutually beneficial for the tribal government, Washington State, and the county to collaborate on public works projects. Teaming up now will help foster good working relationships and benefit projects that arise in the future.

Table 5.11 Transportation Adaptation Goal and Strategies

Goal	Strategy
I-1: Support transportation infrastructure improvements.	1. Continue making transportation infrastructure improvements on the Reservation.
	2. Collaborate with Washington State and Whatcom County on public works projects.

5.5.10. Utilities

As discussed in Section 4.11 – Utilities, there are several impacts of climate change on utilities, ranging from infrastructure damage and service disruptions to higher operating costs and reduced asset life. Several adaptation goals and strategies addressing these climate change impacts are presented in this section (Table 5.12)

Adaptation Goal J-1: Protect the potable groundwater systems on and adjacent to the Reservation.

Adaptation Strategies:

1. *Reduce groundwater withdrawals by implementing voluntary, economic, and/or mandatory water conservation measures.* Saltwater intrusion caused by over pumping has already occurred and resulted in the closures of groundwater extraction wells on the Reservation. If excessive drawdown of groundwater continues, the Reservation's water supplies may become more vulnerable to potential contamination resulting from sea level rise. The Lummi Water Conservation Plan (2004) identifies several avenues to reduce water demand and improve water use efficiency that may be implemented or expanded to reach this goal, including: (1) voluntary measures, (2) economic measures, and (3) mandatory measures. Voluntary water conservation measures include providing public education and outreach, installing water efficient fixtures (e.g., low-flow faucets, showerheads, and toilets) and appliances, preventing and fixing water leaks, and landscaping with native plants and

drought-tolerant vegetation. Economic water conservation measures are primarily focused on adopting a water rate structure that encourages conservation (e.g., more expensive at certain usage levels and/or time periods). Mandatory water conservation measures authorized pursuant to the Water Resources Protection Code (LCL Title 17) may be exercised during droughts or other water supply emergencies and may include restricting nonessential water uses such as lawn watering, car washing, filling swimming pools, washing sidewalks, and irrigating golf courses.

2. *Reevaluate and possibly initiate water reclamation and reuse*. Water reclamation and reuse opportunities on the Reservation and at the Lummi Nation Skookum Creek Hatchery were evaluated by the Lummi Water Resources Division in 1998. At that time, water reclamation and reuse was determined to be cost prohibitive, given the expense to monitor reclaimed water, provide additional treatment to the available wastewater, and convey the reclaimed water to places of reuse, as well as the relatively low cost of potable water (LWRD 2004). A reevaluation of the costs and benefits of water reclamation and reuse opportunities on the Reservation may now be warranted.

Adaptation Goal J-2: Reduce the risk of damage to or failure of wastewater treatment infrastructure.

Adaptation Strategies:

1. *Identify wastewater treatment system vulnerabilities, develop site-specific adaptation strategies, and secure funding for improvement or replacement*. Sea level rise will likely increase saltwater inflow into the wastewater conveyance system, thereby increasing the volume of wastewater that must be transported and treated, increasing energy use and subsequent treatments cost, and increasing maintenance necessary to replace worn or corroded equipment. Reducing the impacts of sea level rise on critical infrastructure requires a proactive approach that begins with identifying potential problems, developing site-specific adaptation strategies, securing funding for improvement or replacement, and implementing changes over time. For instance, the Lummi Tribal Sewer and Water District (LTSWD) has identified Pump Station No. 5 along Lummi Shore Drive as the station most vulnerable to storm surge and high tides and is now seeking funding for improvements (Anderson 2014). In addition, to mitigate the impacts of prolonged power outages that can result due to more severe storm events, the LTSWD has installed back-up generators for all of their wastewater pump stations along Lummi Shore Road and for other stations along their wastewater collection system.

Adaptation Goal J-3: Increase capacity to manage storm water.

Adaptation Strategies:

1. *Reduce storm water runoff through continued implementation of the Lummi Nation Storm Water Management Program.* The goals of the Storm Water Management Program are to (1) minimize the opportunities for storm water to wash pollutants into aquifer recharge zones and resource rich estuaries and tidelands of the Reservation, (2) minimize the downstream impacts of development on storm water quantity and quality, and (3)

maximize the opportunities for infiltration and aquifer recharge. As part of the Storm Water Management Program, Water Resources Division staff members review Storm Water Pollution Prevention Plans (SWPPPs), Large Project Plans, and Site Plans for proposed development on the Reservation, inspect construction sites to ensure compliance with approved pollution prevention measures (e.g., Best Management Practices [BMPs]), and issue CWA Section 401 Certifications for discharges on tribal lands that require federal permits (LWRD 2011a). The program also encourages the use of low impact development (e.g., infiltration swales, dispersion trenches, pervious/porous pavement, wetland area preservation; Low Impact Development [LID]), leading to the successful application of LID practices across the Reservation.

2. *Increase capacity of storm water collection systems to accommodate projected changes in precipitation.* Backup and overflow of storm water facilities from heavy precipitation events, especially during high tide periods, may become more frequent under future climate scenarios. Preventing local flooding as a consequence of inadequate storm water facilities can be prevented by increasing detention storage in areas prone to failure. As discussed previously, Whatcom County is responsible for the maintenance of most of the roads and associated storm water drainage systems on the Reservation. However, the Lummi Nation may also make improvements to storm water infrastructure as necessary.

Table 5.12 Utilities Adaptation Goal and Strategies

Goal	Strategy
J-1: Protect the potable groundwater systems on and adjacent to the Reservation.	1. Reduce groundwater withdrawals by implementing voluntary, economic, and/or mandatory water conservation measures.
	2. Reevaluate and possibly initiate water reclamation and reuse.
J-2: Reduce the risk of damage to or failure of wastewater treatment infrastructure.	1. Identify wastewater treatment system vulnerabilities, develop site-specific adaptation strategies, and secure funding for improvement or replacement.
J-3: Increase capacity to manage storm water.	1. Reduce storm water runoff through continued implementation of the Lummi Nation Storm Water Management Program.
	2. Increase capacity of storm water collection systems to accommodate projected changes in precipitation.

5.6. Core Concepts for Strategy Development

Four core concepts regarding climate mitigation and adaptation are drawn from this chapter. These concepts lend insight into which climate preparedness actions should be prioritized for implementation over the 2016-2026 period. The core concepts are:

1. The most effective climate mitigation strategy on the Reservation will be improving energy conservation.

2. Property and infrastructure damage will likely result from extreme weather events, especially flooding and wildfire, rather than gradual changes in climate. Planning for extremes will provide high levels of protection and ensure that the community is making climate resilient investments.

3. In the natural system, climate change will exacerbate existing problems. Thus, building climate resilient ecosystems will require a reduction in existing stressors. This will present challenges to already imperiled systems, but also an opportunity to make needed improvements.

4. Whereas climate mitigation is largely about carbon, climate adaptation will largely be about water. The importance of water is ubiquitous across the Reservation's natural, social, and built systems and problems related to water quality and quantity are going to become a more critical issue under future climate conditions.

5.7. Mitigation and Adaptation Action Plan 2016-2026

The key recommendations for implementing climate mitigation and adaption actions on the Reservation that will protect public health and the environment are:

1. Establish and maintain a Climate Preparedness Planning Committee with representatives from the Lummi Indian Business Council (LIBC), the Police, Planning and Public Works, Natural Resources, and Cultural Resources departments, the Lummi Tribal Health Center, the Lummi Tribal Sewer and Water District (LTSWD), the Lummi Commercial Company (LCC), the Lummi Housing Authority (LHA), and the Northwest Indian College (NWIC) to provide guidance and oversight in climate mitigation and adaptation planning.

2. Provide community education and outreach to increase awareness of and preparation for climate change impacts and engender community support for climate mitigation and adaption.

3. Focus initial efforts in climate mitigation and adaptation on the following high priority items as determined from the core concepts for strategy development:

    a. Improve building-, behavior-, and transportation-related energy efficiency.

    b. Improve emergency preparedness planning and response capabilities (Goal F-1).

    c. Implement flood risk reduction measures (Goal A-1 and Goal B-1).

    d. Implement wildfire risk reduction measures (Goal C-1).

    e. Reduce existing stressors to salmon populations (Goal D-1).

    f. Improve water quality in shellfish harvest areas (Goal D-2).

    g. Restore and protect instream flow in the Nooksack River basin (Goal A-2).

h. Protect the potable groundwater systems on and adjacent to the Reservation (Goal J-1).

4. Further refine and prioritize climate mitigation and adaptation strategies for implementation based on guidance of the Climate Preparedness Planning Community, community feedback, the recommendations of this report, and other vulnerability assessments as appropriate.

5. Identify and obtain funding to implement selected mitigation and adaptation strategies and determine which tribal entity will be responsible for implementation.

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6. CONCLUSION

The potential impacts of climate change on the Lummi Nation are significant and diverse. These impacts include, but are not limited to, increasing surface temperature, changes in precipitation (i.e., wetter winters, drier summers), changes in the seasonality and magnitude of streamflow (i.e., higher winter flows, earlier spring snowmelt, lower summer flows), increasing extent, frequency, and/or intensity of extreme weather events (e.g., flooding, wildfire, heat waves, drought), and changes in the coastal ocean (i.e., increasing sea surface temperature, sea level rise, ocean acidification). Furthermore, an assessment of the vulnerability (i.e., susceptibility to harm) of the Reservation's natural, social, and built systems to climate change indicates that the majority of planning areas on the Reservation have a high level of vulnerability to climate change impacts.

Building a climate resilient community in the face of these impacts will require coordinated and comprehensive climate preparedness planning. Climate preparedness should include implementation of both climate mitigation and climate adaptation strategies. Climate mitigation means taking action to reduce greenhouse gas concentrations in the atmosphere, the quantity of which will determine the extent and severity of climate change over the coming decades-to-centuries. Although the Reservation accounts for only a relatively minor contribution to global carbon emissions, achieving emissions reduction goals globally will require universal support and participation. Accordingly, the recommendations of this Lummi Nation Climate Change Mitigation and Adaptation Plan: 2016-2026 (CCMAP) are to undertake action on climate mitigation as soon as practicable. To address climate change impacts that are already occurring and impacts that will unavoidably occur in the future regardless of mitigation efforts, it is also recommended that the Lummi Nation take action on climate adaptation as soon as practicable. Several climate mitigation and adaptation strategies are provided for the natural, built, and social systems on the Reservation.

The key recommendations for implementing climate mitigation and adaption actions on the Reservation that will help protect public health and the environment are:

1. Establish and maintain a Climate Preparedness Committee with, at a minimum, one representative from the LIBC, the Natural Resources Department, the Planning and Public Works Department, and the Cultural Resources Department and two representatives from the General Council to provide guidance and oversight in climate mitigation and adaptation planning. Committee membership may be expanded to include additional tribal institutions as is deemed necessary or desirable, for instance the Police Department, the Lummi Tribal Health Center, the Lummi Tribal Sewer and Water District (LTSWD), the Lummi Commercial Company (LCC), the Lummi Housing Authority (LHA), the Northwest Indian College (NWIC), and others may also be considered.

2. Provide community education and outreach to increase awareness of and preparation for climate change impacts and engender community support for climate mitigation and adaption.

3. Focus initial efforts in climate mitigation and adaptation on the following high priority items as determined from the core concepts for strategy development:

    a. Improve building-, behavior-, and transportation-related energy efficiency.

    b. Improve emergency preparedness planning and response capabilities.

    c. Implement flood risk reduction measures.

    d. Implement wildfire risk reduction measures.

    e. Reduce existing stressors to salmon populations.

    f. Improve water quality in shellfish harvest areas.

    g. Restore and protect instream flow in the Nooksack River basin.

    h. Protect the potable groundwater systems on and adjacent to the Reservation.

4. Further refine and prioritize climate mitigation and adaptation strategies for implementation based on guidance of the Climate Preparedness Planning Community, community feedback, the recommendations of this report, and other vulnerability assessments as appropriate.

5. Identify and obtain funding to implement selected mitigation and adaptation strategies and determine which tribal entity will be responsible for implementation.

7. REFERENCES

Anderson, C. 2014. Personal Communication with Lummi Tribal Sewer and Water District (LSTWD) District Manager – Email August 25, 2014.

Alexander, D., and R.N. Palmer. 2007. *Technical Memorandum #8: Impacts of Climate Change on Groundwater Resources – A Literature Review*. Prepared by the Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, Seattle, Washington.

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney, and N. Mantua. 2012. *Restoring Salmon Habitat for a Changing Climate*. River Research and Applications. Published online, DOI: 10.1002/rra.2590.

Boese, B. L., B. D. Robbins, and G. Thursby. 2005. *Desiccation is a Limiting Factor for Eelgrass (Zostera Marina L.) Distribution in the Intertidal Zone of a Northeastern Pacific (USA) Estuary*. Botanica Marina 48:274-283.

Bond, N.A., M.F. Cronin, H. Freeland, and N. Mantua. 2015. *Causes and Impacts of the 2014 Warm Anomaly in the NE Pacific*. Geophysical Research Letters 42: 3,414-3,420.

Bortleson, G.C., M.J. Chrzastowski, and A.K. Helgerson. 1980. *Historical Changes of Shoreline and Wetland at Eleven Major Deltas in the Puget Sound Region, Washington*. U.S. Geological Survey. Hydrologic Investigations Atlas HA-617.

City of Bellingham (COB). 2014. *Lake Whatcom Reservoir Watershed Challenges: Climate Change*. http://www.cob.org/services/environment/lake-whatcom/climate-change.aspx. Website accessed August 20, 2014.

City of Bellingham (COB). 2014. *City of Bellingham: Climate Protection Program*. http://www.cob.org/services/environment/climate/. Website accessed October 28, 2014.

Climate and Traditional Knowledges Workgroup (CTKW). 2014. *Guidelines for Considering Traditional Knowledges in Climate Change Initiatives*. http://climatetkw.wordpress.com/. Website accessed December 15, 2014.

Climate Change Impacts in the United States: The Third National Climate Assessment (NCA). 2014a. *Chapter 2: Our Changing Climate.* J. Walsh, D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville. Prepared for the U.S. Global Change Research Program.

Climate Change Impacts in the United States: The Third National Climate Assessment (NCA). 2014b. *Chapter 12: Indigenous Peoples, Land, and Resources.* Bull Bennett, T.M., N.G Maynard, P. Cochran, R. Gough, K. Lynn, J. Maldonado, G. Voggesser, S. Wotkyns, and K. Cozzetto. Prepared for the U.S. Global Change Research Program.

Climate Change Impacts in the United States: The Third National Climate Assessment (NCA). 2014c. *Chapter 21: Northwest.* P. Mote, A.K. Snover, S. Capalbo, S.D. Eigenbrode, P. Glick, J. Littell, R. Raymondi, and S. Reeder. Prepared for the U.S. Global Change Research Program.

Cline, D.R. 1974. *A Ground Water Investigation of the Lummi Indian Reservation Area, Washington*. Tacoma, U.S. Geological Survey, Open-File Report.

Coastal Geological Services, Inc. 2007. *Final Lummi Reservation Coastal Protection Guidelines*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Crooks, S., Rybczyk, J., O'Connell, K., Devier, D.L., Poppe, K., Emmett-Mattox, S. 2014. *Coastal Blue Carbon Opportunity Assessment for the Snohomish Estuary: The Climate Benefits of Estuary Restoration*. Report by Environmental Science Associates, Western Washington University, EarthCorps, and Restore America's Estuaries. February 2014.

Czuba, J.A., C.S. Magirl, C.R. Czuba, E.E. Grossman, C.A. Curran, A.S. Gendaszek, and R.S. Dinicola. 2011. *Sediment Loads from Major Rivers into Puget Sound and its Adjacent Waters*. U.S. Geological Survey Fact Sheet 2011-3083.

Dalton, M.M., P.W. Mote, and A.K. Snover (eds). 2013. *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*. Island Press, Washington DC.

Deardorff, L. 1992. *A Brief History of the Nooksack River's Delta Distributaries*. Lummi Nation Fisheries Department.

Dickerson-Lange, S.E. and R. Mitchell. 2013. *Modeling the Effects of Climate Change Projections on Streamflow in the Nooksack River Basin, Northwest Washington*. Hydrological Processes, Published Online in Wiley Online Library.

DNV-KEMA. 2012. *Wind Resource and Feasibility Assessment Report for the Lummi Reservation*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Donatuto, J. E.E. Grossman, J. Konovsky, S. Grossman, and L.W. Campbell. 2014. *Indigenous Community Health and Climate Change: Integrating Biophysical and Social Science Indicators*. Coastal Management 42:355-373.

Federal Emergency Management Agency (FEMA). 2004. *Flood Insurance Study: Whatcom County, Washington (All Jurisdictions).* FIS No. 53073CV000A. Prepared by Michael Baker, Jr., Inc. January 16, 2004.

Feely, R., M. Chadsey, J. Newton, T. Klinger, B. Hales and J. Mathis. 2014). *Ocean Acidification in the Pacific Northwest*. Prepared for the West Coast Ocean Acidification and Hypoxia Science Panel.

Frans, C. 2014. *Regional Patterns of Evolving Glacio-Hydrologic Processes in the Pacific Northwest*. Presentation at the Fifth Annual Pacific Northwest Climate Science Conference. September 9, 2014.

Gillies, J. 1998. Personal Communication – Meeting Notes April 13, 1998.

Glick, P., J. Clough, and B. Nunley. 2007. *Sea Level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon*. Prepared for the National Wildlife Federation (NWF).

Hamlet, A.F., S. Lee, K.E.B. Mickelson, and M.M. Elsner. 2010. *Effects of Projected Climate Change on Energy Supply and Demand in the Pacific Northwest and Washington States*. Climatic Change, 102: 103-128.

Hamlet, A.F., M.M. Elsner, G. Mauger, S-Y Lee, and I. Tohver. 2013. *An Overview of the Columbia Basin Climate Change Scenarios Project: Approach, Methods, and Summary of Key Results*. Atmosphere-Ocean, Volume 51, Issue 4.

Harper, K. 1999. *Lummi Nation Wetland Inventory Technical Report*. Sheldon and Associates, Inc., Seattle, Washington. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Institute for Tribal Environmental Professionals (ITEP). 2014. *Climate Change Adaptation Planning*. Workshop at the National Tribal Forum on Air Quality. May 12, 2014.

Intergovernmental Panel on Climate Change (IPCC). 2013. *Summary for Policymakers: The Physical Science Basis.* T.F. Stocker, D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds). Contribution of Working Group I to the Fifth Assessment Report of the IPCC. Cambridge, United Kingdom.

Jamestown S'Klallam Tribe. 2013. *Climate Change Vulnerability Assessment and Adaptation Plan*. S. Peterson and J. Bell (eds). A collaboration of the Jamestown S'Klallam Tribe and Adaptation Internationals.

Kamkoff, V. 2011. *Personal Communication with Jeremy Freimund*.

King County, Washington. 2012. *Hydraulic Analysis of Effects of Sea-Level Rise on King County's Wastewater System: Phase I Report*. Prepared by the Department of Natural Resources and Parks – Wastewater Treatment Division. Seattle, Washington.

Kroeker, K.J., R.L. Kordas, R.N. Crim, and G.G. Singh. 2010. *Meta-Analysis Reveals Negative Yet Variable Effects of Ocean Acidification on Marine Organisms*. Ecology Letters 13: 1419-1434.

Leckman, S. 1990. *A Forest History of the Lummi Indian Reservation*.

Lee, S., A.F. Hamlet, and E.E. Grossman. In press. *Impacts of Climate Change on Regulated Streamflow, Flood Control, Hydropower Production, and Sediment Discharge in the Skagit River Basin*. Northwest Science.

Littell, J.S., E.E. Oneil, D. McKenzie, J.A., Hicke, J.A. Lutz, R.A. Norheim, and M.M. Elsner. 2010. *Forest Ecosystems, Disturbance, and Climatic Change in Washington State, USA*. Climatic Change, Volume 102: 129-158.

Lummi Indian Business Council (LIBC). 1996. *Lummi Nation Comprehensive Environmental Land Use Plan: Background Document*. LIBC, Bellingham, Washington.

Lummi Indian Business Council (LIBC). 2003. *2003 Lummi Tribal Survey*. LIBC, Bellingham, Washington.

Lummi Natural Resources Department (LNR). 2010. *Lummi Intertidal Baseline Inventory*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Lummi Natural Resources Department (LNR). 2011. *Lummi Nation Forest Management Plan*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Lummi Tribal Sewer and Water District (LTSWD). 2014. *Lummi Tribal Water System*. http://ltswd.com/. Website accessed March 23, 2014.

Lummi Water Resources Division (LWRD). 2000. *Lummi Indian Reservation Wetland Management Program Technical Background Document*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Lummi Water Resources Division (LWRD). 2004. *Water Conservation Plan for the Lummi Indian Reservation*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Lummi Water Resources Division (LWRD). 2010. *Lummi Nation Multi-Hazard Mitigation Plan*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Lummi Water Resources Division (LWRD). 2011a. *Lummi Nation Storm Water Management Program Technical Background Document, 2011 Update*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Lummi Water Resources Division (LWRD). 2011b. *Lummi Nation Wellhead Protection Program*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Lummi Water Resources Division (LWRD). 2015. *Lummi Nation Strategic Energy Plan: 2016-2026*. Prepared for Lummi Indian Business Council, Bellingham, Washington.

Lummi Water Resources Division (LWRD). 1988. *Lummi Nation Coastal Zone Management Plan*. Prepared for the Lummi Indian Business Council, Bellingham, Washington.

Lynn, K., J. Daigle, J. Hoffman, F. Lake, N. Michelle, D. Ranco, C. Viles, G. Voggesser, and P. WIlliams. 2013. *The Impacts of Climate Change on Tribal Traditional Foods*. Climatic Change. Published online, DOI: 10.1007/s10584-013-0736-1.

Mantua N., I. Tohver, and A. Hamlet. 2010. *Climate Change Impacts on Streamflow Extremes and Summertime Stream Temperature ant Their Possible Consequences for Freshwater Salmon Habitat in Washington State*. Climatic Change, Volume 102.

Moore, S.K., V.L. Trainer, N.J. Mantua, M.S., Parker, E.A. Laws, L.C. Backer, L.A. Fleming. 2008. *Impacts of Climate Variability and Future Climate Change on Harmful Algal Blooms and Human Health*. Environmental Health 7 (Suppl. 2): S4.

National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. 2006. *Regional Land Cover Database: Data Collected 1995-Present*. Charleston, SC. Data accessed at www.csc.noaa.gov/landcover.

National Oceanic and Atmospheric Administration (NOAA). 2012. *Scientific Summary of Ocean Acidification in Washington State Marine Waters.* R.A. Freely, T. Klinger, J.A. Newton, M. Chadsey (eds). NOAA OAR Special Report prepared for the Washington State Blue Ribbon Panel on Ocean Acidification.

National Oceanic and Atmospheric Administration (NOAA). 2015. *2014: Annual Summary of Ocean Ecosystem Indicators and Pre-Season Outlook for 2015*. http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/b-latest-updates.cfm. Website accessed March 31, 2015.

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

Northern Economics, Inc. (NEI). 2005. *Lummi Nation Workforce Skills Inventory and Analysis: Final Report*. Northern Economics, Inc., Bellingham, WA. Prepared for the Lummi Development Authority and Lummi Indian Business Council, Bellingham, Washington.

Northwest Indian Fisheries Commission (NWIFC). 2012. *Tribal Online Accounting System (TOCAS)*. http://access.nwifc.org/webapps/. Website accessed January 2012.

Office of the Washington State Climatologist (OSWC). 2015. *Office of the Washington State Climatologist Newsletter: June 2014.* http://www.climate.washington.edu/newsletter/. Website accessed March 31, 2015.

Pacific Northwest Geodetic Array (PANGA) Central Washington University. 2014. *GPS Data by Site*. http://www.panga.cwu.edu/data/bysite/. Website accessed May 21, 2014.

Peterson, D. 2014. *Understanding and Managing the Effects of Climate Change on Pacific Northwest Forests*. Webinar prepared for Northern Arizona University's (NAU) Institute for Tribal Environmental Professionals (ITEP) – Climate Change Impacts on Forests. http://www4.nau.edu/itep/climatechange/tcc_webinars.asp. Website accessed July 16, 2014.

Pierson, W. 1953. *The Geography of the Bellingham Lowland, Washington*. University of Chicago, Department of Geography Research Paper No. 28. University of Chicago Press, Chicago, Illinois.

Point, F. 2014. *Personal communication with Flavian Point, Shellfish Manager, Lummi Shellfish Hatchery*. August 26, 2014.

Puget Sound Energy (PSE). 2014. *Puget Sound Energy (PSE): Green Power.* http://pse.com/savingsandenergycenter/GreenPower/. Website accessed October 27, 2014.

Puget Sound Nearshore Ecosystem Restoration Project (PSNERP). 2012. *Puget Sound Nearshore Ecosystem Restoration Project: Strategic Restoration Conceptual Engineering – Design Report*. Prepared for the U.S. Army Corps of Engineers (ACOE) and the Washington Department of Fish and Wildlife (WDFW).

Rogers, B.M., R.P. Neilson, R. Drapek, J.M. Lenihan, J.R. Wells, D. Bachelet, and B.E. Law. 2011. *Impacts of Climate Change on Fire Regimes and Carbon Stocks of the U.S. Pacific Northwest*. Journal of Geophysical Research, Volume 116: G03037.

Snover, A.K., L. Whitely Binder, J. Lopez, E. Willmott, J. Kay, D. Howell, and J. Simmonds. 2007. *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*. In association with and published by ICLEI – Local Governments for Sustainability, Oakland, California.

Smelser, C. 1970. *Sequent Occupance of the Nooksack River Valley and the Influence of Man on the Rate of Sediment Delivery to Bellingham Bay*. Master of Science Thesis, Western Washington State College, Bellingham, Washington.

Suhrbier, A. 2014. Personal Communication with Pacific Shellfish Institute scientist – Meeting August 26, 2014.

Swinomish Indian Tribal Community (Swinomish). 2010. *Swinomish Climate Change Initiative Climate Adaptation Action Plan.* Report prepared for the Swinomish Indian Tribal Community. La Conner, Washington

Thom, R., S. Southard, A. Borde, and P. Stoltz. 2008. *Light Requirements for Growth and Survival of Eelgrass (Zostera Marina L.) in Pacific Northwest (USA) Estuaries*. Estuaries and Coasts 31:969-980.

University of Washington Climate Impacts Group (CIG). 2013. *Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers.* A.K. Snover, G.S. Mauger, L.C. Whitely Binder, M. Krosby, and I. Tohver. State of Knowledge Report prepared for the Washington State Department of Ecology. Seattle, Washington.

University of Washington Climate Impacts Group (CIG). 2009. *The Washington Climate Change Impacts Assessment*. M. McGuire Elsner, J. Littell, and L Whitely Binder (eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington.

University of Washington Climate Impacts Group (CIG). 2008. *Sea Level Rise in the Coastal Waters of Washington State*. P. Mote, A. Petersen, S. Reed, H. Shipman, and L. Whitely Binder. Seattle, Washington.

U.S. Army Corps of Engineers (ACOE). 1997. *Detailed Project Report: Lummi Shore Protection Project, Lummi Indian Reservation, Whatcom County, Washington*. Corps of Engineers, Seattle District, Washington.

U.S. Department of Agriculture – Soil Conservation Service (USDA). 1992. *Soil Survey of Whatcom County Area, Washington*.

U.S. Bureau of Indian Affairs (BIA). 1999. *Indian Service Population and Labor Force Estimates*. U.S. Department of the Interior, Bureau of Indian Affairs.

U.S. Global Change Research Program (USGCRP). 2014. *U.S. Global Change Research Program (USGCRP): About Us*. http://www.globalchange.gov. Website accessed September 19, 2014.

Valz, E. 2003. *LIBC and NWIC Employment Information*. Lummi Nation Statistics Department. Bellingham, WA.

Wade, A.A, T.J. Beechie, E. Fleishman, N.J. Mantua, H. Wu, J.S. Kimball, D.M. Stoms, and J.A. Stanford. 2013. *Steelhead Vulnerability to Climate Change in the Pacific Northwest*. Journal of Applied Ecology 50:1093-1104.

Washington State Blue Ribbon Panel on Ocean Acidification (Blue Ribbon Panel). 2012. *Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response.* H. Adelsman and L. Whitely Binder (eds). Washington State Department of Ecology (Ecology), Olympia, Washington. Publication No. 12-01-015.

Washington State Department of Conservation (WSDC). 1960. *Water Resources of the Nooksack River Basin and Certain Adjacent Streams*. Water Supply Bulletin No. 12.

Washington State Department of Ecology (Ecology). 2012. *Preparing for a Changing Climate: Washington State's Integrated Climate Response Strategy*. Publication No. 12-01-004.

Washington State Department of Health (DOH). 1997. *Sanitary Survey of Portage Bay*. Office of Shellfish Programs.

Washington State Department of Health (DOH). 2012. *Cryptococcus Speciation: Why is it Important?* EpiTrends: A Monthly Bulletin on Epidemiology and Public Health Practice in Washington, Vol. 17, No. 1.

Washington State Department of Health (DOH). 2014. *West Nile Virus Surveillance Maps and Statistics*. http://www.doh.wa.gov/DataandStatisticalReports/DiseasesandChronicConditions/WestNileVirus. Website accessed August 13, 2014.

Werner, K. 2007. *Personal communication with Kevin Werner, Assistant General Manager, Silver Reef Hotel, Casino & Spa*. February 19, 2007.

Western Washington University (WWU). 2013. *Top 25 Employers in Whatcom County*. Western Washington University, College of Business and Economics, Center for Economics and Business Research, Bellingham, WA. http://cbe.wwu.edu/cebr/documents/top25employersinwhatcomcounty2013.pdf.

Whatcom County. 2005. *Whatcom County Comprehensive Plan*. Whatcom County Planning Department, Bellingham, Washington. http://www.co.whatcom.wa.us/pds/planning/comp_plan/comp_plan.jsp.

World Health Organization (WHO). 2014. *Health Topics: Climate Change*. http://www.who.int/topics/climate/en/. Website accessed August 11, 2014.

8. GLOSSARY

The following key terms are used throughout this assessment and were provided by the Institute for Tribal Environmental Professionals (ITEP 2014) and the University of Washington Climate Impacts Group (Snover 2007).

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

Adaptive Capacity: the ability of a system to accommodate or respond to the changes in climate with minimum disruption or cost. Generally, systems that have high adaptive capacities are better able to deal with climate change.

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

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

Climate Resilient Community: a community that takes proactive steps to prepare for (i.e., reduce the vulnerabilities and risks associated with) climate change impacts.

Global Warming: average increase in the temperature of the atmosphere, which can contribute to changes in global climate patterns. Global warming can occur from a variety of causes, both natural and human induced.

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

Mitigation (climate change): actions that reduce the levels of greenhouse gases in the atmosphere; includes reducing emissions of greenhouse gases and enhancing sinks (things that absorb more greenhouse gases than they emit). Examples include switching to renewable energy sources and implementing energy efficiency measures.

Planning Area: this is an area in which the tribal government manages, plans, or makes policy affecting the services and activities associated with built, human, and natural systems. For example, within the sector Utilities, you might have planning areas of Water Supply, Wastewater Treatment, Storm Water Management, and Energy Supply.

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

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

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

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

9. ACRONYMS AND ABBREVIATIONS

Programs, Terms, Agencies, and Organizations:	
BIA	Bureau of Indian Affairs
BMPs	Best Management Practices
CIG	University of Washington Climate Impacts Group
Corps/ACOE	United States Army Corps of Engineers
County	Whatcom County
CWA	Clean Water Act
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GHG	Greenhouse Gas
IAQ	Indoor Air Quality
IPCC	Intergovernmental Panel on Climate Change
LCL	Lummi Nation Code of Laws
LIBC	Lummi Indian Business Council
LIBI	Lummi Intertidal Baseline Inventory
LiDAR	Light Detection and Ranging
LNR	Lummi Natural Resources Department
LTSWD	Lummi Tribal Sewer and Water District
LWRD	Lummi Water Resources Division
MBR	Membrane Bio Reactor
MHMP	Lummi Nation Multi-Hazard Mitigation Plan
NCA	National Climate Assessment
NOAA	National Oceanic and Atmospheric Administration
NAVD88	North American Vertical Datum 1988
NWIC	Northwest Indian College
NWIFC	Northwest Indian Fisheries Commission
OA	Ocean Acidification
Planning	Lummi Planning and Public Works Department
PSE	Puget Sound Energy
RCP	Representative Concentration Pathway
Reservation	Lummi Indian Reservation
SFHA	Special Flood Hazard Area
SWDA	Safe Drinking Water Act
SWPPP	Storm Water Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TRC	Technical Review Committee
TK	Traditional Knowledge
Treaty	1855 Treaty of Point Elliott
U&A	Usual and Accustomed
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
WRIA 1	Water Resources Inventory Area 1
WWTP	Wastewater Treatment Plant

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APPENDIX A

LIBC RESOLUTION NO. 2014-084

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LUMMI INDIAN BUSINESS COUNCIL

2665 KWINA ROAD • BELLINGHAM, WASHINGTON 98226 • (360) 312-2000

RESOLUTION #2014-084 OF THE LUMMI INDIAN BUSINESS COUNCIL

TITLE: Guiding Principles to Address Climate Change

WHEREAS, the Lummi Indian Business Council is the duly constituted governing body of the Lummi Indian Reservation by the authority of the Constitution and By-laws of the Lummi Tribe of the Lummi Reservation, Washington; and

WHEREAS, it is the Mission of the Lummi Indian Business Council "To Preserve, Promote, and Protect our Sche Lang en and Work Together as One Mind and One Spirit"; and

WHEREAS, the Lummi Indian Business Council has the power to safeguard and promote the peace, safety, morals, and general welfare of the Lummi Reservation pursuant to Section VI, Section 1(l) of the Lummi Constitution; and

WHEREAS, there is overwhelming scientific evidence that global climate change, which includes observed 20^{th} century warming (global warming), ocean acidification, sea level rise, increased frequency and intensity of storm events, glacial retreat, and other impacts are driven by anthropogenic activities including the burning of fossil fuels and the release of greenhouse gases into the atmosphere; and

WHEREAS, the Lummi Nation like other place-based American Indian and Alaska Native people live on the front lines of a changing world, where the disruptions to our natural resources caused by changes in the climate are having real and measurable effects on the livelihoods of our people; and

WHEREAS, we agree with President Obama that responding to the very real threat of climate change is a moral obligation to future generations; and

WHEREAS, the effects of climate change, evident on local, regional, and global scales, will significantly impact the Lummi Nation due to local climate change impacts, and other associated effects on the local environment, natural resources, and infrastructure on which the Lummi Nation has traditionally relied; and

WHEREAS, it is the duty and responsibility of the Lummi Nation to provide for the well-being of the community, its local environment, natural resources, and social systems; and

WHEREAS, through traditional knowledge, practice, experience, and relationships with nature the Lummi Nation has an important role in defending, restoring, and healing the natural environment; and

WHEREAS, under Executive Order 13175 and the United Nations Declaration on the Rights of Indigenous Peoples, tribal Nations have the right to be involved directly in all decision-making; and

NOW THEREFORE BE IT RESOLVED, the Lummi Nation will undertake effort as soon as practicable to determine the potential local effects of climate change as may affect the Lummi Nation, including effects and projected impacts on the local environment, forestry resources, fish and wildlife, water resources, as well as critical infrastructure and public health and shall:

(1) develop appropriate policies and strategies for adapting to effects and projected impacts of climate change on the Lummi Nation and for contributing to reduction of the causes of climate change and global warming by reducing emission of heat trapping green house gases through renewable energy production and energy efficiency practices;

(2) develop appropriate goals for addressing effects of climate change and for contributing to reduction of the causes of climate change;

(3) develop potential programmatic and/or regulatory actions and changes consistent with said policies, strategies, and goals as appropriate to addressing the effects of climate change and contributing to reduction of the causes;

(4) communicate and coordinate with other tribes as well as local, state, regional, national, and international entities and jurisdictions on addressing projected impacts of climate change, including government-to-government cooperation and identification of funding sources and opportunities as possible and available;

(5) inform the Lummi people about issues and concerns regarding the causes, effects, and projected impacts of climate change; and

BE IT FURTHER RESOLVED, the Lummi Nation commits to collaborating with the Affiliated Tribes of Northwest Indians (ATNI) and the National Congress of American Indians (NCAI) to develop an action plan which lays guiding principles and action steps to address the impacts of climate change upon tribal governments, cultures, and lifeways; that will protect and advance our treaty, inherent and indigenous rights, tribal lifeways and ecological knowledge; and

BE IT FURTHER RESOLVED, that the Lummi Nation shall collaborate with ATNI and NCAI to evaluate effectiveness of Executive Order 13175, and Secretarial Order 3289, and the United Nation Declaration of Indigenous Peoples (UNDRIP), in protecting and advancing the principles in the context of addressing the causes, effects, and response to global warming and climate change; and

BE IT FURTHER RESOLVED, that the Lummi Nation declares that it is the Federal Government's Trust responsibility to provide the tribes equitable opportunities and funding to participate meaningfully in the development and implementation of federal climate change policies and programs; and

BE IT FINALLY RESOLVED, that the Chairman (or Vice Chair in his absence) is hereby authorized and directed to execute this resolution and any documents connected therewith, and the Secretary (or the Recording Secretary in his absence) is authorized and directed to execute the following certification.

LUMMI NATION

Timothy Ballew II, Chairman
Lummi Indian Business Council

CERTIFICATION

As Secretary of the Lummi Indian Business Council, I hereby certify that the above Resolution **#2014-084** was adopted at a Regular/Special Meeting of the Council held on the **27th** day of **May,** 2014, at which time a quorum of **9** was Present by a vote of **8** For, **0** Against and **0** Abstention (s).

Jeremiah Julius, Secretary
Lummi Indian Business Council

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APPENDIX B

LIBC RESOLUTION NO. 2016-040

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LUMMI INDIAN BUSINESS COUNCIL
2665 KWINA ROAD • BELLINGHAM, WASHINGTON 98226 • (360) 312-2000

RESOLUTION #2016-040 OF THE LUMMI INDIAN BUSINESS COUNCIL

TITLE: Adoption of the Lummi Nation Climate Change Mitigation and Adaptation Plan 2016-2026

WHEREAS, the Lummi Indian Business Council (LIBC) is the duly constituted governing body of the Lummi Nation by the authority of the Constitution and Bylaws, as amended, of the Lummi Tribe of the Lummi Reservation, Washington; and

WHEREAS, pursuant to Article VI, Section (l) of the Lummi Constitution, the LIBC is required to safeguard and promote peace, safety, and welfare of the Lummi People and the Lummi Reservation community; and

WHEREAS, it is the mission of the LIBC "*To Preserve, Promote and Protect our Sche Lang en*" (LIBC Resolution #2012-025); and

WHEREAS, the LIBC is responsible for the protection, restoration, enhancement, and management of the natural resources within the exterior boundaries of the Lummi Reservation and throughout the Lummi Nation's usual and accustomed fishing grounds and stations (U & A) and hunting and gathering territories; and

WHEREAS, the LIBC adopted Resolution #2014-084 "*Guiding Principles to Address Climate Change*" resolving that the Lummi Nation will undertake efforts as soon as practicable to develop appropriate goals, strategies, and policies to address the local effects of climate change on the Lummi Nation and contribute to a reduction of the causes of climate change; and

WHEREAS, the Lummi Natural Resources Department (LNR) has developed the Lummi Nation Climate Change Mitigation and Adaptation Plan: 2016-2026 (CCMAP), pursuant to LIBC Resolution #2014-084; and

WHEREAS, the current and potential future impacts of climate change include, but are not limited to, increasing surface temperature (i.e., global warming), changes in precipitation (i.e., wetter winters, drier summers), changes in the seasonality and magnitude of streamflow (i.e., higher winter flows, earlier spring snowmelt, lower summer flows), increasing extent, frequency, and/or intensity of extreme weather events (e.g., heat waves, drought, flooding, wildfire), and changes in the coastal ocean (i.e., increasing sea surface temperature, sea level rise, ocean acidification); and

WHEREAS, the CCMAP provides a comprehensive analysis of these climate change impacts on and potential mitigation and adaptation strategies for the natural, social, and built systems of the Lummi Reservation and throughout the Lummi Nation's U&A and hunting and gathering territories; and

WHEREAS, the implementation of the climate preparedness actions outlined in the CCMAP will help make the Lummi Nation more resilient to climate change; and

WHEREAS, the LNR Department Director and Deputy Director (meeting on December 1, 2015), the Lummi Fisheries and Natural Resources Commission (meeting on December 3, 2015), and the Lummi Planning Commission (meeting on December 8, 2015) met to review and discuss the CCMAP, and recommend that the LIBC adopt the CCMAP.

NOW, THEREFORE, BE IT RESOLVED that the LIBC adopts the Lummi Nation CCMAP: 2016-2026, in substantial conformity to the attached document; and

BE IT FURTHER RESOLVED that the LIBC authorizes the formation of a Climate Preparedness Committee with, at a minimum, one representative each from the LIBC, the LNR, the Planning and Public Works Department, the Cultural Resources Department, and two representatives from the General Council to provide guidance and oversight in climate mitigation and adaptation planning; and

BE IT FINALLY RESOLVED that the Chairman (or Vice Chair in his absence) is hereby authorized and directed to execute this resolution and any documents connected therewith, and the Secretary (or the Recording Secretary in her absence) is authorized and directed to execute the following certification.

LUMMI NATION

[signature]

Timothy Ballew II, Chairman
Lummi Indian Business Council

CERTIFICATION

As Secretary of the Lummi Indian Business Council, I hereby certify that the above Resolution **#2016-040** was adopted at a **Regular/Special** Meeting of the Council held on the **16th** day of **February, 2016**, at which time a quorum of **11** was present by a vote of **10** for, **0** against, and **0** abstention(s).

[signature]

Shasta Cano-Martin, Secretary
Lummi Indian Business Council

APPENDIX C

SUMMARY VULNERABILITY RANKINGS TABLE

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Table C-1 Summary Vulnerability Rankings Table

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
WATER RESOURCES				
Freshwater	Increasing volume of winter streamflow, more frequent and higher magnitude flood events	High	Low	High
	Decreasing volume of summer streamflow	High	Low	High
	Increasing stream temperature	High	Low	High
	Increasing sediment loads from glacial and snowfield retreat, bank erosion, mass wasting events (e.g., landslides), wildfire activity	Medium	Low	Medium-High
Groundwater	Increasing salinization from saltwater intrusion	High	Low	High
	Possible changes in aquifer recharge	-	-	-
Wetlands	Increasing inundation of estuarine wetlands from relative sea level rise and storm surge	High	Low	High
	Possible degradation of upland wetlands from hydrologic changes	Medium	Medium	Medium
COASTAL RESOURCES				
Shorelines	Increasing to permanent inundation from relative sea level rise	High	Low	High
	Increasing frequency and intensity of coastal flooding from sea level rise and storm surge	High	Low	High
	Increasing coastal erosion from sea level rise and storm events (depending on shoreline type)	High	Low	High
Tidelands	Increasing to permanent inundation from relative sea level rise	High	Low	High
Seawater	Increasing seawater acidity (i.e., decreasing pH)	High	Low	High
	Increasing sea surface temperature	High	Medium	Medium-High
FOREST RESOURCES				
Forest Type	Increasing water-deficits that decrease drought-sensitive species survival and increase drought-tolerant species survival	High	Medium	Medium-High
Wildfire	Increasing area burned by wildfire annually	High	Low	High
Landslides	Increasing risk of landslide activity	High	Low	High
Planning	**Potential Impacts**	**Sensitivity**	**Adaptive**	**Vulnerability**

Area			Capacity	
Insects and Disease	Greater pest infestations or disease outbreaks	Medium	Medium	Medium
FISH, WILDLIFE, AND TRADITIONAL USE PLANTS				
Salmon	Combined impacts of increasing winter high flows, decreasing summer low flows, increasing stream temperatures, increasing sediment loads, sea level rise, and ocean acidification	High	Low	High
Forage Fish	Inundation of spawning habitat	High	Low	High
Shellfish	Combined impacts of sea level rise, ocean acidification, and increasing sea surface temperatures	High	Low	High
Upland Wildlife	Species specific	-	-	-
Plants	Species specific	-	-	-
HUMAN HEALTH				
Heat-Related Illness	Increasing incidence of heat rash, heat syncope (fainting), heat cramps, heat exhaustion, and heat stroke	High	Medium	Medium-High
Extreme Weather Events	Increasing incidence of injury, death, and/or an array of indirect impacts	High	Low	High
Respiratory Disease	Increasing incidence of asthma, allergies, bronchitis, emphysema, and pneumonia	High	Medium	Medium-High
Infectious Disease	Increasing incidence of infection from vector-borne, water-borne, and fungal diseases	Medium	Medium	Medium
Harmful Algal Blooms	Increasing incidence of poisoning from consuming toxin-laden shellfish	High	Low	High
Food Insecurity	Increasing incidence of hunger and malnutrition	High	Low	High
Mental Health	Increasing incidence of anxiety, depression, and post-traumatic stress disorder	High	Low	High
EMERGENCY SERVICES				
Fire	Increasing demand for service	Medium	Medium	Medium
Police	Increasing demand for service	Medium	Medium	Medium
CULTURAL RESOURCES				
Undisclosed	Irretrievable harm to Lummi Nation cultural resources	High	Low	High

Planning Area	Potential Impacts	Sensitivity	Adaptive Capacity	Vulnerability
LAND USE				
Floodplain Infrastructure	Reduced effectiveness of existing floodplain infrastructure given the increasing frequency and intensity of riverine flood events and relative sea level rise	High	Low	High
Residential Development	Increasing property damages in high impacts areas, particularly those susceptible to flooding, erosion, and wildfire	High	Medium	Medium-High
Commercial and Mixed Use Development	Increasing property damages and/or economic consequences in high impacts areas, particularly those susceptible to flooding, erosion, and wildfire	High	Medium	Medium-High
Agriculture	Decreasing viability of farming with sea level rise	High	Low	High
Hazardous Materials Sites	Increasing risk of hazardous materials spills	High	Low	High
TRANSPORTATION				
Road System Integrity	Accelerated weathering of and damage to roads and bridges from various climate change impacts, particularly extreme heat events and flooding	Medium	Medium	Medium
Access and Circulation	Increasing frequency of road closures due to coastal and riverine flooding, possible isolation of the Lummi Peninsula during flooding	High	Low	High
Marine Facilities	Increasing damage sustained during storm events	High	Medium	Medium-High
UTILITIES				
Water Supply	Saltwater intrusion into aquifers and/or altered aquifer recharge	High	Low	High
Wastewater Collection and Treatment	Increasing saltwater inflow at low-lying pump stations and/or increasing hydraulic head at outflows (resulting from relative sea level rise)	High	Medium	Medium-High
Storm water Management	Increasing inundation and/or backup of drainage network from heavy precipitation events and/or storm surge	Medium	Medium	Medium
Energy Supply	Service disruption during and following extreme weather events	Medium	Low	Medium-High

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APPENDIX D

SUMMARY ADAPTATION GOALS AND STRATEGIES TABLE

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Table D-1 Summary Adaptation Goals and Strategies Table

Goal	Strategy
WATER RESOURCES	
A-1: Reduce the risk of property damage from riverine flooding.	1. Strengthen regulatory flood risk reduction measures.
	2. Upgrade infrastructure to accommodate or protect against flooding.
	3. Continue to pursue land acquisition, building relocation or demolition, and open space preservation in special flood hazard areas.
	4. Protect existing development in flood-prone areas.
A-2: Restore instream flow and maintain suitable stream temperature in the Nooksack River basin.	1. Continue to pursue a negotiated or litigated settlement to resolve conflicts over water rights allocations in the Nooksack River basin.
	2. Undertake climate-conscious riparian and floodplain restoration to decrease existing stressors and ameliorate climate change effects on summer instream flow and temperature.
COASTAL RESOURCES	
B-1: Reduce the risk of property damage from coastal flooding and shoreline erosion.	1. Continue to assess coastal areas for flooding and erosion risks.
	2. Facilitate managed retreat through land acquisition, zoning changes, development restrictions, and/or other regulatory tools as appropriate.
	3. Protect coastal buildings and infrastructure through shoreline hardening and/or building elevation and floodproofing.
	4. Encourage soft bank protection, rather than traditional shoreline armoring.
B-2: Maintain and enhance coastal wetland habitats.	1. Facilitate shoreward migration of coastal wetlands though land acquisition and removal of hard shore protection (e.g., bulkheads, dikes, seawalls) or other barriers to tidal flow.
	2. Preserve and restore structural complexity and biological diversity when undertaking wetland enhancement activities.
	3. Promote and maintain mechanisms for sediment transport and deposition.
B-3: Reduce local land-based contributions to ocean acidification.	1. Strengthen pollution reduction actions to reduce nutrient and organic carbon discharge into fresh and marine waters.
FOREST RESOURCES	
C-1: Reduce the risk of property damage from wildfire on the Reservation.	1. Implement “firewise” standards in high-risk residential and commercial areas.
	2. Continue to support wildfire prevention and response capabilities within the Lummi Natural Resources Department.
	3. Implement forest practices that minimize wildfire risk.

Goal	Strategy
FISH, WILDLIFE, AND TRADITIONAL USE PLANTS	
D-1: Protect and restore a harvestable surplus of salmon for the Lummi People.	1. Reduce existing stressors to salmon populations.
	2. Incorporate climate change into salmon recovery and habitat restoration/conservation plans.
	3. Restore habitat diversity and riparian ecosystem function throughout the Nooksack River watershed using methods demonstrated to ameliorate the negative impacts of climate change on salmon.
D-2: Protect and restore a harvestable surplus of shellfish for the Lummi People.	1. Improve water quality in shellfish harvest areas.
	2. Ensure continued water quality monitoring.
	3. Maintain and expand shellfish enhancement on tribal tidelands.
	4. Explore options for seawater chemistry remediation.
D-3: Conserve forestland and other upland habitats throughout the Lummi Nation's Traditional Territories.	1. Advocate for the expansion of protected areas.
	2. Continue to monitor forest practices and encourage better forest management.
HUMAN HEALTH	
E-1: Improve community health.	1. Develop a comprehensive assessment of community health risks, including assessment of Indigenous health indicators.
	2. Improve and expand healthcare services to meet anticipated increased demand.
	3. Help individuals prepare for potential climate-related health risks by providing public outreach and education
EMERGENCY SERVICES	
F-1: Improve emergency planning and preparedness.	1. Increase the capacity of the Lummi Nation to respond to climate-related emergencies.
	2. Provide public education and outreach to inform residents of potential climate change impacts and ways to prepare for these impacts
CULTURAL RESOURCES	
G-1: Preserve and protect the Lummi Nation's cultural resources.	1. Continue implementing the Cultural Resources Protection Code.
	2. Explore the use of Traditional Knowledge (TK) in the context of climate change.

Goal	Strategy
LAND USE	
H-1: Promote climate-conscious land use planning.	1. Complete a Comprehensive Land Use Plan for the Lummi Nation, taking into account climate change impacts.
	2. Adopt a better, more protective building code.
TRANSPORTATION	
I-1: Support transportation infrastructure improvements.	1. Continue making transportation infrastructure improvements on the Reservation.
	2. Collaborate with Washington State and Whatcom County on public works projects.
UTILITIES	
J-1: Protect the potable groundwater systems on and adjacent to the Reservation.	1. Reduce groundwater withdrawals by implementing voluntary, economic, and/or mandatory water conservation measures.
	2. Reevaluate and possibly initiate water reclamation and reuse.
J-2: Reduce the risk of damage to or failure of wastewater treatment infrastructure.	1. Identify wastewater treatment system vulnerabilities, develop site-specific adaptation strategies, and secure funding for improvement or replacement.
J-3: Increase capacity to manage storm water.	1. Reduce storm water runoff through continued implementation of the Lummi Nation Storm Water Management Program.
	2. Increase capacity of storm water collection systems to accommodate projected changes in precipitation.