KITSAP COUNTY

Climate Change Resiliency Assessment

JUNE 2020 | FINAL REPORT

Kitsap County Climate Change Resiliency Assessment

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List of Acronyms

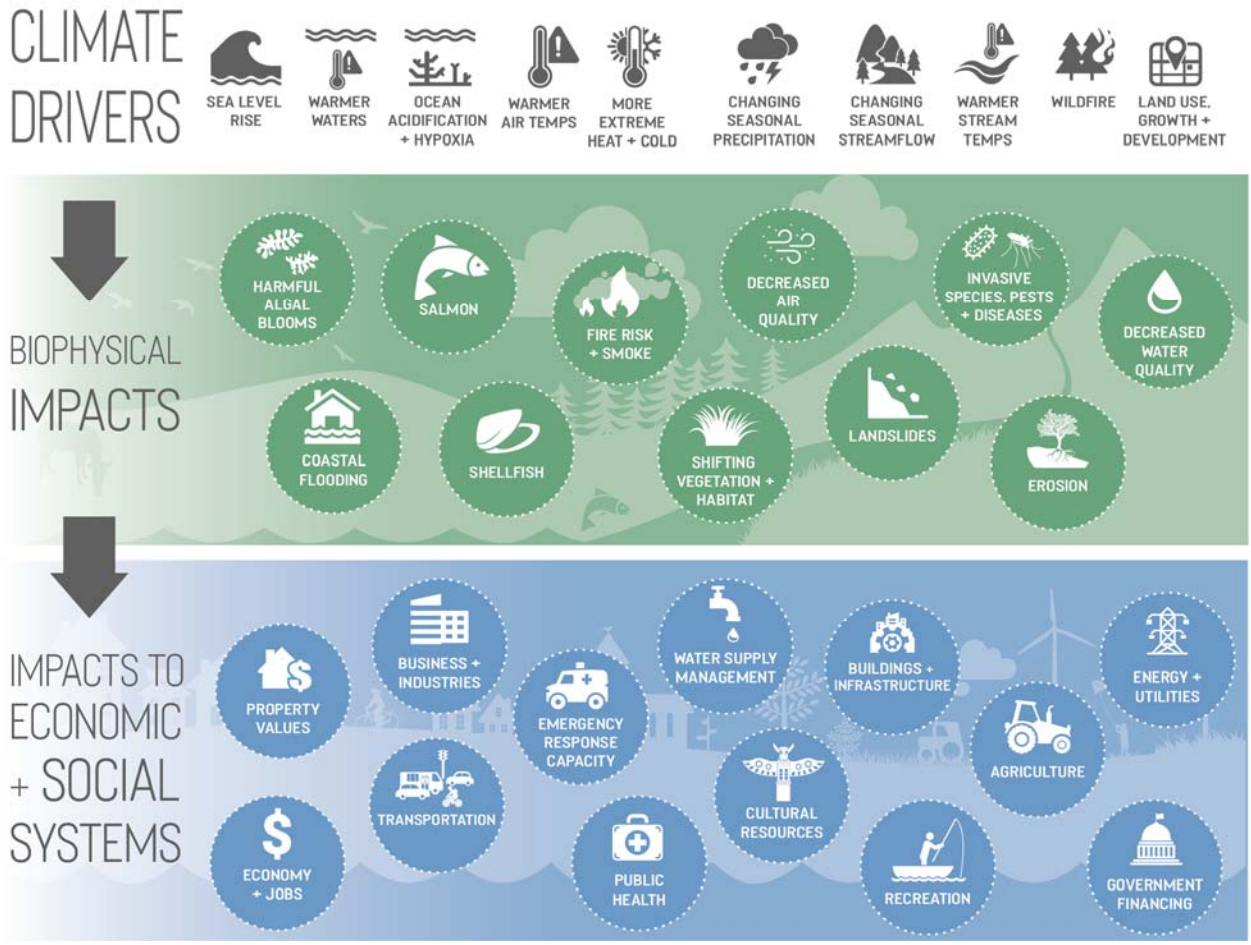
Acronym	Definition
DO	Dissolved oxygen
CO_2	Carbon dioxide
CH_4	Methane
EPA / USEPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GCM	Global climate models
GDP	Gross domestic product
GHG	Greenhouse gas
HAB	Harmful algal bloom
IPCC	Intergovernmental Panel on Climate Change
L	Liter
mg	Milligrams
MHHW	Mean higher high water
N_2O	Nitrous oxide
PSE	Puget Sound Energy
PSP	Paralytic shellfish poisoning
RCM	Regional climate models
RCP	Representative Concentration Pathway (greenhouse gas emissions scenario)
TOD	Transit-oriented development
WUI	Wildland-urban interface

Kitsap County Climate Change Resiliency Assessment

Executive Summary

Climate change has already affected and will continue to affect the infrastructure, natural systems, economy, culture, and livelihoods of people who live and work in Kitsap County. The Pacific Northwest, Puget Sound region, and Kitsap County have experienced measurable and observable climate change trends and impacts. Warmer air temperatures, warmer water temperatures, sea level rise, ocean acidification, increasing frequency and intensity of extreme weather events, changing seasonal precipitation and streamflow patterns, and increasing drought conditions and changing wildfire risk are all expected under future climate scenarios. Additionally, climate change will affect future land use decisions, population growth, and development, which in turn will shape how localized climate impacts are felt and realized.

Figure 1. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems



About the Climate Change Resiliency Assessment

Kitsap County, the City of Bremerton, and the City of Port Orchard commissioned Cascadia Consulting Group, with Greene Economics and Herrera Environmental, to prepare this **Climate Change Resiliency Assessment** to review and summarize climate change drivers, impacts, and risks for Kitsap County. The assessment begins with an overview of climate drivers, biophysical climate impacts, and future climate projections (**Chapter 2. Climate Change Overview**).

The Climate Change Resiliency Assessment then presents syntheses of current and future climate impacts to the following **social and economic systems:**

Impacts to Social and Economic Systems	
Public health and healthcare services	Chapter 3. Public Health
Property values, businesses, energy supply and utilities, and future economic damages	Chapter 4. Economy
Historical and archaeological sites, recreational opportunities, and Tribal cultural resources	Chapter 5. Cultural Resources
Public infrastructure and support systems	Chapter 6. Public Infrastructure
Land use and development	Chapter 7. Land Use and Development
Agricultural crops, livestock, and livelihoods	Chapter 8. Agriculture
Insurance, municipal bonds, and County tax revenue	Chapter 9. Local Government Finance

Following the discussion of impacts to social and economic systems, the assessment then summarizes the **biophysical impacts** of climate change in the following areas:

Biophysical Impacts	
Landslide risk, bluff erosion, sediment transport, and storm surges and coastal flooding risk	Chapter 10. Geologic & Natural Hazards
Hydrologic patterns, stream and riverine flooding, regional hydropower production, and irrigated agriculture	Chapter 11. Hydrology and Hydrogeology
Terrestrial, freshwater, and marine and coastal habitats and the species that depend on them	Chapter 12. Habitat
Wildland-urban interface, wildfire risk, and emergency response capacity	Chapter 13. Fire

Key Findings

Key findings, explored in more detailed in the chapters by topic area, include the following:

Public health

More intense heat waves are likely to increase heat-related and respiratory illnesses and deaths. Food insecurity and mental health problems could increase for people with natural resource-related occupations, such as fishing, forestry, agriculture, recreation, service industries, and construction. Outdoor laborers, elderly people, and youth have a higher risk of a range of climate-related health issues.

Economic impacts

Values of property in low-lying or coastal areas may be adversely affected from future flooding and sea level rise. A wide variety of industries may be affected in the future, including construction and development, manufacturing, food and hospitality services, and natural resource economies. There is a broad range of future economic damages from climate change, most notably lost labor hours.

Culture and recreation

Historical sites and buildings, parks, waterfronts, and archaeological sites are likely to be damaged from future flooding, extreme heat, and shifting precipitation patterns. Flooding, habitat shifts, and impacts to certain species such as salmon will have detrimental cultural and health impacts for Tribes.

Coastal flooding and infrastructure

Coastal flooding impacts from a combination of sea level rise, storm surges, and heavy precipitation events can result in substantial physical, ecological, and infrastructure damage. This includes flooding of transportation routes, damage to waterfronts, inundation and saltwater intrusion of wastewater infrastructure, and overload of stormwater infrastructure.

Land use and local climate impacts

Future urbanization and the increased use of impervious pavements are likely to increase the probability and severity of climate impacts such as urban flood events. Land use and vegetation cover may also shift with warmer temperatures and changing precipitation patterns, which may have secondary effects on natural flood control, urban heat island effect, and wildfire risk.

Geologic and natural hazards

Landslide risk will likely increase due to heavier rain events, soil erosion and destabilization, and sediment transport patterns. Bluff erosion rates may accelerate from winter storms, storm surges, sea level rise, and heavy rain events. Increased rates of bluff erosion will have long-term implications for properties, roads, and habitat on coastal bluffs.

Habitat and fire

Future climate change will likely alter terrestrial, freshwater, marine, and coastal habitats. These habitat changes will have a wide range of impacts to sensitive species and ecological processes. The prevalence of invasive species and diseases is likely to increase. Though wildfire risk remains low for Kitsap County under future climate conditions, the expansion of the wildland-urban interface may increase the likelihood of wildfire spread across a landscape.

Chapter 1. Introduction

Objectives

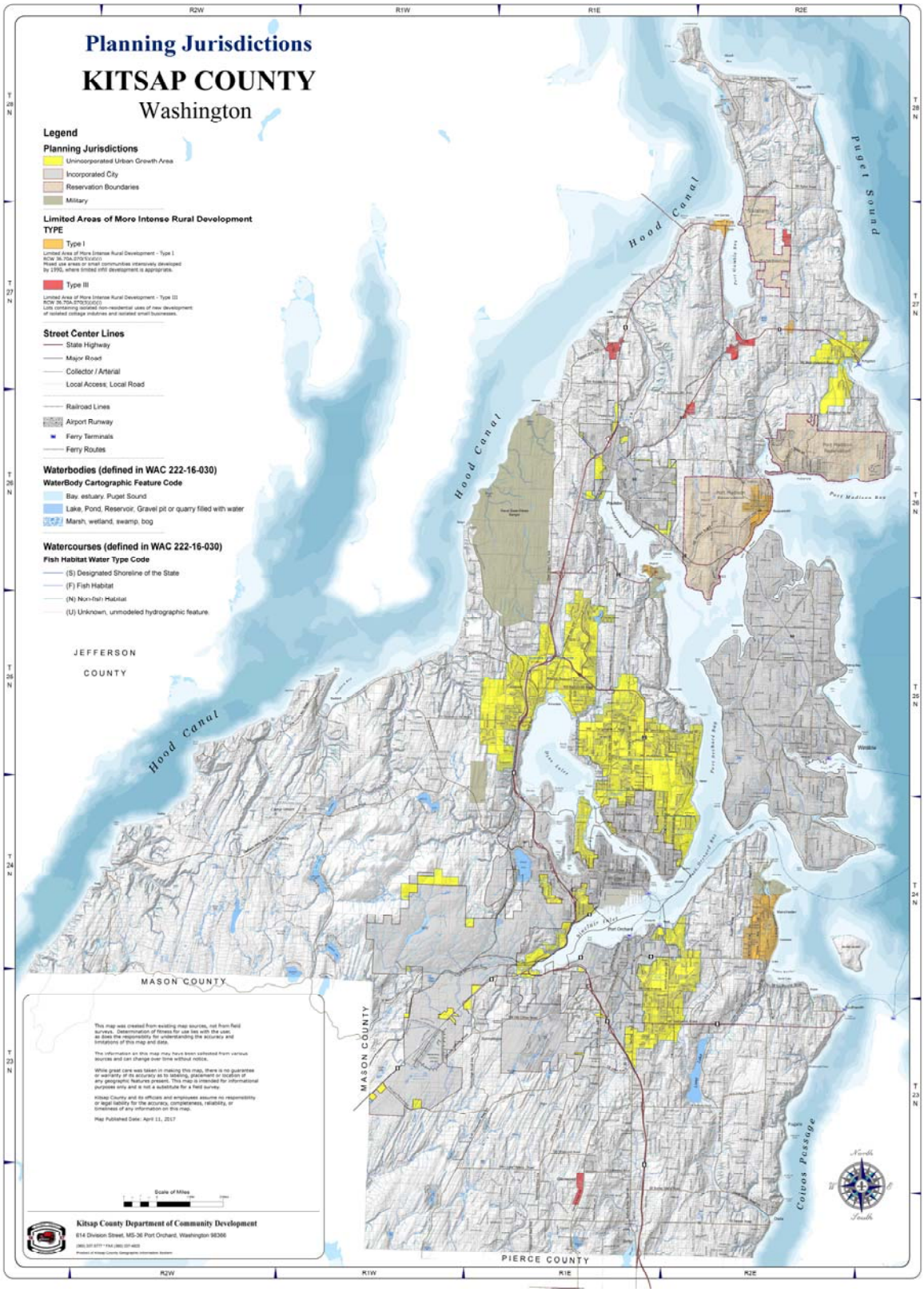
The objective of the Kitsap County Climate Change Resiliency Assessment is to provide the evidence and foundation to support Kitsap County in future resiliency planning to address current and future climate change risks. This assessment is intended to provide a robust scientific synthesis of current and future climate risks and hazards for Kitsap County. Specifically, this assessment focuses on synthesizing future climate projections and relevant climate change impacts to public health, economy, cultural resources, public infrastructure, land use and development, agriculture, local government finance, geologic and natural hazards, hydrology and hydrogeology, habitats and ecosystems, and fire risks.

This assessment includes evidence-based qualitative rankings of the probability, magnitude, and timing of specific climate-driven changes. This research summary is intended to provide the foundational data to inform the County's future development of climate change resiliency strategies, including adaptation and mitigation strategies to enhance the community resilience of Kitsap County's residents and businesses.

Geographic Scope

For the purposes of this report, Kitsap County is defined as the area that lies within the geographical boundaries of Kitsap County's borders (see Figure 2), not limited to the County government structure or processes. Though the review of existing literature and data sources focused on Kitsap County, county-specific data sources were limited. Accordingly, the research also considered Washington State, Pacific Northwest, and Puget Sound regional publications to identify impacts, trends, and risks associated with climate change. This approach recognizes the interconnectedness of systems and that impacts to other areas of Puget Sound and the Pacific Northwest will be reflected locally in Kitsap County.

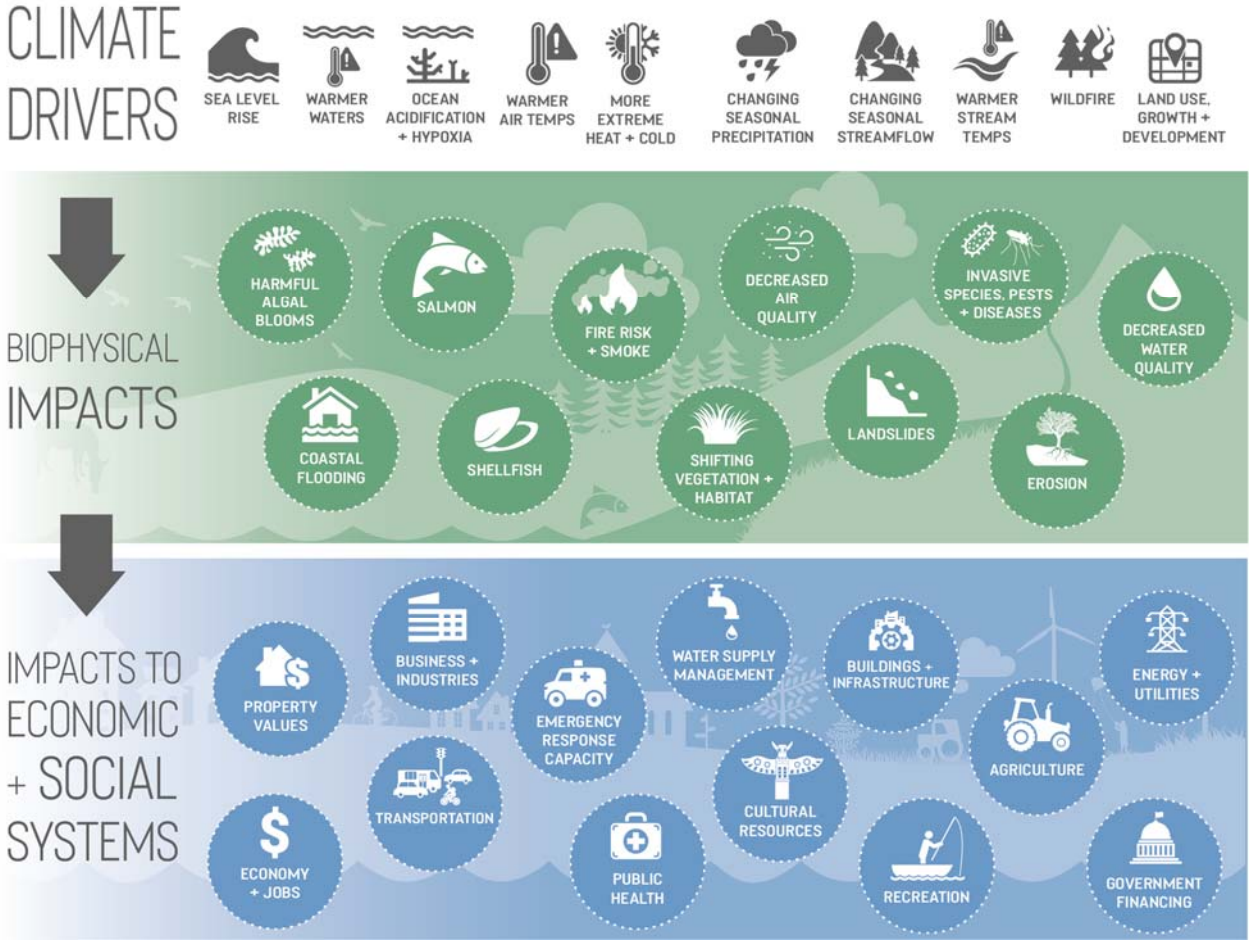
Figure 2. Map of Kitsap County Planning Jurisdictions *(from Kitsap County Dept. of Community Development)*



Summary of Climate Impacts to Sectors

The relationship between climate drivers and associated biophysical, social, and economic impacts is complex and interwoven (Figure 3). Changing ocean conditions, warmer temperatures, more extreme conditions, changing seasonal precipitation and streamflow patterns, changing wildfire risk, and policies and decision-making on future land use and development will very likely result in biophysical changes to habitats, flooding risk, iconic species, air quality, water quality and quantity, fire risk, invasive species, pests and diseases, landslides and other geologic hazards, and erosion. These biophysical changes will subsequently affect many aspects of social and economic systems that support the livelihoods and way of life for Kitsap County's residents, including the health system, the economy, infrastructure, water supply, cultural resources, recreation, energy, financial investments, and agriculture. Many of these impacts and drivers operate in feedback loops. For instance, changes to habitat, vegetation, and agriculture will affect future land use decisions, which in turn will influence further habitat, vegetation, and agriculture changes.

Figure 3. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems



Sources and Methodology

This assessment reviews and incorporates findings from more than 290 publications, reports, articles, and plans. The list of publications includes regional climate assessments, scientific peer-reviewed articles, government publications, nongovernmental organization reports, sector-specific plans, and relevant news articles. Table 1 lists selected major sources.

Table 1. Major Sources Incorporated into this Assessment

Scale	Documents
Global	• *5th IPCC Synthesis Report,* Intergovernmental Panel on Climate Change (IPCC), *2014*. • *Climate Change and Land: A special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. IPCC. *2019*.
National	• *4th National Climate Assessment*. *2018*. • *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. *2016*.
Regional	• *National Climate Assessment—Chapter 24: Northwest*. *2018*. • *State of Knowledge: Climate Change in Puget Sound*. *2015*. • *Projected Sea Level Rise for Washington State*. *2018*. • *Climate Change Preparedness Plan for the North Olympic Peninsula*. *2015*.
County	• Kitsap County Public Works, *Task 700 Climate Change Assessment*. *2019*. • *Kitsap County Multi-Hazard Mitigation Plan. 2015*. • *Kitsap 2036: Growing for a Better Tomorrow.* 2016.
Local	• *Bainbridge Island Climate Impact Assessment*. 2016. • *Hood Canal Climate Change Projections Summary.* 2015. • *Port Gamble S'Klallam Tribe Climate Change Impact Assessment*. 2016.

Magnitude of Impacts

Each of the climate change impacts covered in this assessment includes information on the magnitude, likelihood, confidence, and timing of climate impacts. The **magnitude** of a climate impact is defined qualitatively based on its relative change from historical or current baseline conditions:

- **Low magnitude**: Relatively low change between future climate impacts and current/historical baseline conditions.
- **Medium-low magnitude**: Relatively low to medium/moderate change between future climate impacts and current/historical baseline conditions.
- **Medium magnitude**: Relatively medium or moderate change between future climate impacts and current/historical baseline conditions.
- **Medium-high magnitude**: Relatively medium to high change between future climate change impacts and current/historical baseline conditions.
- **High magnitude**: Relatively high change between future climate change impacts and current/historical baseline conditions.

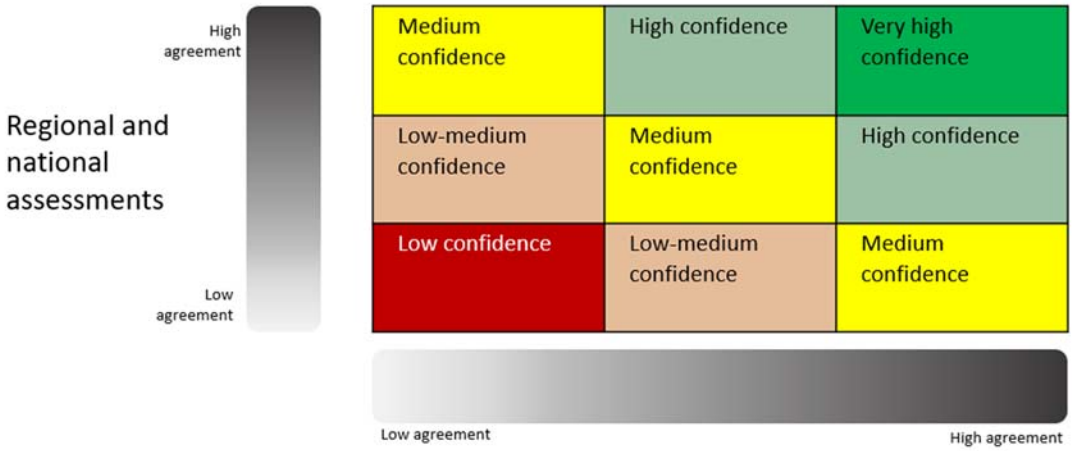
Because of the relative measurement of change, there will be variability in how magnitude of future climate impacts will be considered across sectors.

Likelihood and Confidence

In addition to magnitude, each finding describing a climate impact will have an associated likelihood and confidence statement. The likelihood and confidence assessment are derived from the same definitions from the Intergovernmental Panel on Climate Change (IPCC), as shown in Figure 4. **Likelihood** is the qualitative or quantitative assessment of the probability of an event or outcome occurring. **Confidence** is an assessment of how confident scientists are in certain statements given the consensus level and evidence base. For the purpose of this assessment, confidence is defined according to the consensus and evidence base in regional and national climate assessments as well as locally specific plans and assessments for Kitsap County.[1]

Figure 4. Confidence and Likelihood[2]

Term	Probability of Outcome
Virtually certain	99 to 100% probability
Very likely	90 to 100% probability
Likely	66 to 100% probability
About as likely as not	33 to 66% probability
Unlikely	0 to 33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability



Kitsap County local plans and assessments

[1] Definition adapted from Mastrandea *et al.* 2010. *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*. Intergovernmental Panel on Climate Change.

[2] Impacts with a low confidence or concurrence are excluded from this document.

Socioeconomic Overview of Kitsap County

The people and the economy of Kitsap County will experience the biophysical impacts of climate change in different ways. This overview of the county's population and economy provides background for understanding the potential impacts of climate change on economic and social systems.

Population and Demographics

Kitsap County's population in 2019 was an estimated 270,100, representing about 3.6% of Washington State's population. The county grew from 251,133 in 2010, with a percentage change of 7.6% between 2010 and 2019 (Table 2). The state population increased by 12.2% during the same period. It is anticipated that by 2040, the population of Kitsap County will reach approximately 323,000, an increase of nearly 29% between 2010 and 2040.[3] This growth rate is lower than the state's projected population increase of 37% during that period but shows substantial, continued growth and development in Kitsap County.

Table 2. Population of Kitsap County and the State of Washington[4,5]

	Kitsap County	Washington State
Population 2010	251,133	6,724,540
Percent change, 2010 to 2019	*7.6%*	*12.2%*
Population 2019	270,100	7,546,410
Population 2020	275,913	7,638,423
Population 2030	303,528	8,503,191
Population 2040	322,859	9,242,028
Percent change, 2010 to 2040	*28.6%*	*37.4%*

In terms of age, Kitsap County's population is somewhat older than that of Washington State, with 21.6% of county residents 65 years and older in 2019, compared to 16.3% in the state (Table 3). Residents under 20 years of age made up 16.9% of the population in the county, while this age group accounted for 18.8% of residents in the state. Women make up 49.4% of Kitsap County population, compared to 50.1% for the state, and the median age of women is 46.3 years or about 7 years older than men with a median age of 39.5 years.

Kitsap County showed less ethnic and racial diversity in 2019 compared to Washington State in most racial/ethnic categories, as shown in Table 3. In Kitsap County, 81.5% of the people identify themselves as White, compared to 78.8% in the state.

[3] Office of Financial Management, State of Washington. 2018. 2017 Projections: County Growth Management Population Projections by Age and Sex: 2010–40. Available at: https://ofm.wa.gov/sites/default/files/public/dataresearch/pop/GMA/projections17/GMA_2017_county_pop_projections.pdf

[4] Office of Financial Management. 2018.

[5] U.S. Census Bureau. 2019. QuickFacts: Kitsap County, Washington, United States. www.census.gov/quickfacts/fact/table/WA,kitsapcountywashington/PST045219

Table 3. Population by Age, Sex, Race/Ethnicity, and Household Size in Kitsap County and Washington[6,7]

	Kitsap County (% of total population)	Washington State (% of total population)
Population by Age, 2019		
Under 5 years old	6.0%	6.0%
Under 20 years old	16.9%	18.8%
65 years and older	21.6%	16.3%
Median Age, 2019		
Male	39.5 years	37.4 years
Female	46.3 years	39.2 years
Females, 2019		
Females	49.4%	50.1%
Race, 2019		
White	81.5%	78.8%
Black or African American	3.1%	4.2%
American Indian and Alaska Native	1.7%	1.8%
Asian	5.8%	9.2%
Native Hawaiian and other Pacific Islander	1.1%	0.8%
Two or More Races	6.7%	5.1%
Percent Latino/Hispanic Ethnicity	*8.0%*	*12.9%*
Average Household Size and Number of Households, 2014-2018		
Number of Households	101,662 households	2,800,423 households
Average Household Size	2.51 people/household	2.55 people/household

Employment and Industries

[Note that this assessment reflects economic information as of 2019, but it does not address the severe recent economic and health impacts of the COVID-19 global pandemic that began affecting Washington in early 2020.]

Kitsap County has a diversity of industries that support a growing economy. The businesses that support the county economy range from public services to military operations to private businesses to natural resource economies (Table 4).[8] The proximity and connectivity of Kitsap County to the greater Seattle market, which is the center of commerce and industry supply chains in the region, plays a major role in the county's economic

[6] Office of Financial Management State of Washington. 2020. Estimates of April 1 population by age, sex, race and Hispanic origin. https://ofm.wa.gov/washington-data-research/population-demographics/population-estimates/estimates-april-1-population-age-sex-race-and-hispanic-origin

[7] U.S. Census Bureau. 2019.

[8] Washington State Employment Security Department. 2019. Labor area summaries: Nonfarm industry employment: Kitsap County. https://esd.wa.gov/labormarketinfo/labor-area-summaries.

vitality.[9] It is also important to note that water transportation plays a dominant role in the culture and economy of Kitsap County.[10] Because of the County's geographic configuration, the Washington State Ferries system, along with Kitsap Transit ferries, are an important infrastructure link for its residents.

Defense; advanced manufacturing (maritime and aerospace); technology (information and communication technology, e-commerce, cybersecurity, and clean technology); healthcare; business services; specialty foods; and tourism are some of the leading economic sectors in Kitsap County. The defense sector accounts for nearly 50% of Kitsap County's economic output and workforce, corresponding with the county's local economy ranking high within the region in key economic development indicators, such as workforce educational attainment; engineering talent; development of intellectual property; per-capita economic output; employment levels; and median household incomes.[11]

Overall, Kitsap County has experienced steady economic growth since 2012.[12] For example, job numbers have continued to rebound and have surpassed the losses that were incurred between 2006 and 2012. In 2018, the county had, on average, 93,200 nonfarm jobs, compared to 87,400 in 2006.[13] Figure 5 presents this growth in Kitsap County compared to Washington State and the United States.[14] Unemployment rates declined in the County from 8.6% in 2010 to 4.6% in 2018 (Figure 6).[15]

Table 4. Non-Farm Employment in Kitsap County, Non-Seasonally Adjusted[16]

	2019		2018		2017
Industry Title	October	November	October	November	November
Total Nonfarm	96,000	96,500	94,300	94,800	91,700
Total Private	61,900	62,000	60,900	61,200	58,800
Goods Producing	8,300	8,300	8,200	8,200	7,500
Mining, Logging, and Construction	5,400	5,300	5,200	5,200	4,700
Manufacturing	2,900	3,000	3,000	3,000	2,800
Service Providing	87,700	88,200	86,100	86,600	84,200
Private Service Providing	53,600	53,700	52,700	53,000	51,300
Trade, Transportation, and Utilities	14,200	14,300	14,000	14,400	14,000
Retail Trade	11,400	11,400	11,300	11,600	11,400
Professional and Business Services	8,700	8,700	8,400	8,400	7,500
Leisure and Hospitality	9,700	9,700	9,700	9,600	9,200
Government	34,100	34,500	33,400	33,600	32,900
Federal Government	20,100	20,200	19,800	19,800	19,300
Local Government	11,800	12,100	11,500	11,700	11,500
State Government	2,200	2,200	2,100	2,100	2,100
Workers in Labor/Management Disputes	0	0	0	0	0

[9] Kitsap County Department of Community Development Planning and Environmental Programs. 2016. Kitsap County Comprehensive Plan 2016-2036. www.kitsapgov.com/dcd/Pages/2016_Comprehensive_Plan.aspx

[10] Employment Security Department State of Washington. 2019. Kitsap County profile. https://esd.wa.gov/labormarketinfo/county-profiles/kitsap

[11] Kitsap County Department of Community Development Planning and Environmental Programs. 2016.

[12] Vleming, J. 2019. Kitsap County profile. Washington State Employment Security Department. https://esd.wa.gov/labormarketinfo/county-profiles/kitsap#outlook.

[13] Kitsap County Department of Community Development Planning and Environmental Programs. 2016.

[14] State of Washington Employment Security Department. 2020. Kitsap County Labor Market Information – Kitsap County Data Tables. https://esd.wa.gov/labormarketinfo/kitsap.

[15] State of Washington Employment Security Department. 2020.

[16] State of Washington Employment Security Department. 2020.

Figure 5. Annual Growth in Nonfarm Employment in Kitsap County, Washington State, and the United States, 1991-2018 [17]

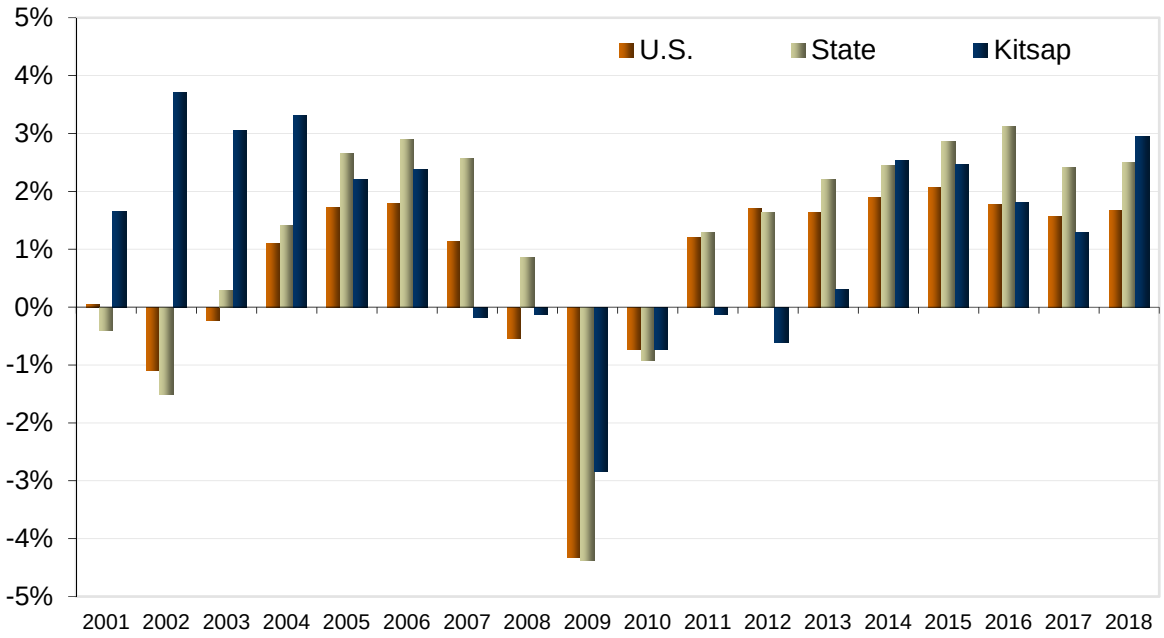
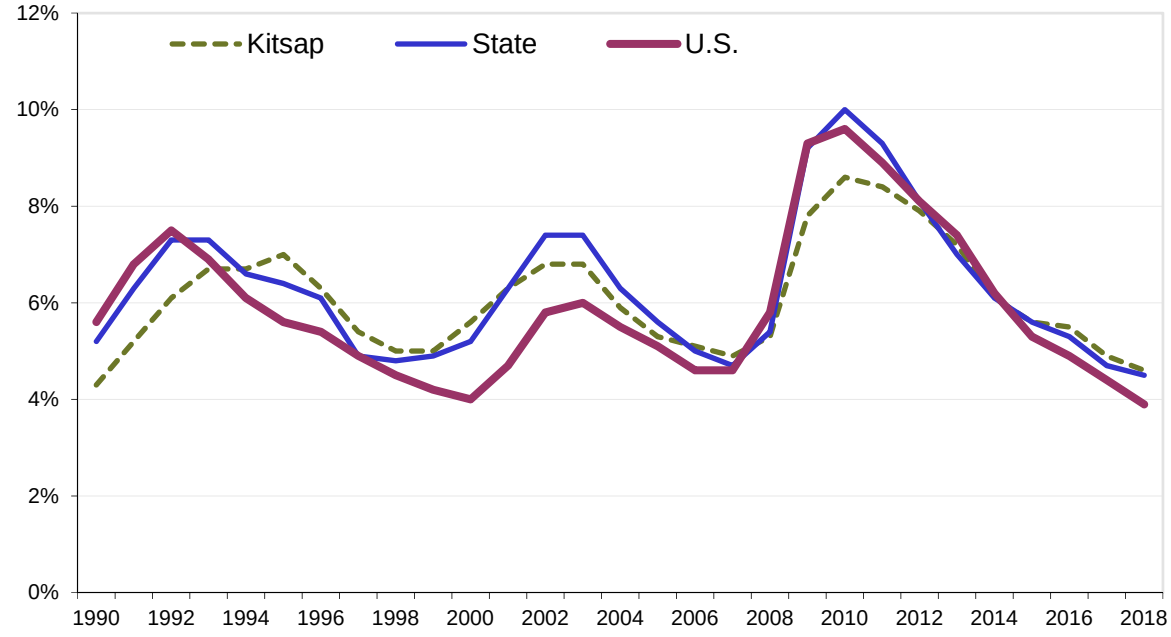


Figure 6. Annual Unemployment Rates in Kitsap County, Washington State, and United States, 1990-2018 [18]



[17] State of Washington Employment Security Department. 2020.
[18] State of Washington Employment Security Department. 2020.

The largest employer of Kitsap County residents is Naval Base Kitsap, employing approximately 33,800 people in 2018, although not all employees are Kitsap County residents.[19,20] Natural resource economies, such as logging, mining, fishing, and agriculture compose a small portion of the economic industries in the county and are important parts of the history and culture of Kitsap County.[21] In 2019, mining, logging, and construction industries employed approximately 5,400 people, and the hospitality and leisure industry employed approximately 9,700 people in Kitsap County (Table 4). Fishing and shellfish are also important for Port Gamble S'Klallam Tribe and the Suquamish Tribe's commercial operations and subsistence economy.[22,23] The county's maritime services and transportation industries, such as shipbuilding and maintenance, shipyard workers, and ferry and boat workers, also contribute to the regional Puget Sound maritime economy.[24]

Other indicators of a healthy economy appeared solid, with retail sales of approximately $5 billion in 2018, gross business income approximately $775 million in 2017, and out-of-state and foreign trade growing more than threefold, from $700 million in 2007 to approximately $2.4 billion in 2017 (Figure 7).[25]

[19] Kitsap County. 2018. 2018 Top Employers. http://kitsapeda.org/wp-content/uploads/2019/08/2018-TOP-EMPLOYERS.pdf.
[20] Center of Economic and Business Research. 2019. Kitsap County 2017/2018 Economic Profile. http://kitsapeda.org/wp-content/uploads/2019/07/County-Profile_Kitsap-7-1-19_web.pdf.
[21] See Chapter 5. Cultural Resources. Finding 3: Tribal Cultural, Ceremonial, and Harvesting Sites and Chapter 8. Agriculture. Finding 4: Agricultural Economies and Livelihoods.
[22] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment. A collaboration of the Port Gamble S'Klallam Tribe, Cascadia Consulting Group, and the University of Washington Climate Impacts Group.
[23] Suquamish Tribe. Tribal Fishing & Hunting Information. https://suquamish.nsn.us/home/departments/fisheries/tribal-fishing-hunting/.
[24] Kitsap Economic Development Alliance. Maritime. http://kitsapeda.org/key-industries/maritime/.
[25] State of Washington Department of Revenue, https://dor.wa.gov/about/statistics-reports/local-retail-sales-2018; Center for Economic and Business Research. 2019.

Figure 7. Retail and Business Sales and Income in Kitsap County[26]

[26] Center for Economic and Business Research. 2019.

Housing

Kitsap County had 113,733 housing units in 2018, with 66% of that owner-occupied.[27] Although the total housing units are not provided by city, the housing units within each incorporated city are estimated based on the share of households within each city. Using this estimation process, rural Kitsap County has the largest share of housing units at nearly 65%. Of the four cities within Kitsap County, Bremerton has the most housing units (approximately 17% of the county total). Table 5 shows how the housing units are distributed within the county.

Table 5. Kitsap County Households and Housing Units by Incorporated City and Rural Areas[28]

	Kitsap County	Bremerton	Bainbridge Island	Port Orchard	Poulsbo	Rural Kitsap County
Households	101,662	16,798	9,857	4,880	4,250	65,877
Housing Units	113,733	18,793	11,027	5,459	4,755	73,699

[27] U.S. Bureau of Census. 2014-2018.

[28] U.S. Bureau of Census. 2014-2018. Greene Economics calculations.

Chapter 2. Climate Change Overview

Drivers of Climate Change

Climate change is defined as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods," according to the United Nations Framework Convention on Climate Change. Human activities, especially activities that emit greenhouse gases (GHGs), are the primary driver of global climate change.[29] Increasing GHG emissions have driven the warming of land and ocean temperatures, which has led to multiple cascading biophysical impacts.[30] Natural feedback processes, such as the El Niño-Southern Oscillation and the Pacific Decadal Oscillation in the Pacific Northwest, may account for interannual and interdecadal variability of air temperature, extreme weather events, precipitation, and ocean conditions.[31,32] Despite this natural variability, the rate of climate change from human activities is exceeding any natural climate variability from feedback processes, resulting in a global net warming of the Earth's lands and waters. The *State of Knowledge: Climate Change in Puget Sound* report found "Climate variability and change will affect the Puget Sound region by altering key climate-related factors shaping the local environment," including temperature, precipitation, heavy rainfall, sea level, and ocean acidification.[33]

Biophysical Impacts of Climate Change

The global increase in air, land, and ocean temperatures has driven biophysical systems to change. Globally, climate change has led to increasing temperatures, melting glaciers, sea level rise, ocean acidification, diminishing snow cover, increasing intensity of extreme storms, increasing frequency of extreme heat and cold waves, increasing frequency and intensity of fires, and shifting precipitation regimes.[34,35]

Climate change impacts in the Puget Sound region and the Pacific Northwest are strongly connected to the global climate. The Puget Sound region has experienced warmer temperatures, longer frost-free seasons, less summer precipitation, nighttime warming, increases in heavy rainfall events, more acidic oceans, increasing

[29] U.S. Global Change Research Program (USGCRP). 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. U.S. Global Change Research Program, Washington, DC, USA, 470 pp. https://science2017.globalchange.gov/.
[30] IPCC. 2014: *Climate Change 2014: Synthesis Report*. *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland, 151 pp. www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf.
[31] USGCRP. 2017.
[32] May *et al.* 2018. Chapter 24: Northwest. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. U.S. Global Change Research Program, Washington, DC, USA, pp. 1036–1100. https://nca2018.globalchange.gov/chapter/24/.
[33] Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. *State of Knowledge: Climate Change in Puget Sound*. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle.
[34] Wuebbles *et al.* 2017: Executive summary. In *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. U.S. Global Change Research Program, Washington, DC, USA, pp. 12-34. https://science2017.globalchange.gov/downloads/CSSR_Executive_Summary.pdf.
[35] IPCC. 2014.

sea levels, marine dead zones, and increases in extreme heat events.[36,37] These collective climate impacts have already affected local economies, cultures, infrastructure, and the health and wellbeing of Northwest communities.[38]

Many of these Puget Sound climate impacts have also been experienced locally in Kitsap County. Since 1900, sea levels in Bremerton have risen at a rate of approximately 1 inch every 12.3 years, and heavy rainfall event intensity increased by 50%.[39] The cities of Bainbridge Island and Port Orchard have experienced similar precipitation and sea level rise impacts.[40]

Although average annual precipitation since 1950 has not changed in quantity, there have been changes to average seasonal precipitation, with increasing spring precipitation, declining summer precipitation, and winter precipitation shifting from snow to rain.[41,42] These seasonal precipitation shifts have impacts to salmon and other aquatic species and habitats.[43]

Puget Sound's waters have warmed since 1950, ranging from 0.8°F to 1.6°F across different areas of Puget Sound including Hood Canal. Warmer water temperatures increase the likelihood of harmful algal blooms, which can damage local shellfish species and habitat.[44] Kitsap County shorelines regularly experience beach and shellfish closures due to biotoxin accumulation.[45,46] Puget Sound has also experienced acidification, especially in Hood Canal, with the regional waters acidifying by approximately 26% since pre-industrial era levels.[47] Ocean acidification is also affected by natural variability from upwelling systems as well as other human sources such as nutrient runoff.

[36] May *et al.* 2018.
[37] Mauger *et al.* 2015. *State of Knowledge: Climate Change in Puget Sound*. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. https://cig.uw.edu/resources/special-reports/ps-sok/.
[38] May *et al.* 2018.
[39] Kitsap County. 2019. Task 700 Climate Change Assessment.
[40] Hansen *et al.* 2016. Bainbridge Island Climate Impact Assessment. EcoAdapt, Bainbridge Island, WA. www.cakex.org/sites/default/files/documents/BICIA%20Final%2028%20July%202016.pdf.
[41] Mauger *et al.* 2015. Section 1: Climate Change Projections.
[42] Hansen *et al.* 2016.
[43] Mauger *et al.* 2015. Section 1: Climate Change Projections.
[44] Mauger *et al.* 2015. Section 1: Climate Change Projections.
[45] Washington Department of Health. 2019. Marine Biotoxin Bulletin. https://fortress.wa.gov/doh/eh/portal/odw/si/BiotoxinBulletin.aspx.
[46] Washington Department of Health. 2019. Shellfish Safety Information. https://fortress.wa.gov/doh/biotoxin/biotoxin.html.
[47] Mauger *et al.* 2015. Section 7: Water Quality.

Figure 8. Relative Sea Level Rise Trend[48] *(data for relative sea level rise in Seattle were used as a proxy since long-term trends for Kitsap County are currently unavailable)*

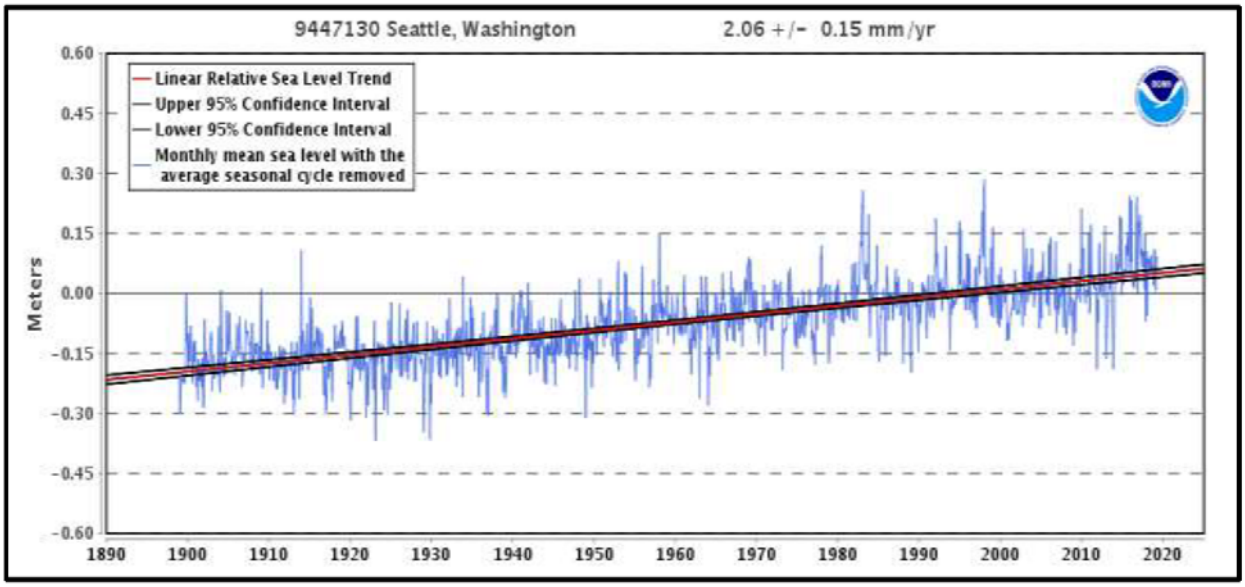
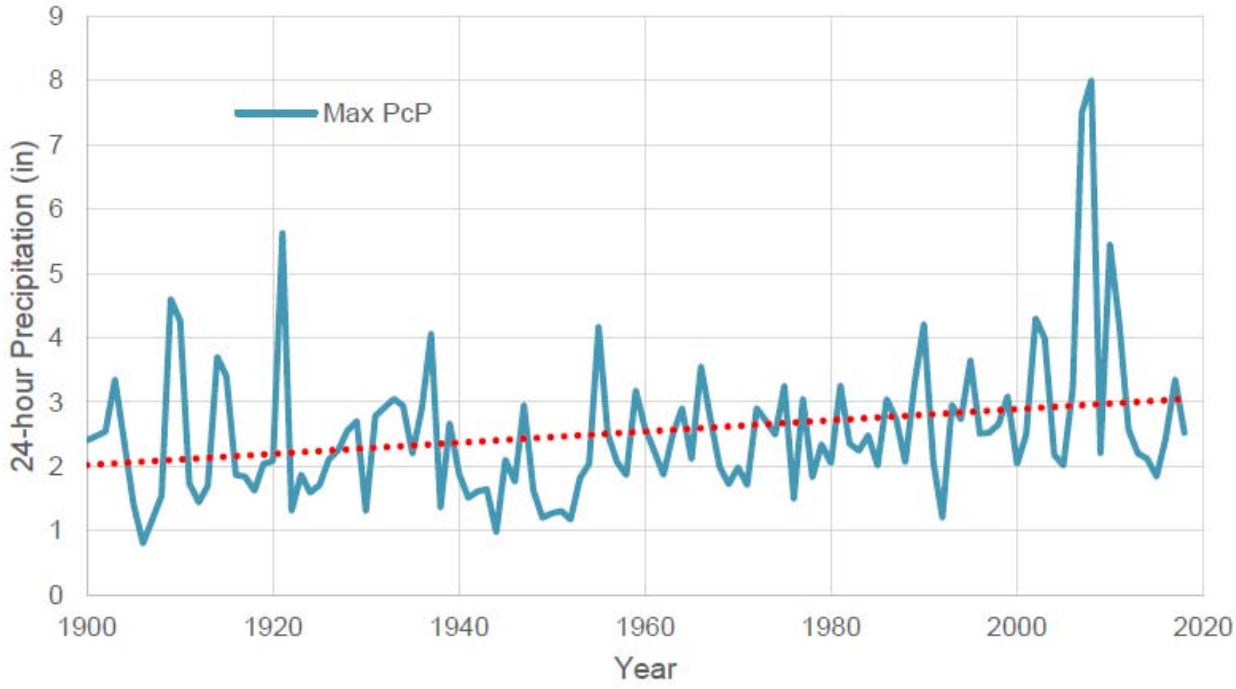


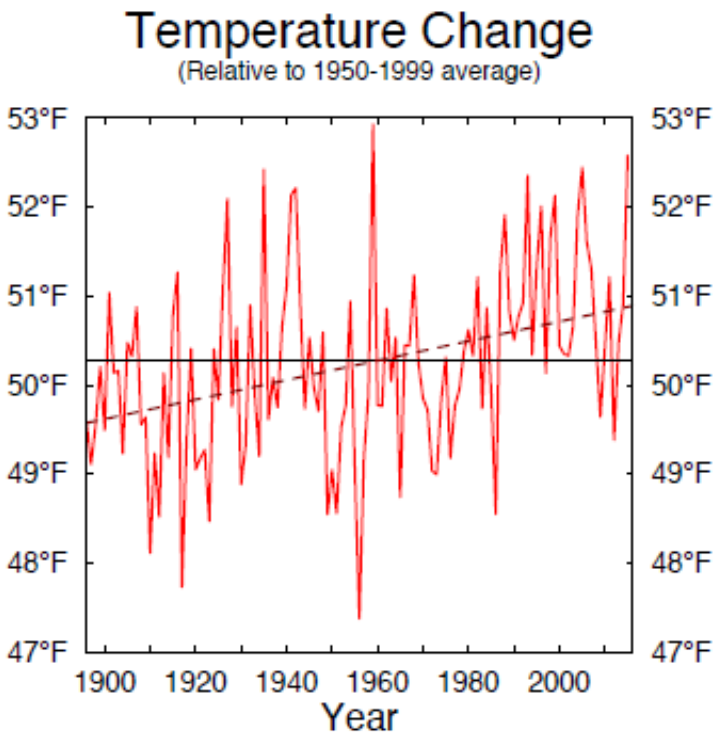
Figure 9. Annual 24-hour Maximum Precipitation (7:00 a.m. – 7:00 a.m.) for Bremerton (1900-2018)[49]



[48] Kitsap County. 2019. Task 700 Climate Change Assessment.
[49] Kitsap County. 2019. Task 700 Climate Change Assessment.

There has also been regional warming of air temperatures since 1895 in the Puget Sound lowland regions, with all but six of the warmest years on record occurring between 1980 and 2014. Warmer nights will become more frequent and there will be a longer frost-free season in Puget Sound.[50] Warmer air temperatures will have cascading impacts on increasing drought conditions, shifting vegetation habitat and types, increasing fire risk, and potentially increasing risk of geologic hazards.[51,52,53]

Figure 10. Average Annual Air Temperature for Puget Sound Lowlands Relative to 1950-1999 Average (50.3°F)[54] *(dashed line represents the fitted trendline, indicating a warming of 1.3°F from 1895-2014)*



[50] Mauger *et al.* 2015. Section 1: Climate Change Projections.
[51] Mauger *et al.* 2015. Section 1: Climate Change Projections.
[52] May *et al.* 2018.
[53] Hansen *et al.* 2016.
[54] Mauger *et al.* 2015. Section 2: Climate. Originally adapted from Vose *et al.* 2014. Improved historical temperature and precipitation time series for US climate divisions. *Journal of Applied Meteorology and Climatology*. 53(5): 1232-1251.

Future Climate Change Projections

The following sections outline future projections for these climate change impacts:

- Sea level rise
- Marine water temperature
- Ocean acidification and dissolved oxygen
- Temperature trends, extreme heat, and freeze-free days
- Precipitation
- Streamflow
- Wildfires

Understanding future climate change projections is critical to inform and understand the intersecting climate stressors that affect local economies, health and wellbeing, and infrastructure in Kitsap County.

Climate Change Scenarios

Future projections of climate change depend on multiple factors such as level of future greenhouse gas emissions, carbon mitigation policies, and climate adaptation and resiliency strategies. Considering these factors, the Intergovernmental Panel on Climate Change (IPCC) has developed a range of scenarios for its reports to portray the range of climate impacts. For the 5th IPCC Report, a new set of scenarios were developed called Representative Concentration Pathways (RCPs) that account for socioeconomic scenarios, global growth, and climate mitigation policies. Four main scenarios emerged: RCP2.6, RCP4.5, RCP6.0, and RCP8.5. These scenarios range from a highly ambitious reduction of global GHG emissions (RCP2.6) to a "business-as-usual" emissions scenario (RCP8.5).

This report summarizes future climate projections with regard to a low-emissions scenario (RCP4.5) and a high-emissions business-as-usual scenario (RCP8.5). The **RCP4.5 scenario, or the low-emissions scenario**, assumes that there will be coordinated global GHG mitigation policies to reduce GHG emissions to stabilize climate change.[55] The **RCP8.5 scenario, or the high-emissions scenario**, is considered to be the **business-as-usual scenario** and assumes a scenario without coordinated global policies to reduce GHG emissions.[56] In this climate impacts assessment, projections are generally framed under these two scenarios to project the range of future climate impacts to Kitsap County, though in certain instances RCP6.0, or a moderate-emissions scenario, may also be referenced.

Sea Level Rise

Kitsap County's relative sea level is largely projected to rise by 2100, with a range from -0.1 feet to 2.7 feet. Multiple geologic and climatic factors influence sea level projections. Relative sea level projections are calculated by accounting for vertical land movement, or the vertical movement of land due to geologic forces,

[55] Thomson *et al.* 2011. RCP4.5: A pathway for stabilization of radiative forcing by 2100. *Climatic Change*. 109(77): https://doi.org/10.1007/s10584-011-0151-4.
[56] Riahi, K. *et al.* 2011. RCP8.5: A scenario of comparatively high greenhouse gas emissions. *Climatic Change*. 109: 33. https://doi.org/10.1007/s10584-011-0149-y.

and the absolute sea level change. Sea level rise projections do not factor in the risk of a subduction zone earthquake, which could lead to rapid localized sea level rise.[57]

Table 6 and As shown in Table 7, under the low-emissions scenario, Bremerton will as likely as not (50% likelihood) experience sea level rise of 0.35 feet by 2030, 0.7 feet by 2050, and 1.75 feet by 2100 and virtually certain (99% likelihood) to experience sea level rise of 0.15 feet by 2100. Under the high-emissions scenario, Bremerton will as likely as not (50% likelihood) experience sea level rise of 0.35 feet by 2030, 0.75 feet by 2050, and 2.15 feet by 2100 and virtually certain (99% likelihood) to experience sea level rise of 0.1 feet by 2050 and 0.45 feet by 2100.

Table 7 summarize the probabilistic projections of sea level rise based on high- and low-emissions scenarios for Port Orchard and Bremerton. Under the low-emissions scenario, Port Orchard will as likely as not (50% likelihood) experience sea level rise of 0.4 feet by 2030, 0.8 feet by 2050, and 2.2 feet by 2100. Port Orchard is virtually certain (99% likelihood) to experience sea level rise of 0.05 feet by 2050 and 0.3 feet by 2100. Under the high-emissions scenario, Port Orchard will as likely as not (50% likelihood) experience sea level rise of 0.35 feet by 2030, 0.75 feet by 2050, and 2.15 feet by 2100 and virtually certain (99% likelihood) to experience sea level rise of 0.1 feet by 2050 and 0.45 feet by 2100.

[57] Miller *et al.* 2018. Projected Sea Level Rise for Washington State – A 2018 Assessment. A Collaboration of Washington Sea Grant, UW Climate Impacts Group, Oregon State University, and US Geological Survey. Prepared for the Washington Coastal Resilience Project. https://cig.uw.edu/resources/special-reports/sea-level-rise-in-washington-state-a-2018-assessment/.

Table 6. Probabilistic Sea Level Rise Projections for Port Orchard[58]

Emissions Scenario	Likelihood	Location		Year (sea level rise, ft)			Location Notes
		Lat.	Long.	2030	2050	2100	
RCP4.5 Low Emissions Scenario	50%	47.6°N	122.7°W	0.4	0.8	2.2	NW Bremerton & West Port Orchard
	90%	47.6°N	122.7°W	0.2	0.4	1.3	NW Bremerton & West Port Orchard
	95%	47.6°N	122.7°W	0.2	0.3	1.1	NW Bremerton & West Port Orchard
	99%	47.6°N	122.7°W	0.1	0.2	0.6	NW Bremerton & West Port Orchard
	50%	47.6°N	122.6°W	0.3	0.7	1.7	Port Orchard & Bremerton
	90%	47.6°N	122.6°W	0.1	0.3	0.7	Port Orchard & Bremerton
	95%	47.6°N	122.6°W	0	0.2	0.5	Port Orchard & Bremerton
	99%	47.6°N	122.6°W	-0.1	-0.1	0	Port Orchard & Bremerton
	50%			0.35	0.75	1.95	Average sea level rise
	90%			0.15	0.35	1.0	Average sea level rise
	95%			0.1	0.25	0.8	Average sea level rise
	99%			0	0.05	0.3	Average sea level rise
RCP8.5 High Emissions Scenario	50%	47.6°N	122.7°W	0.4	0.8	2.2	NW Bremerton & West Port Orchard
	90%	47.6°N	122.7°W	0.2	0.4	1.3	NW Bremerton & West Port Orchard
	95%	47.6°N	122.7°W	0.2	0.3	1.1	NW Bremerton & West Port Orchard
	99%	47.6°N	122.7°W	0.1	0.2	0.6	NW Bremerton & West Port Orchard
	50%	47.6°N	122.6°W	0.3	0.7	2.1	Port Orchard & Bremerton
	90%	47.6°N	122.6°W	0.1	0.3	1.1	Port Orchard & Bremerton
	95%	47.6°N	122.6°W	0.1	0.2	0.8	Port Orchard & Bremerton
	99%	47.6°N	122.6°W	-0.1	0	0.3	Port Orchard & Bremerton
	50%			0.35	0.75	2.15	Average sea level rise
	90%			0.15	0.35	1.2	Average sea level rise
	95%			0.15	0.25	0.95	Average sea level rise
	99%			0	0.1	0.45	Average sea level rise

As shown in Table 7, under the low-emissions scenario, Bremerton will as likely as not (50% likelihood) experience sea level rise of 0.35 feet by 2030, 0.7 feet by 2050, and 1.75 feet by 2100 and virtually certain (99% likelihood) to experience sea level rise of 0.15 feet by 2100. Under the high-emissions scenario, Bremerton will as likely as not (50% likelihood) experience sea level rise of 0.35 feet by 2030, 0.75 feet by 2050, and 2.15 feet by 2100 and virtually certain (99% likelihood) to experience sea level rise of 0.1 feet by 2050 and 0.45 feet by 2100.

[58] See all Kitsap County Sea Level Rise projections in Appendix D. CIG Sea Level Rise Projections, Likelihood Maps, and Graphs.

Table 7. Probabilistic Sea Level Rise Projections for Bremerton[59]

Emissions Scenario	Likelihood	Location		Year (sea level rise, ft)			Location Notes
		Lat.	Long.	2030	2050	2100	
RCP4.5 Low Emissions Scenario	50%	47.6°N	122.6°W	0.3	0.7	1.7	SW Bainbridge Island & Bremerton
	90%	47.6°N	122.6°W	0.1	0.3	0.7	SW Bainbridge Island & Bremerton
	95%	47.6°N	122.6°W	0	0.2	0.5	SW Bainbridge Island & Bremerton
	99%	47.6°N	122.6°W	-0.1	-0.1	0	SW Bainbridge Island & Bremerton
	50%	47.6°N	122.7°W	0.4	0.7	1.8	NW Bremerton
	90%	47.6°N	122.7°W	0.2	0.4	0.9	NW Bremerton
	95%	47.6°N	122.7°W	0.1	0.3	0.7	NW Bremerton
	99%	47.6°N	122.7°W	0	0.1	0.3	NW Bremerton
	50%			0.35	0.7	1.75	Average sea level rise
	90%			0.15	0.35	0.8	Average sea level rise
	95%			0.05	0.25	0.6	Average sea level rise
	99%			-0.05	0	0.15	Average sea level rise
RCP8.5 High Emissions Scenario	50%	47.6°N	122.6°W	0.3	0.7	2.1	SW Bainbridge Island & Bremerton
	90%	47.6°N	122.6°W	0.1	0.3	1.1	SW Bainbridge Island & Bremerton
	95%	47.6°N	122.6°W	0.1	0.2	0.8	SW Bainbridge Island & Bremerton
	99%	47.6°N	122.6°W	-0.1	0	0.3	SW Bainbridge Island & Bremerton
	50%	47.6°N	122.7°W	0.4	0.8	2.2	NW Bremerton
	90%	47.6°N	122.7°W	0.2	0.4	1.3	NW Bremerton
	95%	47.6°N	122.7°W	0.2	0.3	1.1	NW Bremerton
	99%	47.6°N	122.7°W	0.1	0.2	0.6	NW Bremerton
	50%			0.35	0.75	2.15	Average sea level rise
	90%			0.15	0.35	1.2	Average sea level rise
	95%			0.15	0.25	0.95	Average sea level rise
	99%			0	0.1	0.45	Average sea level rise

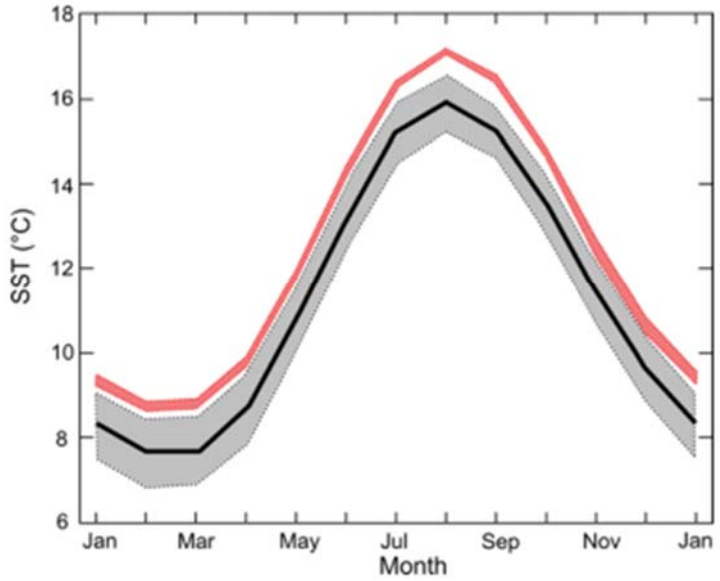
[59] See all Kitsap County Sea Level Rise projections in Appendix D. CIG Sea Level Rise Projections, Likelihood Maps, and Graphs.

Marine Water Temperature

The surface and subsurface water temperatures in Hood Canal and Puget Sound have warmed from 0.8°F to 1.6°F since 1950.[60] Surface water temperatures are projected to continue warming in the future.[61,62] Though it is difficult to accurately project future marine water temperature increases for Kitsap County due to natural variability, local conditions, and weather,[63] model projections for the coastal waters of the Pacific Northwest estimate that there will be an increase of 2.2°F by mid-century (2030-2059) under moderate emissions scenarios (A2/A1B/B1 or RCP4.5 and RCP6.0 equivalent) (Figure 11).[64,65]

Warmer waters for Kitsap County and the broader Puget Sound will have cascading impacts, including decreasing dissolved oxygen levels, increasing the likelihood of harmful algal blooms, and stressing marine species dependent on colder water, such as salmon and shellfish.[66]

Figure 11. Current and Projected Sea Surface Temperature for Pacific Northwest Coastal Waters[67]
(Black line and gray shading are the historical (1970-1999) sea surface temperatures and its range. The red line shows the projected increase in sea surface temperature by mid-century (2030-2059) under A2/A1B/B1 emissions scenarios, or RCP4.5 and RCP6.0 equivalent.)



[60] Newton *et al.* 2011. Hood Canal Dissolved Oxygen Program Integrated Assessment and Modeling Report. https://pdfs.semanticscholar.org/6648/a004109940877351c0b248d1dfd23d5fcc63.pdf.
[61] Mote *et al.* 2014. Ch. 21: Northwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*. https://nca2014.globalchange.gov/report/regions/northwest.
[62] Mauger *et al.* 2015. Section 7: Water Quality.
[63] Vynne & Harguth. 2015. Hood Canal Climate Change Projections Summary. Prepared by the Hood Canal Coordinating Council. http://hccc.wa.gov/sites/default/files/resources/downloads/Hood_Canal_Climate_Projection_Summary_May_2015.pdf.
[64] Mote & Salathé. 2010. Future climate in the Pacific Northwest. *Climatic Change* 102(1-2), 29-50.
[65] Petersen *et al.* 2015. Climate Change Preparedness Plan for the North Olympic Peninsula. A Project of the North Olympic Peninsula Resource Conservation & Development Council and the Washington Department of Commerce. www.noprcd.org.
[66] Mauger *et al.* 2015. Section 7: Water Quality.
[67] Mote & Salathé. 2010. Adapted in Petersen *et al.* 2015.

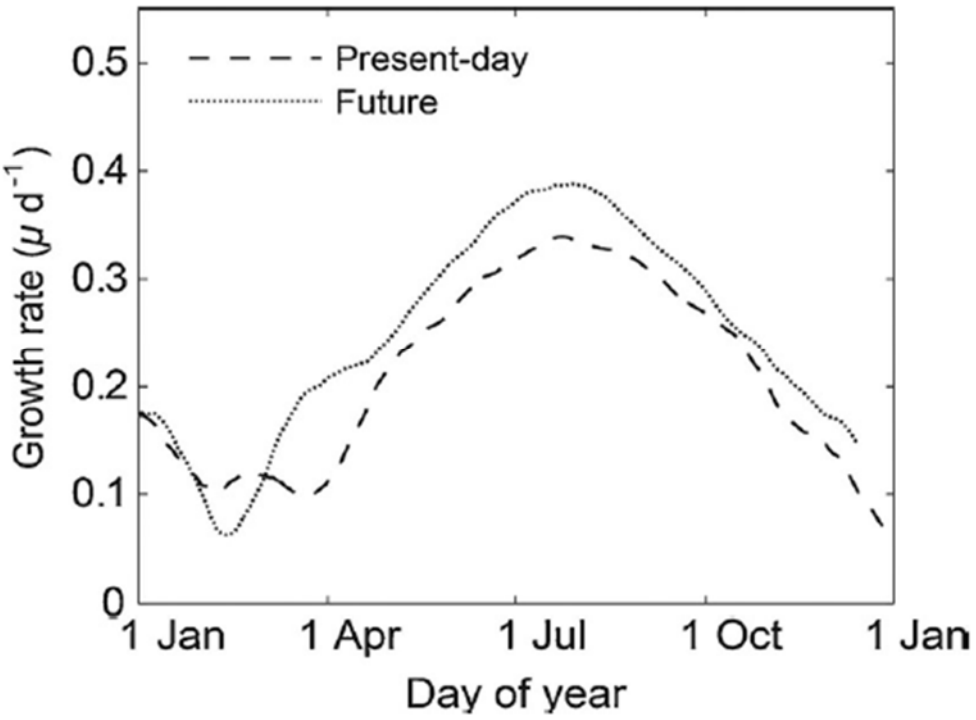
Ocean Acidification and Dissolved Oxygen

Kitsap County's waters are currently experiencing acidification (low pH) due to multiple interacting processes, such as circulation patterns, mixing, biological processes, nutrient loading from human sources, and increases in atmospheric carbon dioxide (CO_2).[68] In Hood Canal, up to 40% of acidification is attributed to human activity, though there is considerable spatial and temporal variability.[69] Overall, Hood Canal's waters are trending toward becoming more acidic.[70,71] The atmospheric CO_2 is projected to double by 2100 under RCP4.5 and by 2050 under RCP8.5.[72]

Although uncertainty exists around the magnitude of ocean acidification in the future, there is consensus that the ocean will continue acidifying in Puget Sound.[73] These projections are consistent with global ocean acidification projections.[74] Ocean acidification will have increasingly significant impacts on shellfish and salmon.[75,76] These impacts to marine species will have cascading impacts on Kitsap County's ecosystems, natural resource economies, and culture.[77] Furthermore, the compounding impacts of ocean acidification and warmer surface waters will increase risk and expand the window of opportunity for harmful algal blooms (Figure 12). Harmful algal blooms are projected to increase the frequency and severity of toxin accumulation in shellfish, which can cause paralytic shellfish poisoning if consumed.[78] Projected increases in frequency and severity of harmful algal blooms will also likely correlate to increases in frequency and severity of eutrophication and low dissolved-oxygen, hypoxia events, and dead zones.[79,80]

[68] Feely *et al.* 2010. The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. *Estuarine, Coastal and Shelf Science*. 88(4): 442–449.
[69] Feely *et al.* 2010.
[70] Mauger *et al.* 2015. Section 7: Water Quality.
[71] Feely *et al.* 2012. Scientific summary of ocean acidification in Washington State Marine Waters. *NOAA OAR Special Report*. https://fortress.wa.gov/ecy/publications/documents/1201016.pdf.
[72] Mauger *et al.* 2015. Section 7: Water Quality.
[73] Feely *et al.* 2012.
[74] Jewett, L. and A. Romanou, 2017: Ocean acidification and other ocean changes. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume I.* U.S. Global Change Research Program, Washington, DC, USA, pp. 364-392, doi: 10.7930/J0QV3JQB.
[75] Waldbusser *et al.* 2014. Saturation-state sensitivity of marine bivalve larvae to ocean acidification. *Nature Climate Change.* 5: 273-280.
[76] Busch *et al.* 2013. Potential impacts of ocean acidification on the Puget Sound food web*. ICES Journal of Marine Science*. 70: 823-833.
[77] Vynne & Harguth. 2015.
[78] Mote *et al.* 2014.
[79] Mauger *et al.* 2015. Section 7: Water Quality.
[80] Anderson *et al.* 2008. Harmful algal blooms and eutrophication: Examining linkages from selected coastal regions of the United States. *Harmful Algae*. 9(1): 39-53.

Figure 12. Projections of a Longer Season of Elevated Risk for Harmful Algal Blooms (HABs) in Puget Sound[81]
(Based on mean growth rates of Alexandrium *by mid-century, or the year 2047, under a moderate GHG scenario, A1B or RCP6.0 equivalent.)*



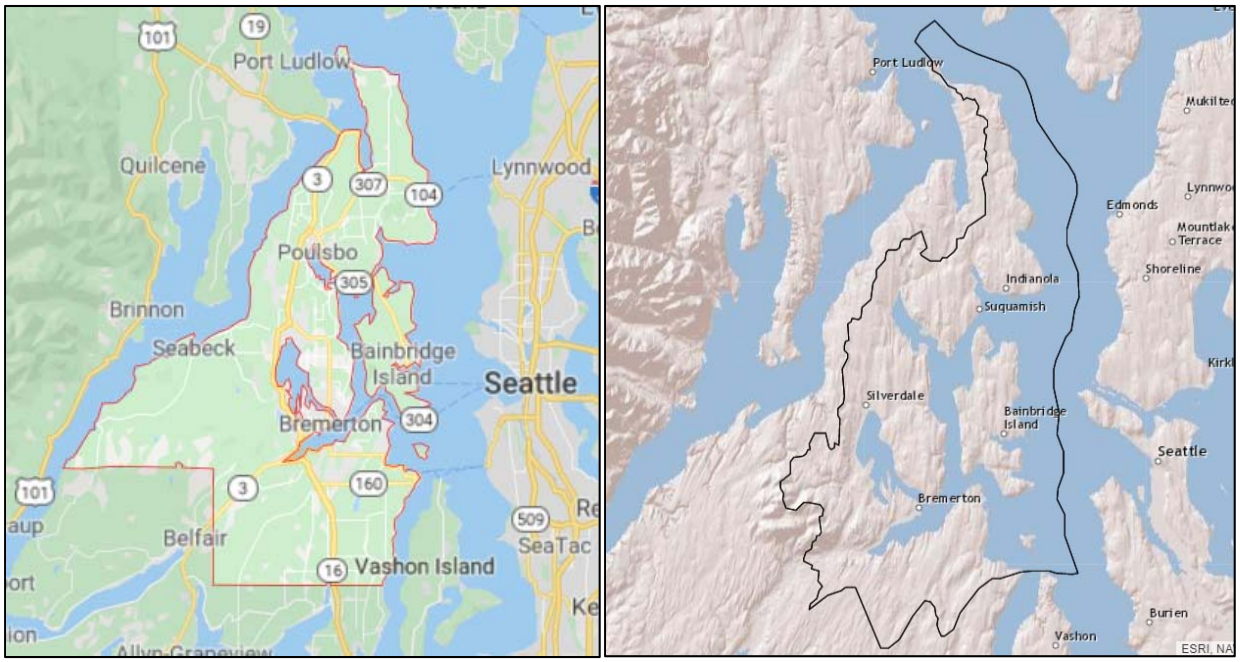
In Puget Sound and Hood Canal, dissolved oxygen (DO) levels are declining and are expected to decline in the future.[82] Similar to ocean acidification, natural variability in DO levels occurs due to coastal upwelling, mixing and entrainment within the vertical water column, global climate change, eddies, and the mixing of North Pacific waters with Puget Sound waters.[83] Projections of DO levels in the future are limited by data availability and geographic scope. Models project that Central Puget Sound and Hood Canal are likely to experience a decline of 0.6 mg/liter of DO levels, although attribution of declining DO levels to global climate change is still being refined.[84,85] Lower DO levels can stress marine species, especially salmon, and hypoxia events can lead to fish die-offs.[86]

[81] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[82] Mauger *et al.* 2015. Section 7: Water Quality.
[83] Feely *et al.* 2012.
[84] Moore *et al.* 2008. Local and large-scale climate forcing of Puget Sound oceanographic properties on seasonal to interdecadal timescales. *Limnol. Oceanogr.*, 53(5), 1746-1758.
[85] Roberts *et al.* 2014. Puget Sound and the Straits Dissolved Oxygen Assessment: Impacts of Current and Future Human Nitrogen Sources and Climate Change through 2070. Washington Department of Ecology, Publication No. 14-03-007, Olympia, Washington. https://fortress.wa.gov/ecy/publications/documents/1403007.pdf.
[86] Vaquer-Sunyer & Duarte. 2008. Thresholds of hypoxia for marine biodiversity. *Proc. Natl. Acad. Sci.,* 105(40), 15452-15457.

Temperature Trends, Extreme Heat, and Freeze-Free Days

Downscaled climate models for future projections in temperature trends were not available for Kitsap County. However, downscaled climate models are available for the Suquamish Tribe's area of interest, which covers a large portion of Kitsap County (Figure 13).

Figure 13. Comparative Maps of Kitsap County and the Suquamish Indian Tribe of the Port Madison Reservations' Area of Interest[87,88]

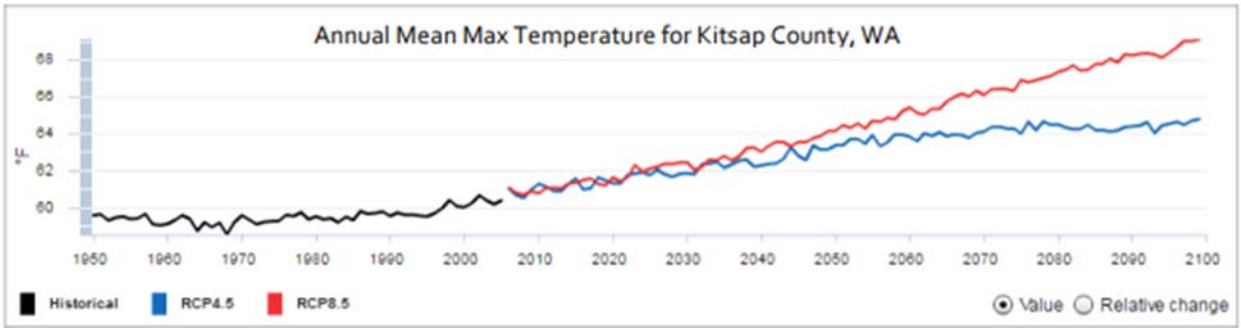


The annual average daily temperature will significantly increase by the end of the century in all climate scenarios (Figure 14). Under a low-emissions scenario, annual average temperature will warm 4.9°F and the maximum daily summer temperature will warm 6°F by the end of the century. Under a high-emissions business-as-usual scenario, annual average temperature will warm 8.5°F and the maximum daily summer temperature will warm 10.5°F by the end of the century (Table 8).

[87] Google Maps. 2020.

[88] University of Washington's Climate Impacts Group. Tribal Climate Tool. https://cig.uw.edu/resources/tribal-vulnerability-assessment-resources/tribal-climate-tool/.

Figure 14. Annual Mean Maximum Temperature Projections for Kitsap County under RCP4.5 and RCP8.5[89]
(low and high-emissions scenarios, respectively)



Warmer temperatures will significantly increase the number of extreme heat and freeze-free days (Table 9). By 2100, the number of extreme heat days are projected to increase by 17.1 days under a low-emissions scenario and 42.9 days under a high-emissions business-as-usual scenario. Furthermore, Kitsap County historically experienced approximately a month of temperatures below freezing (32°F/0°C), which was critical for cold stream temperatures and adequate streamflow in the spring and summer time for sensitive species like salmon. Future climate models project that there will be an average of a week of below-freezing temperatures under a low-emissions scenario, and virtually no days with freezing temperatures in a high-emissions business-as-usual scenario. These impacts, coupled with the shift of winter precipitation from snow to rain, will further compound and stress sensitive habitat and species reliant on snowpack and cold freshwater stream temperatures.[90] The increase in extreme heat days will also likely increase the number of heat-related illnesses in the summertime, with youth and elderly people at disproportionately higher risks.[91]

[89] USGS. 2014. Adapted in: Vynne & Harguth. 2015.
[90] Mote *et al.* 2014.
[91] May *et al.* 2018.

Table 8. Projections in Average Annual Daily Temperature and Maximum Daily Temperature under RCP4.5 and RCP8.5 through 2100 for the Suquamish Area of Interest, a proxy for Kitsap County[92]

Emissions Scenario	Time Period	Average Model Temperature (°F)	Change from Historical Baseline (°F)
Average Annual Daily Temperature			
RCP4.5	Historical	52.1	–
	2010-2039	54.1	+2.0
	2040-2069	56.0	+3.9
	2070-2099	57.0	+4.9
RCP8.5	Historical	52.1	–
	2010-2039	54.5	+2.4
	2040-2069	57.3	+5.2
	2070-2099	60.6	+8.5
Maximum Daily Temperature, June-August			
RCP4.5	Historical	73.6	–
	2010-2039	76.3	+2.7
	2040-2069	78.5	+4.9
	2070-2099	79.6	+6.0
RCP8.5	Historical	73.6	–
	2010-2039	76.7	+3.1
	2040-2069	80.2	+6.6
	2070-2099	84.1	+10.5

[92] UW Climate Impacts Group. 2018. Tribal Climate Tool. https://climate.northwestknowledge.net/NWTOOLBOX/tribalProjections.php.

Table 9. Projections to Changes in Extreme Heat Days (maximum temperature above 86°F) and Freeze-Free Days (minimum temperature above 32°F) for the Suquamish Area of Interest, a proxy for Kitsap County[93]

Emissions Scenario	Time Period	Average Model (Days)	Change from Historical Baseline
Annual Days with Max. Temperature Above 86°F (30°C)			
RCP4.5	Historical	3.5	–
	2010-2039	8.3	+4.8
	2040-2069	15.4	+11.9
	2070-2099	20.6	+17.1
RCP8.5	Historical	3.5	–
	2010-2039	9.8	+6.3
	2040-2069	23.3	+19.8
	2070-2099	46.4	+42.9
Annual Freeze-Free Days, with Min. Temperature Above 32°F (0°C)			
RCP4.5	Historical	335.7	–
	2010-2039	349.0	+13.3
	2040-2069	356.3	+20.6
	2070-2099	358.0	+22.3
RCP8.5	Historical	335.7	–
	2010-2039	351.9	+16.2
	2040-2069	358.5	+22.8
	2070-2099	362.4	+26.7

Precipitation

Two sources of information were used to provide future projections of changes in precipitations in Kitsap County. Both data sources use global climate models (GCMs) and a statistical downscaling method, called Multivariate Adaptive Constructed Analogs (MACA), to project the regional climate at a more localized scale under RCP4.5 and RCP8.5 scenarios.

1. The Tribal Climate tool projects annual and seasonal changes in precipitation for the Suquamish Tribe's area of interest, which covers most of Kitsap County (Figure 13).
2. King County's Climate Change GIS Open Data site provides access to climate projections for hydrologic units on the east and west side of King County.

Extreme Precipitation Events

The maximum 24-hour precipitation event in Kitsap County is projected to increase by 15% by 2080s under RCP4.5 and by 24% by the 2080s under RCP8.5 (Table 10). Large precipitation events will affect the ability of stormwater infrastructure to convey storm flow and potentially increase flooding impacts. Flooding impacts may be exacerbated by sea level rise in areas near marine outfalls. Larger precipitation events may also result in more stream erosion and negatively affect aquatic habitat, particularly in places where flows are already high due to development and associated impervious surfaces. Recently, the University of Washington's

[93] https://climate.northwestknowledge.net/NWTOOLBOX/tribalProjections.php

Climate Impacts Group has used GCMs to drive the regional climate models' (RCMs) Weather Research and Forecasting (WRF) community mesoscale model to generate 13 simulations (that is, they used 13 different GCMs to drive WRF) of precipitation at an hourly timestep in order to facilitate stormwater analysis.[94] Precipitation was simulated for nearly 150 rain gauge locations in the region. Though no site-specific projections are available within Kitsap County, review of surrounding stations in Jefferson, Mason, and King counties support the general trend of extreme precipitation events becoming more intense by the 2050s and 2080s.

Table 10. Changes in Maximum 24-Hour and Seasonal Precipitation under Low- and High-Emissions Scenarios for Hydrologic Units in Kitsap County, averaged as a proxy for Kitsap County

Emissions Scenario	Time Period	Percent Change
Maximum 24-hour Precipitation		
RCP4.5	2040-2069	*13%*
	2070-2099	*15%*
RCP8.5	2040-2069	*15%*
	2070-2099	*24%*
October-March Precipitation		
RCP4.5	2040-2069	8%
	2070-2099	11%
RCP8.5	2040-2069	9%
	2070-2099	13%
April-September Precipitation		
RCP4.5	2040-2069	-7%
	2070-2099	-8%
RCP8.5	2040-2069	-7%
	2070-2099	-10%

Annual and Seasonal Precipitation

Annual total precipitation will increase by the end of the century in both low- and high-emissions scenarios. Furthermore, winter precipitation is projected to increase and shift from snow to rain, and summer precipitation is projected to decrease under all emission scenarios (Table 11).[95] These changes will have significant implications for hydrological regimes in shifting timing of peak streamflow, stream temperatures, declining summer flows, and increased risk of flooding.[96,97] These hydrologic changes will have damaging impacts for habitat and iconic species like salmon.[98]

[94] UW Climate Impacts Group. Regional Model Projections of Heavy Precipitation for use in Stormwater Planning. https://cig.uw.edu/our-work/applied-research/heavy-precip-and-stormwater/.
[95] Mauger *et al.* 2015. Section 3: Water Cycle.
[96] Mauger *et al.* 2015. Section 3: Water Cycle.
[97] Mote *et al.* 2014.
[98] May *et al.* 2018.

Furthermore, intense rain events, and subsequent flooding, will likely increase for Kitsap County across every climate scenario. The timing of the increase in future intense rain events will most likely occur in the winter, especially in the southern portion of Kitsap County where Bremerton and Port Orchard are located. Impacts of sea level rise will compound the magnitude of flooding events and risk.[99]

Table 11. Changes in Annual and Seasonal Precipitation under Low- and High-Emissions Scenario for Suquamish Area of Interest, a proxy for Kitsap County

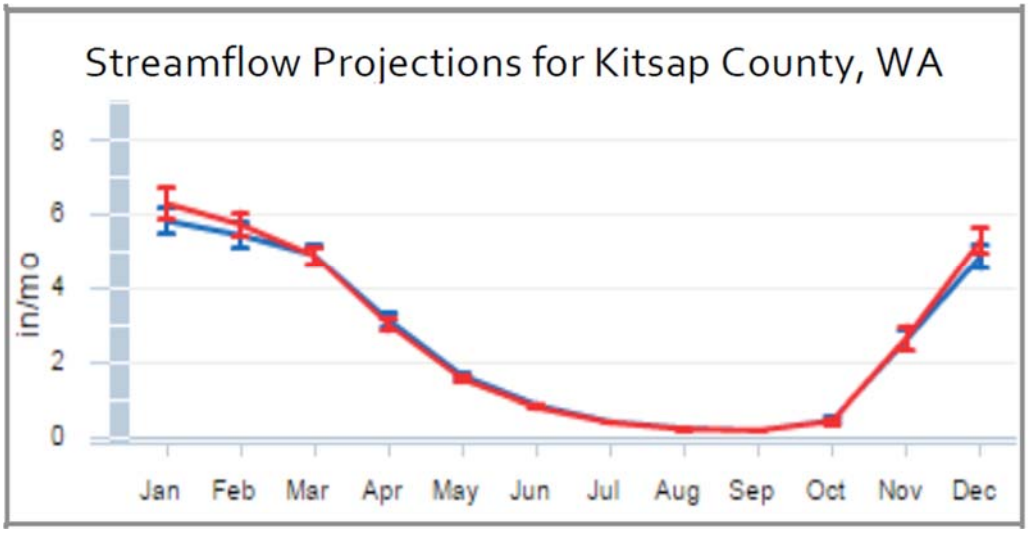
Emissions Scenario	Time Period	Percent Change
Annual Precipitation		
RCP4.5	2010-2039	3%
	2040-2069	5%
	2070-2099	6%
RCP8.5	2010-2039	2%
	2040-2069	5%
	2070-2099	9%
October-March Precipitation		
RCP4.5	2010-2039	3%
	2040-2069	7%
	2070-2099	9%
RCP8.5	2010-2039	3%
	2040-2069	7%
	2070-2099	13%
April-September Precipitation		
RCP4.5	2010-2039	-1%
	2040-2069	-3%
	2070-2099	-5%
RCP8.5	2010-2039	-2%
	2040-2069	-3%
	2070-2099	-6%

[99] Kitsap County Public Works. 2019. Task 700 Climate Change Assessment.

Streamflow

Under both low- and high-emissions scenarios, streamflow in Kitsap County will increase during winter months due to shifting precipitation from snow to rain and will decrease in late spring and summer by mid-century (Figure 15).[100] Earlier peak flows in the winter months could lead to increased frequency of winter flooding, damaging infrastructure, homes, and habitats.[101] Lower streamflow in late spring and summer can harm salmon runs.[102] By the end of the century, virtually all watersheds in the Puget Sound area will shift from either snow-dominated basins or mixed rain- and snow-dominated basins to rain-dominated basins.[103] This can shift the peak flow for rivers and streams in Puget Sound anywhere from 15 to 40 days earlier under moderate or high-emissions scenarios.[104] Furthermore, minimum flows for Puget Sound rivers and streams are projected to decrease from 16% to 51% under moderate and high-emissions scenarios.[105] Though these impacts may not be directly observed in Kitsap County, there may be other subsequent climate impacts and decision-making impacts for Kitsap County.

Figure 15. Seasonal Streamflow Projections (in inches) for Kitsap County under Historic Conditions (blue line) and Mid-Century Conditions (red line)[106]



[100] Vynne & Harguth. 2015.
[101] Mauger *et al.* 2015. Section 3: Water Cycle.
[102] Mote *et al.* 2014.
[103] Mauger *et al.* 2015. Section 3: Water Cycle.
[104] Hamlet. *et al.* 2013. An Overview of the Columbia Basin Climate Change Scenarios Project: Approach, methods, and summary of key results. *Atmosphere---Ocean,* 51(4), 392-415, doi:10.1080/07055900.2013.819555.
[105] Mauger *et al.* 2015. Section 3: Water Cycle.
[106] USGS. 2014. Adapted in: Vynne & Harguth. 2015.

Stream Temperature

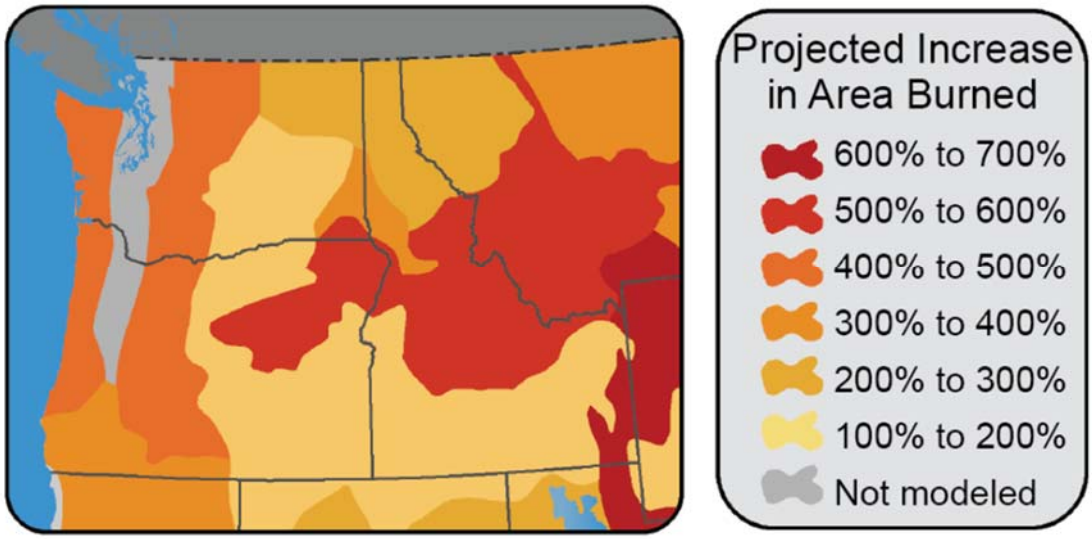
Under all climate scenarios, stream temperatures are projected to increase by 4.0°F to 4.5°F in response to warmer air temperatures and decreasing summer streamflow by the end of the century.[107,108] This warming is driven by a combination of projected decreases in streamflow, the decline of winter snowpack, glacier recession, and the shift from snow-dominated and mixed-precipitation basins to rain-dominated basins.[109, 110] Furthermore, by the 2080s, Puget Sound rivers will regularly exceed the thermal tolerance threshold for cold-water species, such as salmon and char, ranging from an average annual increase of a few days to 7.5 weeks.[111] For the Port Gamble S'Klallam Tribe, the Dungeness and Skokomish rivers are expected to increase 0 to 3 river miles with August stream temperatures exceeding thermal tolerances for salmon (>64°F) and 32 to 120 miles with August stream temperatures exceeding thermal tolerances for char (>54°F).[112] These future projections will have severe consequences for cold-water fish species.

Wildfires

Climate change is projected to increase the frequency of wildfires in western Washington, although it is difficult to project future wildfire risk with accuracy and confidence due to the low number of fires west of the Cascade Range.[113] Increased wildfire risk is driven by warmer spring and summer temperatures, reduced summer precipitation, increased evaporation, declining snowpack, and increasing prevalence of pests and diseases.[114] Projections of area burned across the Pacific Northwest (Figure 16) is expected to have detrimental impacts to air quality in Kitsap County.[115]

[107] Vose *et al.* 2014. Improved historical temperature and precipitation time series for US climate divisions. *Journal of Applied Meteorology and Climatology.* 53(5): 1232-1251.
[108] Mote *et al.* 2014.
[109] Hamlet *et al.* 2013.
[110] Mauger *et al.* 2015. Section 3: Water Cycle.
[111] Mantua *et al.* 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. *Clim Change.* 102:187–223.
[112] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment. A collaboration of the Port Gamble S'Klallam Tribe, Cascadia Consulting Group, and the University of Washington Climate Impacts Group. http://nr.pgst.nsn.us/wp-content/uploads/2017/08/PGST_climate-impact-assessment_report_0518-FINAL.pdf.
[113] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[114] Mote *et al.* 2014.
[115] May *et al.* 2018.

Figure 16. Projections for Increase in Area Burned [116] *(Map indicates the increases in area projected to be burned that would result from the regional temperature and precipitation changes associated with a 2.2°F global warming across areas that share broad climatic and vegetation characteristics. Local impacts will vary greatly within these broad areas with sensitivity of fuels to climate.)*



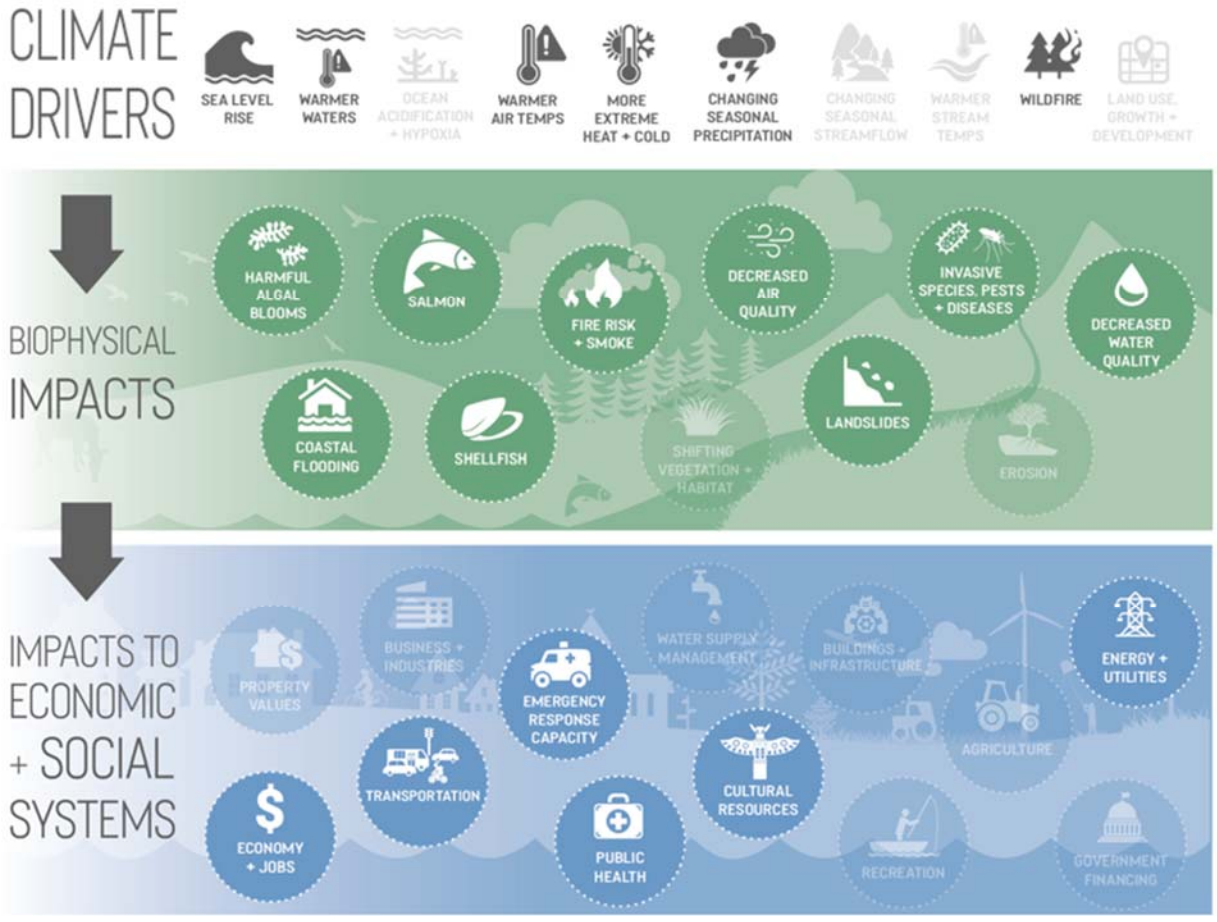
[116] Mote *et al.* 2014.

Chapter 3. Public Health

Summary of Findings

Regionally relevant publications and scientific research identify multiple health considerations for Kitsap County. Substantial evidence links certain health risks and premature mortality with climate change, such as heat-related illnesses, respiratory illnesses, chronic illnesses and conditions, mental health challenges, and vector-borne diseases. Future climate change projections will exacerbate health risks for the region, including for Kitsap County, and likely lead to multiple detrimental health outcomes for people. Extreme weather events can lead to acute physical injuries, death, and long-term physical and mental health challenges. Climate change is likely to increase food insecurity for some groups of people. Certain groups of people are of concern, mainly because they often experience the first and worst impacts of climate change and bear a disproportionate burden. These groups of people include elderly people, children, communities of color, people with chronic illnesses, Tribal and Indigenous peoples, and outdoor laborers. Additionally, concerns exist about whether local health departments and health providers can meet future demand and increased stress from climate-related illnesses and injuries.

Figure 17. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Public Health



Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Heat-related illnesses	**High** • More intense heat waves *are likely* to increase heat-related illnesses and deaths. • Outdoor laborers, elderly people, and youth have a higher risk of heat-related illnesses [*very high confidence*].	**Long-term** • It is very likely that extreme heat days will increase under all climate scenarios [*very high confidence*], which may lead to more than 250 excess heat-related deaths each year by the end of the century [*medium confidence*].
2. Respiratory illnesses	**Low-Medium** • Air quality degradation, especially from wildfires, has been linked to a range of health outcomes from acute respiratory illnesses and increased school absences [*high confidence*]. • The extension of the pollen season has already affected people with seasonal allergies [*medium confidence*].	**Long-term** • Acute and chronic respiratory illnesses due to air quality degradation will likely increase in prevalence and impact for Kitsap County residents [*medium confidence*].
3. Acute injuries from extreme weather events	**High** • Extreme events, such as flooding, winter storms, and landslides, will likely increase in intensity or frequency, which may result in acute injuries, death, and disruption of medical services [*medium confidence*].	**Already happening** • Extreme events are already happening, and climate change exacerbating these events will very likely affect Kitsap residents' health and resilience to extreme events [*high confidence*].
4. Vector-borne diseases	**Medium** • Variety of vector-borne diseases (e.g., *C. gattii*, West Nile virus, Lyme disease, paralytic shellfish poisoning) will likely increase in prevalence [*medium confidence*].	**Near-term** • Prevalence and ranges of vector-borne disease will likely expand due to climate change in the near term [*medium confidence*].
5. Food security	**Low-Medium** • People who are more reliant on natural resources and subsistence livelihoods vulnerable to climate change are at risk of food insecurity [*medium confidence*].	**Already happening** • These impacts are already manifesting for Tribal and Indigenous peoples in Kitsap County [*very high confidence*]. **Near-term** • Food insecurity will likely increase with increasing frequency and intensity of climate impacts and extreme events [*medium confidence*].
6. Mental health and wellbeing	**Low** • Research finds some linkages between mental health illnesses (e.g., post-traumatic stress disorder, anxiety, depression) and climate change and extreme events [*medium confidence*].	**Near-term** • Children and people dependent on natural resources are more at risk in the near term due to climate change, and mental health care services may be unable to meet this need [*medium confidence*].

Key Findings	Magnitude of Impact & Key Metrics	Timeline
7. Communities of concern	**High** • Children, elderly people, Tribal and Indigenous peoples, outdoor laborers, homeless people, people with chronic illnesses, and low-income people will be disproportionately at risk of climate-related health risks [*very high confidence*].	**Neat to long-term** • Many of these health risks will manifest in the near to long term, depending on health impact [*medium confidence*]. • There will likely be heterogeneity in how health outcomes are realized.
8. Health and social safety net	**Medium** • Long-term climate impacts will likely increase hospital admissions, emergency service calls, and long-term healthcare services [*high confidence*].	**Long-term** • Health service providers may be unable to meet the need for health services under long-term future climate conditions [*low to medium confidence*].

Finding 1: Heat-related Illnesses

There are already clearly established associations between extreme heat events and heat waves with increased heat-related illnesses and deaths in the Puget Sound region and Pacific Northwest. Future increases in extreme heat events will very likely lead to an increase of premature heat-related illnesses and deaths during the summer by the end of the century for Kitsap County residents. People who work outdoors, elderly people, and children have a higher risk of heat-related injuries. Future conditions will likely stress health service providers and capacity.

There are already clearly established associations between extreme heat events and heat waves with increased heat-related illnesses and deaths in the Puget Sound region and the Pacific Northwest.[117,118] Although research has not been conducted establishing a linkage between heat-related illnesses and climate change specifically in Kitsap County, there have been multiple studies conducted of climate impacts driving heat-related illnesses and deaths in nearby King County, which is consistent with broader regional and national trends.[119,120] Heat-related illnesses range from natural heat exposure (heat exhaustion and heat strokes), nephritis and nephrotic symptoms, acute renal failure, asthma, and chronic obstructive pulmonary disease.[121,122,123] In King County, there are statistically significant associations between heat-related hospital

[117] May *et al.* 2018. Chapter 24: Northwest. *In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment.* Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 1036–1100. https://nca2018.globalchange.gov/chapter/24/.

[118] Mauger *et al.* 2015. Section 13: Human Health. https://cig.uw.edu/resources/special-reports/ps-sok/.

[119] May *et al.* 2018.

[120] Sarofim *et al.* 2016. Ch. 2: Temperature-Related Death and Illness. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. U.S. Global Change Research Program, Washington, DC, 43–68. http://dx.doi.org/10.7930/J0MG7MDX.

[121] Isaksen *et al.* 2015. Increased hospital admissions associated with extreme-heat exposure in King County, Washington, 1990–2010. *Reviews on Environmental Health*. 30 (1): 51-64. http://dx.doi.org/10.1515/reveh-2014-0050.

[122] Anderson, G.B. *et al.* 2013. Heat-related emergency hospitalizations for respiratory diseases in the Medicare population. *American Journal of Respiratory and Critical Care Medicine*. 187(10): https://doi.org/10.1164/rccm.201211-1969OC.

[123] Glaser *et al.* 2016. Climate change and the emergent epidemic of CKD from heat-stress in rural communities: the case for heat stress nephropathy. *Clinical Journal of the American Society of Nephrology*. 11(8): 1472-1483. DOI: 10.2215/CJN.13841215.

admissions and illnesses when the humidity index (humidex) factor is 37.4°C or greater, or when the temperature is approximately 83°F with average summer humidity of 66.1%.[124,125] Furthermore, there is a statistically significant correlation in King County between extremely warm days, or days when the humidex factor is 36°C or greater or days when the temperature is 82°F at average summer humidity of 66.1%, and heat-related mortality.[126]

Future increases in extreme heat events will likely lead to an increase in premature heat-related illnesses and deaths during the summer by the end of the century for Kitsap County residents.[127] By 2100 in Kitsap County, projections estimate that the number of extreme heat days, or days with a maximum temperature of above 86°F, will increase by 17.1 days per year or 42.9 days per year under RCP4.5 and RCP8.5, respectively.[128] The future increase in the number of extreme heat days will have significant health consequences for residents of Kitsap County based on climate and health studies in the city of Seattle and King County, which are projected to have increases in heat-related deaths across all climate scenarios.[129] Elderly people, or people over the age of 65, are projected to have the largest number of projected heat-related deaths in Seattle. Under RCP4.5, elderly people are projected to experience 96 excess deaths per year by 2025, 148 by 2045, and 266 excess deaths per year by 2085.[130] These numbers may shift as these projections do not account for expected future migration patterns to the region, population growth, or adaptation strategies.[131]

In King County, when the humidex factor is 36°C, or when the temperature is 82°F at average summer humidity, there is a 10% increase in the risk of death.[132] This increased risk of premature heat-related mortality is consistent with national projections, which estimate a national increase of thousands to tens of thousands of premature heat-related deaths during the summertime.[133] Residents of urban areas, such as Bremerton, may experience more heat impacts due to the urban heat island effect, which refers to the tendency of buildings and pavement to absorb and emit heat.[134] **People who work outdoors, elderly people, communities of color, and children have a higher risk of heat-related injuries.**[135]

[124] These calculations were based on average humidity of Seattle in the summertime and temperature to humidex calculations.
[125] Isaksen *et al.* 2015.
[126] Isaksen *et al.* 2016. Increased mortality associated with extreme-heat exposure in King County, Washington, 1980–2010. *International Journal of Biometeorology.* 60 (1), 85-98. http://dx.doi. org/10.1007/s00484-015-1007-9.
[127] Sarofim *et al.* 2016.
[128] See Chapter 2. Climate Change Overview: Temperature Trends, Extreme Heat, and Freeze-Free Days
[129] Jackson *et al.* 2010. Public health impacts of climate change in Washington State: projected mortality risks due to heat events and air pollution. *Climatic Change*. 102(1-2): 159-186. DOI: 10.1007/s10584-010-9852-3.
[130] Jackson *et al.* 2010.
[131] Schwartz *et al.* 2015. Projections of temperature-attributable premature deaths in 209 U.S. cities using a cluster-based Poisson approach. *Environmental Health*. 85: doi:10.1186/s12940-015-0071-2.
[132] Isaksen *et al.* 2016.
[133] Sarofim *et al.* 2016.
[134] May *et al.* 2018.
[135] Calkins *et al.* 2016. Impacts of extreme heat on emergency medical service calls in King County, Washington, 2007–2012: Relative risk and time series analyses of basic and advanced life support. *Environmental Health*. 15 (1): 13. http://dx.doi. org/10.1186/s12940-016-0109-0.

Finding 2: Respiratory Illnesses

There are clear historical correlations between climate change and air quality, as air quality degrades from wildfire smoke, increases in ozone, and increases in airborne allergens. Degraded air quality is clearly linked to acute and chronic health diseases, particularly respiratory illnesses. Air quality is projected to continue to degrade under future climate conditions, leading to a range of potential health outcomes.

There are clear historical correlations between climate change and air quality, as air quality degrades from wildfire smoke, increases in ozone, and increases in airborne allergens. Degraded air quality is clearly linked to acute and chronic health disease, particularly respiratory illnesses. Warmer temperatures and drought conditions have contributed to longer wildfire seasons across the Pacific Northwest and West Coast.[136] Smoke has caused increased particulate matter pollution and decreased air quality across western Washington and the Puget Sound area in recent years.[137,138,139] In 2017 and 2018, Seattle experienced 24 days of increased air pollution due to wildfires across the Northwest, with multiple days in each year being deemed "unhealthy for all."[140] Wildfire smoke has been linked to increased hospitalizations for acute respiratory illnesses and increased school absences in Washington State.[141,142]

Additionally, warmer summers and wildfire smoke has already manifested in longer pollen seasons and is likely to extend future pollen seasons and degrade air quality, exacerbating challenges for people with chronic conditions such as allergies and asthma.[143] Though asthma hospitalization rates have decreased since the 1990s in Kitsap County, the prevalence of asthma conditions has increased.[144]

Air quality is projected to continue to degrade under future climate conditions, leading to a range of potential health outcomes.[145,146] In Kitsap County, there will be an increase in instances of days with poor air quality due to more frequent wildfires and air quality conditions.[147] Increases in ground-level ozone (smog), small particulate matter, and airborne allergens are projected.[148,149] Future conditions will very likely lead to increased prevalence of acute respiratory illnesses and create complications for people with chronic health

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[136] Mote *et al.* 2014. Ch. 21: Northwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*. https://nca2014.globalchange.gov/report/regions/northwest.

[137] May *et al.* 2018.

[138] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment. A collaboration of the Port Gamble S'Klallam Tribe, Cascadia Consulting Group, and the University of Washington Climate Impacts Group. http://nr.pgst.nsn.us/wp-content/uploads/2017/08/PGST_climate-impact-assessment_report_0518-FINAL.pdf.

[139] Mauger *et al.* 2015. Section 13: Human Health.

[140] Contreras. 2019. "Seattle prepares for health consequences of wildfire smoke." Published in *The Seattle Times.* 19 July 2019, www.seattletimes.com/seattle-news/health/seattle-prepares-for-health-consequences-of-wildfire-smoke/.

[141] Mauger *et al.* Section 13: Human Health.

[142] May *et al.* 2018.

[143] May *et al.* 2018.

[144] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

[145] May *et al.* 2018.

[146] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

[147] See Chapter 2. Climate Change Overview: Wildfires.

[148] Jackson *et al.* 2010.

[149] Fann *et al.* 2016. Ch. 3: Air Quality Impacts. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC, 69–98. http://dx.doi.org/10.10.7930/J0GQ6VP6.

conditions, especially people with cardiovascular conditions, cancer, and respiratory illnesses.[150,151] This will likely lead to increased premature deaths across the Northwest, including for residents of Kitsap County.

Finding 3: Acute Injuries from Extreme Weather

Extreme weather events can disrupt emergency support systems and services and cause damage to homes and infrastructure, which can lead to acute and chronic injuries. As extreme weather events will likely increase in frequency and intensity in the Northwest, there will likely be cascading acute and chronic health impacts for Kitsap County residents during and after extreme events.

Extreme weather events can disrupt emergency support systems and services and cause damage to homes and infrastructure, which can lead to acute and chronic injuries.[152] Increasing floods, droughts, storms, landslides, and wildfires can lead to physical injuries, reduced potable water availability, disruption of health and emergency services, and damage to infrastructure.[153,154] Flooding is already the most common extreme weather event that Kitsap County experiences, with 9 different disaster or emergency declarations for flooding between 1990-2007.[155] A suite of other environmental hazards has caused damage in Kitsap County over the past few decades, such as severe storms, landslides, earthquakes, and droughts (Table 12). Although not every extreme event is directly associated with climate change, compounding hazard risks and adaptive capacity will likely be influenced by climate change. These extreme events have led to a range of health impacts from physical injury and death to disruption of emergency medical and support services and power outages.[156] Kitsap County Emergency Management Department has also developed mitigation planning strategies for severe storms, land shifts, earthquakes, droughts, and tsunamis.[157,158]

[150] Nolte *et al.* 2018. Air Quality. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment.* Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 512–538. https://nca2018.globalchange.gov/chapter/13/.

[151] Cosselman *et al.* 2015. Environmental factors in cardiovascular disease. *Nature Reviews Cardiology*. 12: 627-642. Doi:10.1038/nrcardio.2015.152.

[152] May *et al.* 2018.

[153] Washington Department of Ecology. 2012. Human Health: Preparing Washington for a Changing Climate. https://fortress.wa.gov/ecy/publications/publications/1201004.pdf.

[154] Bell *et al.* 2016. Ch. 4: Impacts of Extreme Events on Human Health. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. U.S. Global Change Research Program, Washington, DC. 99–128. http://dx.doi.org/10.7930/J0BZ63ZV.

[155] Kitsap County Department of Emergency Management. 2015. Kitsap County Multi-Hazard Mitigation Plan. Bremerton, WA.

[156] Kitsap County Department of Emergency Management. 2015.

[157] Kitsap County Department of Emergency Management. 2015.

[158] See Chapter 6: Public Infrastructure. Finding 6: Power and Energy.

Table 12. Partial History of Extreme Events in Kitsap County Since Mid-20th Century[159]

Type of Extreme Event	Year(s)	Locations Affected	Health Impacts
Flooding disasters	1990, 1994, 1995, 1996, 1997, 1999, 2003, 2006, 2007	All locations and residents of Kitsap County	Loss of life, disruption of transportation routes for emergency services, waterborne diseases
Severe winds	1962 "Columbus Day" storm, 1993 "Inauguration Day" storm	Kitsap County	Disruption of communication lines and transportation routes, damages to residences, physical injuries
Severe snowstorms	1949, 1950, 1951, 1961, 1969, 1971, 1985, 1990, 1996	Kitsap County	Disruption of communication and transportation routes, loss of life from extreme cold or accidents
Landslides	1996	Bainbridge Island	Disruption of transportation routes, loss of life, physical injuries, damages to property and residences
Earthquakes	1999, 2001, 2009	Near Bremerton, Nisqually, Kingston, respectively	Physical injuries, loss of life, damages to residences, disruption of communication lines and transportation routes
Severe droughts	1976-1977, 2001	Kitsap County	Potable water availability, air quality impacts
Tsunamis	1949	South Kitsap County	Disruption of communication lines and transportation routes, physical injuries, loss of life, potable water availability, emergency services capacity

As extreme weather events will likely increase in frequency and intensity in the future in the Pacific Northwest, there will likely be cascading acute and chronic health impacts for Kitsap County residents during and after extreme events.[160] With projections of increasing heavy rain events, sea level rise, coupled with growth and development of urban areas such as Bremerton and Bainbridge Island, flooding events will likely become more frequent and severe in the future, affecting all residents in Kitsap County.[161,162] This will likely result in flooding-related deaths, damages to homes and businesses, damages to public and transportation infrastructure. Urban areas in Kitsap County have been identified as particularly vulnerable due to older drainage and stormwater systems.[163]

[159] Kitsap County Department of Emergency Management. 2015.
[160] Bell *et al.* 2016.
[161] See Chapter 2. Future climate change projections. Sea Level Rise
[162] See Chapter 2. Future climate change projections. Precipitation.
[163] Kitsap County Department of Emergency Management. 2015.

Heavy rainfall is also likely to lead to increased risk of slope instabilities and landslides.[164] Increased intensity and frequency of extreme weather and storms is also likely across the Northwest and Puget Sound region.[165] These will have substantial health impacts for Kitsap County and its communities in the future, as this may lead to increased premature death, physical injuries, and long-term health problems following the extreme event.[166] Furthermore, future climate conditions may also impact ability of emergency and health providers to respond during and after extreme events and affect the adaptive capacity and post-event recovery of Kitsap County communities.[167] Extreme events, including droughts and flooding, will also very likely affect the potable water availability.[168]

Finding 4: Vector-borne Diseases

Diseases through a range of vectors, such as food, water, and insects, have increased over the past few decades in the Northwest. These types of vector-borne diseases are likely to increase under all climate scenarios from future increases in heavy precipitation events, prevalence of invasive pests and diseases, and harmful algal blooms.

Diseases through a range of vectors, such as food, water, and insects, have increased over the past few decades in the Pacific Northwest.[169,170] There is a clear linkage between the increase of some diseases and associated vectors, such as insects, food, and water. For instance, there has already been an increase in Lyme disease and West Nile virus cases in Washington State and the Puget Sound region.[171] The timing and habitats of ticks and West Nile virus-carrying mosquitoes have been expanding due to warmer temperatures.[172,173] Water-borne diseases and parasites have also been increasing.[174] *Cryptosporidiosis* spp. parasites have increased in Puget Sound's waters, which can cause diarrhea.[175] Harmful algal blooms (HABs) have led to increased prevalence of shellfish toxins in Puget Sound and Hood Canal, which can lead to acute illnesses and death.[176,177]

[164] Stauch *et al.* 2015. Adapting transportation to climate change on federal lands in Washington State, U.S.A. *Climatic Change*. 130(2): 185-199. Doi:10.1007/s10584-015-1357-7.
[165] May *et al.* 2018.
[166] Bell *et al.* 2016.
[167] May *et al.* 2018.
[168] Mauger *et al.* 2015. Section 13: Human Health.
[169] Beard *et al.* 2016. Ch. 5: Vectorborne Diseases. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. U.S. Global Change Research Program, Washington, DC, 129–156. http://dx.doi.org/10.7930/J0765C7V.
[170] Mauger *et al.* 2015. Section 13: Human Health.
[171] May *et al.* 2018.
[172] Washington State Department of Health. 2018. Washington Tracking Network: A Source for Environmental Public Health Data. https://fortress.wa.gov/doh/wtn/WTNIBL/.
[173] Beard *et al.* 2016.
[174] Mauger *et al.* 2015. Section 13: Human Health.
[175] Semenza *et al.* 2012. Climate Change Impact Assessment of Food- and Waterborne Diseases. *Critical Reviews in Environmental Science and Technology.* 42(8): 857-890. www.ncbi.nlm.nih.gov/pmc/articles/PMC3996521/.
[176] Vynne & Harguth. 2015. Hood Canal Climate Change Projections Summary. Prepared by the Hood Canal Coordinating Council. http://hccc.wa.gov/sites/default/files/resources/downloads/Hood_Canal_Climate_Projection_Summary_May_2015.pdf.
[177] Mauger *et al.* 2015. Section 13: Human Health.

Across the Northwest, there have been outbreaks of shigellosis (a diarrheal disease associated with precipitation that disproportionately affects homeless people), *Cryptococcis gattii* (an infectious disease associated with climate change that can cause premature death), and outbreaks of salmonella and *E. coli* (associated with extreme heat).[178,179]

These types of vector-borne diseases are likely to increase under all climate scenarios from future increases in heavy precipitation events, prevalence of invasive pests and diseases, and harmful algal blooms.[180] Increasing frequency of heavy rainfall events will likely lead to increased exposure of waterborne diseases, especially in drinking water.[181] Harmful algal blooms are likely to increase in frequency and intensity under all scenarios, and HABs are very likely to increase the prevalence of shellfish poisoning for people who consume shellfish.[182] There is some likelihood that tropical and subtropical fungal diseases, such as *C. gattii*, which is already found in the Northwest, can lead to more frequent outbreaks and associated mortality.[183] Other vector-borne diseases are likely to expand into the Puget Sound region, leading to a range of risks and exposures to new illnesses and diseases.[184]

Finding 5: Food Security

Food insecurity will likely increase in the future, especially for people who depend on the natural resource economy. Food sovereignty will be affected, especially for Tribal members who rely on subsistence and cultural foods as part of their diets.

Food insecurity will likely increase in the future, especially for people who depend on the natural resource economy. There are some indirect linkages between food security and climate change impacts. Future climate projections for Kitsap County will likely impact people and families who are reliant on natural resources for their livelihoods and wages.[185] Projected future climate impacts, from warming to ocean acidification to extreme events, will likely lead to income loss and increase the number of families experiencing food insecurity.[186] For example, in Long Beach, Washington, shellfish closures from elevated toxin levels led to significant income loss associated with the recreational shellfish industry and supporting businesses, leading to a 25% increase of families requesting assistance from the local food bank for the following six months.[187]

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[178] May *et al.* 2018.

[179] Datta *et al.* 2009. *Cryptococcus gattii*: Emergence in Western North America: Exploitation of a Novel Ecological Niche. *Interdiscip Perspect Infect Dis.* Doi: 10.1155/2009/176532.

[180] Trtanj *et al.* 2016. Ch. 6: Climate Impacts on Water-Related Illness. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.* U.S. Global Change Research Program, Washington, DC, 157–188. http://dx.doi.org/10.7930/J03F4MH4.

[181] May *et al.* 2018.

[182] Moore *et al.* 2015. Present-day and future climate pathways affecting *Alexandrium* blooms in Puget Sound, WA, USA. *Harmful Algae*. 41:1-11. Doi: 10.1016/j.hal.2015.08.2008.

[183] Upton *et al.* 2007. First contemporary case of human infection with *Crypotococcus gattii* in Puget Sound: Evidence for spread of the Vancouver Island outbreak. *Journal of Clinical Microbiology.* 45(9): 3086-2088.

[184] May *et al.* 2018.

[185] May *et al.* 2018.

[186] Haggerty *et al.* 2014. Oregon Climate and Health Profile Report. Oregon Healthy Authority, Portland, OR. 87 pp. www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/CLIMATECHANGE/Documents/oregon-climate-and-health-profile-report.pdf.

[187] May *et al.* 2018.

On Bainbridge Island, there is concern that climate impacts on food systems may lead to increased food prices, increasing financial burden and food insecurity for families.[188]

Food sovereignty will be affected, especially for Tribal members who rely on subsistence and cultural foods as part of their diets.[189,190] Food sovereignty is the right of peoples to healthy and culturally appropriate foods through sustainable practices. Many Tribal members from the Port Gamble S'Klallam Tribe and the Suquamish Tribe, as well as nearby Tribes with adjudicated usual and accustomed areas in and around Kitsap County, who rely on subsistence and cultural foods such as shellfish, salmon, marine plants, game, berries and plants, will likely have their diets changed by future climate conditions.[191,192] Many of these foods are not only important for Tribal members' diets and nutritional health, but also serve as critically important resources for cultural traditions, ceremonies, livelihoods, and wellbeing.[193,194] The loss of reliable access to important cultural and subsistence foods will have multiple physical, mental, and cultural health impacts for Tribal and Indigenous peoples in the future and will likely compound historical trauma that is still being experienced.[195,196]

Finding 6: Mental Health and Wellbeing

Some evidence has linked climate change impacts to mental health challenges. There is a growing body of research that provides clarifying linkages around potential impacts of climate change on mental health, with people reliant on natural resources for their wages and livelihoods, children, and Tribal and Indigenous peoples facing disproportionate cumulative impacts.

Some evidence has linked climate change impacts to mental health challenges.[197] There is clear evidence that extreme weather events can lead to increased risk of post-traumatic stress disorder, anxiety, and depression in affected people.[198] There is also evidence in Washington that links early exposure to pollution and trauma to detrimental near-term health outcomes for children, which may have adverse long-term health

[188] Hansen *et al.* 2016. Bainbridge Island Climate Impact Assessment. EcoAdapt, Bainbridge Island, WA. www.cakex.org/sites/default/files/documents/BICIA%20Final%2028%20July%202016.pdf.
[189] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[190] Lynn *et al.* 2013. The impacts of climate change on tribal traditional foods. *Climatic Change*. 120(3): 545–556. doi:10.1007/s10584-013-0736-1.
[191] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[192] May *et al.* 2018.
[193] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[194] Lynn *et al.* 2013.
[195] May *et al.* 2018.
[196] Jantarasami *et al.* 2018. Tribes and Indigenous Peoples. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment. Volume II*: 572–603. doi: 10.7930/NCA4.2018.CH15.
[197] Dodgen *et al.* 2016. Ch. 8: Mental Health and Well-Being. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. 217–246. http://dx.doi.org/10.7930/J0TX3C9H
[198] Clayton *et al.* 2014. Beyond storms and droughts: The psychological impacts of climate change. *American Psychological Association and ecoAmerica*. 51 pp. http://ecoamerica.org/wp-content/uploads/2014/06/eA_Beyond_Storms_and_Droughts_Psych_Impacts_of_Climate_Change.pdf.

and socioeconomic impacts.[199,200] In King County, there is an association between extreme heat conditions and mental health-related deaths for elderly people, with 43% more mental health-related deaths occurring on extreme heat days as compared to non-extreme heat days.[201,202] Climate grief, uncertainty about the future, and loss of control about the future could lead to anxiety and depression.[203,204]

There is a growing body of research that provides clarifying linkages around the potential climate impacts on mental health, with people reliant on natural resources for their wages and livelihoods, children, and Tribal and Indigenous peoples facing disproportionate cumulative impacts.[205,206] Future climate projections will likely increase mental health challenges and social impacts for people in the Northwest. Climate-driven hardships such as income loss, food insecurity, and homelessness are likely to increase in the Puget Sound region and can lead to stress and anxiety for households.[207,208] Children may face multiple long-term negative mental health outcomes from associated exposure and risk of climate impacts.[209,210] Additionally, Tribal and Indigenous peoples will likely experience additional cumulative health challenges that are often worsened by historical and multi-generational trauma.[211]

One area of emerging research is the climate risk factors for homeless people. Although the number of homeless people has decreased since the early 2000s in Kitsap County, there is consensus that people lacking houses and shelters face increased and compounding climate risks in the future.[212] Finally, there is a need to appropriately prepare health systems for increased demand for climate-informed services, as Washington State ranks among the top 10 states with a high prevalence of mental illness and lowest access to mental health care services.[213]

[199] Anda & Brown. 2010. Adverse childhood experiences & population health in Washington: the face of a chronic public health disaster. *Results from the 2009 Behavioral Risk Factor Surveillance System.* Washington State Family Policy Council. 130 pp. www.wvlegislature.gov/senate1/majority/poverty/ACEsinWashington2009BRFSSFinalReport%20-%20Crittenton.pdf.
[200] Currie *et al.* 2014. What do we know about short- and long-term effects of early-life exposure to pollution? *Annual Review of Resource Economics.* 6(1): 217-247. www.annualreviews.org/doi/10.1146/annurev-resource-100913-012610.
[201] Dodgen *et al.* 2016.
[202] Isaksen *et al.* 2016.
[203] Berry *et al.* 2010. Climate change and mental health: A causal pathways framework. *International Journal of Public Health*. 55(2): 123-132.
[204] Mauger *et al.* 2015. Section 13: Human Health.
[205] Dodgen *et al.* 2016.
[206] May *et al.* 2018.
[207] May *et al.* 2018.
[208] Vynne & Harguth 2015.
[209] Anda & Brown 2010.
[210] Currie *et al.* 2014.
[211] Jantarasami *et al.* 2018.
[212] May *et al.* 2018.
[213] Hellebuyck *et al.* 2018. The State of Mental Health in America: Ranking the States. *Mental Health America*, Alexandria, VA. www.mentalhealthamerica.net/issues/ranking-states.

Finding 7: Communities of Concern

Frontline communities, or communities that often face the first and worst impacts of climate change, will experience disproportionately higher climate-related health risks. These groups of people include children, elderly people, Tribal and Indigenous peoples, outdoor laborers, homeless people, communities of color, and people with chronic illnesses, among others. There is heterogeneity across and within communities, and health risks and outcomes will vary.

Frontline communities, or communities that often face the first and worst impacts of climate change, will experience disproportionately higher climate-related health risks.[214] These groups of people include children, elderly people, Tribal and Indigenous peoples, outdoor laborers, homeless people, and people with chronic illnesses, among others. Across all findings in the chapter, certain groups of people will experience disproportionately higher risks of certain health outcomes. For example, elderly people, outdoor laborers, and children are likely to experience higher risks of heat-related illness and death and health complications from degraded air quality.[215,216] Children are also likely to experience higher risks for long-term mental health and socioeconomic impacts from climate change.[217] Outdoor laborers and other people dependent on natural resources may also experience stress and anxiety from income loss.[218] In Kitsap County, communities of color experience higher risks for chronic diseases and adverse behavioral health, some of which are linked to environmental conditions.[219] Homeless people are more susceptible to a range of climate impacts, especially waterborne diseases resulting from heavy precipitation events and flooding.[220] Tribal and Indigenous peoples are likely to experience a suite of nutritional, physical, mental, and cultural health and wellbeing impacts from future climate change, which will be compounded by historical and multigenerational trauma.[221]

There is heterogeneity across and within communities and health risks and outcomes will vary.[222] Better understanding the intersection of determinants of health, climate change impacts, and health outcomes as well as access to various health and support services will help guide equitable and effective climate change resilience strategies.

[214] May *et al.* 2018.
[215] Isaksen *et al.* 2015.
[216] Nolte *et al.* 2016.
[217] Currie *et al.* 2014.
[218] Haggerty *et al.* 2014.
[219] Kitsap Public Health District. 2017. Kitsap County Health Disparity Report. https://kitsappublichealth.org/information/files/2017_June_Health_Disparity_Report.pdf
[220] May *et al.* 2018.
[221] Jantarasami *et al.* 2018.
[222] Gamble *et al.* 2016. Ch. 9: Populations of Concern. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. 247–286. http://dx.doi.org/10.7930/J0Q81B0T.

Finding 8: Health and Social Safety Net

Future conditions will likely stress health service providers and capacity. Although much progress has been made in establishing causal linkages between health problems and risks to climate change, there is still needed capacity to prepare local health departments for future stress and demand for their services.

Future conditions will likely stress health service providers and capacity. Mortality, hospital admissions, and emergency medical service calls are all likely to increase under future climate conditions, across all climate scenarios.[223] Though the magnitude remains unclear, it is generally accepted that there will more stress and demand for climate-related health services in the future.[224]

Although much progress has been made in establishing causal linkages between health problems and risks to climate change, there is still needed capacity to prepare local health departments for future stress and demand for their services.[225] In Oregon, local health departments have minimal ability to identify and address environmental health hazards.[226] Some local health jurisdictions have created climate and health plans and there is increasing coordination between local health departments and state health agencies across the Pacific Northwest.[227,228] Kitsap County Public Health District already collects data around health indicators for the county, though establishing the associations between the health indicator data and climate impact trends can increase the District's resilience in the future.[229]

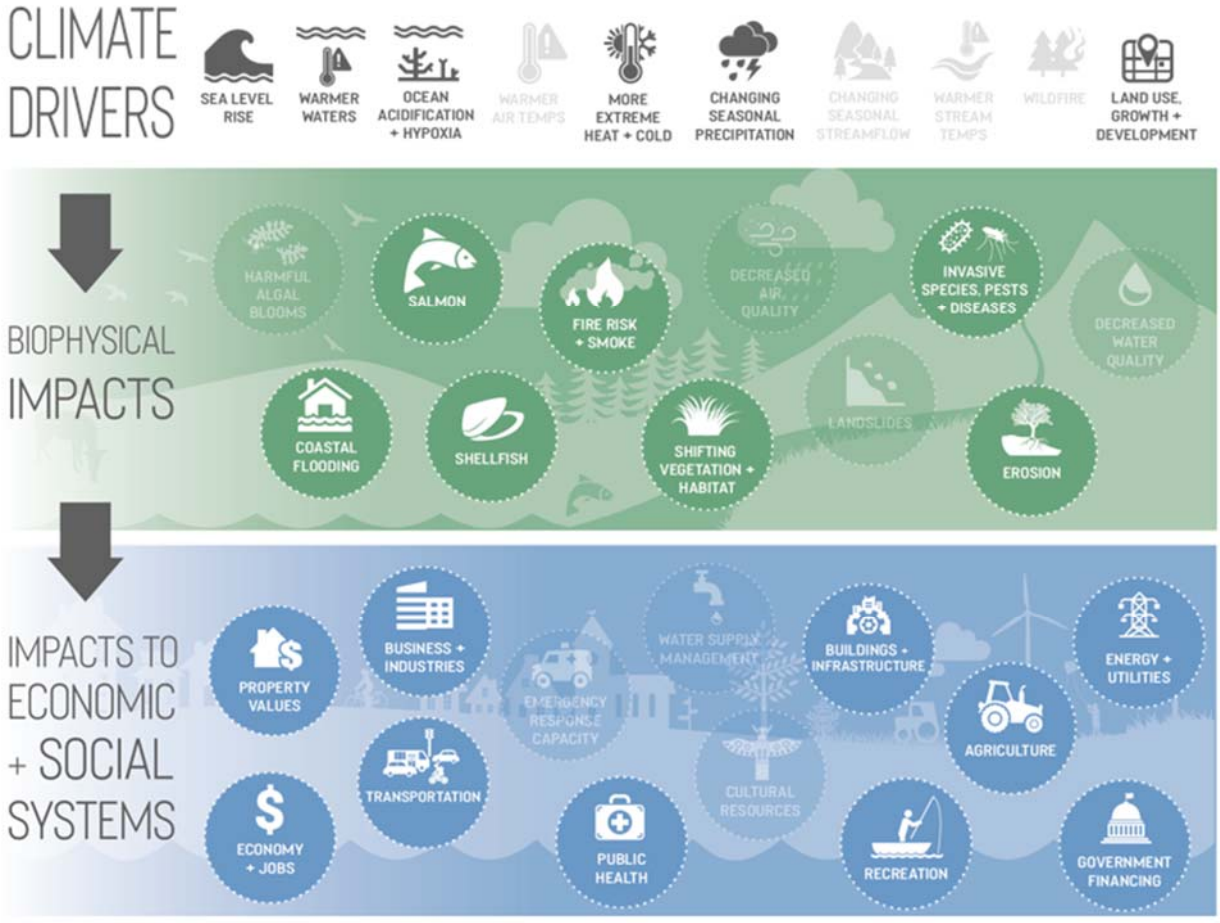
[223] Mauger *et al.* 2015. Section 13: Human Health.
[224] Balbus *et al.* 2016. Ch. 1: Introduction: Climate Change and Human Health. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. 25–42. http://dx.doi.org/10.7930/J0VX0DFW.
[225] May *et al.* 2018.
[226] State of Oregon. 2016. State of Oregon: Public Health Modernization Assessment Report. www.oregon.gov/oha/PH/ABOUT/TASKFORCE/Documents/PHModernizationReportwithAppendices.pdf.
[227] May *et al.* 2018.
[228] York & Sifuentes. 2016. Oregon Climate and Health Resilience Plan. *Oregon Health Authority*. www.oregon.gov/oha/PH/HealthyEnvironments/climatechange/Pages/resilience-plan.aspx.
[229] Kitsap Public Health District. 2019. Health Indicators, Reports, and Fact Sheets. https://kitsappublichealth.org/information/data_Indicators.php.

Chapter 4. Economy

Summary of Findings

Kitsap County's economic health is critical to maintain County and municipal operations and sustain the communities and livelihoods for its residents. Kitsap County's property values are currently increasing at comparable rates to growth in the Puget Sound region. However, sea level rise and more extreme weather events may affect the property values and buildable land area in Kitsap County, which are not expected to affect County tax revenue in the near term but may have substantial negative impacts over the long term without adaptation and mitigation measures. The businesses and industries related to natural resources have the most at risk under future climate conditions, as warmer waters, ocean acidification, rising temperatures, drought conditions, and more extreme heat days will affect business operations and the labor force. Increasing intensity of summer heat days will very likely disrupt the energy infrastructure and flow in the region, leading to economic and service damages. The economic costs of future climate change in the region can be large, though preemptive adaptation and mitigation strategies can result in long-term cost savings for Kitsap County.

Figure 18. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Economic Factors



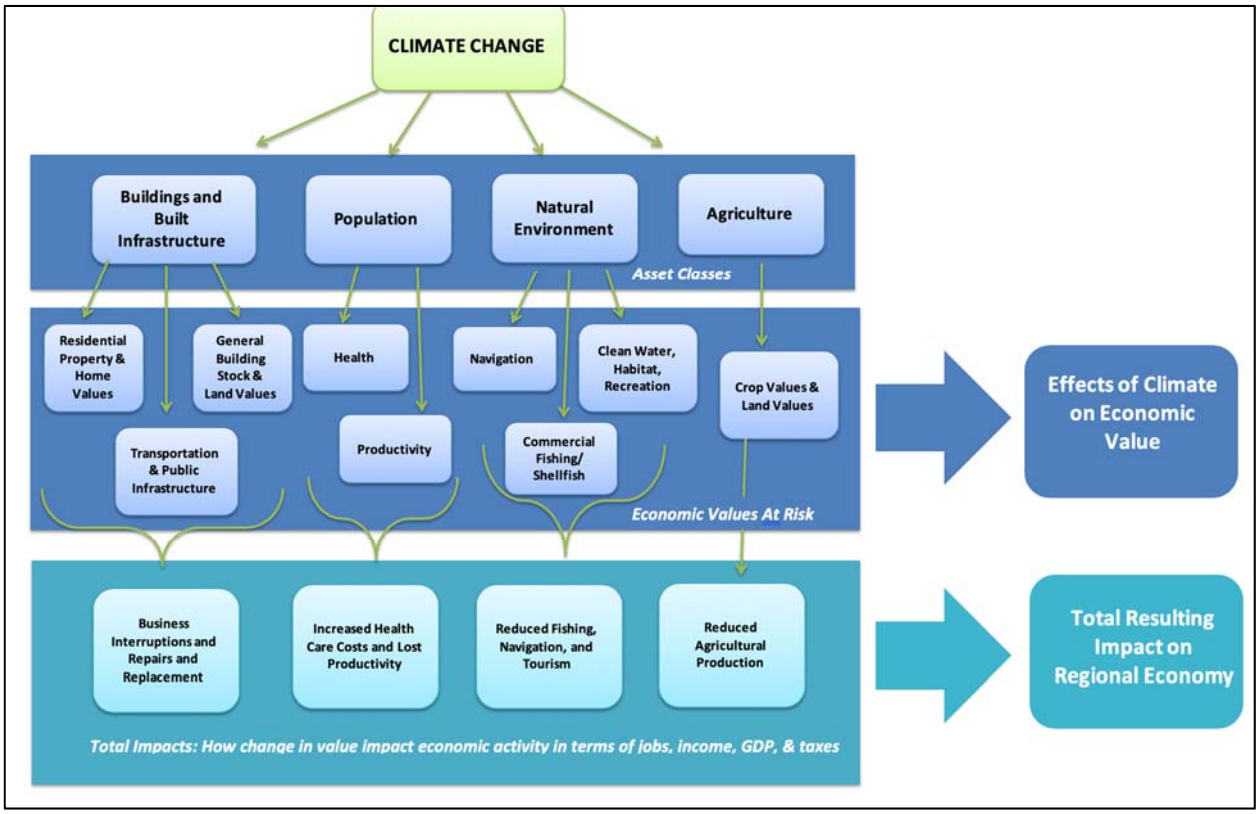
Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Property values and buildable land	**Low-Medium** • Property values and buildable land will likely be affected by flooding events, sea level, rise, and increasing winter storms [*medium confidence*].	**Long-term** • Property values in Kitsap County will likely not be substantially harmed by climate change due to a healthy Puget Sound economy [*very high confidence*].
2. Shifts in business opportunities	**Low-Medium** • Natural resource economies and industries with outside laborers will likely be impacted by climate change [*high confidence*]. • There may be some emerging business opportunities due to climate change [*medium confidence*].	**Near-term** • Many industries are already beginning to see impacts, and additional impacts (e.g., hours of labor lost, loss of sales and revenue, shifting species composition) will affect Kitsap County businesses by mid-century [*medium confidence*].
3. Energy demand and utilities	**Medium-High** • Seasonal energy demand will change, with more cooling energy demand in the summer months [*high confidence*]. • Economic damages related to utilities and energy infrastructure may be up to $550 million annually in the Northwest [*high confidence*].	**Near-term** • Lost revenue from energy transmissions and economic damages to energy and utility infrastructure will likely result in monetary costs by 2050 under all climate scenarios [*medium confidence*].
4. Economic costs of climate change	**High** • Economic damages of climate change can be significant, and yet may be under-estimating the full range of costs and damages [*high confidence*].	**Near-term** • Labor hours and wages lost due to climate change is the most significant contributor to economic damages [*medium confidence*]. • Operational, maintenance, and repair of infrastructure and support services will likely increase in the near to long term [*medium confidence*].

As described in this assessment, many of the factors of production are at risk of a change in value stemming from climate change. Storms and sea level rise can damage capital such as buildings, ports, and roadways. Declines in overall health of the population can reduce the productive value of employees, reducing overall productive output and in turn tax revenues and public services. Rising temperatures will affect habitat conditions and reduce the productive capacity of the marine environment.

The figure below outlines some of the potential economic impacts of climate change in Kitsap County (Figure 19). At the top of the figure are some classes of assets for the county; considering the factors of production, these asset classes include the built environment: buildings, infrastructure, homes, equipment, ships, and more. The factors of production are generally considered to be land, labor, capital, and entrepreneurship. Land or the natural environment represents the natural resources used in economic production (e.g., real estate, fish habitat) and current conditions such as air and water quality. Agriculture is different than the rest of the natural environment, because it is highly managed for production and so it falls somewhere between the natural and built environment. Labor represents the human contribution to the economy including wage-labor, services, management, and artisans. The population of the county includes the current status of the population in terms of numbers of people, diverse cultures, education levels, and the health of that

population. Capital is the humanmade material used to produce goods and services such as buildings, equipment, tools, and infrastructure. Each of these factors of production can be thought of as a stock, and those stocks generate the flow of the circular economy, which is the flow of money in exchange for goods and services used by households that provide labor and other inputs to the production of those goods and services. When the value or stock of productive factors declines, then this not only means a loss of value, but it also reduces the flow of the circular economy. A reduction in one flow can cause a "ripple effect" throughout a regional economy as a loss in one sector triggers reduced demand for inputs used in that sector and reduced spending by employees in that sector. The ripple effect occurs when a loss (or a gain) in the one sector triggers the same impacts in other sectors that are linked to the first, and then the impact repeats in the linked sector.

Figure 19. Factors of Production and the Circular Economy of Kitsap County



The changing climate will affect these different asset classes and influence the overall value of the different types of county assets: land values could fall in places of repetitive flooding; businesses may need to shut down temporarily when property is damaged during a storm; the health of the population may decline causing more sick days and less productivity; the marine environment may become less productive and reduce the value of recreational and commercial fishing; rising sea levels could affect shipping infrastructure and marine transportation could become more costly and/or move to other ports; crop yields could fall or rise with changes in precipitation and temperature, and land value may be affected. These impacts represent changes in the value of the factors of production, which is illustrated in the figure as the middle blue banner of examples of economic value at risk.

Finally, the "flow" of the county economy is represented in the lighter blue banner at the bottom of the graphic. This flow of economic activity is collectively called the regional economy, and impacts to the regional

economy stem from changes in economic value that then stimulate a ripple throughout the county. Note that the changes that occur in the flow of the circular economy in the county may either represent a loss to the overall county output that is not replaced, or a loss to Kitsap County when an economic activity shifts to another location. In the latter case, for example, Kitsap County could decline in productivity while the state of Washington might not lose in total output if a business relocated to another location in the state.

Finding 1: Property Values and Buildable Land

Property values fluctuate with economic growth, rather than environmental impacts. However, future climate change may affect investments in new structures, growth, and property values. Risk assessments can provide more precise estimates on climate impacts to financial investments.

Property values generally fluctuate with economic growth, rather than environmental impacts. Since 2011, housing sales and values have been holding steady and increasing in Kitsap County.[230] Prior to 2011, the average home sales price had been declining annually, but between 2011 and 2019, average annual home sales prices increased between 1% and 12%, with the greatest annual growth in the most recent three years through 2019. Average home sales price and the associated year-over-year change is presented in Table 13. Though future climate change may affect future property values, current property values in Kitsap County mirror the increasing growth trends across the Puget Sound region.[231,232] In Kitsap County, the median housing resale price in 2018 was $346,100, up from the median resale price of $267,800 in 2015. The median apartment rental price in 2018 was $1,345, up from the median rental price of $998 in 2015.[233]

The average home value varies significantly by area, with Bainbridge Island achieving a two-fold value over other areas within and near Kitsap County (school districts in this analysis).[234] This variation is displayed in Table 13 indicates that any impact to property values (climate change or other) may differ between areas, and therefore affect the total county revenues to a greater or lesser degree.

Table 13. Kitsap County Housing Sales Values, 2019 [235]

School District	Average Sales Price
Bainbridge Island	$751,496
North Kitsap (includes Poulsbo)	$358,169
North Mason	$310,431
Central Kitsap	$302,192
South Kitsap (includes Port Orchard)	$291,390
Bremerton	$232,430

[230] Center of Economic and Business Research. 2019.

[231] Kitsap County Department of Community Development. 2014. Kitsap County 2014 Buildable Lands Report. www.kitsapgov.com/dcd/PEP%20Documents/Complete%20Kitsap%20County%20BLR.pdf.

[232] Center of Economic and Business Research. 2019.

[233] Center of Economic and Business Research. 2019. Dollar years are not reported.

[234] Kitsap County Assessor Single-Family Residence Sales History. 2020. https://app.powerbigov.us/view?r=eyJrIjoiZWY3ZjdkZjEtYzdmOC00OWZjLTg4OGYtMTRhNmQ2N2M2ZGIxIiwidCI6ImFmNzUzYjk0LTQxNTktNDRlMS04OWU4LTNjYWU1N2I5NGU1YyJ9

[235] Kitsap County Assessor Single Family Residence Sales History. 2020

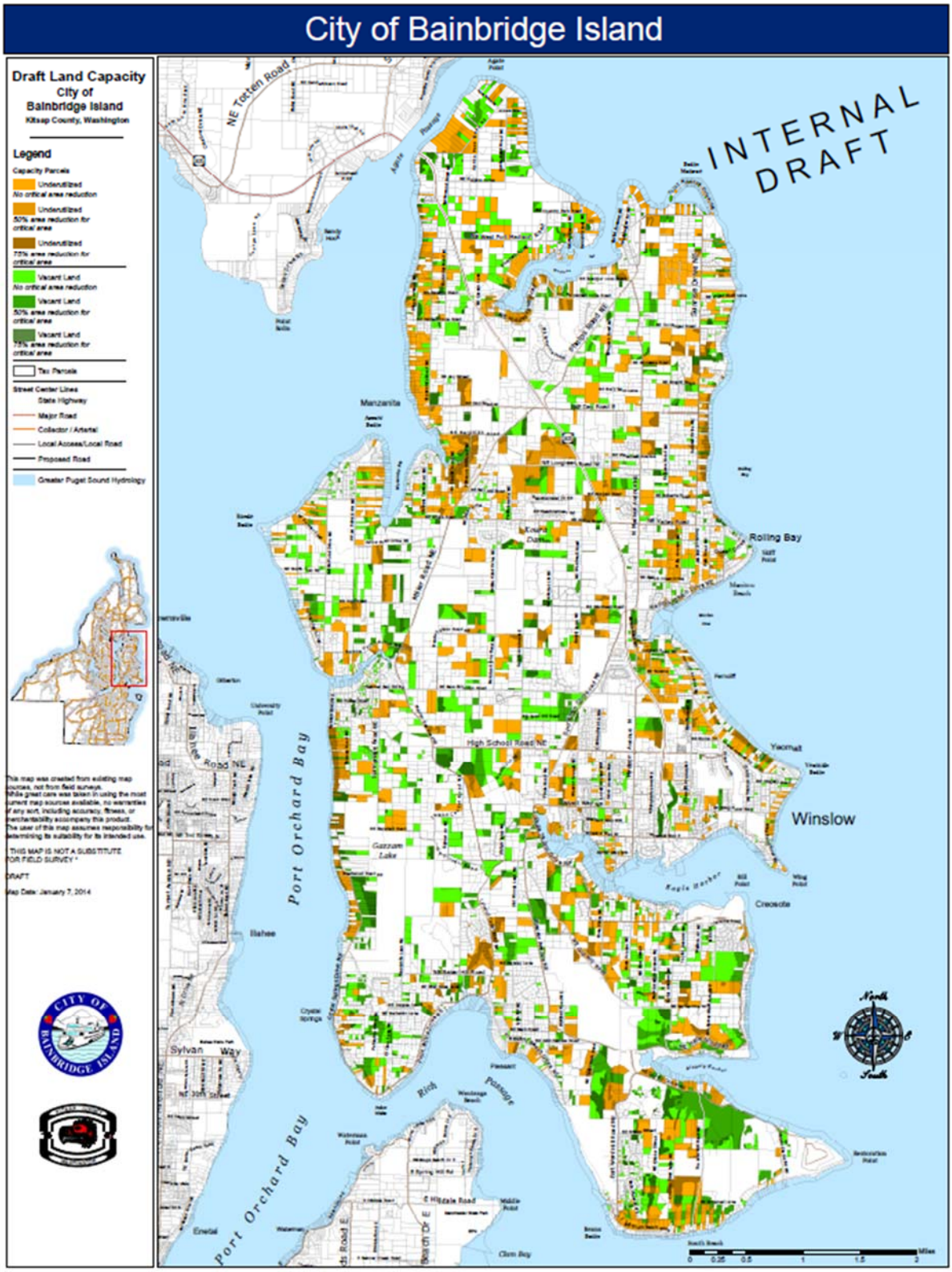
However, future climate change may affect investments in new structures, growth, and property values. As Kitsap County's population has steadily increased since 2010, most of the new residents have concentrated in urban areas and incorporated cities.[236] Between 2006 and 2012, 5,492 new housing units were permitted within Kitsap County. Most of these were in unincorporated but urban areas. The 2014 Buildable Lands Assessment stated that 68% of new permitted housing units occurred in urban areas and 32% of new permitted housing units occurred in rural areas. In 2006, it was almost a 50/50 split, but over those years the trend has been increasing in the urban areas and declining in rural areas. The majority of recent (2006 to 2012) building permits has been issued for existing legal lots.[237] Though future climate change may affect new structures, growth, and property values, current growth trends in property values is largely a reflection of the region's economic health.[238] Despite this growth, the increased frequency of flood events from sea level rise and storm surge and a potential increase of fire risk can be expected to affect land and properties more vulnerable to those hazards in the future.[239] Additional fire risk may be more prominent for new rural development and housing.[240] Private insurance companies may also elect not to cover new structures based on future climate conditions, which is likely as not to affect future potential of buildable land.[241]

For example, on Bainbridge Island, a draft land capacity analysis determined an approximate geographic map for underutilized and vacant lands (Figure 20).[242] New housing and structures built along the coast may experience increased risk of flooding from sea level rise and storm surge, which is projected rise anywhere from 0 to 1.9 feet by 2100 under a low-emissions scenario or 0.3 to 2.4 feet by 2100 under a high-emissions scenario.[243] Additionally, new housing and structures built inland will experience increased fire risk due to being part of the wildland-urban interface.[244]

Risk assessments can provide more precise estimates on climate impacts to financial investments. Because of the uncertainty of how future climate change may affect future housing choices and development opportunities, additional climate risk assessments could provide additional context for financial investments of new housing developers.[245] Additionally, shifting vegetation and habitats may also affect designated critical habitat areas in the future, which may also affect the amount of buildable land designated in Kitsap County.[246]

[236] United States Census Bureau. 2019.
[237] Kitsap County Department of Community Development. 2014.
[238] Center of Economic and Business Research. 2019.
[239] See Chapter 10. Geologic Hazards. Finding 3: Storm Surge and Coastal Flooding and Chapter 13: Fire. Finding 1: Wildfires.
[240] See Chapter 13. Fire. Finding 2: Wildland-Urban Interface (WUI)
[241] See: Chapter 9. Local Government Finance. Finding 1: Insurance.
[242] Kitsap County Department of Community Development. 2014.
[243] See Chapter 10. Geologic Hazards. Finding 3: Storm Surge and Coastal Flooding and Chapter 2. Climate Change Overview. Future Climate Change Projections: Sea Level Rise
[244] See Chapter 13. Fire. Finding 2: Wildland-Urban Interface (WUI)
[245] Urban Land Institute. 2019. Future-proofing real estate from climate risks. 4 pp. https://ia71z1oozio1p7cpp37o43o1-wpengine.netdna-ssl.com/wp-content/uploads/sites/2/ULI-Documents/Future-Proofing-Real-Estate-Web.pdf.
[246] See Chapter 7. Land Use, Finding 2: Climate Impacts on Land Use and Cover.

Figure 20. Draft Land Capacity Assessment for the City of Bainbridge Island[247]



[247] City of Bainbridge Island. 2016. Draft Land Capacity Map. In: *City of Bainbridge Island 2016 Comprehensive Plan*.

Finding 2: Shifts in Business Opportunities

Kitsap County has a diversity of industries that support a growing and robust economy. Future climate change projections will likely affect current industries and businesses in Kitsap County, especially those dependent on the natural resources, leading to impacts on revenue and worker health. However, there may be emerging business opportunities in the future (e.g., viticulture).

Kitsap County has a diversity of industries that support a growing and robust economy. The businesses that support Kitsap County's economy are diverse, ranging from public services to military operations to private businesses to natural resource economies (Table 4).[248] Overall, the county has experienced steady economic growth since 2012.[249] The largest employer is Naval Base Kitsap, employing approximately 33,800 people in 2018, although all employees may not be Kitsap County residents.[250]

Port facilities, naval facilities, ferry terminals, fishing fleets, and public utilities form the backbone of the county's economy, and these are the very resources that generally receive the most severe damage from storms and flooding. Until debris can be cleared, wharves and piers rebuilt, utilities restored, and the fishing fleets reconstituted, communities may find themselves without fuel.[251] Collectively, these industries support Kitsap County and the region's economy. The Department of Defense contributes approximately $4 billion to the County's economy annually, which includes $2.1 billion in payroll, $1.9 billion in industry output, and $129 million in state and local taxes (dollar year not reported). Furthermore, the Kitsap Fast Ferry had 27,293 passengers in the 3rd quarter of 2018, retail sales totaled approximately $5,000,000 in 2018, gross business income totaled approximately $775 million in 2017, and out-of-state and foreign trade grew to approximately $2.4 billion in 2017 (Figure 7).[252] Opportunities exist to work toward building resilience strategies in these key industry sectors, which support the county's economy.

Natural resource economies, such as logging, mining, fishing, and agriculture, represent a small portion of the economic industries in the county but are important parts of the history and culture of Kitsap County.[253] In 2019, mining, logging, and construction industries employed approximately 5,400 people, and the hospitality and leisure industry employed approximately 9,700 people in Kitsap County (Table 4). Fishing and shellfish are also important for the Port Gamble S'Klallam Tribe and the Suquamish Tribe's commercial operations and subsistence economy.[254,255]

The importance of the Naval Base Kitsap to the county economy is key to understanding potential impacts from climate change to the overall economy. Naval Base Kitsap is estimated to contribute approximately 55% to the overall county economy.[256] Impacts to that facility will ripple through the rest of the county's

[248] Washington State Employment Security Department. 2019.
[249] Vleming. 2019.
[250] Kitsap County. 2018.
[251] Kitsap County Department of Emergency Management. 2015. Kitsap County Washington: Hazard Identification and Vulnerability Assessment. www.kitsapdem.org/pdfs/kc_plans/Kitsap%20County%20HIVA%202015.pdf.
[252] Center of Economic and Business Research. 2019.
[253] See Chapter 5. Cultural Resources. Finding 3: Tribal Cultural, Ceremonial, and Harvesting Sites and Chapter 8. Agriculture. Finding 4: Agricultural Economies and Livelihoods.
[254] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[255] Suquamish Tribe. Tribal Fishing & Hunting Information.
[256] Kitsap County. 2019. Budget Book. Available at www.kitsapgov.com. page 35.

economy. The Department of Defense spending totals $2.1 billion in the region (including Jefferson and Mason counties, but predominantly Kitsap County), including support for 17,600 civilian jobs in addition to the 16,200 active duty military personnel and another 7,500 jobs that are supported through defense contractors (totaling 45,532 jobs when contractors are included) (dollar year not reported). The regional economic impacts assess how the spending then generates additional employment and outcome in the economy through businesses that provide inputs to the Naval Base operations and through household spending from the income. An additional $1.9 billion is generated through this "ripple" effect in the economy bringing the total Naval Base contribution to the economy to $4 billion, with $129 million going to state and local taxes (dollar year not reported). The industries that support the base are the maritime services and transportation industries, such as shipbuilding and maintenance; ferry and boat workers also contribute to the regional Puget Sound maritime economy.[257]

Future climate change projections will likely affect current industries and businesses in Kitsap County, especially those dependent on the natural resources, leading to a variety of impacts such as loss of revenue and worker health. Future climate conditions will likely increase agricultural costs, affect crop productivity, and alter livestock management.[258] Future climate change, coupled with non-climate stressors such as urbanization and growth, may likely lead to fewer agricultural business opportunities in the future and a decrease in the economic contribution of agriculture in Kitsap County.[259] Other industries that rely on natural resources, such as timber and commercial fishing, will also be impacted.[260] In Kitsap County, wildfires, insect infestations, diseases, and pathogens may affect logging production and timber quality.[261] Warmer temperatures, water availability, and pests and diseases may shift vegetation and forest composition in the Puget Sound area.[262,263] Warmer water temperatures, ocean acidifications, dissolved oxygen levels, and suitable coastal and nearshore habitat will likely affect regional salmon populations and affecting future commercial fishery yields and quotas.[264,265]

Future climate change may also affect the supply and demand for outdoor recreation and tourism activities. Winter recreation, especially snow-based recreation, will very likely decrease in the Northwest due to warmer winters and less snowpack.[266] Although Kitsap County is not known as a winter recreation destination, it serves as the gateway to the Olympic Peninsula, especially for residents living in the greater Seattle area. Impacts to future winter recreation may indirectly affect Kitsap hospitality businesses from lost revenue from pass-through visitors.[267] Furthermore, summer recreation opportunities may also shift in the future. Ocean acidification, warmer waters, and increased frequency and intensity of harmful algal blooms will decrease

[257] Kitsap Economic Development Alliance. Maritime.
[258] May *et al.* 2018. Chapter 24: Northwest. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 1036–1100. https://nca2018.globalchange.gov/chapter/24/.
[259] See Chapter 8: Agriculture. Finding 4: Agricultural Economies and Livelihoods
[260] May *et al.* 2018.
[261] Port Gamble S'Klallam Tribe Natural Resources Department. 2016..
[262] Mote *et al.* 2014. Ch. 21: Northwest. Climate Change Impacts in the United States: The Third National Climate Assessment. https://nca2014.globalchange.gov/report/regions/northwest.
[263] See Chapter 12. Habitat. Finding 1: Terrestrial Habitat
[264] See Chapter 12. Habitat. Finding 3: Marine and Coastal Habitat.
[265] Morley *et al.* 2018. Projecting shifts in thermal habitat for 686 species on the North American continental shelf. *PLoS ONE*. 13(5): e0196127.
[266] May *et al.* 2018.
[267] Hagenstad. 2018. The economic contributions of winter sports in a changing climate. 69 pp. https://protectourwinters.org/how-climate-change-will-impact-the-snowsports-industry/.

opportunities for recreational shellfish harvesting in Kitsap County.[268] Shifting summer water supplies may also likely affect summer water-based recreation.[269] Collective impacts to summer recreational opportunities will likely impact the County's recreational and tourism economy and the hospitality businesses that support visitors and residents.

In addition to impacts to business opportunities, climate change will likely affect part of Kitsap County's workforce. Industries reliant on outdoor laborers, such as mining, logging, construction, fishing, agriculture, shipyard operations, and maritime transportation, may likely see work days lost due to poor air quality from regional wildfires, which could lead to lost economic productivity and revenue and increased long-term health risks for outdoor laborers and workers.[270,271,272] Under RCP4.5, the Northwest will experience 4.3 million hours of labor lost per year by 2050 and 8.8 million hours of labor lost by 2080, resulting in economic damages of $220 million per year by 2050 and $730 million per year by 2080 (2015 dollars).[273] Under RCP8.5, the Northwest will experience 6.9 million hours of labor lost per year by 2050 and 23 million hours of labor lost by 2080, resulting in economic damages of $350 million per year by 2050 and $1.9 billion per year by 2080 (2015 dollars).[274]

However, there may be emerging business opportunities in the future, such as viticulture. Despite some of the negative consequences of climate change, there may be emerging economic opportunities in the future. In particular, the Puget Sound region has been identified as a novel area where wine grapes may likely thrive under future climate conditions.[275] Furthermore, there are emerging business opportunities in sustainable technology and low-carbon energy efficiency industries.[276]

[268] Langdon-Pollock, J. 2004. West Coast Marine Fishing Community Descriptions. www.psmfc.org/efin/docs/communities_2004/communities_entirereport.pdf.

[269] See Chapter 5. Cultural Resources. Finding 2: Recreation.

[270] May *et al.* 2018.

[271] Crimmins *et al.* 2016.Ch. 9: Populations of Concern. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. pp. 247–286. http://dx.doi.org/10.7930/J0Q81B0T.

[272] Kiefer *et al.* 2016. Worker health and safety and climate change in the Americas: issues and research needs. *Rev Panam Salud Publica.* 40(3): 192-197.

[273] EPA. 2017. Multi-Model Framework for Quantitative Sectoral Impacts Analysis: *A Technical Report for the Fourth National Climate Assessment.* 430-R-17-001.

[274] EPA. 2017.

[275] Hannah *et al.* 2013. Climate change, wine, and conservation. *Proceedings of the National Academy of Sciences*. 110(17): 6907-6912. DOI: 10.1073/pnas.1210127110.

[276] Washington State Community, Trade, and Economic Development. 2006. Impacts of Climate Change on Washington's Economy: A Preliminary Assessment of Risks and opportunities. https://fortress.wa.gov/ecy/publications/publications/0701010.pdf

Finding 3: Energy Demand and Utilities

Future climate change will likely affect the seasonal supply and demand for power and energy demand. Climate change impacts on the energy and power system in Kitsap County can lead to a range of short-term and long-term economic impacts.

Future climate change will likely affect the seasonal supply and demand for power and energy demand. Cumulative impacts of warmer temperatures, less winter snowpack, shifts in precipitation regimes from winter snow to rain, and earlier peak streamflow will likely shift seasonal hydropower energy supply shift, which account for approximately of Puget Sound Energy's (PSE) energy portfolio.[277,278] By the 2040s, hydropower productions is projected in increase by 4.7-5.0% in the winter and decrease by 12.1-15.4% in the summer, with annual reduction of 2.0-3.4%, and by the 2080s summer hydropower production will decrease 17.1%-20.8%.[279] Due to warmer temperatures, the overall and per-person energy demand for cooling is projected to increase from <1% of current residential demand to 4.8%-9.1% of residential demand by the 2080s during summer months.[280,281] Summer energy production from hydropower may be insufficient to meet this projected increase in residential cooling energy demand, especially considering potential future population growth in the Pacific Northwest.[282,283]

Climate change impacts on the energy and power system in Kitsap County can lead to a range of short-term and long-term economic impacts. Collectively, the risk for power outages may likely increase due to climate change impacts to energy sources and damage to energy transmission and distribution infrastructure.[284] Energy is essential for businesses, homes, and services, and power outages may pose short-term economic impacts for Kitsap County for local businesses.[285] Estimations of lost revenue for energy transmissions under a business-as-usual scenario are $85 million by 2040 and $241 million by 2080 (dollar year not reported).[286]

There may be long-term economic impacts associated with repairing and rebuilding energy and utility systems and service disruptions.[287] For instance, the Goodell wildfire in 2015 led to Seattle City Light de-energizing transmission lines in parts of its grid for several days, leading to an economic cost of $3 million

[277] Puget Sound Energy. 2018. PSE Electricity Supply. www.pse.com/pages/energy-supply/electric-supply.

[278] Hamlet *et al.* 2010. Effects of projected climate change on energy supply and demand in the Pacific Northwest and Washington State. *Climatic Change*. 102: 103-128. doi:10.1007/s10584-010-9857-y.

[279] Hamlet *et al.* 2010.

[280] See Chapter 6. Public Infrastructure. Finding 6: Power and Energy.

[281] Hamlet *et al.* 2010.

[282] Hamlet *et al.* 2010.

[283] Whitely Binder *et al.* 2016. Winds of Change? Exploring Climate Change-Driven Migration and Related Impacts in the Pacific Northwest. https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=1037&context=prc_pub.

[284] Zamuda *et al.* 2018. Energy Supply, Delivery, and Demand. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*. Volume II: 174–201. doi: 10.7930/NCA4.2018.CH4.

[285] Zamuda *et al.* 2018.

[286] Niemi, E. 2009. An Overview of Potential Economic Costs to Washington of a Business-as-Usual Approach to Climate Change. A report from the *Program on Climate Economics, Climate Leadership Initiative, and the University of Oregon's Institute for Sustainable Environment*. http://static1.1.sqspcdn.com/static/f/551504/6389698/1270246458393/economicreport_washington.pdf?token=Qk%2F%2FkDhdp6aWGqOeXnrqQ%2FL2RPI%3D.

[287] Zamuda *et al.* 2018.

(2015 dollars) due to fire damage and lost power production.[288] Across the Northwest, expected seasonal changes in energy demand and supply will likely result in economic damages ranging from $100 million to $180 million under RCP4.5 and $160 million to $550 million under RCP8.5 (2015 dollars).[289] Additionally, these long-term economic costs could be mitigated with sufficient investments into resilient energy infrastructure.[290]

Finally, Washington's investor-owned utilities, which include PSE, are required to account for the Social Cost of Carbon, or the monetary estimate of economic damage for each metric ton of carbon dioxide emitted, within their integrated resource plans.[291] The Social Cost of Carbon has steadily increased since 2010 and projected to almost double by 2050.[292] This accounting could lead to a suite of economic impacts, including developing energy demand projections, energy resource portfolios, and electricity rates.[293]

Finding 4: Economic Costs of Climate Change

There are many expected economic costs due to climate change in the Northwest, Washington State, the Puget Sound region, and Kitsap County. Despite these economic costs, there are likely climate impacts and extreme weather events that these estimations do not accurately capture, and thus may be an underestimation of the range of potential economic costs of climate change. Investments into resilient systems and coordinated planning can mitigate the economic costs of climate change.

There are many expected economic costs due to climate change in the Pacific Northwest, Washington State, the Puget Sound region, and Kitsap County. Climate change has already affected the economy in Washington State and the Northwest and will likely result in more pronounced future economic costs if no proactive measures are taken (Table 14). The estimates shown in Table 14 represent estimates for Washington, Oregon, and Idaho, pointing out that health impacts to outdoor labor exposed to heat and other impacts represent the largest cost of climate change under RCP8.5. Air quality is the next largest impact in dollar values for the region, largely influenced by exposure to fire. Compared to other regions, the Northwest is expected to have a lower heat-related mortality rate and lower costs related to neuro-invasive and harmful algal blooms. Other regions will likely see additional economic costs in the form of reduced availability of municipal and industrial water, which may not affect the Northwest as severely as other regions. Further, the analysis shows that significant gains will be recovered in the Northwest if one of the less severe emission scenarios proves closer to reality (RCP6.0 or RCP4.5) as a result of proactive mitigation and adaptation strategies.

[288] Raymond. 2015. Seattle City Light climate change vulnerability assessment and adaptation plan. 97 pp. www.seattle.gov/light/enviro/docs/Seattle_City_Light_Climate_Change_Vulnerability_Assessment_and_Adaptation_Plan.pdf.
[289] EPA. 2017.
[290] See Chapter 6. Public Infrastructure. Finding 6: Power and Energy.
[291] Grab *et al.* 2019. Opportunities for Valuing Climate Impacts in U.S. State Electricity Policy. https://policyintegrity.org/files/publications/Pricing_Climate_Impacts.pdf.
[292] Washington Utilities and Transportation Commission. 2019. Social Cost of Carbon. www.utc.wa.gov/regulatedIndustries/utilities/Pages/SocialCostofCarbon.aspx.
[293] Grab *et al.* 2019.

On the other hand, the Northwest region is forecasted to experience the highest economic costs associated with urban drainage damages. The costs are associated with implementing improved stormwater best management practices during peak rainfall events. For Kitsap County, this may present a very real risk, as winter flows in 2019 have already exceeded conveyance capacities.[294] The region is also expected to suffer from geoduck and oyster production declines.

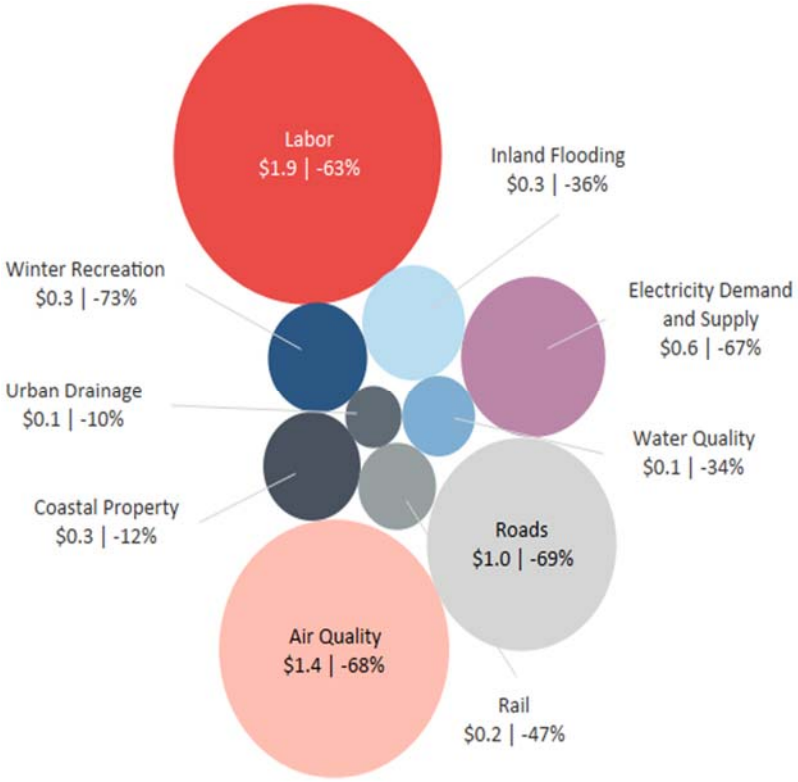
Economies reliant on the natural resources, such as commercial fishing, forestry, agriculture, and outdoor recreation, have already experienced economic damages from climate change.[295,296] Additionally, many industries reliant on outdoor laborers will very likely experience economic damages from fewer days worked due to extreme heat and air quality.[297] Across the Northwest, lost labor hours from extreme temperature days by 2090 could range from 8.8 million hours per year under RCP4.5 to 23 million hours per year under RCP8.5.[298] Similarly, damages to the maritime industry infrastructure and operations from more intense storms will likely affect the County's economy more severely than other locations.

In addition to the business and industry impacts, there will also be a range of economic costs affecting the Pacific Northwest and Kitsap County's health industry, recreation industry, and infrastructure systems. For example, by 2090 under RCP8.5, premature deaths associated with excess ozone will lead to approximately $1.4 billion in economic damages to the Northwest region's health system (2015 dollars). Across the Northwest, future climate change will also affect recreational and commercial fishing and shellfish harvesting, leading to an annual cumulative loss of 8.1 million fishing days under RCP8.5 and 2.1 million fishing days by RCP4.5 by 2090. This is equivalent to about $34 million in economic damages by RCP8.5 (2015 dollars).[299]

Water and transportation infrastructure will also likely experience economic costs and damages. Municipal water supply in Seattle is projected to continuously decline by 6.1 million gallons per day for each decade through 2040 without appropriate and comparable water conservation investments.[300] Urban drainage systems, which are anticipated to face significantly higher risks, are projected to be overwhelmed by 10-year storms across the Northwest region under RCP4.5 and RCP8.5. Managing roads across the Northwest region in light of sea level rise is projected to rise by $360 million annually by 2050 and $950 million annually by 2090 (2015 dollars). Warmer temperatures will substantially increase the annual per-lane mile cost for maintenance and repair across all scenarios by 2050.[301]

[294] Macalus, A. 2020. 82,000-gallon sewage spill reported in Bremerton. *Kitsap Sun.* www.kitsapsun.com/story/news/2020/01/24/82-000-gallon-sewage-spill-reported-bremerton/4559680002/.
[295] May *et al.* 2018.
[296] See Chapter 4. Economy. Finding 2: Shifts in Business Opportunities and Chapter 8. Agriculture. Finding 4: Agricultural Economies and Livelihoods
[297] See Chapter 4. Economy. Finding 2: Shifts in Business Opportunities.
[298] EPA. 2017.
[299] EPA. 2017.
[300] Washington Department of Ecology. 2006. Impacts of Climate Change on Washington's Economy: A Preliminary Assessment of Risks and Opportunities. https://fortress.wa.gov/ecy/publications/publications/0701010.pdf.
[301] EPA. 2017.

Figure 21. Largest Economic Damages of Climate Change in the Northwest[302]
(Annual damages for the 10 sectors with the greatest projected costs in the Northwest in 2090 under RCP8.5 are shown by relative circle size and with the labeled monetary value, in $ billions. The difference between RCP8.5 and RCP4.5 in 2090 is shown as the second value, in % change.)



Despite these economic costs, there are likely climate impacts and extreme weather events that these estimations do not accurately capture, and thus the range of potential economic costs of climate change may be underestimated. Economics measures the value and wellbeing of society. Much of this is measured by considering goods and services traded in markets, for which there are prices which serve as estimates of value. But other measures of wellbeing in a community—such as environmental amenities, health, recreation, and public safety—are important and valuable, but do not typically have a direct market or market price that can be used to estimate the value of the good or service. For such items, economists use a variety of tools often called "non-market" valuation techniques to develop estimates of value. For example, good health is not something that can be bought and sold in a market but estimates of the value of good health may be developed by analyzing health care costs avoided, and potential loss of wages associated with being sick, and a host of other metrics. Similarly, while outdoor recreation does not directly have a market that produces an estimate of the value of that aspect of society, techniques such as travel cost method are used to impute the value by analyzing data on what people are willing to spend to travel to recreate.

Due to this, it is difficult to project a full estimation of the range of potential economic costs to climate change. Indirect impacts from climate change may not be reflected in some of these projected economic damages. For instance, fewer visitors for recreating in the Olympic or Cascade Mountains due to less snowpack in the future may lead to lost revenue for businesses and restaurants passing through Kitsap

[302] EPA. 2017.

County from pass-through visitors.[303] Increased operational costs for local services and operations due to climate change and extreme events are also not represented.[304] Other elements of a community also have inherent value, but may only be evaluated qualitatively, such as cultural and religious values, emotional and psychological values, or long-term trauma associated with relocation (Table 14).

Table 14. Climate Impacts on Market-based Values, Non-market-based Values, and Qualitative Values

Impact Source	Market	Non-Market	Qualitative
Extreme storms and weather events	Structure repair/replace/reinforce Infrastructure repair/replace/reinforce Medical costs Temporary relocations Insurance claims Navigation	Reduced access to beaches Toxic risks Deaths/injuries Relocation dis-amenity	Post-traumatic stress disorder Permanent relocation Cultural losses
Sea Level Rise	Property values Coastal infrastructure Transportation costs Tax revenues Tourism	Beach access Saltwater intrusion Risks of toxic release Recreational shellfish	Cultural losses Historic sites
Warmer Air Temperature	Electricity and energy demand Agricultural shifts Labor hours Healthcare costs	Deaths and illnesses Violent crime Viruses Algal blooms	Lifestyle value
Precipitation and Floods	Infrastructure (Railways, Bridges, Roads) Property values Tax revenue Water supply and availability	Recreational fishing/snow sports Transportation slow-downs Emergency response	Community Loss
Air Quality	Healthcare costs	Ozone concentrations Aeroallergens	Visual/aesthetics Spiritual/emotional
Ecosystem Response	Fire Water supplies	Recreational fishing Recreational skiing/tourism Water quality Hypoxia	Food security Cultural losses Visual/aesthetics Irreversible Impacts

[303] See Chapter 5. Cultural Resources. Finding 2: Recreation.

[304] See Chapter 6. Public Infrastructure. Finding 4: Urban Infrastructure and Chapter 5. Cultural Resources. Finding 1: Historic and Archaeological Sites.

There is still much uncertainty and variables that are currently unaccounted for within models despite knowing that these impacts exist (e.g., lost trips resulting in lost revenue for hotels, restaurants, and businesses; climate impacts to telecommunication networks;[305] long-term repair of infrastructure damage from climate impacts and extreme events; operational costs for utilities and managers[306]). These uncertainties exist because stronger attribution models between future climate change projections and specific sectors are still being developed to better reflect economic and social conditions and impacts.[307]

Investments into resilient systems and coordinated planning can mitigate the economic costs of climate change. Despite a range of potential economic costs and damages from future climate change, proactive investments in developing resilient infrastructure, systems, policies, and economic industries will likely reduce future economic costs and damages. For example, investing in coastal infrastructure durable and resilient to future sea level rise and coastal flooding risks will likely lead to long-term savings in infrastructure maintenance. Proactive mitigation and adaptation policies have not been factored into the economic forecasting of future costs and damages; however, the difference between economic damages between RCP4.5 and RCP8.5 highlight potential cost savings if proactive measures are taken.[308]

[305] EPA. 2017.

[306] See Chapter 5. Cultural Resources. Finding 1: Historic and Archaeological Sites and Finding 2: Recreation and Chapter 6. Public Infrastructure. Finding 2: Water.

[307] Roesch-McNally *et al.* 2020. Beyond climate impacts: knowledge gaps and process-based reflection on preparing a regional chapter for the Fourth National Climate Assessment. Weather, Climate, and Society. Forthcoming.

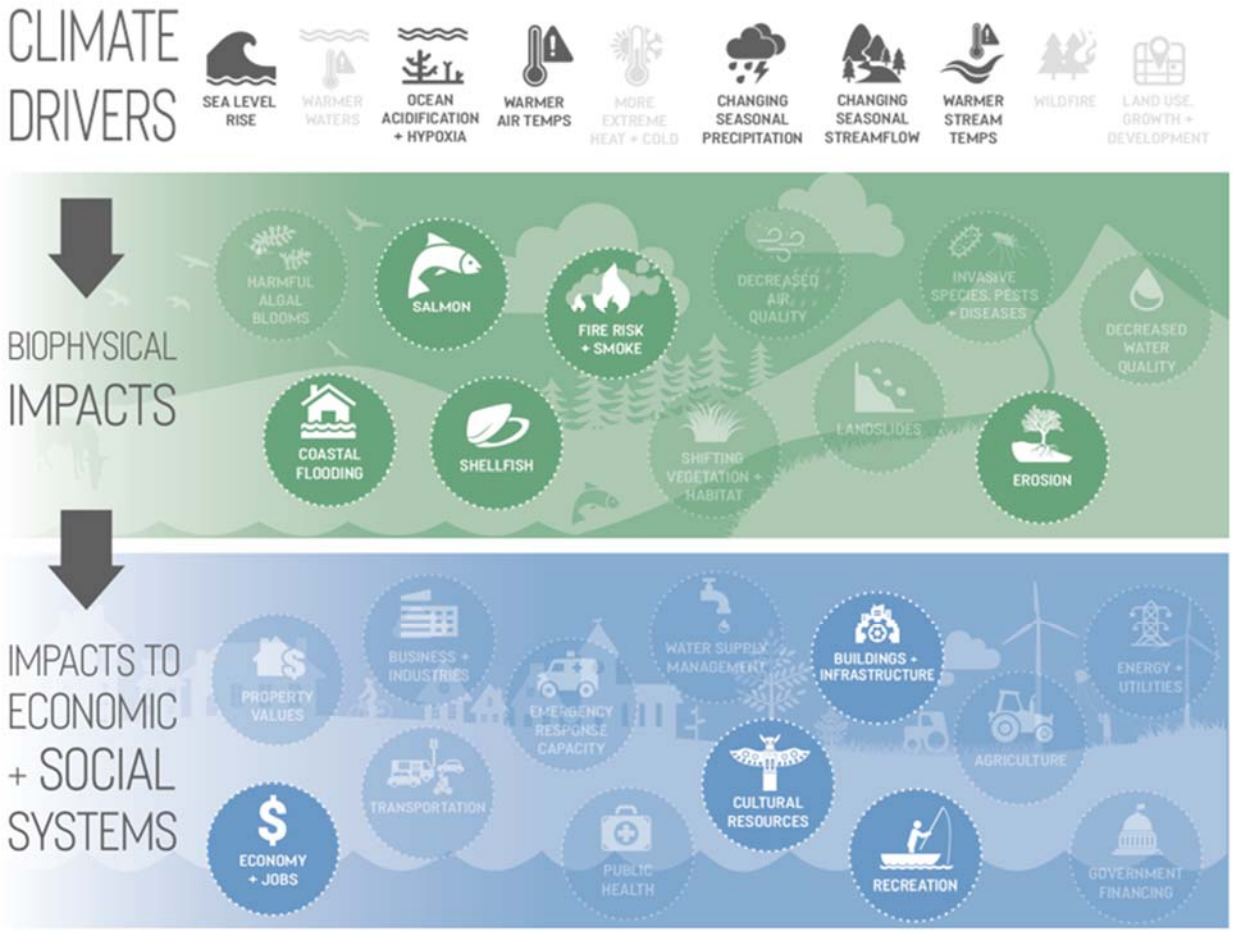
[308] EPA. 2017.

Chapter 5. Cultural Resources

Summary of Findings

Kitsap County's cultural, historic, and recreational sites are important for the county's economy and businesses. Future climate projections of sea level rise, increased frequency of heavy rainfall events, increased frequency and intensity of wildfires, warmer air and water temperatures, and ocean acidification will have compounding impacts on the quality and access of historical, archaeological, and recreational sites. Flooding and wildfire may damage sites, destabilize soils, and amplify the risk factor for other natural hazards to occur. These collective impacts will lead to lost revenue while increasing operating costs for the County and its businesses. For the Port Gamble S'Klallam Tribe and the Suquamish Tribe, as well as other surrounding Tribes with ancestral and historical territories in Kitsap County, climate change will affect important cultural, ceremonial, and harvesting sites. The cumulative impact of climate change on Tribal cultural resources threatens the place-based relationships and traditions that are foundational to Tribes' cultural heritage, identity, health, and wellbeing.

Figure 22. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Cultural Resources



Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Historic and archaeological sites	**Medium-High** • More frequent flooding events [*very likely*] will likely damage and disrupt access to historical sites [*low-medium confidence*]. • Potential thermal stress, decay, and damage to artifacts and archaeological projects [*medium confidence*].	**Near-term** • Flooding is already happening regularly in Kitsap County, and impacts to historical and archaeological sites are *likely* to manifest in the near-term future.
2. Recreational sites and opportunities	**Low-Medium** • More frequent flooding events may threaten recreational sites (e.g., parks, open spaces, hiking trails, waterways) [*medium confidence*]. • Increasing demand for summer recreation but fewer opportunities [*medium confidence*]. • Fewer opportunities for winter recreation [*medium confidence*].	**Near-term** • Flooding is already happening in Kitsap County and will *likely* impact recreational sites in the near-term future [*medium confidence*]. • There may be indirect effects to Kitsap County [*low confidence*].
3. Tribal cultural, ceremonial, and harvesting sites	**High** • Flooding, habitat shifts, and impacts to certain species (such as salmon) will have detrimental cultural and health impacts for Tribes [*very high confidence*].	**Already happening** • These impacts are already affecting Tribal resources and sites [*very high confidence*]. **Long-term** • There may be long-term health and wellness effects for Tribes in Kitsap County [*very high confidence*].

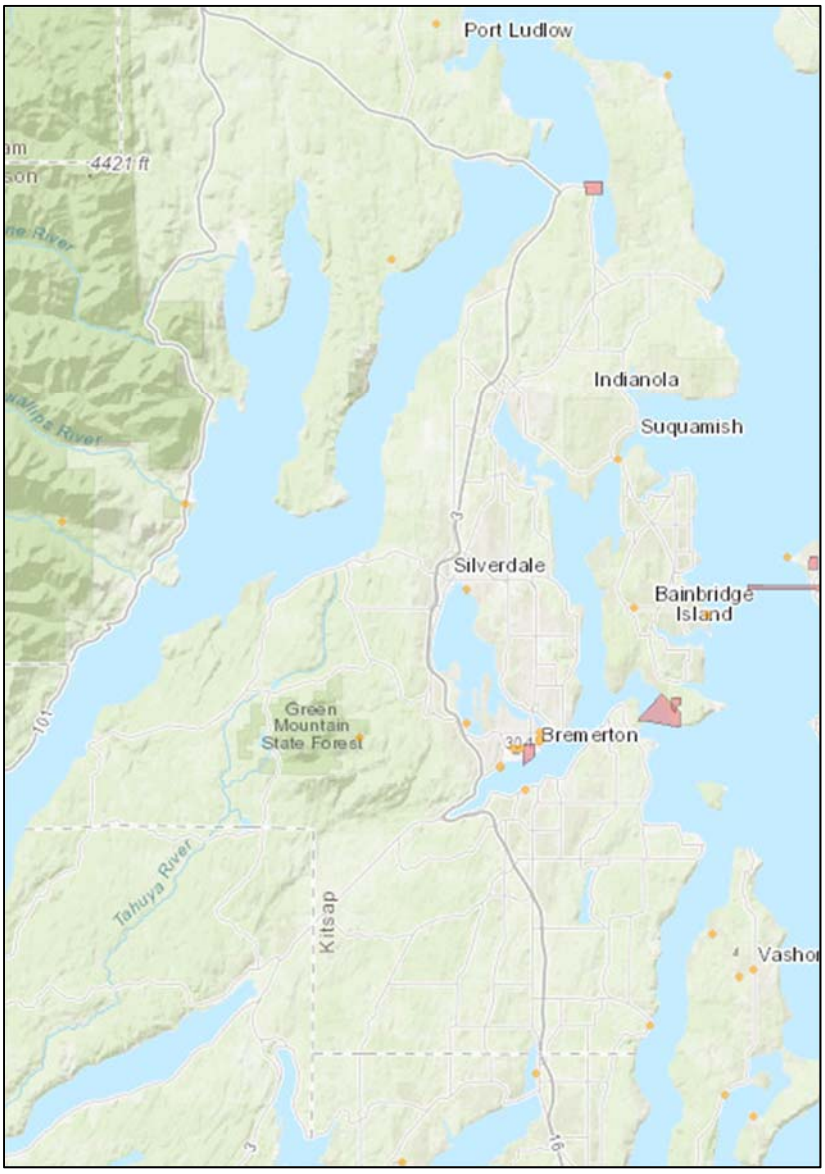
Finding 1: Historic and Archaeological Sites

There are 21 nationally registered historic places and 201 archaeological sites in Kitsap County. Future flooding risks from heavy precipitation and sea level rise will likely inundate and reduce access to important historical and archaeological sites for Tribes, Kitsap County, and municipalities. Other potential impacts on archaeological resources could include thermal stress and decay on artifacts, disruption of archaeological processes, and operating costs.

There are 21 nationally registered historic places and 201 archaeological sites in Kitsap County. In Kitsap County, places and districts listed in the National Register of Historic Places include Agate Pass Bridge, Bremerton Elks Temple Lodge No. 1181 Building, Camp Major Hopkins, Coder-Coleman House, Doe-Kag-Wats, Filipino-American Community Hall, Fort Ward Historic District, Jackson Hall Memorial Community Hall, Marine Reservations Historic District, Masonic Hall-Port Orchard, Navy Yard Puget Sound, Charles F. Nelson House, Officers' Row Historic District, Old-Man-House Site, Point no Point Lighthouse, Port Gamble Historic District, Puget Sound Radio Station Historic District, Shelbanks, U.S. Post Office-Bremerton Main, and Yama &

Nagaya Village (Figure 23).[309] There are also 201 archaeological sites in Kitsap County registered with the Washington Department of Archaeology and Historic Preservation.[310] In addition to places and districts on the National Register of Historic Places and archaeologic sites, there are additional local historic preservation efforts through the Kitsap County Historical Society & Museum.[311]

Figure 23. Places (orange dots) and Districts (red polygons) on the National Register of Historic Places[312]



[309] National Register of Historic Places. Washington – Kitsap County. https://nationalregisterofhistoricplaces.com/wa/kitsap/state.html.

[310] Washington Department of Archaeology and Historic Preservation. Archaeology Sites per County. https://dahp.wa.gov/sites/default/files/ArchyStatusMap2017.pdf.

[311] Kitsap County Historical Society & Museum. Kitsap County Register of Historic Places. https://kitsapmuseum.org/research-archives/kitsap-county-register-of-historic-places/.

[312] National Park Service. National Register of Historic Places. www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466.

Future flooding risks from heavy precipitation and sea level rise will likely inundate and reduce access to important historical and archaeological sites for Tribes, Kitsap County, and municipalities.[313,314] Kitsap County is projected to have rising sea levels, changing precipitation patterns, warmer summer temperatures, and increased risk of wildfire spillover impacts and risks.[315] Rising sea levels, increased winter rainfall, and more frequent heavier rain events will likely lead to increasing flood risk in the future, which will likely disrupt access, damage and erode, and partial or complete submersion of historical and archaeological sites.[316,317] Increased winter precipitation and more frequent heavy rain events will likely lead to increasing site erosion and risk of soil destabilization and landslides.[318,319] Increasing wildfire risk can also lead to site damage and increased likelihood of erosion or land shifts that could affect stability and access to sites.[320,321]

Other potential impacts on archaeological resources could include thermal stress and decay on artifacts, disruption of archaeological processes, and operating costs. Projected warmer temperatures, especially in the summer, may increase stress on important historical and archaeological artifacts. Increasing flood and wildfire risks may also disrupt archaeological processes and excavation projects.[322,323] Cumulative climate stressors will also likely increase costs associated with historic preservation. Artifact and site maintenance costs and expected facility needs to mitigate future climate impacts, such as special air filtration technologies, will increase operating costs of museums and historical preservation organizations. Future flooding and wildfire events may prompt salvage operations from museums and historical societies, which may lead to increased environmental compliance costs.[324]

[313] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment. http://nr.pgst.nsn.us/wp-content/uploads/2017/08/PGST_climate-impact-assessment_report_0518-FINAL.pdf.
[314] Puyallup Tribe of Indians. 2016. Climate Change Impact Assessment and Adaptation Options.
[315] See Chapter 2. Future Climate Change Projections. Sea Level Rise, Precipitation, and Wildfires.
[316] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[317] Morgan *et al.* 2016. Climate Change Impacts on Cultural Resources. *Cultural Resources Partnerships and Science.* www.nps.gov/subjects/climatechange/upload/NPS-Climate-Impacts-to-Cultural-Resources_7-2016.pdf.
[318] Morgan *et al.* 2016.
[319] Cassar, M. 2005. Climate Change and the Historic Environment. London: Centre for Sustainable Heritage, University College London. https://discovery.ucl.ac.uk/id/eprint/2082/1/2082.pdf.
[320] Morgan *et al.* 2016.
[321] Ryan *et al.*2012. Wildland Fire in Ecosystems: Effects of Fire on Cultural Resources and Archaeology. *General Technical Report RMRS-GTR-42*. Volume 3. Fort Collins: U.S. Forest Service.
[322] Morgan *et al.* 2016.
[323] Howard *et al.* 2008. The Impact of Climate Change on Archaeological Resources in Britain: A Catchment Scale Assessment. *Climatic Change*. 91(3-4): 414.
[324] Morgan *et al.* 2016.

Finding 2: Recreation

Kitsap County has a diverse portfolio of recreational sites, from parks, waterways and waterfronts, open spaces, special use parks, recreational complexes, open spaces, and hiking trails that span over 10,000 acres. Climate change impacts, such as flooding and sea level rise, are likely to pose threats to these recreational sites and activities. Furthermore, access and opportunities for residents and visitors to use these sites may be limited by future conditions.

Kitsap County has a diverse portfolio of recreational sites, from parks, waterways and waterfronts, open spaces, special use parks, recreational complexes, open spaces, and hiking trails that span over 10,000 acres (Figure 24).[325] Recreation and tourism was identified as one of the six key industries of Kitsap County.[326] Kitsap County has 6,700 jobs related to outdoor recreation and generates nearly $600 million in revenue and $35 million in local taxes, ranking 4th and 9th, respectively, out of 39 counties in Washington State (2014 dollars).[327]

Outdoor recreation offers multiple social, economic, and health benefits.[328,329] Access to recreational opportunities attracts visitors to Kitsap County and is an important component of residents' quality of life and wellbeing.[330,331,332,333] For instance, Kitsap County has recreational shellfish harvesting and angling activities, which provide outdoor recreational opportunities for residents and visitors alike, are a source of local economic revenue, and provide an important part of subsistence diets for Tribal members.[334] Outdoor fields and complexes host youth and adult sport activities, and agritourism has been growing in Kitsap County.[335]

Climate change impacts, such as flooding and sea level rise, are likely to pose threats to these recreational sites and activities. Future sea level rise, increased winter precipitation, and heavy rain events will lead to higher risks of flooding and damage to Kitsap County's recreational sites and activities. Increased wildfire risk in the future may also lead to damages to recreation sites and infrastructure.[336] These damages will likely lead to higher operating and maintenance costs for Kitsap County and the outdoor recreational industry.

[325] Kitsap County. 2019. Parks Inventory by Category. www.kitsapgov.com/parks/Pages/ParksByCategory.aspx.
[326] Kitsap Economic Development Alliance. 2020. Key Industries. http://kitsapeda.org/key-industries/.
[327] Briceno & Schundler. 2015. Economic Analysis of Outdoor Recreation in Washington State. www.visitkitsap.com/pdfs/EconomicAnalysisOutdoorRec_Web.pdf
[328] Winter *et al.* 2020. Outdoor Recreation, Nature-Based Tourism, and Sustainability. Sustainability. 12(1): https://doi.org/10.3390/su12010081.
[329] Rosenberger *et al.* 2017. Recreation economic values for estimating outdoor recreation economic benefits from the National Forest System. Gen. Tech. 33 p.
[330] Visit Kitsap Peninsula. About Visit Kitsap Peninsula. www.visitkitsap.com/about-vkp.
[331] May *et al.* 2018. Chapter 24: Northwest. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*: 1036–1100. https://nca2018.globalchange.gov/chapter/24/.
[332] Biedenweg *et al.* 2014. Developing Human Wellbeing Indicators in the Puget Sound: Focusing on the Watershed Scale. *Coastal Management*. 42(4): 374-390. DOI: 10.1080/08920753.2014.923136
[333] Zion *et al.* 2015. Indicators of climate change in Idaho: An assessment framework for coupling biophysical change and social perception. *Weather, Climate, and Society.* 7(3): 238-254. https://doi.org/10.1175/WCAS-D-13-00070.1.
[334] Biedenweg *et al.* 2014.
[335] Visit Kitsap Peninsula. 2020. Agritourism and Farms. www.visitkitsap.com/agritourism.
[336] May *et al.* 2018.

Furthermore, access and opportunities for residents and visitors to use these sites may be limited by future conditions. Warmer water temperatures and ocean acidification will likely shift opportunities for recreational fishing and shellfish harvesting.[337,338] Warmer temperatures and less spring and summer rainfall may impact recreational gardening activities. These shifts will lead to lost tax and fee revenue for Kitsap County and tourism revenue for local businesses.[339]

Demand for outdoor and water-based recreation in the spring and summer will likely increase in the future, such as boating, camping, biking, hiking, youth sports, and hunting.[340,341,342] However, with projected lower summer streamflow, snowpack, and associated water supply impacts, water-based recreational opportunities is unlikely to sufficiently meet future summer demand.[343] Wildfire risks and wildfire smoke impacts will very likely lead to fewer suitable summer days for outdoor recreation. These impacts will have cascading social and economic consequences for Kitsap County, its residents, and its outdoor recreation businesses. Furthermore, winter sports and snow-based recreational activities have already been hindered by climate change and will continue to be impacted by shifting winter precipitation regimes, reduced snowfall, and reduced snowpack.[344] Although this may not directly affect Kitsap County, there may be indirect consequences associated with quality of life and lost economic revenue from visitors or pass-through visitors to recreation sites in the Cascades or the Olympic Mountains.

[337] Hansen *et al.* 2016. Bainbridge Island Climate Impact Assessment. EcoAdapt, Bainbridge Island, WA. www.cakex.org/sites/default/files/documents/BICIA%20Final%2028%20July%202016.pdf.

[338] May *et al.* 2018.

[339] Hansen *et al.* 2016.

[340] Fisichelli *et al.* 2015. Protected area tourism in a changing climate: Will visitation at U.S. national parks warm up or overheat? *PLoS ONE*. 10(6): e0128226. https://doi.org/10.1371/journal.pone.0128226.

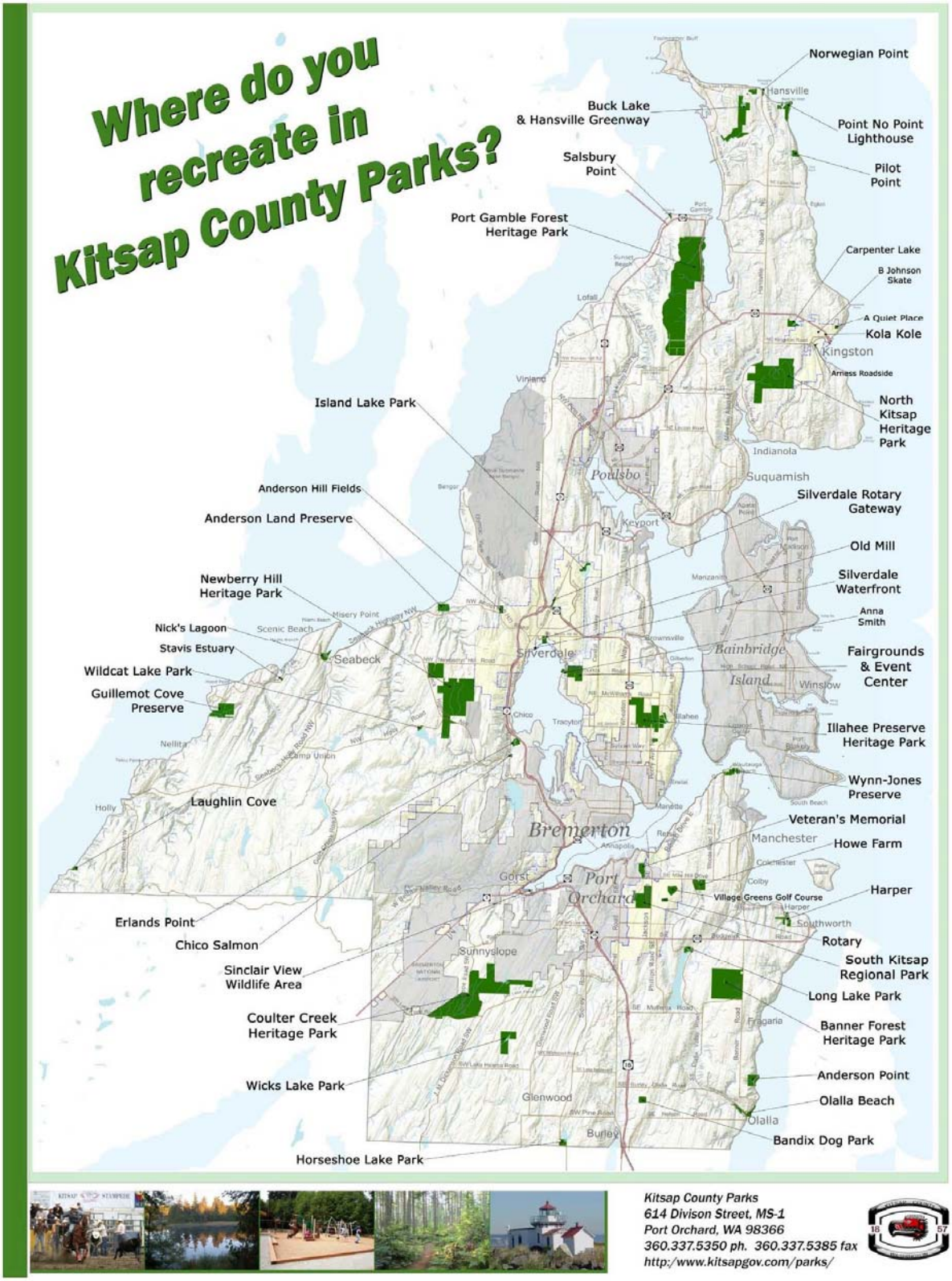
[341] Buckle and Foushee. 2012. Footprints of climate change in US national park visitation. *International Journal of Biometeorology*. 56(6): 1173-1177. https://doi.org/10.1007/s00484-011-0508-4.

[342] Whitehead, J. and D. Willard. 2016. The impact of climate change on marine recreational fishing with implications for the social cost of carbon. Journal of Ocean and Coastal Economics. 3(2): 7. https://doi.org/10.15351/2373-8456.1071.

[343] May *et al.* 2018.

[344] May *et al.* 2018.

Figure 24. Map of Parks and Recreational Sites in Kitsap County[345]



[345] Kitsap County Parks. www.kitsapgov.com/parks/Documents/ParksMap_8x11.pdf.

Finding 3: Tribal Cultural, Ceremonial, and Harvesting Sites

There are countless sites that are important for cultural, ceremonial, traditional, and harvesting activities for Tribes in the region within the borders of Kitsap County. Future climate change will very likely limit access to these sites and opportunities to hold traditional activities, harvest, hunt, and fish, which will have cascading detrimental health and wellbeing effects for Tribal peoples.

There are countless sites that are important for cultural, ceremonial, traditional, and harvesting activities for Tribes in the region within the borders of Kitsap County.[346,347] The Port Gamble S'Klallam Tribe and the Suquamish Tribe are based in Kitsap County, and many surrounding Tribes have adjudicated usual and accustomed areas or ceded ancestral lands in Kitsap County.[348,349] Important ceremonial and burial sites span the lands and waterways of Kitsap County and require Tribal consultation before development on or near these sites. [350,351] Many of these sites are also important sites for harvesting, hunting, and fishing for culturally important foods, which are protected rights for Tribal members, contributing to subsistence diets and modern Tribal livelihoods.[352,353,354]

Future climate change will very likely limit access to these sites and opportunities to hold traditional activities, harvest, hunt, and fish, which will have cascading detrimental health and wellbeing effects for Tribal peoples.[355] It is projected that sea level rise, ocean acidification, and storm surges will threaten important coastal harvesting and fishing sites.[356] Salmon, an important cultural keystone species for Tribes in the Northwest, will be impacted by changes in stream temperature, changing ocean conditions, and freshwater and nearshore marine habitats.[357] Future wildfire risk, warmer temperatures, and shifting vegetation patterns, will very likely impact sites and habitats for traditional plants, berries, roots, seeds, and game species.[358] Culturally important resources shifting out of historical geographies can be disastrous for Tribal and Indigenous peoples, especially if species and resources shift out of a Tribe's Usual & Accustomed area, which can effectively end specific resource access for a Tribe and its membership.[359]

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[346] Suquamish Tribe. Historic Preservation. https://suquamish.nsn.us/home/departments/fisheries/historic-preservation/#tab-id-3.

[347] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

[348] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

[349] Washington Department of Fish and Wildlife. 2017. Tribal Ceded Areas in Washington State. https://wdfw.wa.gov/sites/default/files/2018-12/tribal_ceded_areas_in_washington_state.pdf.

[350] Suquamish Tribe. 2020. Historic Preservation.

[351] Section 106, National Historic Preservation Act of 1966 and Native American Graves Protection and Repatriation Act.

[352] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

[353] May *et al.* 2018.

[354] Lynn *et al.* 2013. The impacts of climate change on tribal traditional foods. Climatic Change. 120(3): 545–556. doi:10.1007/s10584-013-0736-1.

[355] May *et al.* 2018.

[356] Lynn *et al.* 2013.

[357] Cozzetto *et al.* 2013. Climate change impacts on the water resources of American Indians and Alaska Natives in the U.S. Climatic Change. 120(3); 569-584. https://doi.org/10.1007/s10584-013-0852-y.

[358] Voggesser *et al.* 2013. Cultural impacts to tribes from climate change influences on forests. *Climatic Change*. 120(3): 615-626. https://doi.org/10.1007/s10584-013-0733-4.

[359] May *et al.* 2018.

Future flooding and inundation, sea level rise, and wildfires may also reduce access to specific cultural, ceremonial, or burial sites for Tribal and Indigenous peoples.[360] Loss of important cultural sites is linked to mental health impacts, especially for Tribal and Indigenous peoples, as the interconnectedness of culture, places, and health will be affected.[361,362] The projected cumulative climate impacts, including impacts to important cultural sites and resources for Tribes, will adversely affect the physical, mental, and spiritual health of Tribes and Indigenous peoples across the Puget Sound region.[363,364,365366]

[360] Morgan *et al.* 2016.

[361] Jantarasami *et al.* 2018. Tribes and Indigenous Peoples. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*. U.S. Global Change Research Program, Washington, DC, USA. 2: 572–603. doi: 10.7930/NCA4.2018.CH15

[362] Hambrecht and Rockman. 2017. International approaches to climate change and cultural heritage. *American Antiquity*. 82(4): 627-641. https://doi.org/10.1017/aaq.2017.30.

[363] Jantarasami *et al.* 2018.

[364] May *et al.* 2018. Chapter 24: Northwest. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II.

[365] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment.

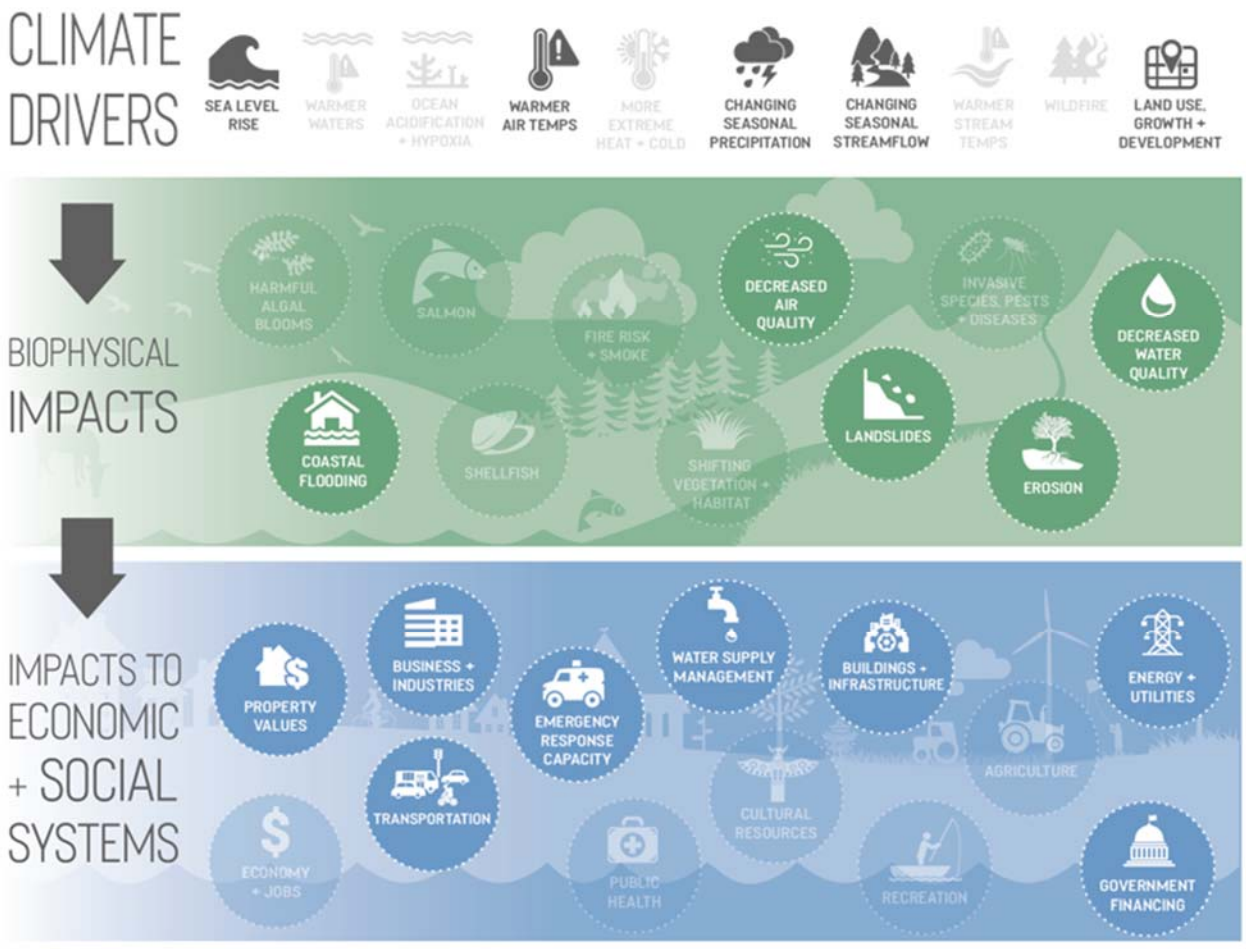
[366] See Chapter 3. Finding 7: Communities of Concern.

Chapter 6. Public Infrastructure

Summary of Findings

Public infrastructure systems support the residents, businesses, and economy for Kitsap County. Increased flooding risks, sea level rise, and extreme weather will likely lead to the disruption and damage of transportation, water supply, wastewater, stormwater, and energy infrastructure. Future climate impacts of warmer air temperatures and less summer precipitation are expected to reduce water supply and availability and potentially increase demand for irrigation. Future extreme heat days will also very likely increase energy demand for summer cooling, and current energy infrastructure and sources may be unable to meet this future expected demand. Additionally, climate change will likely affect both urban and rural infrastructure, however, there will be differences in adaptive capacity in how urban and rural residents are able to respond to infrastructure damage and service disruption. Strategic investments in resilient infrastructure can help alleviate future infrastructure impacts and result in long-term cost-savings.

Figure 25. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Infrastructure



Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Transportation	**Low-Medium** • Extreme events will very likely disrupt and damage transportation routes [*high confidence*].	**Long-term** • Ferry terminals have relatively low vulnerability to climate change [*very high confidence*], though extreme events can cause acute and expensive disruption and damages to transportation systems [*high confidence*].
2. Water, Wastewater, and Stormwater	**Medium-High** • Sea level rise and heavy precipitation events will likely overload and potentially damage stormwater and wastewater infrastructure [*high confidence*]. • Potable drinking water supply may also be affected by seasonal precipitation shifts and more frequent drought conditions [*high confidence*].	**Near-term** • Wastewater and stormwater facilities and infrastructure is likely to be inundated regularly by 2050 and capacity may be exceeded more frequently [*medium confidence*]. **Long-term** • Several communities in Kitsap County are extremely vulnerable to climate impacts on water supply in the long term due to reliance on single-source groundwater systems [*high confidence*].
3. Coastal Infrastructure	**High** • Low-lying coastal infrastructure, such as roads, structures, and facilities, will face more frequent and intense flooding events [*high confidence*].	**Near-term** • Flooding is an already regular natural hazard in Kitsap County and is projected to increase in intensity and frequency in the near term [*high confidence*].
4. Urban Infrastructure	**Medium** • Urban infrastructure will likely face damage and degradation from climate change impacts [*medium confidence*].	**Near- to Long-term** • Though climate impacts may manifest in the near term, investments in resilient infrastructure can mitigate these impacts in the long term [*medium confidence*].
5. Rural Infrastructure	**Medium-High** • Rural infrastructure is at risk from climate change impacts and extreme events [*high confidence*]. • Services for rural areas will be impacted by infrastructure damage or disruption [*high confidence*].	**Near-term** • Climate impacts to rural infrastructure and areas will exacerbate particular challenges facing rural communities [*medium confidence*].
6. Power and Energy	**Medium** • Extreme events and climate impacts may damage or disrupt energy grid infrastructure in all seasons [*high confidence*].	**Already happening** • Energy infrastructure disruptions are already happening and will likely worsen in the near term due to climate change [*medium confidence*].

Finding 1: Transportation

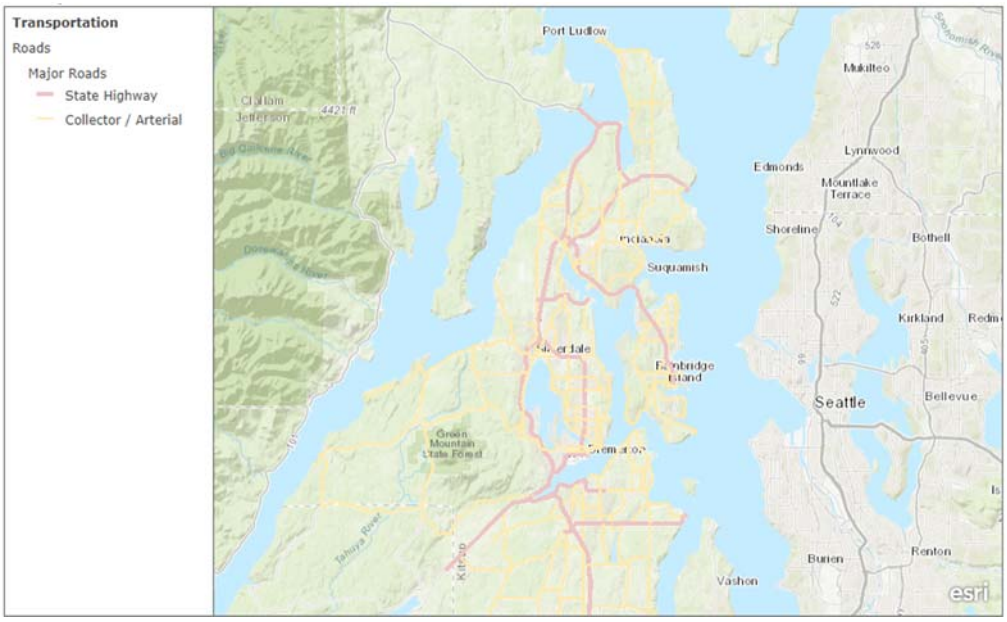
Natural hazards have sometimes disrupted the transportation routes that connect residents and communities across Kitsap County. Future climate change will likely increase risks to disruption of transportation routes, which will impact connectivity and emergency response capacity.

Natural hazards have sometimes disrupted the transportation routes that connect residents and communities across Kitsap County. Kitsap County is reliant on the transportation infrastructure and network to maintain connectivity between communities and districts, with state and county roads and a ferry system.[367,368] Kitsap County's transportation infrastructure includes the Bremerton Airport, state highways (State Routes 3, 14, and 104), bridges (Tacoma Narrows Bridge, Hood Canal Bridge, and Agate Pass Bridge), public transportation (Kitsap Transit), rail services (Puget Sound Pacific Railroad), county-run ferries (Kitsap Transit service to Bremerton/Port Orchard, Bremerton/Annapolis, and Bremerton/Seattle), Washington State Ferries (Bremerton, Bainbridge Island, Kingston, and Southworth), and many arterials, suburban, and local streets (Figure 26).[369]

In the Puget Sound area, heavy rains, sea level rise, wildfire activity, and heat waves have led to transportation closures, delays, or detours, especially in low-lying coastal areas.[370] Within Kitsap County, intense wave action in the winter has led to occasional lengthy closures of the Hood Canal Bridge.[371] Flooding and congestion routinely happens on SR-3 around Gorst, which has extremely low-lying roads.[372,373] Landslides have disrupted transportation routes, especially during times of heavy rains and winter storms. Annual flooding inhibits access and ability for movement. High waves and storm surges have damaged ports and piers and deposited debris that affects maritime transportation access and services.[374]

[367] Kitsap County Department of Emergency Management. 2015. Kitsap County Washington: Hazard Identification and Vulnerability Assessment. www.kitsapdem.org/pdfs/kc_plans/Kitsap%20County%20HIVA%202015.pdf.
[368] Hansen *et al.* 2016. Bainbridge Island Climate Impact Assessment. EcoAdapt, Bainbridge Island, WA. www.cakex.org/sites/default/files/documents/BICIA%20Final%2028%20July%202016.pdf.
[369] Kitsap County Department of Emergency Management. 2015.
[370] Mauger *et al.* 2015. Section 12: Built Environment.
[371] Washington State Department of Transportation. Hood Canal Bridge Area Traffic Alerts and Cameras. www.wsdot.com/traffic/hoodcanal/default.aspx.
[372] Kitsap County and City of Bremerton. 2013. Volume 3: Gorst Subarea Plan. www.bremertonwa.gov/DocumentCenter/View/1527/Gorst-Plans-Volume-3-Gorst-Subarea-Plan-PDF.
[373] Washington State Department of Transportation. 2018. SR 16, Tacoma Narrows Bridge to SR3, Congestion Study. www.wsdot.wa.gov/sites/default/files/2019/02/19/sr16_congestionstudy_report.pdf.
[374] Kitsap County Department of Emergency Management. 2015.

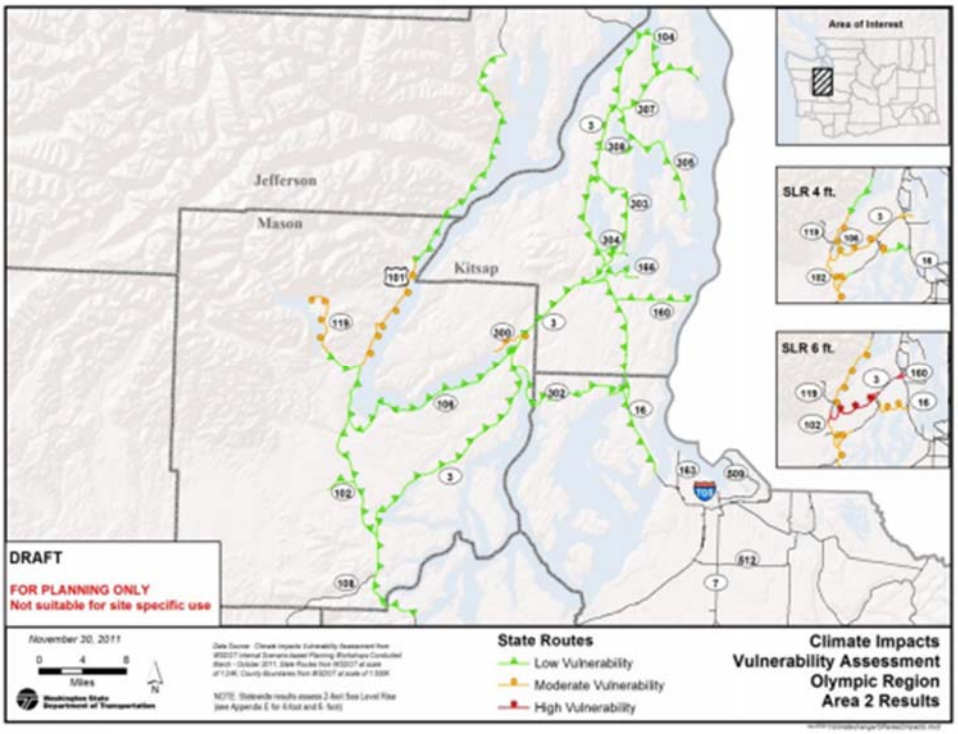
Figure 26. Road and Highway Transportation Map for Kitsap County[375]
(includes state highways and collector/arterial roads)



Future climate change will likely increase risks to disruption of transportation routes, especially from extreme events, which will impact connectivity and emergency response capacity. The Washington State Department of Transportation identifies the state highways in Kitsap County as having relatively low to moderate vulnerability to future climate change impacts (Figure 27).[376] These results do not necessarily align with local experiences, as the highway and roads in Gorst are low-lying and often flooded.[377] Future climate change will likely create conditions for more frequent or severe natural hazards, such as flooding and landslides, which would cause more severe but rarer disturbances to Kitsap County's transportation infrastructure.[378,379] Risk of winter flooding in low-lying areas will likely be exacerbated due to higher winter streamflow, potential culvert failure, and bluff erosion.[380,381] Disruptions in transportation networks and infrastructure will very likely have cascading impacts to public health, access to food and services, and emergency response capabilities.[382] In the Pacific Northwest, extreme weather events have already had costly and disastrous impacts for residents. For example, extreme winter storms in 2015 led to the isolation of a few coastal communities in Oregon, highlighting the need to create alternative transportation routes and detours in case of extreme events.[383]

[375] Kitsap County. Online GIS Resource: Maps, Apps, Data. https://kitcowa.maps.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=b7bd9baa19f347cb8195fa9775c46993.
[376] Washington State Department of Transportation. 2011. Climate Impacts Vulnerability Assessment. www.wsdot.wa.gov/sites/default/files/2017/11/15/ENV-Climate-VulnerabilityAssessment.pdf.
[377] Kitsap County and City of Bremerton. 2013.
[378] Kitsap County Department of Emergency Management. 2015.
[379] Mauger *et al.* 2015, Section 12: Built Environment.
[380] May *et al.* 2018. Chapter 24: Northwest. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: 1036–1100. https://nca2018.globalchange.gov/chapter/24/.
[381] See Chapter 10. Geologic Hazards. Finding 2: Bluff Erosion.
[382] May *et al.* 2018.
[383] May *et al.* 2018.

Figure 27. Climate Vulnerability of State Roads and Highways in Kitsap County and Surrounding Areas
(Olympic Region – Area 2, Washington State Department of Transportation)



Ferry terminals have moderate to high adaptive capacity to future sea level rise impacts, as terminal design can accommodate rising sea levels. However, increased wave action that brings more debris could increase ferry terminal operational expenses, and large waves coupled with future sea level rise could damage and move cars.[384] In the case of damage and disruption of access to Agate Pass Bridge, Bainbridge Island would need to rely on maritime transportation services and alternatives.[385]

[384] Washington State Department of Transportation. 2011.
[385] Kitsap County Department of Emergency Management. 2015.

Finding 2: Water, Wastewater, and Stormwater

In the Puget Sound region, concern is growing on how water, wastewater, and stormwater infrastructure will be impacted by sea level rise, changes in precipitation, and higher temperatures. Future sea level rise and increased flooding risks are likely to worsen saltwater intrusion and corrosion, potentially leading to more expensive operating costs and additional health risks for Kitsap County and its residents.

In the Puget Sound region, there is growing concern on how water, wastewater, and stormwater infrastructure will be impacted by sea level rise and flooding. Stormwater and wastewater facilities are critical to prevent flooding and maintain water quality for Kitsap County and the region.[386] The County has extensive stormwater infrastructure and a wastewater treatment plant, Central Kitsap Treatment Plant. Current observed trends have shown that stormwater outfalls in Bremerton have been inundated from sea level rise and heavy precipitation.[387] In recent years, the City of Bremerton has dealt with higher than normal saltwater concentrations in its wastewater systems resulting in additional operating costs and implications for water quality compliance.[388]

Furthermore, Kitsap County relies on groundwater for drinking water, which is provided to residents through private wells and public water systems.[389,390] Parts of Kitsap County have witnessed steady declines in annual well water levels, though this trend is due to a variety of factors (Figure 28).[391] For example, Well AAC720, located near the Port Gamble S'Klallam Tribe near Kingston, shows a decreasing trend in water level.

[386] Kitsap County Public Works Department. 2019 Stormwater Management Program (SWMP) for National Pollutant Discharge Elimination System (NPDES) Permit Implementation in Kitsap County, Washington. 2019. www.kitsapgov.com/pw/Documents/2019_Kitsap_County_SWMP.pdf.

[387] Kitsap County. 2019. Task 700 Climate Change Assessment.

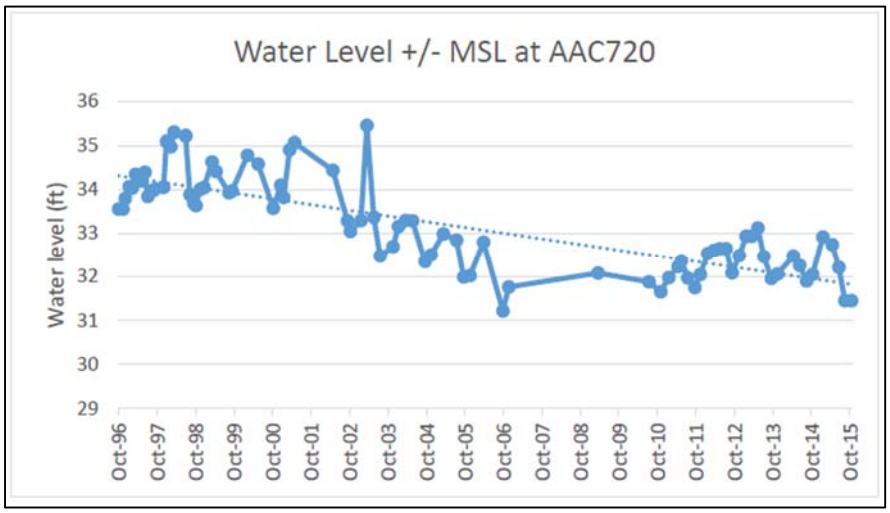
[388] Vosler, C. 2019. Bremerton calls on Navy to curb saltwater coming into city's sewer system. *Kitsap Sun*. www.kitsapsun.com/story/news/2019/04/27/bremerton-tells-navy-stop-saltwater-entering-city-sewer-system/3601506002/.

[389] Kitsap Public Health District. 2020. Managing Group B Public Water Systems. https://kitsappublichealth.org/environment/water_managing_groupB.php.

[390] Washington State Department of Health. 2020. Source Water Assessment Program (SWAP). Mapping Application. https://fortress.wa.gov/doh/swap/index.html.

[391] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment. http://nr.pgst.nsn.us/wp-content/uploads/2017/08/PGST_climate-impact-assessment_report_0518-FINAL.pdf.

Figure 28. Kitsap PUD Well AAC720 Level Readings near Port Gamble S'Klallam Reservation[392]

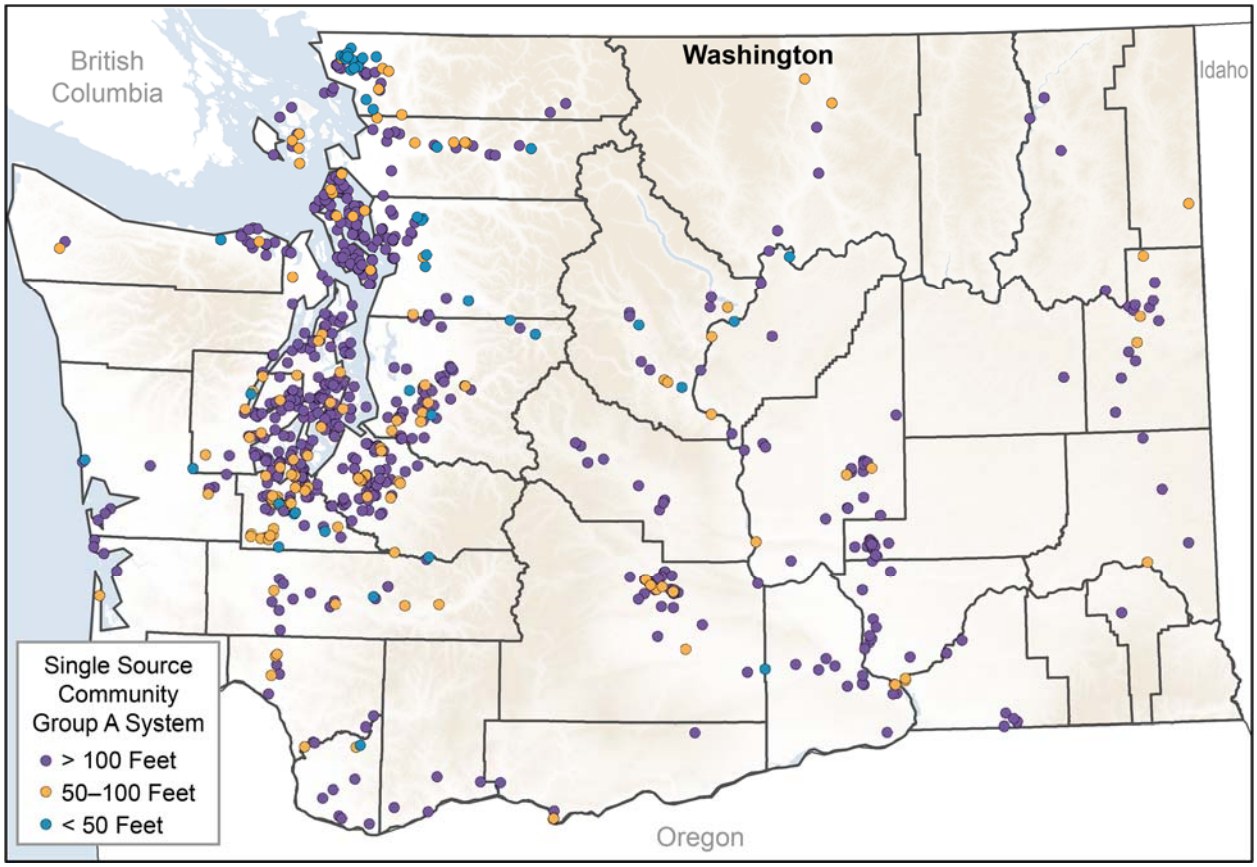


Future sea level rise is likely to worsen saltwater intrusion and corrosion of the wastewater system, and larger storm events are likely to increase flooding of the stormwater system, potentially leading to more expensive operating costs and additional health risks for Kitsap County and its residents. Though there is a lack of localized evidence for future climate change impacts on Kitsap County's stormwater and wastewater infrastructure, studies done across Puget Sound suggest some likelihood that future sea level rise and larger precipitation events will affect stormwater and wastewater infrastructure.[393,394] In King County, sea level rise is projected to temporarily or permanently inundate at least three King County Wastewater Treatment Division facilities by 2050.[395] Projected increase in the frequency and intensity of coastal flooding will likely increase the risk of saltwater inflow for wastewater systems for King and Thurston counties, corroding conveyance systems and increasing the operating costs for wastewater plants.[396,397,398] The Kitsap County system would benefit from more detailed analysis. Flooding events may also worsen, depending on stormwater infrastructure and wastewater conveyance capacity, which could lead to potential emerging health risks, such as vector-borne diseases or surface-water quality impairment.[399]

[392] Adapted in Port Gamble S'Klallam Natural Resource Department. 2016 from Bumbaco *et al.* 2013.
[393] Kitsap County, 2019. Task 700 Climate Change Assessment. Also see: Chapter 6: Public Infrastructure. Finding 4: Urban Infrastructure.
[394] Mauger *et al.* 2015. Section 12: Built Environment.
[395] King County Wastewater Treatment Division. 2008. Vulnerability of Major Wastewater Facilities to Flooding from Sea Level Rise.
[396] King County Wastewater Treatment Division. 2012. Hydraulic Analysis of Sea-level Rise on King County's Wastewater System.
[397] King County Wastewater Treatment Division. 2011. Saltwater Intrusion and Infiltration into the King County Wastewater System.
[398] Simpson, D.P. 2012. City of Olympia Engineered Response to Sea Level Rise.
[399] See Chapter 3. Public Health. Finding 4: Vector-borne Diseases

Future warming, longer drought seasons, less winter snowpack, and changing seasonal precipitation will likely exacerbate summer water deficits in the future.[400,401] Less water supply in the summer will very likely have substantial effects on drinking water supply and agricultural irrigation. [402] In Kitsap County, multiple public water systems that serve at least 25 people or have 15 or more connections have only a single water source, meaning that there is no back-up water supply (Figure 29). Communities and residents reliant on these single-source systems may be vulnerable to future water shortages or water quality degradation.[403] Kitsap County would benefit from more detailed analyses of these systems.

Figure 29. Single-Source Water Systems in Washington State[404]
(The map shows public water systems in Washington that are single source, meaning they lack a back-up supply, and service at least 25 people per day or have 15 or more connections. Smaller public water systems are not shown. Approximate well depth is indicated by color.)



[400] May *et al.* 2018.
[401] Mauger *et al.* 2015. Section 12: Built Environment.
[402] See Chapter 8. Agriculture. Finding 1: Crops.
[403] May *et al.* 2018.
[404] Washington State Department of Health adapted for the Northwest Chapter of NCA4.

Finding 3: Coastal Infrastructure

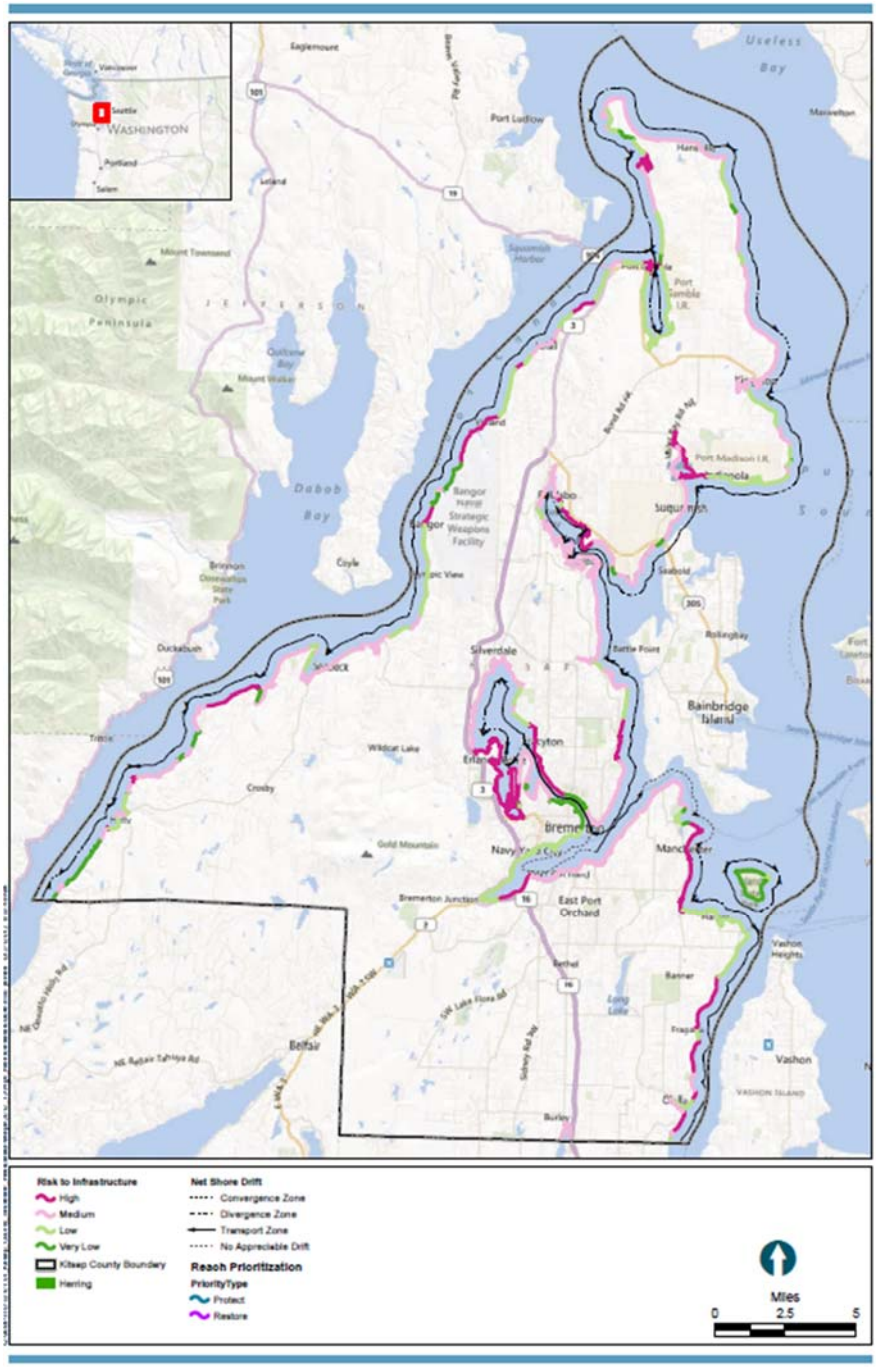
Low-lying coastal areas have already been more susceptible to recurring flooding events in Kitsap County. Future climate projections for the Puget Sound area will continue to exacerbate the vulnerability of low-lying coastal areas to climate impacts.

Low-lying coastal areas have already been more susceptible to recurring flooding events in Kitsap County. Many residences, transportation routes, utility infrastructure and facilities, and businesses reside within low-lying areas, which already face frequent flooding events, especially during the winter.[405,406,407,408] Low-lying coastal areas face particular risk due to the "coastal squeeze" phenomenon—that is, the dual impacts of future climate change (e.g., heavier winter rains, rising sea levels) and growing development, leading to more intense flooding events and less nearshore habitat.[409] Flooding is already an annual occurrence in Kitsap County and is the most repetitive and damaging natural hazard that occurs in the county.[410] Additionally, several communities in Kitsap County, such as Bremerton and Poulsbo, have sewer lines that run under beaches, and have experienced saltwater intrusion and submerged sewer lines in the past.

Future climate projections for the Puget Sound area will continue to exacerbate the vulnerability of low-lying coastal areas to climate impacts. Collectively, heavier rain events, more winter precipitation, sea level rise, and more intense winter storms will very likely lead to increased flooding risk for low-lying coastal areas in the Puget Sound area, affecting many homes, businesses, and infrastructure and support systems.[411,412] Coastal cities and areas in Kitsap County may also see additional risk to their infrastructure and structures, worth approximately $13.4 million (dollar year not reported).[413,414] In particular, Naval Base Kitsap – Bremerton will likely be affected by future sea level rise and flooding events.[415]

[405] See Chapter 11. Hydrology. Finding 2: Stream and Riverine Flooding.
[406] Kitsap County Department of Emergency Management. 2015.
[407] Hansen *et al.* 2016.
[408] Port Gamble S'Klallam Tribe Natural Resource Department. 2016.
[409] Christie *et al.* 2017. Navigating Coastal Squeeze: Identifying Needs and Priorities to Scale Up Estuarine Restoration in Puget Sound Workshop. https://smea.uw.edu/wp-content/uploads/sites/11/2014/12/Coastal-Squeeze-Workshop_Report_Final.pdf.
[410] Kitsap County Department of Emergency Management. 2015.
[411] Mauger *et al.* 2015. Section 12: Built Environment.
[412] May *et al.* 2018.
[413] See Chapter 10. Geologic Hazards. Finding 3: Storm Surge and Coastal Flooding.
[414] Federal Emergency Management Agency (FEMA). 2015. Risk Report: For Kitsap County, including the Cities of Bremerton, Bainbridge, Port Orchard, Poulsbo, the Port Gamble S'Klallam Indian Reservation, the Suquamish Tribe, and Unincorporated Kitsap County. https://fortress.wa.gov/ecy/gispublic/AppResources/SEA/RiskMAP/Kitsap/Kitsap_Project_Docs/Risk%20Report%20-%20Kitsap%20County%20-%20Final.pdf.
[415] Smith, R.W. 2015. The Good, The Bad, and the Robust: Climate Change Adaptation Choices for the Port of Rotterdam, Port of San Diego, and Naval Base Kitsap – Bremerton. Master's Thesis, University of Washington.

Figure 30. Risk Analysis to Coastal Infrastructure in Kitsap County[416]
(The preliminary risk analysis assumed that the closer structures were to the shoreline, the higher the risk of removing shoreline armoring and the lower likelihood of identifying willing landowners. The GIS analysis of average distance from structures to shoreline was used to categorize shorelines into one of four categories ranging from very high risk to low risk. The average distance calculation was deemed acceptable at the reach scale because conditions in reaches tended to be homogenous; that is, the distances to structures were similar throughout the extent of each reach. Notes: Forage fish layers have been omitted to more clearly show at-risk coastal areas.)



[416] Kitsap County Regional Shoreline Restoration and Feasibility and Prioritization Study.

Finding 4: Urban Infrastructure

Kitsap County has multiple cities and urbanized areas that already experience natural hazards. Future climate projections will very likely worsen current impacts and may present new challenges for Kitsap urban areas if growth, development, and renovations do not plan for future climate change conditions.

Kitsap County has multiple cities and urbanized areas that already experience natural hazards. From the 2010 Census, there are multiple urban classified areas in Kitsap County (Figure 31).[417] The largest urban area in Kitsap County is Bremerton, which has approximately 41,235 residents as of 2018.[418] There are many other urban places in Kitsap County, including Bainbridge Island, Port Orchard, and Poulsbo, and the Kingston and Silverdale urban growth areas.[419] Urban areas face multiple climate and human stressors, and oftentimes these cumulative stressors present unique challenges for urban areas. For instance, an urban area may be more likely to experience flooding due to climate stressors (such as heavy rains, storm surges, and sea level rise) and human stressors (amount of impervious surface and adequacy of stormwater infrastructure).[420,421] Floods are the most common natural hazard in Kitsap County, and they have already affected multiple urban areas.[422] As of 2015, Bainbridge Island has had 6 flood insurance claims with an estimated flood insurance coverage of $64 million, and Bremerton has had 5 flood insurance claims with an estimated flood insurance coverage of $15 million (dollar year not reported) through FEMA's National Flood Insurance Program.[423]

Future climate projections will very likely worsen current impacts and may present new challenges for Kitsap urban areas if growth, development, and renovations do not plan for future climate change conditions. Future risk of flooding will very likely increase in urban areas, especially Bremerton, due to increasing heavy rains, sea level rise, and storm surges, which may overwhelm existing stormwater infrastructure capacity.[424,425,426] Additionally, there may be emerging challenges in urban areas due to future climate stressors. Building structures and roads may experience a higher rate of degradation from future climate impacts, such as flooding, erosion, wildfires, and degradation.[427] This degradation will likely lead to

[417] U.S. Census Bureau. 2018. Chapter 12 – The Urban and Rural Classification. Geographic Areas Reference Manual. www.census.gov/programs-surveys/geography/guidance/geographic-areas-reference-manual.html.

[418] U.S. Census Bureau. 2018. QuickFacts: Kitsap County. www.census.gov/quickfacts/fact/table/poulsbocitywashington,bremertoncitywashington,bainbridgeislandcitywashington,kitsapcountywashington/PST045219.

[419] Kitsap 2035. Chapter 3: Countywide Population and Housing Growth. Kitsap 2035: Growing for a Better Tomorrow. www.kitsapgov.com/dcd/PEP%20Documents/BLR_2014_3%20Countywide%20Population%20and%20Housing%20Growth.pdf.

[420] Maxwell *et al.* 2018: Built Environment, Urban Systems, and Cities. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment.* Volume II: 438–478. doi: 10.7930/NCA4.2018.CH11.

[421] U.S. Geological Survey. 2020. Impervious surfaces and flooding. www.usgs.gov/special-topic/water-science-school/science/impervious-surfaces-and-flooding?qt-science_center_objects=0#qt-science_center_objects.

[422] See Chapter 10. Geologic Hazards. Finding 3: Storm Surge and Coastal Flooding and Chapter 11. Hydrology. Finding 2: Stream and Riverine Flooding.

[423] Kitsap County Department of Emergency Management. 2015.

[424] Kitsap County. 2019. Task 700 Climate Change Assessment.

[425] Kitsap County Department of Emergency Management. 2015.

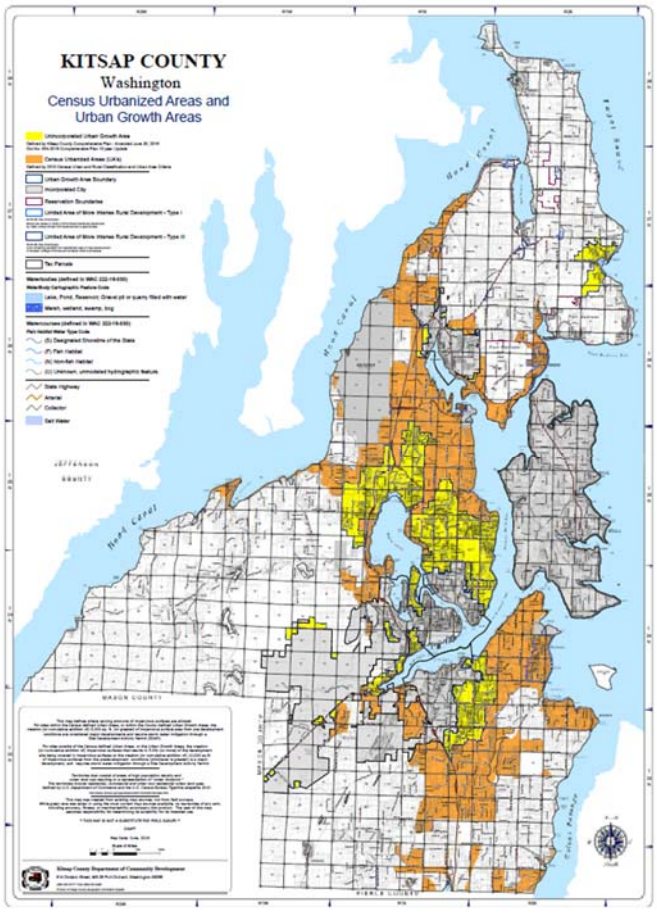
[426] See Chapter 6. Public Infrastructure. Finding 2: Water and Chapter 10. Geologic Hazards. Finding 3: Storm Surge and Coastal Flooding.

[427] Wilbanks & Fernandez. 2013. Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report for the U.S. Department of Energy in Support of the National Climate Assessment.

shorter infrastructure life spans, higher infrastructure investment cost, and infrastructure failure or service disruption much more likely during extreme weather events.[428]

Furthermore, there may be newly emerging climate challenges for the infrastructure of Kitsap County's urban areas. Warmer summer temperatures will very likely increase the air-conditioning and cooling demand during summer months, which may potentially raise questions about energy grid capacity for increased demand and hydropower supply due to lower summer flows and hydropower production.[429] Investments into resilient infrastructure, such as designing and planning for future climate conditions, standardizing methodologies, and updating building codes and standards can help protect urban assets and reduce future risk exposure while decreasing GHG emissions.[430,431]

Figure 31. Census Urbanized Areas, Urban Growth Areas, and Incorporated Cities in Kitsap County[432]
(This 2016 map defines where varying amounts of impervious surfaces are allowed based on Census-defined Urban Areas or County-defined Urban Growth Areas. Territories that consist of areas of high population density and urban land use result in a representation of "urban footprint.")



[428] Maxwell *et al.* 2018.
[429] Hamlet *et al.* 2010. Effects of projected climate change on energy supply and demand in the Pacific Northwest and Washington State. *Climatic Change*. 102: 103-128. doi:10.1007/s10584-010-9857-y.
[430] Maxwell *et al.* 2018.
[431] Hansen *et al.* 2016.
[432] Kitsap County Department of Community Development. 2016. www.kitsapgov.com/dcd/DCD%20GIS%20Maps/Census_Urbanized%20Areas.pdf.

Finding 5: Rural Infrastructure

The rural areas of Kitsap County are an important part of the cultural and economic fabric of Kitsap County, and they face certain types of risks to natural hazards and climate impacts. Climate change will continue to alter the landscape of risk for rural areas and infrastructure, and any potential disruption to transportation routes will affect the emergency response capacity for rural residents.

The rural areas of Kitsap County are an important part of the cultural and economic fabric of Kitsap County, and they face certain types of risks to natural hazards and climate impacts. A large population of Kitsap County lives in exurban or rural areas outside of urban areas.[433] The character and lifestyle associated with rural areas has been a draw for residents in rural areas.[434] There are many rural areas in Kitsap County that face a different landscape of climate-related risks as compared to Kitsap County's urban areas. Rural areas in Kitsap County are important for recreational opportunities, open space access, and fish and wildlife habitat. Agricultural farmers and producers are an important part of local history and culture, though there has been a decline in agricultural contribution to the county's economy over the past several decades due to factors such as a growing county population, urbanization and growth, and a more diversified economy.[435] Agricultural infrastructure has already been impaired by past flooding, leading to decreased crop productivity and revenue.[436] Additionally, flooding has impacted infrastructure, parks and facilities, and transportation access for rural communities in Kitsap County.[437] Rural areas may also experience more frequent power outages during storms than urban areas due to grid infrastructure and fallen trees and branches.[438,439]

Climate change will continue to alter the landscape of risk for rural areas and infrastructure, and any potential disruption to transportation routes will affect the emergency response capacity for rural residents. Rural areas already experience longer response times for emergency services (approximately 11 to 20 minutes) as compared to their urban and suburban counterparts (approximately 1.5 to 8 minutes), and future risks to transportation routes from increased flooding or landslides or erosion will affect the ability of rural residents to access County emergency services.[440,441] Though extremely rare in Kitsap County, wildfires are more likely to spread through rural and exurban areas in the wildland-urban interface of Kitsap County, damaging and destroying residences, facilities, and other structures.[442] There may be emerging challenges in

[433] Kitsap County Department of Emergency Management. 2015.
[434] Kitsap 2036. 2016. Chapter 1: Land Use. Kitsap County Comprehensive Plan 2016-2036. Prepared for Kitsap 2036: Growing for a Better Tomorrow. www.kitsapgov.com/dcd/Pages/2016_Comprehensive_Plan.aspx.
[435] See Chapter 8. Agriculture. Finding 4: Agricultural Economies and Livelihoods.
[436] See Chapter 8. Agriculture. Finding 3: Flood Risks.
[437] Kitsap County Department of Emergency Management. 2015.
[438] May *et al.* 2018.
[439] Farley, J. 2015. Why Bremerton weathers the storm better than the rest of Kitsap. *Kitsap Sun*. https://pugetsoundblogs.com/bremertonbeat/2015/12/10/why-bremerton-weathers-the-storm-better-than-the-rest-of-kitsap/.
[440] Kitsap 2036. 2016.
[441] See Chapter 3. Public Health. Finding 3: Acute Injuries from Extreme Weather and Chapter 3. Public Health. Finding 8: Health and Social Safety Net.
[442] See Chapter 13. Fires. Finding 2: Wildland-Urban Interface (WUI).

energy grid capacity to meet future growth and increased cooling or warming demand may require alternative energy production in rural areas.[443,444]

Finding 6: Power and Energy

Power outages already occur in Kitsap County due to natural hazards and damage to the energy infrastructure and future climate conditions are likely to lead to increased frequency of power outages without resilient energy infrastructure and system redundancies. Reducing power outage risk can be achieved by making energy infrastructure more resilient.

Power outages already occur in Kitsap County due to natural hazards and damage to the energy infrastructure, and future climate conditions are likely to lead to increased frequency of power outages without resilient energy infrastructure and systematic redundancies. Kitsap County communities receive energy provided by Puget Sound Energy (PSE) and Cascade Natural Gas Company.[445,446] Previously, winter storms, earthquakes, and landslides have led to power outages by damaging energy infrastructure in Kitsap County.[447] Power outages, which already affect rural areas more so than urban areas due to downed trees and lack of energy grid redundancy, may become more frequent due to future projections of increased wildfire risk, winter storms, heavy precipitation, and intensity of extreme weather events.[448,449] Wildfires, even in the broader Puget Sound region, may affect energy transmission by disrupting or damaging power generation and distribution facilities and infrastructure.[450,451] Future climate change may require PSE to expand production of energy to meet rising energy demand for cooling in the summer.[452]

Reducing power outage risk can be achieved by making energy infrastructure more resilient. Redundancy within the energy transmission system can help mitigate risk, especially for rural communities.[453,454] Creating a diverse and efficient energy portfolio will also help mitigate seasonal variation and ensure energy reliability for future projected energy demand increases during the summer months in the Puget Sound region.[455]

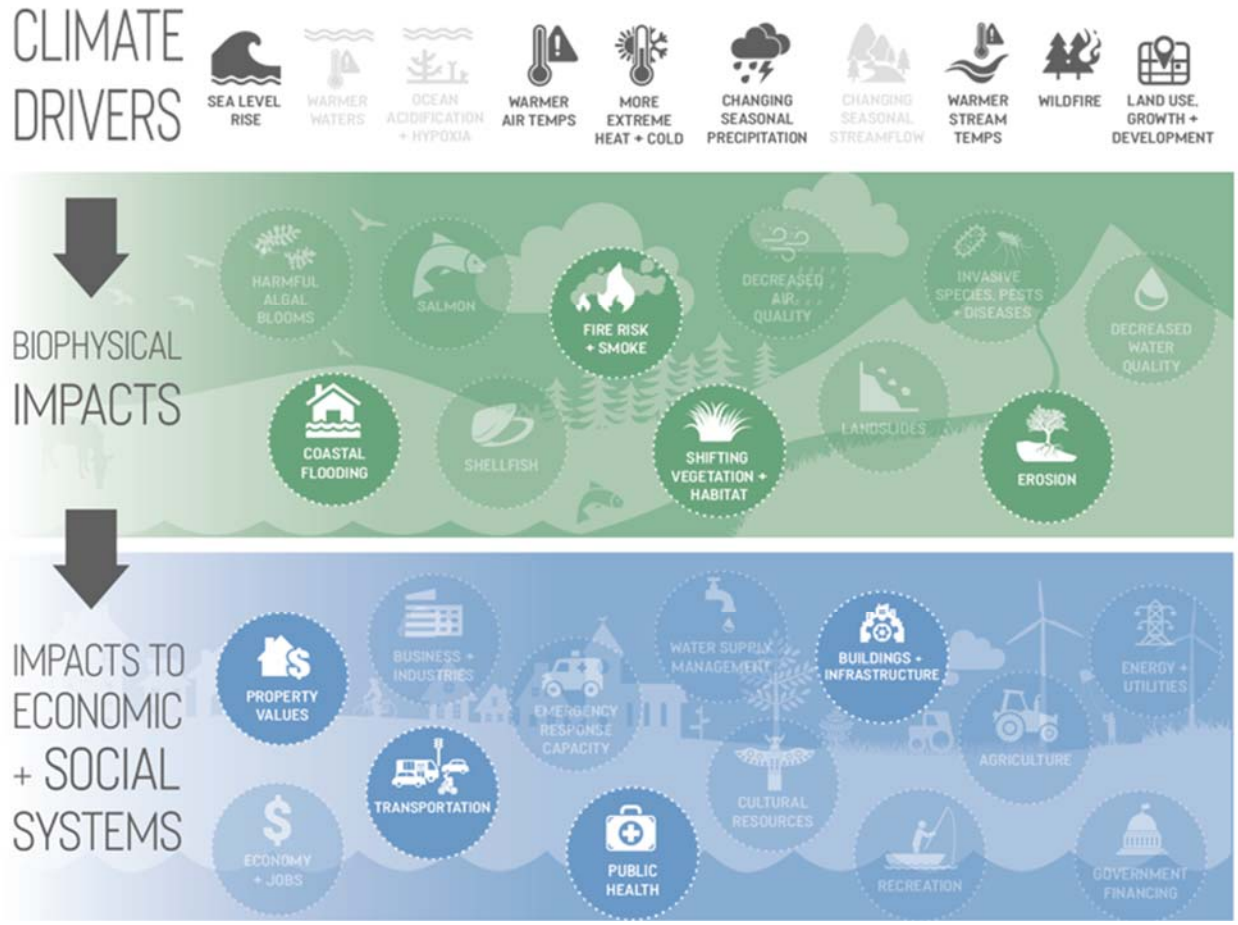
[443] See Chapter 6. Public Infrastructure. Finding 6: Power and Energy.
[444] Kitsap 2036. 2016.
[445] Hansen *et al.* 2016.
[446] Kitsap County Department of Emergency Management. 2015.
[447] Kitsap County Department of Emergency Management. 2015.
[448] Mauger *et al.* 2015. Section 12: Built Environment.
[449] See Chapter 6. Public Infrastructure. Finding 5: Rural Infrastructure.
[450] Mauger *et al.* 2015, Section 12: Built Environment.
[451] May *et al.* 2018.
[452] See Chapter 4. Economy. Finding 3: Energy Demand and Utilities.
[453] Zamuda *et al.* 2018. Energy Supply, Delivery, and Demand. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*. Volume II: 174–201. doi: 10.7930/NCA4.2018.CH4.
[454] U.S. Department of Energy. 2016. Climate Change and the Electricity Sector: Guide for Climate Change Resilience Planning. Office of Energy Policy and Systems Analysis, U.S. Department of Energy.
[455] Zamuda *et al.* 2018.

Chapter 7. Land Use & Development

Summary of Impacts

Land use and development and climate change are in a feedback cycle where land use affects climate impacts and climate impacts affect land use. Many climate change impacts are connected to land use and development. Examples of direct changes include deforestation, reforestation/afforestation, agriculture, and urbanization. Some examples of indirect changes include changes to precipitation patterns, temperature changes, and increasing carbon dioxide concentrations that force changes in vegetation and ecosystems, indirectly influencing land use and development. Although data on localized feedbacks between land use and climate in Kitsap County are incomplete, there is high confidence that humans have had significant impact on land use which has directly contributed to climate impacts. Future climate projections will continue to alter local land use decisions with increasing populations and urbanization, multi-hazard planning and comprehensive land use and development planning can help increase the climate resiliency of Kitsap County. Future land use and development practices can contribute to and/or mitigate the impacts of climate change.

Figure 32. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Land Use and Development



Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Land Use Affects Local Climate Impacts	**Medium-High** • Cities and dense urban areas will likely experience higher average temperatures due to the heat island effect [*high confidence*]. • Future urbanization and the increased use of impervious pavements are likely to increase the probability and severity of climate impacts such as urban flood events [*medium confidence*].	**Long-term** • Though climate impacts may manifest in the near term, land use decisions (e.g., reforestation, hazard planning) can mitigate these impacts in the long term [*medium confidence*].
2. Climate Impacts on Land Use and Cover	**Medium** • Climate change will likely alter how land is used by directly and indirectly shifting species distribution, increasing the risk of hazards near development, and changing the suitability of land for specific uses [*high confidence*].	**Near-term & Long-term** • Climate change is very likely to shift vegetation cover, forest cover, habitats, and land uses in the future, with impacts depending on local land use decisions and climate impacts (e.g., agriculture in previously unsuitable locations) [*high confidence*].
3. Adaptive Capacity	**Medium-High** • The use of multi-hazard and comprehensive land use and development planning can increase the climate resiliency of Kitsap County while offering adaptation and mitigation benefits [*very high confidence*].	**Long-term** • In Kitsap County, long-term coordination between climate action strategies and land use decision-making could help mitigate impacts from climate, including landslides, wildfires, flooding, and sea level rise [*medium confidence*].

Finding 1: Land Use Affects Local Climate Impacts

Humans have had a significant impact on land use and development planning which has directly contributed to climate change by altering the interactions between energy, water, land, and greenhouse gases. Land use changes alter the likelihood, strength, and length of extreme weather events, such as heat waves and heavy precipitation. Cities and urban areas typically experience higher average temperatures due to the heat island effect. Although historical data are insufficient to define connections between land use and localized climate impacts in Kitsap County, regional evidence supports that the combination of land use, urbanization, and population growth will amplify the magnitude of some climate impacts.

Humans have had a significant impact on land use and development planning which has directly contributed to climate change by altering the interactions between energy, water, land, and greenhouse gases.[456] Changes in land use alter the likelihood, strength, and length of heat waves and heavy

[456] Sleeter *et al.* 2018: Land Cover and Land-Use Change. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: 202–231. doi: 10.7930/NCA4.2018.CH5.

precipitation.[457] There is also high confidence that cities and dense urban areas typically experience higher average temperatures due to the heat island effect. Though there is a lack of localized studies between land use and local impacts in Kitsap County, regional evidence robustly supports that the combination of land use decisions, urbanization, and population growth will amplify the magnitude of some climate impacts.

Land use decisions will affect localized impacts of climate change by altering natural systems. When natural systems are disturbed, the greenhouse gases trapped in the vegetation is released back into the atmosphere, further contributing to climate change. [458] There is high confidence that human driven land use, such as urban development, agriculture and forestry are significant sources of GHG emissions, contributing nearly 23% of global carbon dioxide, methane, and nitrous oxide emissions between 2007-2016.[459]

Land use changes alter the likelihood, strength, and length of extreme weather events, such as heat waves and heavy precipitation. Cities and urban areas typically experience higher average temperatures due to the heat island effect. For example, areas with dry soils or building materials can amplify the impact of heatwaves due to decreased evapotranspiration rates.[460,461] The effect of land use on localized climate impacts is largely dependent on the type of land cover present within an area. There is high confidence that cities and dense urban areas typically experience higher average temperatures due to the urban heat island effect. The urban heat island effect manifests in both urban and suburban landscapes and is a result of a high concentration of concrete structures, roads, and buildings that lead to areas with hotter air and surface temperatures. During any given summer day, roof and pavement surface temperatures can be approximately 50-90°F hotter than the air temperatures.[462] After sunset, cities and other high-density developments can experience air temperatures that can be as high as 22°F hotter than nearby, less-developed areas.[463] Other land use changes, including deforestation, reforestation, agriculture development, and urbanization, will alter how climate change is experienced at the local scale.[464] Historical data have not been collected in Kitsap County to ground-truth these regional trends, though the county's growth rates and development patterns will likely create conditions for heat island effects to be a concern for some county areas in the near future.

Urbanization has also increased the intensity and frequency of urban flooding.[465] Urban flooding occurs when extreme levels of rainfall overwhelm local stormwater capacity, causing flooding to occur in densely populated areas and typically outside of mapped floodplains.[466] Urbanization promotes land use changes that convert natural systems to built systems, which alter natural drainage systems (e.g., vegetation) and utilizes

[457] Shukla *et al.* 2019. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.
[458] Sleeter *et al.* 2018
[459] Shukla *et al.* 2019.
[460] Shukla *et al.* 2019.
[461] IPCC. 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 151 pp. www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf.
[462] Berdahl & Bretz. 1997. Preliminary survey of the solar reflectance of cool roofing materials. *Energy and Buildings*. 25:149-158.
[463] Akbari, H. 2005. Energy Saving Potentials and Air Quality Benefits of Urban Heat Island Mitigation. www.osti.gov/bridge/servlets/purl/860475-UlHWIq/860475.PDF
[464] The Environmental Literacy Council. 2020. Land Use Changes & Climate. https://enviroliteracy.org/air-climate-weather/climate/land-use-changes-climate/.
[465] University of Maryland *et al.* 2018. The Growing Threat of Urban Flooding: A National Challenge.
[466] University of Maryland *et al.* 2018.

impervious material like parking lots, sidewalks, and buildings. These impervious surfaces accumulate water and often exceed the capacity of stormwater infrastructure during intense rain events and storms.[467]

Although there is insufficient historical data to establish the associations between land use and localized climate impacts in Kitsap County, more localized data can support land use decisions that can mitigate harmful climate-related impacts, such as heat waves.[468] Although more data are needed on the interaction local impacts and land use decisions in Kitsap County, evidence clearly suggests that land use decisions can have significant benefits on local climate impacts. For example, peak air temperatures in tree groves are approximately 9°F cooler compared to open land; peak air temperatures over irrigated agricultural land is nearly 6°F cooler than fallow land; and suburban areas with mature tree growth are 4-6°F cooler than suburban areas without trees.[469] Other land use practices, like agriculture and reforestation, have the potential to offset the effect of climate impacts through increased evapotranspiration and carbon sequestration rates during the growing seasons.[470] However, urbanization and development has been increasing in Kitsap County.[471] Furthermore, future urbanization and associated increases in impervious surfaces will very likely increase the probability and severity of future urban flood events.[472]

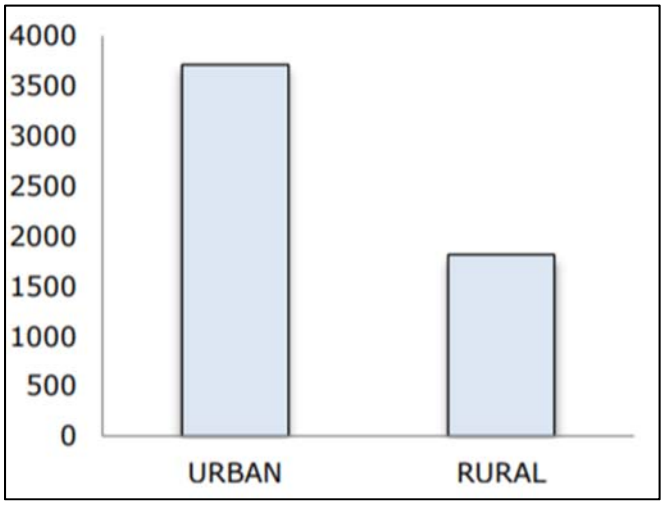
Population growth and urbanization will very likely continue to occur in Kitsap County; however, there is little evidence on what its local effects will be. Kitsap County has historically been a mix of urban and rural areas. Between 2006-2012, approximately 68% of all new units were permitted in cities and urban growth areas. As shown in Figure 33, Kitsap County continues to see a moderately high rate of new rural housing units, indicating a general preference for rural development. Kitsap County is projected to experience significant population growth and urbanization, with over 80,000 new residents arriving by 2035.[473] Guided by the Growth Management Act, future development in Kitsap County is focused on urban areas to accommodate future population growth.[474]

Throughout Kitsap County, over $500 million in new mixed-use/commercial/multifamily/industrial developments are anticipated (dollar year not reported). Major anticipated urban developments in Kitsap County include the CHI Franciscan Medical Center ($500-million Level III Tertiary Hospital), Harbor Square in Bremerton ($120-million mixed-use development), and Port Orchard's waterfront ($50 million mixed-use development).[475] Other notable projects include Circuit of the NW ($30-million motor-sports complex) at Olympic View Industrial Park; Port Gamble master-plan redevelopment; 100,000-square-foot industrial warehouse planned for the Puget Sound Industrial Center at Bremerton; several new industrial buildings at the Port of Bremerton; and a 30,000-square-foot addition to Watson Furniture's manufacturing facility in

[467] NRDC. 2020. www.nrdc.org/stories/flooding-and-climate-change-everything-you-need-know
[468] EPA. 2008. Reducing urban heat islands: Compendium of strategies. www.epa.gov/heat-islands/heat-island-compendium.
[469] EPA. 2008.
[470] Shukla *et al.* 2019.
[471] Kitsap County Urbanized Areas and Urban Growth Areas Map. 2016. www.kitsapgov.com/dcd/DCD%20GIS%20Maps/Census_Urbanized%20Areas.pdf
[472] Sleeter *et al.* 2018.
[473] Kitsap 2036. 2016.
[474] Kitsap 2036. 2016. There is currently a 76% urban to 24% rural growth target ratio, meaning that the current target is focusing on directing 76% of growth into the urban growth areas and 24% into rural areas. The Kitsap Comprehensive Plan states that once the 76% target is reached, the urban growth target is reset to 84% urban growth to 16% rural.
[475] Power, John. 2019. Kitsap's Economy: Another solid year, with more to follow. www.kitsapsun.com/story/money/columnists/business-journal/2019/12/18/john-powers-solid-economic-year-kitsap-more-follow/2693407001/

North Kitsap.[476] These investments are projected to create thousands of new jobs throughout Kitsap County in the next few years and provide continued economic growth. Future planning should look to maintain Kitsap County's identity to "preserve existing open space in rural areas, enhance recreational opportunities, conserve fish and wildlife habitat, increase access to natural resource lands and water, and develop parks and recreation facilities" through sustainable growth, which can result in multiple benefits for the County's economy and resilience to climate change.[477,478]

Figure 33. Percentage of Urban Housing Units Compared to Rural (2016)[479]



Finding 2: Climate Impacts on Land Use and Cover

Climate change is a driver of land use changes across the Puget Sound region. Land use is sensitive to temperature, precipitation, and temperature extremes. These impacts affect natural ecosystems and how, when, and where cities can develop. Climate projections are very likely to shift vegetation cover, forest cover, habitats, and land uses in the future.

Climate change is a driver of land use changes across the Puget Sound region. Land use is sensitive to temperature, precipitation, and temperature extremes. These impacts affect natural ecosystems and how, when, and where cities can develop.[480] Due to the complex physical and socioeconomic interactions within local systems, further study is needed to ground truth on the extent of climate change impacts on land use in Kitsap County It is very likely that future climate change will alter land use due to projected impacts on ecosystems and habitats sensitive to changes in temperature and precipitation patterns, which will likely

[476] Power, J. 2019.
[477] Kitsap 2036. 2016.
[478] IPCC. 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 151 pp. www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf.
[479] Kitsap 2036. 2016.
[480] Sleeter *et al.* 2018.

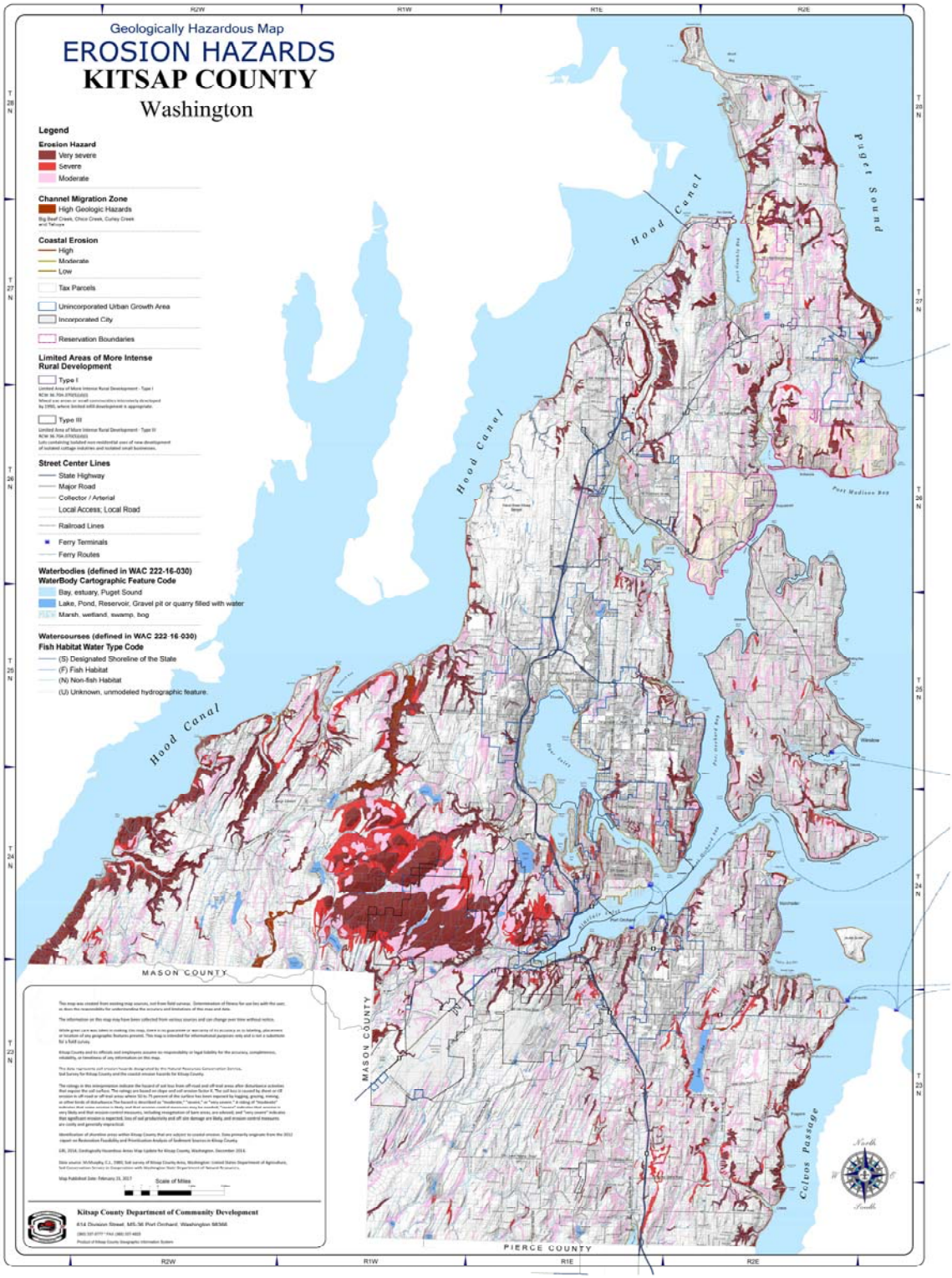
affect ecosystem structures, function, and biodiversity.[481] For example, temperatures and precipitation shifts are projected to affect the spatial distribution of species, change forest productivity, increase wildfire risk and activity, and alter species-species interactions, which will likely influence where and how land can be used.[482]

Climate projections are very likely to shift vegetation cover, forest cover, habitats, and land uses in the future, although exact magnitudes are dependent on local land cover and land use changes.[483,484] Climate change is projected to affect future agriculture and housing sector land use and land use decisions. These impacts will be further exacerbated if residents and land use planning are unable to adapt to future climate conditions.[485] While greater variability in rainfall patterns can decrease overall plant growth, higher temperatures can extend growing seasons, possibly allowing for more new agricultural development in areas previously unsuitable.[486,487,488] Shifting vegetation cover and type will likely have impacts on fire risk, depending on the fire-tolerance characteristics of new vegetation. If a wildfire does occur, subsequent changes to the ecosystem and lands will likely have cascading impacts and decrease water quality, alter streamflow, and increase flooding risk.[489]

Climate change can worsen degrading land use processes through increases in rainfall intensity, flooding, heat waves, and sea level rise. For example, coastal erosion is further exacerbated by sea level rise and a loss of soil quality is another form of degradation. This can be through a loss of nutrients, such as nitrogen, which can be removed during extreme precipitation events.[490] Furthermore, increasing rates of coastal erosion and sea level rise is intensifying and impinging on coastal communities and development, with sea level rise reducing viable shoreline and further stressing land use pressures and habitat quality (Figure 34).[491,492]

[481] Shukla *et al.* 2019.
[482] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[483] Shukla *et al.* 2019.
[484] May *et al.* 2018.
[485] May *et al.* 2018.
[486] Sleeter *et al.* 2018.
[487] Mauger *et al.* 2015, Section 9: Terrestrial Ecosystems.
[488] See Chapter 4. Finding 2: Shifts in Business Opportunities.
[489] Shukla *et al.* 2019.
[490] IPCC. 2014.
[491] Sleeter *et al.* 2018.
[492] See Chapter 12. Finding 3: Marine and Coastal Habitat.

Figure 34. Kitsap County Erosion Hazard Map[493] *(Red coloration indicates the level of erosion severity that an area faces; the darker the shade of red, the more severe the risk is for erosion to occur in that area.)*



[493] Kitsap County Department of Community Development.

Finding 3: Adaptive Capacity

Climate change impacts will affect the adaptive capacity of communities to cope with change. Future integration of multi-hazard planning and comprehensive land use and development planning will increase the climate resiliency of Kitsap County while offering adaptation and mitigation benefits.

Climate change impacts will affect the adaptive capacity of communities to cope with change.[494] Projected increases in extreme precipitation and flooding increase the risk of interruptions to transit, food systems, ecosystems, and municipal operations while damaging critical infrastructure located in or near current floodplains.[495] Anticipating these impacts will have implications for strategic land use planning in mitigating future impacts and risks in Kitsap County.

Future integration of multi-hazard planning and comprehensive land use and development planning will increase the climate resiliency of Kitsap County while offering adaptation and mitigation benefits.[496] In Kitsap County, synchronization between climate action strategies and land use decision-making can mitigate many climate impacts, including landslides, wildfires, flooding, and sea level rise impacts.[497]

Projected increases in wildfire risk in western Washington is likely to increase protection costs for homes, especially within the wildland-urban interface (WUI). [498,499]As more development occurs near wildfire-prone land, there is an increasing need to mitigate risk through improved land use policies and tools. Examples include, researching drought-related risks, improving the reliability of ecosystem service infrastructure, and protecting forest-related ecosystems.[500] Furthermore, education and awareness campaigns for homeowners in WUI areas can mitigate potential risks of fire spreading across the landscape.[501] Improvements made on agricultural lands, such as improved land management and reforestation decrease emissions and can mitigate local climate impacts.[502]

Urban flooding impacts both large and small communities. It is important to consider that for smaller communities like Poulsbo or unincorporated areas like Kingston, the impact is more severe because they typically lack the resources to cope with significant rainfall and flooding events.[503] Sea level rise and associated bluff erosion may require adaptive strategies as many residences and infrastructure along coastal regions face long-term risk from decreasing viable property from bluff erosion.[504]

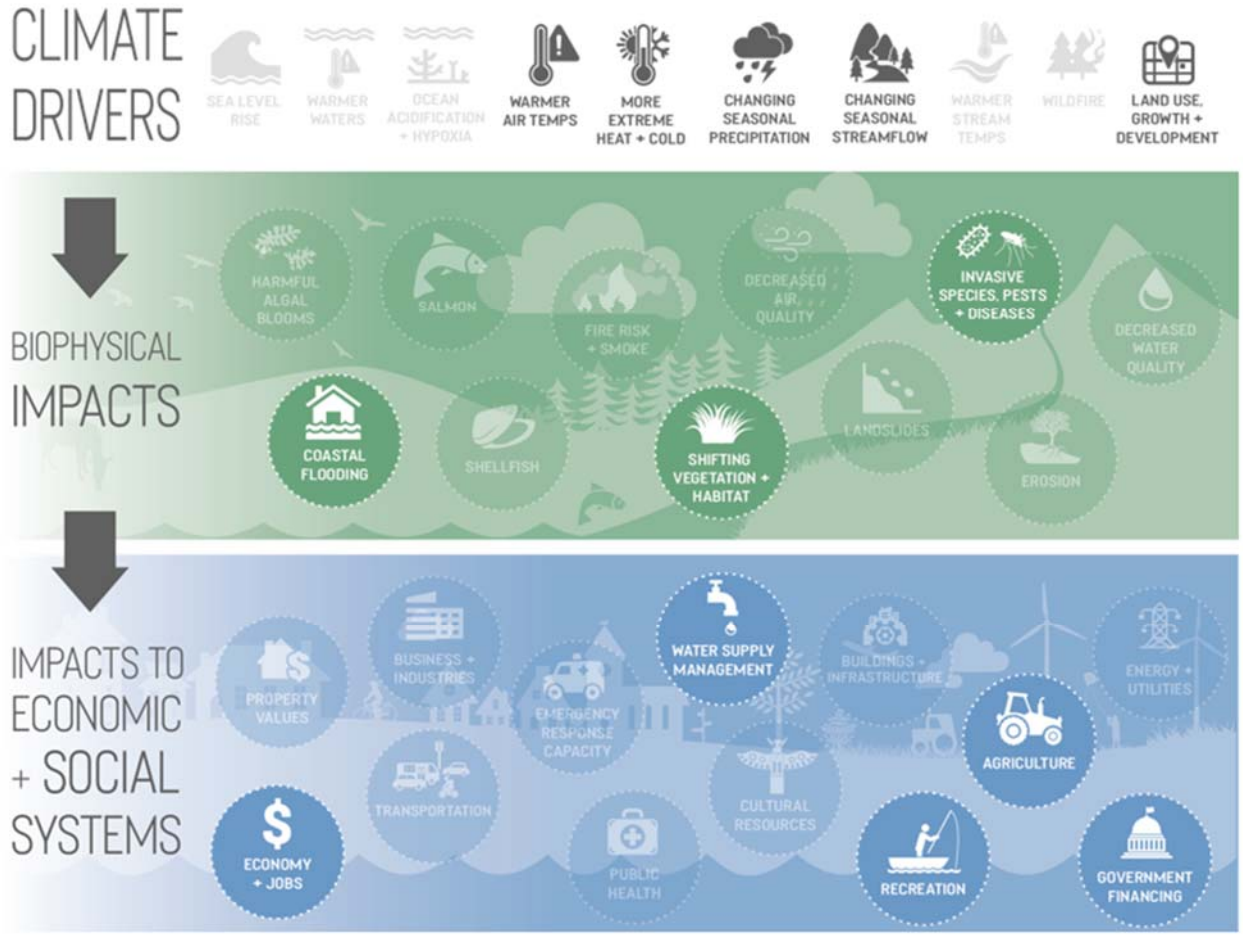
[494] Sleeter *et al.* 2018.
[495] See Chapter 3. Finding 3: Acute Injuries from Extreme Weather
[496] Sleeter *et al.* 2018.
[497] Kitsap County Multi-Hazard Mitigation Plan. 2015.
[498] May *et al.* 2018.
[499] Headwater Economics. 2016. Land Use Planning to Reduce Wildfire Risk: Lessons from Five Western Cities
[500] May *et al.* 2018.
[501] See Chapter 13. Wildfires. Finding 2: Wildland-Urban Interface (WUI).
[502] Shukla *et al.* 2019
[503] University of Maryland *et al.* 2018.
[504] See Chapter 10. Finding 2: Bluff Erosion.

Chapter 8. Agriculture

Summary of Findings

Agriculture is a component of Kitsap County's culture and economy despite declining employment and sales over the past few decades. Agriculture provides wages and revenue for laborers and farmers, attracts tourist visitors, and is an important part of Kitsap County's landscape. There will be a variety of crop responses to future warming and increased regional carbon dioxide concentration trends, with some "winners" (e.g., viticulture) and "losers" (some fruit and vegetables). Future warming and changing precipitation regimes will collectively increase the risk of floods and pests, which will very likely affect crop productivity and livestock. Cumulative risks from natural hazards will affect farm infrastructure, especially farms that are in floodplains or coastal areas. Future climate change will also increase the operating costs of many agricultural producers due to shifting irrigation water supply and decreasing quality of forage for livestock. Selling prices of agricultural goods may also decrease, as the quality of goods may be affected. However, the agricultural sector has historically been relatively resilient to natural and weather hazards.

Figure 35. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Agriculture



Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Crops	**Low-Medium** • Some crops may benefit from climate change, with warmer temperatures and increased carbon dioxide concentrations extending growing seasons [*medium confidence*]. • Water availability, heat stress, and flooding may affect other crops [*high confidence*].	**Near-term** • Climate change may continue to drive up insurance costs and damages in the near and long term as insured losses and damages increase [*medium confidence*].
2. Pests and diseases	**Low** • Pests and diseases will likely expand their ranges and prevalence, resulting in decreased crop and livestock productivity [*medium confidence*].	**Long-term** • There may be some long-term impacts on how pests and diseases affect crops in Kitsap County [*low confidence*].
3. Flood risks	**Low-Medium** • Annual flooding already impacts Kitsap County's agricultural production and will likely worsen and affect yields and farm infrastructure [*medium confidence*].	**Already happening** • Flooding already happens regularly, though more intense and frequent flood events may further stress local farmers [*medium confidence*].
4. Agricultural economies and livelihoods	**Low-Medium** • Climate change will continue to threaten agricultural economies and livelihoods [*medium confidence*].	**Already happening** • Kitsap County's agricultural economy has already decreased in the past few decades, with economic shifts to other industries [*high confidence*].
5. Adaptive capacity	**Medium** • Agriculture can play a role in increasing Kitsap County's climate resilience and adaptive capacity [*high confidence*].	**Long-term** • Long-term investments from all levels of government and from private landowners can result in multi-benefit outcomes for climate resilience [*medium confidence*].

Finding 1: Crops

Agricultural crops across the Puget Sound region are sensitive to temperature, precipitation, and temperature extremes, which affects the water availability and growing season for crops. Future climate projections will reduce irrigation water supply and increase heat stress to crops, livestock, and fruits. There will be variability in crop response to future climate conditions.

Agricultural crops across the Puget Sound region are sensitive to temperature, precipitation, and temperature extremes, which affects the water availability and growing season for crops.[505] In Kitsap County, crops account for 73% of all sales, including grains, oilseeds, dry beans, dry peas, vegetables, melons, potatoes, sweet potatoes, fruits, tree nuts, berries, nursery plants, Christmas trees, hay, and other crops.[506] Warmer spring temperatures have caused early flowering events for fruits across the region, which can reduce fruit quality and yield from mismatched timing between flowering events and pollinator availability.[507] Warmer summer temperatures and extreme heat days have led to heat stress and sunburns for fruit, decreasing their quality and affecting selling price.[508,509]

Though there are few studies outside of specific commodity sectors linking climate change to agricultural impacts in the Pacific Northwest, there have been a few high-profile climate extremes that have affected farmers and farm operations in the region.[510,511] In 2015, an extreme temperature year illustrative of the climate conditions by mid-century RCP8.5 or late-century RCP4.5 that led to greatly reduced winter snowpack, extreme warm winter and summer temperatures, and substantial decrease in annual and seasonal precipitation, directly harmed Northwest agricultural operations and profits.[512,513] The suite of climate impacts led to a significant shortage of available water for agricultural irrigation across the Pacific Northwest, which led to a limited window of irrigation for water rights holders.[514] The year also saw damaged crops, reduced crop yields, fewer crops planted, land left idle, and altered livestock management, resulting in estimated agricultural economic losses of $633 million to $773 million in Washington State and estimated dairy industry losses of $33 million (dollar year not reported).[515]

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[505] Mote *et al.* 2014.Ch. 21: Northwest. Climate Change Impacts in the United States: The Third National Climate Assessment. pp. 487-513. doi:10.7930/J04Q7RWX.

[506] USDA National Agricultural Statistics Service. 2017. County Profile: Kitsap County, Washington. www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Washington/cp53035.pdf.

[507] Houston *et al.* 2018. Specialty fruit production in the Pacific Northwest: Adaptation strategies for a changing climate. *Climatic Change*. 146(1-2): 159-171. Doi: https://doi.org/10.1007/s10584-017-1951-y.

[508] Houston *et al.* 2018.

[509] May *et al.* 2018. Chapter 24: Northwest. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment.* Volume II: 1036–1100. https://nca2018.globalchange.gov/chapter/24/.

[510] Eigenbrode *et al.* 2013. Chapter 6. Agriculture. In *Climate change in the Northwest: Implication for our Landscapes, Waters, and Communities*. http://cses.washington.edu/db/pdf/daltonetal678.pdf.

[511] May *et al.* 2018.

[512] Rupp *et al.* 2017. Projections of the 21st century climate of the Columbia River Basin. *Climate Dynamics*. 49(5): 1783-1799. Doi: https://doi.org/10.1007/s00382-016-3418-7.

[513] May *et al.* 2018.

[514] Mucken & Bateman. 2017. Oregon's 2017 Integrated Water Resources Strategy. 186 pp. www.oregon.gov/owrd/wrdpublications1/2017_IWRS_Final.pdf.

[515] McLain *et al.* 2017. 2015 Drought and Agriculture: A Study by the Washington State Department of Agriculture. *Washington State Academy of Sciences.* 15 pp. https://agr.wa.gov/getmedia/d814e329-dde6-4034-a878-8b6ba1b3f9b7/495-2015droughtreport.pdf.

Future climate projections will reduce irrigation water supply and increase heat stress to crops, livestock, and fruits.[516] There will be variability in crop response to future climate conditions.[517] Water availability, supply, and quality will very likely be impacted by future climate conditions.[518,519] Future sea level rise and reduced summer water supply can increase the risk of saltwater intrusion, exacerbating expected future water availability challenges.[520,521] Changing seasonal precipitation patterns, earlier snowmelt (if any), and declining summer flows will lead to limited water availability in the future, adversely affecting crop productivity.[522,523] Warmer spring and summer temperatures will increase the demand for water and irrigation, which will conflict with limited water availability. [524,525]

Warmer air temperatures will elicit varied responses from crops and livestock. Warmer temperatures, coupled with increasing carbon dioxide concentrations will likely lead to extended growing seasons for some crops and may create conditions and opportunities for new crops under certain climate scenarios.[526,527] For instance, wheat yields are projected to increase under both RP4.5 and RCP8.5 scenarios and some parts of Puget Sound will have conditions suitable for growing important wine grape varietals by mid-century under all climate scenarios. [528,529,530] Projected warmer temperatures will also likely further stress temperature-sensitive crops, such as fruits and some vegetables, and cause production quantity and quality to decline.[531]

Future warming will also affect livestock health and productivity. Warmer temperatures may lead to reduced milk production of dairy cattle from heat stress and higher metabolic costs.[532,533] Forage quality and quantity will also be adversely impacted by future warming and increased frequency and intensity of drought conditions, increasing farmers' operating costs by purchasing more feed for livestock.[534,535]

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[516] May *et al.* 2018.
[517] Hatfield *et al.* 2011. Climate impacts on agriculture: Implications for crop production. Agronomy Journal. 103: 351-370. doi:10.2134/agronj2010.0303.
[518] May *et al.* 2018.
[519] Gowda *et al.* 2018: Agriculture and Rural Communities. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: pp. 391–437. doi: 10.7930/NCA4.2018.CH10.
[520] Mauger *et al.* 2015. Section 8: Agriculture. https://cig.uw.edu/resources/special-reports/ps-sok/.
[521] Tibbot, E.B. 1992. Seawater intrusion control in coastal Washington. Department of Ecology Policy and Practice. EPA.
[522] May *et al.* 2018.
[523] Gowda *et al.* 2018.
[524] Hansen *et al.* 2016. Bainbridge Island Climate Impact Assessment. EcoAdapt, Bainbridge Island, WA. www.cakex.org/sites/default/files/documents/BICIA%20Final%2028%20July%202016.pdf.
[525] May *et al.* 2018.
[526] Mauger *et al.* 2015. Section 8: Agriculture.
[527] May *et al.* 2018.
[528] Stöckle *et al.* 2018. Evaluating opportunities for an increased role of winter crops as adaptation to climate change in dryland cropping systems of the U.S. Inland Pacific Northwest. *Climatic Change.* 146: (247–261). doi:10.1007/s10584-017-1950-z.
[529] Karimi *et al.* 2018. Climate change and dryland wheat systems in the US Pacific Northwest. *Agricultural Systems*. 159: 144-156. Doi: https://doi.org/10.1016/j.agsy.2017.03.014.
[530] Hannah *et al.* 2013.
[531] May *et al.* 2018.
[532] Key *et al.* 2014. Climate change, heat stress, and U.S. dairy production. U.S. Department of Agriculture, Economic Research Service.
[533] Mauger *et al.* 2014. Impacts of climate change on milk production in the United States. *The Professional Geographer*. 67: 121-131.
[534] Izaurralde *et al.* 2011. Climate Impacts on Agriculture: Implications for Forage and Rangeland Production. *Agronomy Journal*. 103(2): https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2356&context=usdaarsfacpub.
[535] May *et al.* 2018.

Finding 2: Pests

In general, there is a link between warmer temperatures and the expansion of pest and disease ranges. Future projections will likely add potential futures risks to agricultural productivity by expanding pest and disease ranges and shifting phenological cycles.

In general, there is a link between warmer temperatures and the expansion of pest and disease ranges.[536] There are many different insect pests, diseases and pathogens that already affect the quantity and quality of crops in Puget Sound and the Northwest. There is some evidence that well-known pests, such as grasshoppers, will increase with warmer temperatures and reduce forage quantity and quality for livestock.[537] Many tree fruit pests and diseases, such as codling moths and powdery mildew, already affect the quality of fruits, and may worsen under future conditions.[538] Past warming trends have been correlated to the range expansion of some pest and disease vector ranges, such as the potato psyllid.[539,540]

Future projections will likely add potential futures risks to agricultural productivity by expanding pest and disease ranges and shifting phenological cycles.[541,542] Warmer temperatures will likely expand pest and disease ranges, potentially introducing new pests and diseases in the Puget Sound region and creating conditions for current pests to continue persisting.[543,544] Warmer summer temperatures and longer growing seasons will likely extend reproductive cycles and warmer winters will likely lead to increased chance of winter pest survival.[545] However, shifts in phenological events and predatory-prey dynamics may mitigate future impacts from pests.[546,547,548] Warmer temperatures will also very likely stress livestock, decrease their health, and increase their susceptibility to parasites and pathogens. Kitsap County's livestock accounts for nearly a quarter (23%) of agricultural sales for the county.[549]

[536] Gowda *et al.* 2018.
[537] Eigenbrode *et al.* 2013.
[538] Eigenbrode *et al.* 2013.
[539] Liu *et al.* 2007. Comparative Fitness of Invasive and Native Populations of the Potato Psyllid (*Bactericera cockerelli*). *Entomologia Experimentalis et Applicata*. 123 (1): 35-42. doi: 10.1111/j.1570-7458.2007.00521.x.
[540] See Chapter 12. Habitats. Finding 4: Invasive Species and Diseases.
[541] Mote *et al.* 2014.
[542] Mauger *et al.* 2015. Section 8: Agriculture.
[543] Gowda *et al.* 2018.
[544] Mote *et al.* 2014.
[545] Mauger *et al.* 2015. Section 8: Agriculture.
[546] Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics.* 37: 637-669.
[547] Trumble & Butler. 2009. Climate change will exacerbate California's insect pest problems. *California Agriculture*. 63: 73-78..
[548] Mauger *et al.* 2015. Section 8. Section 8: Agriculture.
[549] Polley *et al.* 2013. Climate change and North American rangelands: Trends, projections, and implications. *Rangeland Ecology & Management*. 66(5): 493-511. Doi: 10.2111/REM-D-12-00068.1.

Finding 3: Flood Risks

Flooding is already a natural occurrence in Kitsap County and has affected agricultural products, land, water quality, and infrastructure across Puget Sound. Future flooding risks from increased winter precipitation, sea level rise, and heavy rainfall events will likely impact soil and water resources, crop productivity, livestock, and infrastructure.

Flooding is already a natural occurrence in Kitsap County and has affected agricultural products, land, water quality, and infrastructure across Puget Sound.[550] Floods occur every year and have already impacted almost every part of Kitsap County.[551] Floodplain zones and areas near streams are particularly vulnerable to flooding, especially during heavy rainfall events and storms.[552,553,554] Many farms in the Puget Sound region are located in valleys or floodplains, which has already led to impacts to agricultural productivity, water quality and supply, and damages to farm infrastructure and land. [555]

Future flooding risks from increased winter precipitation, sea level rise, and heavy rainfall events will likely impact soil and water resources, crop productivity, livestock, and infrastructure.[556,557] Flooding on agricultural land can degrade the soil quality and productivity and can increase contaminant presence.[558] This will likely result in loss of arable land and decreased livestock health.[559,560] Flood events may also lead to livestock mortality.[561] Farmlands and farms infrastructure will likely be damaged from future flooding events, especially in Kitsap County where many farms are located in or near floodplains.[562,563] There may likely be downstream consequences to human health from agricultural runoff and increase operating costs for agricultural producers and farmers.[564,565]

[550] Mauger *et al.* 2015. Section 8: Agriculture.
[551] Kitsap County Department of Emergency Management. 2015. Kitsap County Multi-Hazard Mitigation Plan.
[552] Kitsap County Department of Emergency Management. 2015.
[553] Kitsap County. 2019. Task 700 Climate Change Assessment.
[554] Hansen *et al.* 2016.
[555] Mauger *et al.* 2015. Section 8: Agriculture.
[556] May *et al.* 2018.
[557] Gowda *et al.* 2016.
[558] Olson *et al.* 2015. Impact of levee breaches, flooding, and land scouring on soil productivity. *Journal of Soil and Water Conservation*. 70(1): 5A-11A. Doi: 10.2489/jswc.70.1.5A.
[559] May *et al.* 2018.
[560] Izaurralde *et al.* 2011.
[561] Abdela & Jilo. 2016. Impact of climate change on livestock health: A review. *Global Veterinaria*. 16(5): 419-424. DOI: 10.5829/idosi.gv.2016.16.05.10370.
[562] Kitsap County Department of Emergency Management. 2015.
[563] Mauger *et al.* 2015. Section 8: Agriculture.
[564] May *et al.* 2018.
[565] EPA. 2017. Multi-Model Framework for Quantitative Sectoral Impacts Analysis: *A Technical Report for the Fourth National Climate Assessment.* 430-R-17-001.

Finding 4: Agricultural Economies and Livelihoods

Kitsap County's agricultural and agritourism industry contribute to the county's economy and culture. Future climate projections will likely have adverse impacts on livelihoods in the agricultural sector by affecting productivity and market dynamics.

Kitsap County's agricultural and agritourism industry contribute to the county's economy and culture.[566] Agriculture has historically been an important part of Kitsap County's economy, but has been decreasing over the past decade due to growing county population, urbanization, and a diversified economy.[567] As of 2017, Kitsap County had 698 farms covering 9,391 acres, a slight decrease from 2012. Farms in Kitsap County contribute to the County's economic and cultural profile, with $6.6 million of farm products sold, 97% of farms being family farms or homesteads, 20% selling directly to consumers, and 22% employing farm labor.[568] Agritourism also attracts visitors and adds additional revenue for some working farms.[569]

There has been a decrease in the total sales of agricultural products of Kitsap County farms since 2002.[570,571] Though it is unclear how much of this decrease can be directly attributed to climate change rather than other factors such as market demand and value, it is likely that a combination of climate change, land use and development, and changing economic industries has played a role in the decrease of the county's agricultural sales.[572,573] This declining trend is reflective of the declining agricultural sales of other counties in the Central Puget Sound region.[574]

Future climate projections will likely have detrimental impacts the livelihoods of people in the agricultural sector by affecting productivity and market dynamics.[575] On Bainbridge Island, combined impacts of warmer temperatures and shifting land use (e.g., urbanization, changing vegetation types) may impact agricultural costs and production.[576] Warmer temperatures, pests and diseases, and shifting precipitation regimes will very likely decrease crop productivity and quality for some crops, such as fruits and some vegetables, impacting farmers' selling price.[577] Rising costs to feed and water livestock due to shifting forage quantity and quality will impact the short and long-term economic viability of farmers.[578,579] Agritourism may also be impacted by shifting supply and demand.[580] Collectively, these climate impacts pose a high risk to Kitsap County's agricultural sector in the future without comparative sectoral adaptation and mitigation strategies.

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[566] USDA National Agricultural Statistics Service. 2017.
[567] Kitsap County Agriculture Sustainability Strategic Plan. 2011. Appendix C: Kitsap County Agriculture Sustainability Situation and Analysis. www.kitsapgov.com/BOC_p/Policy%20Documents/Appendix%20C.pdf.
[568] USDA National Agricultural Statistics Service. 2017. Dollar year not reported.
[569] Visit Kitsap Peninsula. Agritourism and Farms. 2020. www.visitkitsap.com/agritourism.
[570] USDA National Agricultural Statistics Service. 2017.
[571] Kitsap County Agriculture Sustainability Plan. 2011.
[572] Kitsap County Agriculture Sustainability Plan. 2011.
[573] Mauger *et al.* 2015. Section 8: Agriculture.
[574] Kitsap County Agriculture Sustainability Plan. 2011.
[575] May *et al.* 2018.
[576] Hansen *et al.* 2016.
[577] Houston *et al.* 2018.
[578] Izaurralde *et al.* 2011
[579] May *et al.* 2018.
[580] Hansen *et al.* 2016.

Finding 5: Adaptive Capacity

Despite the cumulative climate risks and exposures for agriculture, the sector is considered resilient. Innovative and proactive adaptation strategies will reduce climate risks and increase long-term viability of the sector.

Despite the cumulative climate risks and exposures for agriculture, the sector is considered resilient. Because of its nature and importance to peoples' livelihoods, agriculture has been a particularly resilient and flexible sector to climate change impacts.[581] Regional and global agricultural trade dynamics present additional uncertainties in how climate change may collectively impact the agricultural sector.[582,583] Furthermore, the diversity and variety of impacts to agriculture and livestock present future challenges as well as future opportunities for agricultural producers in the region.

Innovative and proactive adaptation strategies will reduce climate risks and increase long-term viability of the sector. Climate-smart strategies, especially strategies that lead to adaptation and mitigation co-benefits, will be particularly salient in increasing adaptive capacity of Kitsap farmers while contributing to regional climate resilience in the greater Puget Sound area.[584,585] Flexible cropping methods and soil conservation strategies can produce multiple co-benefits of reducing soil erosion, improving soil health, improving weed and pest management, and increasing overall revenue.[586,587] Agricultural systems also have the potential to mitigate greenhouse gas emissions by serving as carbon sinks through reducing tillage of annual crops and improving nitrogen fertilization practices.[588,589] Resilience strategies within the agricultural sector will be diverse and varied depending on the range and severity of impacts that farmers and producers experience but could serve an important role in enhancing the county's collective resilience.

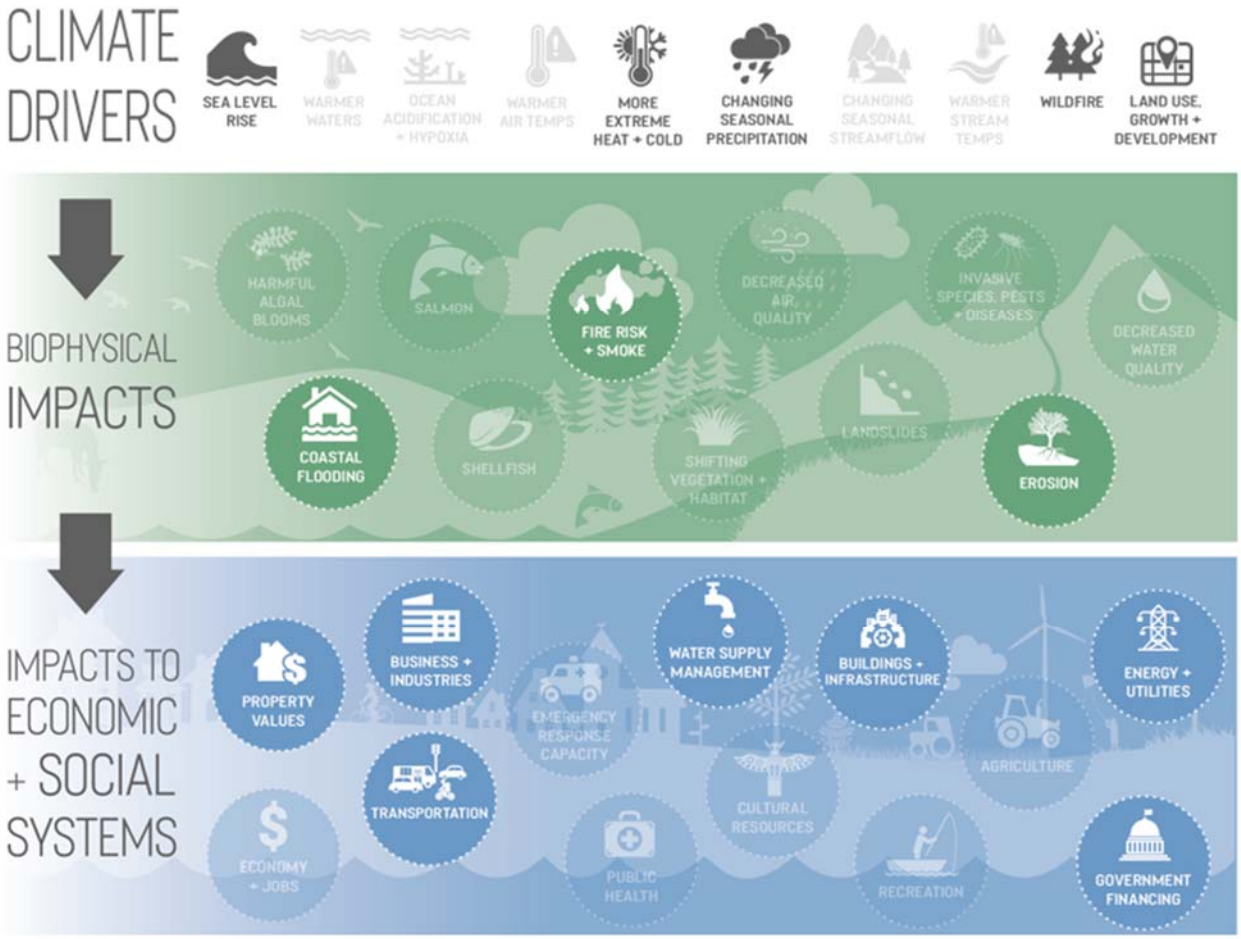
[581] Eigenbrode *et al.* 2013.
[582] Smith *et al.* 2018. Climate Effects on U.S. International Interests. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*. Volume II: pp. 604–637. doi: 10.7930/NCA4.2018.CH16.
[583] Gowda *et al.* 2018.
[584] Gowda *et al.* 2018.
[585] Eigenbrode *et al.* 2013.
[586] Yorgey *et al.* 2016. Flex cropping and precision agriculture technologies: Bill Jepsen: A farmer to farmer case study. 15 pp. http://hdl.handle.net/2376/6026.
[587] Yorgey *et al.* 2018.
[588] Eigenbrode *et al.* 2013.
[589] Altieri *et al.* 2017. The adaptation and mitigation potential of traditional agriculture in a changing climate. Climatic Change. 140(1): 33-45. https://doi.org/10.1007/s10584-013-0909-.

Chapter 9. Local Government Finance

Summary of Findings

Kitsap County's assets are important for the long-term financial health of the County's operations, investments, and services. Although the economic vitality of the Puget Sound region has bolstered Kitsap County's current financial health and security, long-term climate change impacts may alter likely future financial investments and credit. Future sea level rise, extreme weather events, and fire risk will likely affect the insurance rates and property values of current building structures and residential housing. These impacts will also likely affect the viability of new infrastructure and housing investments for certain areas of Kitsap County, affecting county land use decisions. Other elements of the County's financial portfolio, such as municipal bonds and property tax revenue, will also likely be affected by future climate risks. Strategic financial planning that incorporates future climate projections and risk will increase the long-term resilience and adaptive capacity of the County's financial wellbeing.

Figure 36. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Local Government Finance



Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Insurance	**Low-Medium** • Insurance premiums will likely rise due to climate change [*medium confidence*]. • Rising insurance costs may incentivize climate adaptation and mitigation actions [*low confidence*].	**Near- to long-term** • Climate change may continue to drive insurance costs and damages up in the near and long term as insured losses and damages increase [*medium confidence*].
2. Municipal bonds	**Low** • Municipal bond credit ratings may worsen in the long term due to extreme weather events or climate-related risks [*medium confidence*].	**Near-term** • Due to the Puget Sound region's growing economy, climate change will unlikely harm the municipal bonds of Kitsap County in the near term [*high confidence*].
3. Tax revenue	**Low-Medium** • Climate change may affect tax revenue by affecting property values, though these impacts may be tempered by a growing population [*medium confidence*].	**Near-term** • The tax base will unlikely decrease in the near term due to the Puget Sound region's healthy economy [*high confidence*].

Finding 1: Insurance

The insurance industry is seeking ways to mitigate current and future risks of climate change due to the rising costs of more intense and frequent extreme weather events. Accordingly, the insurance industry has begun incorporating current and potential future climate risk and impact into their rates and policies in an effort to use market mechanisms to deter risky behavior or investments. Despite the private market insurance industry's ability to drive private and public landowners to implement more climate-resilient actions through various policies, backstop insurance programs may counteract this progress. Insurance also becomes an equity issue, especially for low-income or place-based peoples, both in terms of the ability to afford private insurance or mobility and accessibility considerations of moving out of high-risk areas.

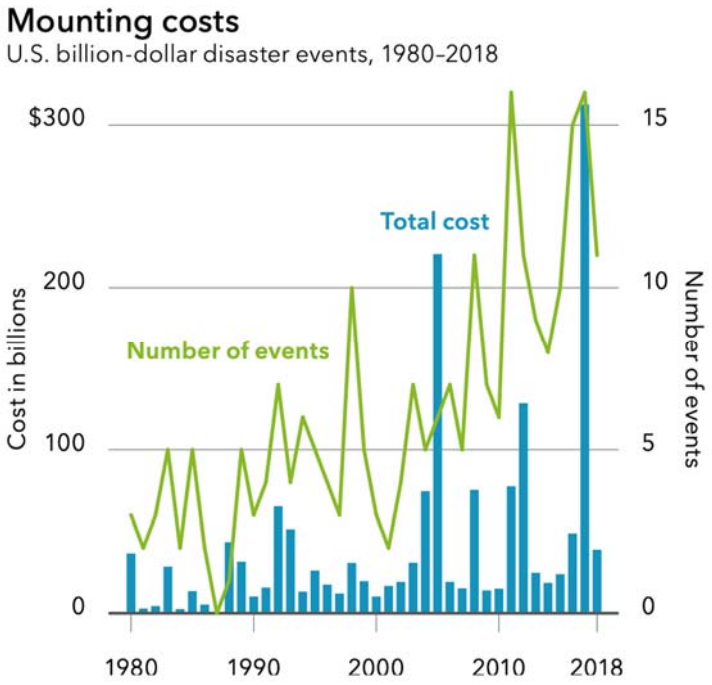
The insurance industry is seeking ways to mitigate current and future risks of climate change due to the rising costs of more intense and frequent extreme weather events.[590] Climate change has already led to more frequent and intense extreme events, which has resulted in increasing damages and claims for the insurance industry (Figure 37).[591] There has been an increasing number of extreme events and associated costs with those extreme events. Kitsap County is projected to see more frequent flooding events, more frequent and intense winter storms, more intense heat waves and droughts, and natural hazards such as landslides. In 2018, these four types of events resulted in an estimated $32.7 billion of damages and an

[590] Lout *et al.* 2012. Municipal climate change adaptation and the insurance industry. Harvard Law School Emmett Environmental Law & Policy Clinic. http://clinics.law.harvard.edu/environment/files/2014/09/municipal-cc-adaptation-and-insurance-industry_final.pdf.

[591] BlackRock. 2019. Getting physical: Scenario analysis for assessing climate-related risks. www.blackrock.com/us/individual/literature/whitepaper/bii-physical-climate-risks-april-2019.pdf.

estimated $22.6 billion of insured losses across the United States (2018 dollars).[592] As extreme events continue to increase in frequency and intensity, and as other climate-related costs increase in the future, projections suggest that insured losses will increase by 40% in the next decade.[593] Kitsap County and localities such as Bainbridge Island are considering future increases of insurance costs and premiums for local governments, businesses, and homeowners due to sea level rise, flooding, and heavy precipitation.[594]

Figure 37. Mounting Costs of Natural Disasters[595] *(The line shows the number of climate events with losses exceeding $1 billion. The data include droughts, flooding, severe storms, tropical cyclones, wildfires, winter storms and freezes. The bars show the total cost. Data are adjusted for inflation using 2018 dollars.)*



The insurance industry has begun incorporating current and potential future climate risk and impact into their rates and policies in an effort to apply market mechanisms to deter risky behavior or investments.[596] For example, some insurance companies offer lower premiums for LEED-certified buildings, which often result in climate adaptation and mitigation benefits as well as fewer and smaller insurance claims for the insurer.[597] Other insurance companies offer lower premiums for risk mitigation investments for homeowners or localities.[598] For rebuilding or renovating after natural disasters, insurance companies may also offer

[592] Insurance Information Institute. 2019. Insurance Handbook: Facts + Statistics: U.S. Catastrophes. www.iii.org/publications/insurance-handbook/insurance-and-disasters/facts-statistics-us-catastrophes.
[593] Lout *et al.* 2012.
[594] Hansen *et al.* 2016. Bainbridge Island Climate Impact Assessment. EcoAdapt, Bainbridge Island, WA. www.cakex.org/sites/default/files/documents/BICIA%20Final%2028%20July%202016.pdf.
[595] BlackRock. 2019. And also NOAA National Center for Environmental Information NCEI. October 2018.
[596] Headwaters Economics. 2016. Does Insurance Influence Home Building on Fire-Prone Lands? https://headwaterseconomics.org/wp-content/uploads/Insurance-Wildfire-Home-Development.pdf.
[597] Lout *et al.* 2012.
[598] Botzen *et al.* 2009. Willingness of homeowners to mitigate climate risk through insurance. *Ecological Economics*. 68(8-9): 2265-2277. https://doi.org/10.1016/j.ecolecon.2009.02.019.

incentives for or require specific "green" investments to reduce future claims and losses.[599] Alternatively, if climate risks become too great or uncertain, insurance providers may elect not to cover certain types of damage, especially due to extreme weather events, and increase premiums for risky behavior and choices.[600]

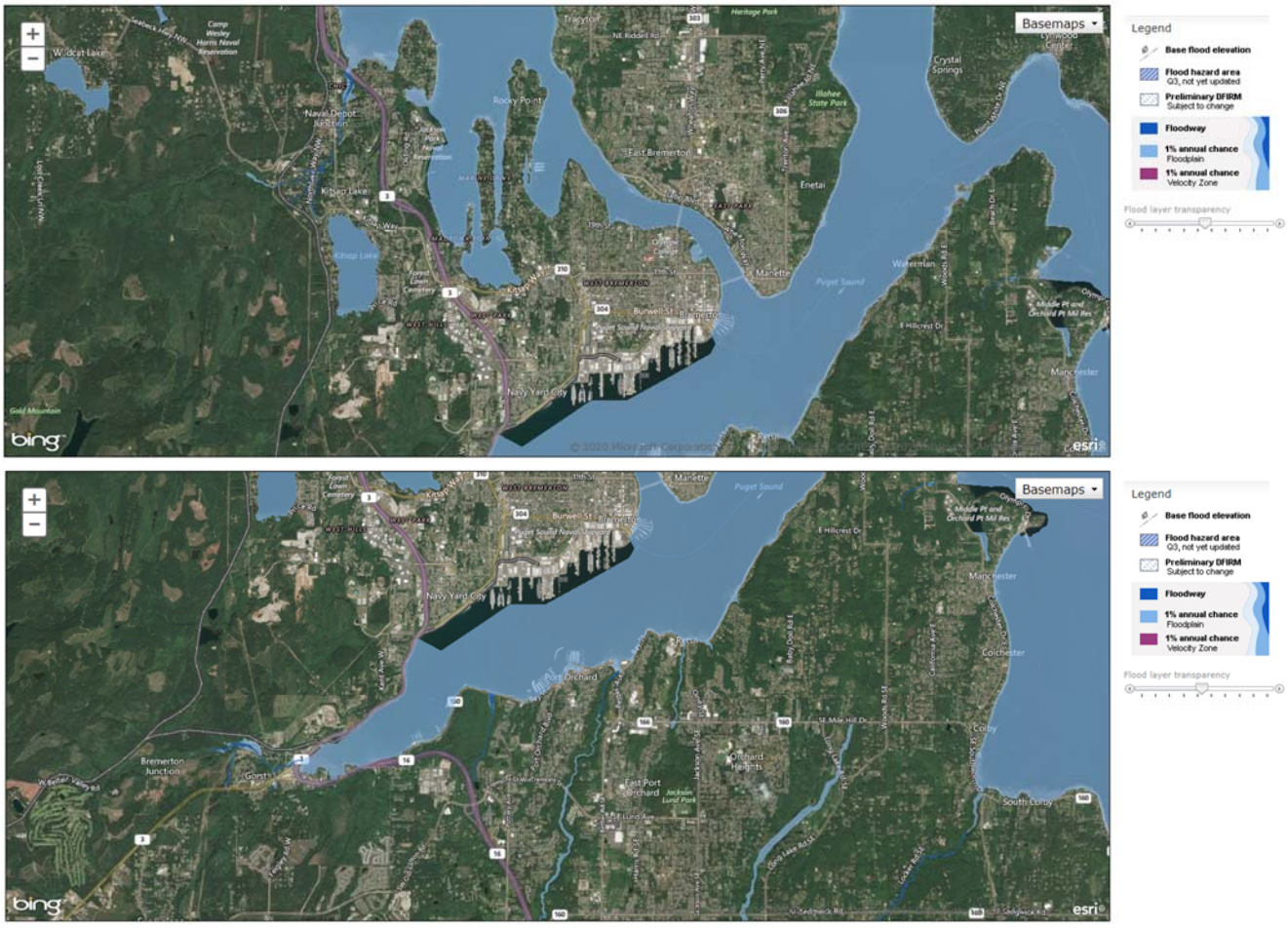
Despite the private market insurance industry's ability to drive private and public landowners to implement more climate-resilient actions through various policies, backstop insurance programs may counteract this progress by providing insurance for maladaptive investments. For example, the National Flood Insurance Program (NFIP) provides affordable insurance for communities unable to attain flood insurance from private insurance companies, whether due to cost or coverage issues.[601] The NFIP also supports some local governments' credit ratings by supplementing other federal funds to pay for mitigation and infrastructure investments.[602,603] Backstop insurance programs, such as the NFIP, are important from an environmental equity perspective as they help insure people unable to buy their own private insurance, but they may continue to support risky behaviors and investments in housing and structures in flood zones (see Figure 38). In Kitsap County, an estimated $13.4 million of housing and building values and 355 building structures are located in the 100-year floodplain, or the area in which an extreme flooding event has a 1% chance of happening annually (though frequency of severe floods has increased and may need to be remapped).[604]

In 2019, Washington State approved and voted into law Substitute Senate Bill 5106, "An Act Relating to the creation of a work group to study and make recommendations on natural disaster mitigation and resiliency activities." The intent of this legislation is for the state to be better prepared for and mitigate the impact of disasters. The work group is expected to review disaster mitigation and preparation projects currently within Washington and other states, make recommendations in terms of coordinating and expanding state efforts to mitigate natural disaster impacts, and determine whether to create an ongoing disaster resiliency program. It includes the review of disaster-related insurance, such as flood and earthquake insurance. The final report of recommendations is due by December 1, 2020.[605] Depending on the results, this effort may make it possible to provide some insurance premium relief for both the state and local governments.

[599] Lout *et al.* 2012.
[600] BlackRock. 2019.
[601] FEMA. 2018. The National Flood Insurance Program. Accessed 6 February 2020. www.fema.gov/national-flood-insurance-program.
[602] Okuji *et al.* 2017. Evaluating the impacts of climate change on US state and local issuers. *Moody's Investors Service*. 21 pp. https://southeastfloridaclimatecompact.org/wp-content/uploads/2017/12/Evaluating-the-impact-of-climate-change-on-US-state-and-local-issuers-11-28-17.pdf.
[603] Lout *et al.* 2012.
[604] FEMA. 2015. Risk Report: For Kitsap County, including the Cities of Bremerton, Bainbridge, Port Orchard, Poulsbo, the Port Gamble S'Klallam Indian Reservation, the Suquamish Tribe, and Unincorporated Kitsap County. https://fortress.wa.gov/ecy/gispublic/AppResources/SEA/RiskMAP/Kitsap/Kitsap_Project_Docs/Risk%20Report%20-%20Kitsap%20County%20-%20Final.pdf.
[605] Certification of Enrollment, Substitute Senate Bill 5106, Chapter 388, Laws of 2019, 66th Legislature, 2019 Regular Session. Natural Disaster and Resiliency Activities Work Group Effective Date: July 28, 2019.

Insurance also becomes an equity issue, especially for low-income or place-based peoples, both in terms of the ability to afford private insurance or mobility and accessibility considerations of moving out of high-risk areas.[606,607] Within Kitsap County, 8.3% of the population was below the poverty line in 2017, and per-capita income is approximately $34,412 (in 2016 dollars). Though the unemployment rate declined steadily from 2010 to 2019, it is important to understand the socioeconomic conditions that may make certain people more resilient than others to future climate change impacts, especially around ability to purchase private insurance.

Figure 38. FEMA Flood Insurance Maps for the 1% Annual Chance Floodplain for Bremerton (top) and Port Orchard (bottom). *Flood insurance rate maps outline flood hazards in a community and include flood insurance risk zones (1% and 0.2% annual chance floodplains).*



[606] EPA. 2016. Climate change, health, and environmental justice. www.cmu.edu/steinbrenner/EPA%20Factsheets/ej-health-climate-change.pdf.

[607] Montgomery & Chakraborty. 2015. Assessing the environmental justice consequences of flood risk: a case study in Miami, Florida. *Environ. Res. Lett*. 10: 095010. https://doi.org/10.1088/1748-9326/10/9/095010.

Finding 2: Municipal Bonds

The municipal bond market—a historically resilient market worth $3.8 trillion and that is essential to the financial portfolio of many local governments, states, counties, public utility districts, school districts, and ports—is beginning to incorporate climate risk assessments into its credit rating assessments. Credit firms and the bond market are placing considerable weight on the likelihood of future frequency and intensity of extreme weather events, and future climate conditions, such as sea level rise and warmer temperatures, are also being considered. For Kitsap County, there should be caution and considerations of how their municipal bonds will be impacted. However, bond markets in the Puget Sound area may not be impacted as much as other U.S. metropolitan regions.

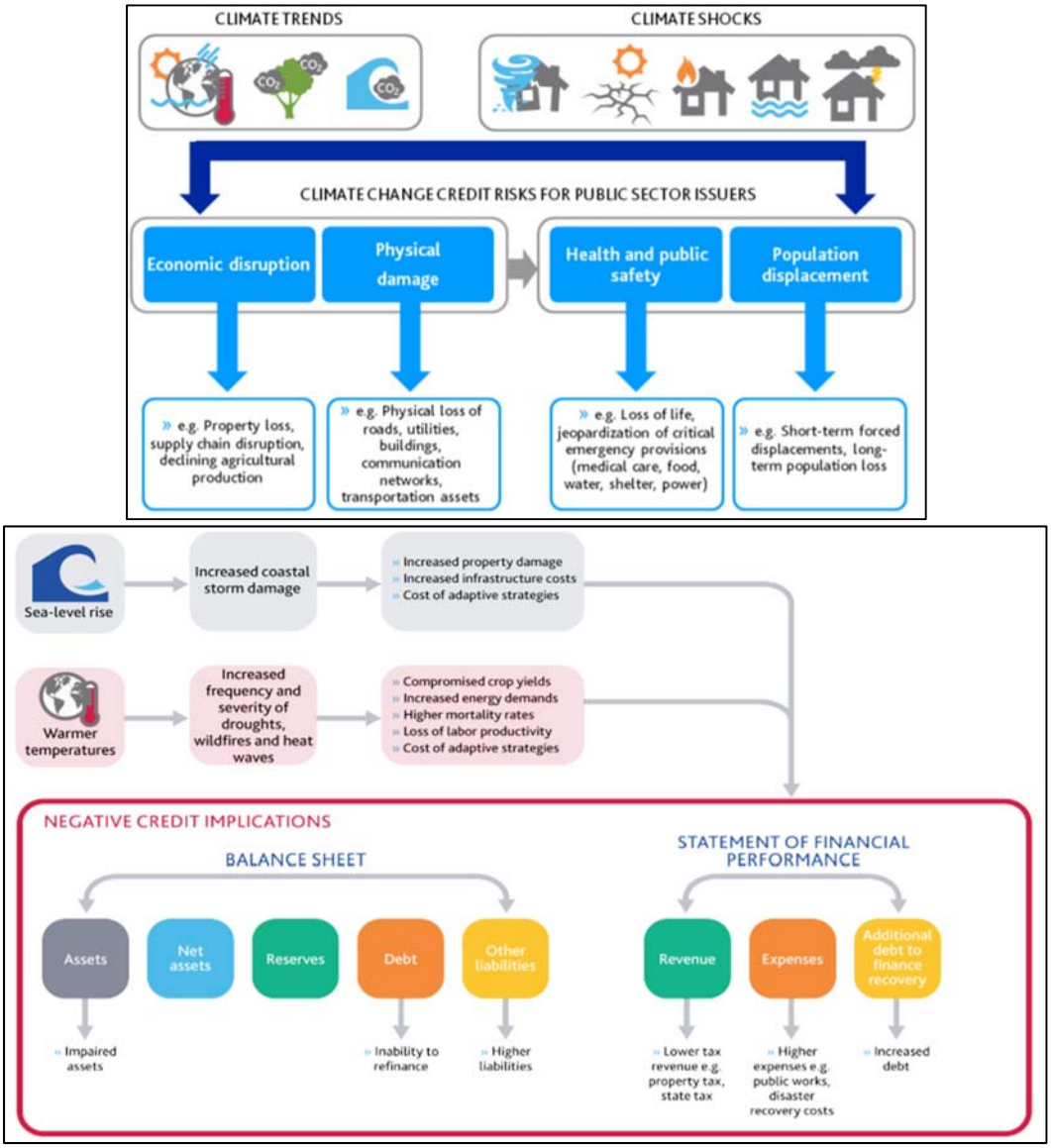
The municipal bond market—which is essential to the financial portfolio of many local governments, states, counties, public utility districts, school districts, and ports—is beginning to incorporate climate risk assessments in its credit rating assessments. In the past few years, climate change has played more of a factor in determining the stability of municipal bonds. The U.S. municipal bond market is worth $3.8 trillion and is a historically resilient market (dollar year not reported).[608] Climate change has increasingly become a topic where credit firms and markets are beginning to explicitly account for. [609,610,611,612] Credit ratings agencies are beginning to account for future climate risk in their assessments of municipal bond issuers, which may affect municipal bond revenue for capital projects.[613,614]

Credit firms and the bond market are placing considerable weight on the likelihood of future frequency and intensity of extreme weather events, and future climate conditions, such as sea level rise and warmer temperatures, are also being considered. Many firms and agencies are scrutinizing the links and attributions of future climate change with extreme weather events, which have been increasing in frequency and intensity and have subsequently significantly increased financial damages and credit risks (Figure 39). For instance, future sea level rise will likely lead to increased frequency and intensity of coastal flooding events, leading to economic disruption, infrastructure damage, health and public safety risks, and potential population displacement.[615,616] The suite of physical and social risks from climate change may result in impaired assets, inability to refinance debts, higher liabilities, increased debts, lower tax revenue, and higher expenses,

[608] BlackRock. 2019.
[609] Howard, C. 2019. Is Climate Change a Risk to the Muni Market? Charles Schwab. www.schwab.com/resource-center/insights/content/is-climate-change-risk-to-muni-market.
[610] Hauter *et al.* 2019. A Climate Change Reckoning for the Municipal Bond Market. Brown Advisory.www.brownadvisory.com/us/climate-change-reckoning-municipal-bond-market.
[611] Norton, L.P. 2019. Muni Bonds Face Climate Change. And Investors are Ignoring the Risk. Barron's. www.barrons.com/articles/muni-bonds-face-climate-change-and-investors-are-ignoring-the-risks-51569010788.
[612] Whieldon & Charbonneau. 2019. Climate change poses new threat to US cities' long-term creditworthiness. S&P Global Market Intelligence. www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/53085464.
[613] Moran, D. 2019. Muni Bonds Contain New Fine Print: Beware of Climate Change. 2019. *Bloomberg Businessweek*. www.bloomberg.com/news/articles/2019-11-05/how-serious-is-the-climate-change-risk-ask-a-banker.
[614] Nauman, B. 2020. Municipal bond issuers face steeper borrowing costs from climate change. *Financial Times*. www.ft.com/content/6794c3d2-1d7d-11ea-9186-7348c2f183af.
[615] Okuji *et al.* 2017.
[616] See Chapter 6. Public Infrastructure. Finding 3: Coastal Infrastructure and Chapter 10. Geologic Hazards. Finding 3: Storm Surge and Coastal Flooding.

subsequently affecting the value and rates of municipal bonds (Figure 39).[617,618] Cleanup and response from extreme weather events will likely affect general obligation bonds; tax bases could shrink from large-scale natural disasters and gradual climate change; and revenue bonds, especially for water and sewer utilities, may directly suffer from sea level rise, increased flooding events, and droughts.[619]

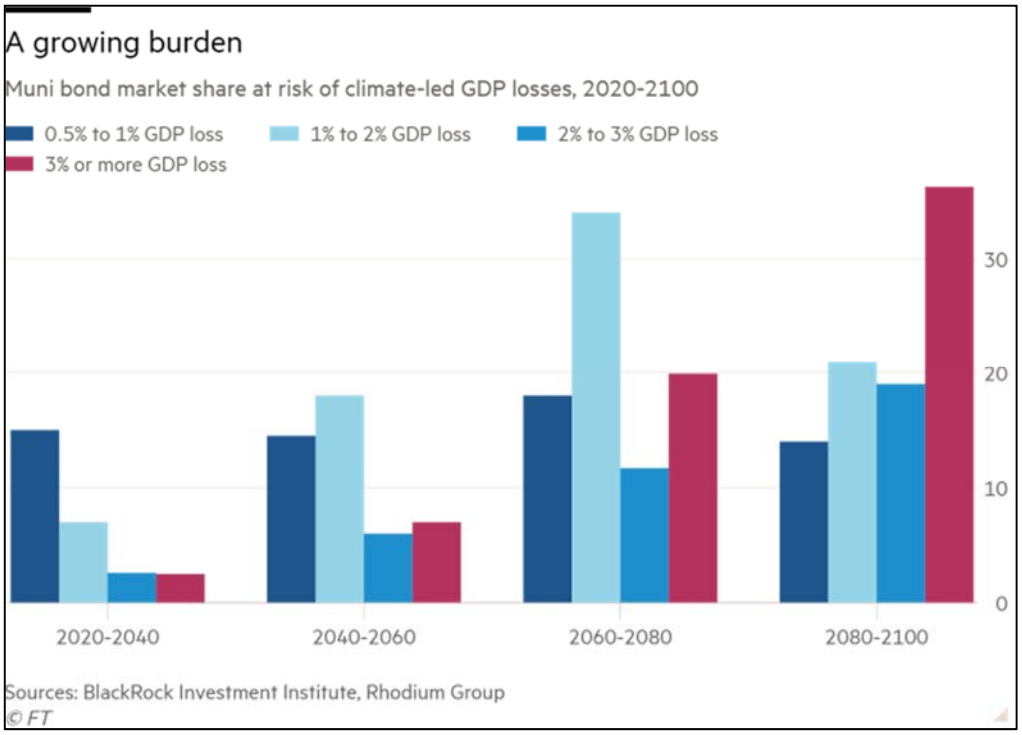
Figure 39. Examples of How Climate Change Impacts Place Public Sectors at Risk (top), which can be transmitted to credit risk (bottom)[620]



[617] Okuji *et al.* 2017.
[618] Painter, M. 2020. An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*. 135(2): 468-482. https://doi.org/10.1016/j.jfineco.2019.06.006.
[619] BlackRock. 2019.
[620] Okuji *et al.* 2017.

An assessment by BlackRock Investment Institute and Rhodium Group concluded that aging infrastructure face particularly high risks from future climate change and extreme events, likely leading to increasing climate vulnerability of the electric utility sector. These risks are currently underpriced, and projections suggest that future accounting of climate risk in the municipal bond market will likely lead to increasing premiums for electric utilities as climate risks compound.[621] Under a no-climate-action scenario, equivalent to RCP8.5, financial challenges will intensify from climate impacts, with approximately 85% of U.S. metropolitan areas experiencing at least 1% climate-related loss of annual gross domestic product (GDP) by 2100.

Figure 40. Muni Index Share at Risk of Climate-Related GDP Loss, 2020-2100[622]
(The S&P National Municipal Bond Index represents the muni market. The chart shows the estimated market value share of the muni market exposed to GDP losses of various magnitude through 2100 under a "no climate action" scenario. For example, roughly 20% of the market value of the current muni index is expected to come from regions suffering annualized average losses of up to 3% or more of GDP from climate change by 2060-2080s. This analysis uses the upper bound of 66%, or likely range of losses, to illustrate plausible risk scenarios.)



For Kitsap County, there should be caution and considerations of how their municipal bonds will be impacted. However, bond markets in the Puget Sound area may not be affected as much as other U.S. metropolitan regions. The Puget Sound region will likely experience relatively less GDP impacts than the rest of the United States (Figure 41). Though climate change will impact the Puget Sound region through multiple avenues, its projected GDP losses from climate change are buoyed by the diverse industries, the relative infrequent extreme weather events and natural disasters, and the steady population growth of the tax

[621] BlackRock. 2019.
[622] BlackRock. 2019. With data from Rhodium Group. 2019.

base.[623,624] For instance, in 2019, Bremerton received a credit rating upgrade to Aa2 due to its strong tax base, material improvement in municipal reserves, health total government liability, fixed costs (debt, pensions, and post-employment obligations), diversity of economic industries, and socioeconomic measures.[625]

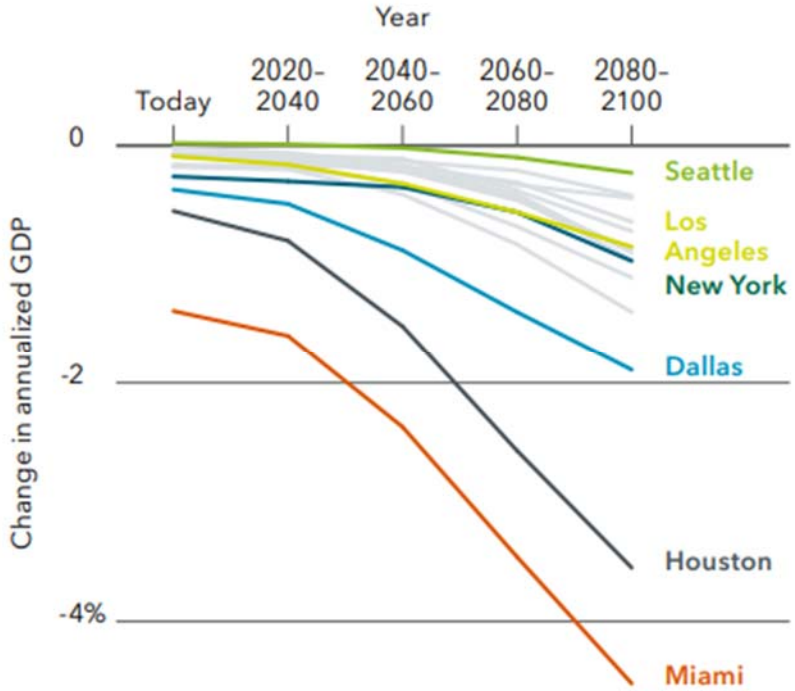
Despite this outlook, even a 0.5% GDP loss could result in hundreds of thousands to millions of dollars lost for the Puget Sound region. Furthermore, unexpected climate "surprises" are not accounted for within these economic forecasts, and any potential surprises, such as extreme events or natural disasters, may likely affect future ratings.[626] For example, Kitsap County's coastlines are likely to experience more frequent and intense coastal flooding events, which may affect future credit ratings.[627] Credit firms and agencies have warned local governments and municipalities not to be "climate complacent," which can be easy to do due to lack of attention, time horizon and discounting of risks, insurance, and reliance on Federal Emergency Management Agency (FEMA) disaster funding.[628]

U.S. municipal bond issuers benefit from local efforts to manage the immediate physical impacts of extreme weather, as well as any resources that may expedite the long-term recovery of their economic base. Credit risks resulting from climate change are included in the Moody's analysis of key credit factors. Fiscal strength and the ability to raise additional revenue are also key to the assessment of climate risks as well as asset management and governance evaluation. There are many actions that local governments, municipalities, and counties can take to ensure that municipal bonds and credit ratings are resilient from future climate change risks.[629,630] These strategies may include:

- Long-term planning can ensure that current and future investments in infrastructure are resilient to extreme events and gradual climate change. These plans can result in cost-savings for maintenance operations and post-disaster response and recovery.
- Local ordinances and policies that promote risk-averse actions, such as rebuilding or relocating structures outside of vulnerable areas (e.g., floodplains) after extreme events.
- Diversifying local economic industries to absorb potential climate-related economic damages.

[623] Okuji *et al.* 2017.
[624] BlackRock. 2019.
[625] Moody's Investors Service. 2019. Moody's upgrades Bremerton, WA's bonds to Aa2; outlook stable. Moody's Investors Service. www.moodys.com/research/Moodys-upgrades-Bremerton-WAs-bonds-to-Aa2-outlook-stable--PR_905998861.
[626] EPA. 2017. Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment. 430-R-17-001.
[627] Okuji *et al.* 2017.
[628] BlackRock. 2019.
[629] Howard. 2019.
[630] BlackRock. 2019.

Figure 41. Estimated Climate Impacts on GDP of Top-15 U.S. Metropolitan Statistical Areas by Economic Weight, 2018-2100[631] *(The cities shown represent the top 15 U.S. metro areas by GDP. The chart shows projected annualized GDP losses (upper bound of the 66%, or the likely ranges) due to cumulative changes in climate since 1980 under a "no climate action" scenario (equivalent RCP8.5). The current time is represented by a 2010-2030 estimate.)*



Finding 3: Tax Revenue

Kitsap County will likely see a steady growth of its tax base and revenue. However, future climate change may affect this growth rate, especially if developers and potential residents are deterred from investing due to perceived climate-related risks. With projected expenses outpacing revenues, any additional costs incurred due to climate change could result in a deficit budget, thereby potentially neglecting some needs in the county.

Kitsap County will likely see a steady growth of its tax base and revenue. Kitsap County has had a steady growth in its population and development, with a 7.4% increase in population between 2010 and 2018. This growth is expected to continue because of Kitsap County's proximity to the Puget Sound metropolitan region, relatively affordable housing prices, and diverse commuting options.[632] Furthermore, there has been an increase in rural and urban housing units and a steady increase in housing rental and housing market prices, leading to a higher-value tax base.[633] These factors suggest that the tax revenue and tax base for Kitsap

[631] BlackRock. 2019. With data from Rhodium Group. 2019.
[632] Vleming. 2019.
[633] See Chapter 4. Economy. Finding 1: Property Values and Buildable Land.

County will continue to grow as the Puget Sound metropolitan region and economy grows even in light of future climate impacts and natural hazards.[634,635,636]

However, despite future growth and development, future climate change may impact future tax base, especially if developers and potential residents are deterred from investing due to perceived climate-related risks. Though Kitsap County will likely experience future growth in its tax revenue base from regional population growth, housing developments, and increasing housing prices, there is some likelihood that climate change may affect this growth in the future. Property values and buildable land may decline due to future climate and flooding risks.[637] Kitsap County has more than 250 miles of coastline, and thus many coastal homes and structures that are vulnerable to sea level rise, storm surges, and coastal flooding.[638] The risk of coastal flooding will likely affect the taxable property and the property values of houses already built within the coastal floodplain zone and future homes.[639] The loss of taxable property will also have negative impacts on the credit ratings of municipalities and local government agencies.[640] In the greater Seattle and Puget Sound area, approximately $1.8 billion of housing is at risk of future flooding under RCP4.5 and $1.85 billion of housing are at risk to flooding under RCP8.5, which could result in lost tax revenue from property taxes in the future.[641]

Additionally, housing prices may be affected based on homeowners' perception of climate risk. Studies have shown that despite high levels of awareness around climate change impacts, homeowners have low risk perceptions of climate change, leading to a lack of investment into adaptive or mitigative actions for their houses. [642,643,644] Homeowners' behaviors may not only affect their own home's value, but may result in externalities for neighboring home values as well. Though tax base is increasing, some local governments offer property tax relief following natural disasters, which could also mean revenue loss.[645]

The average home sales price in Kitsap County has been increasing, especially in the most recent three years. The year 2017 experienced a 12% growth in home sales price over 2016, and 2018 and 2019 experiencing 10% and 8% annual growth, respectively. These rising prices have had a positive effect on property tax revenues, with greater value providing greater tax revenues. However, the average home value varies

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[634] Cook, P. 2018. Kitsap County Statement of Assessments: 2018 Assessment for Taxes Payable in 2019. *Kitsap County Assessor*. www.kitsapgov.com/assessor/Documents/Book2019.pdf.

[635] Cook, P. 2017. Kitsap County Statement of Assessments: 2017 Assessment for Taxes Payable in 2018. *Kitsap County Assessor*. www.kitsapgov.com/assessor/Documents/Book2018.pdf.

[636] Center of Economic and Business Research. 2019. Kitsap County 2017/2018 Economic Profile.http://kitsapeda.org/wp-content/uploads/2019/07/County-Profile_Kitsap-7-1-19_web.pdf.

[637] See Chapter 4. Economy. Finding 1: Property Values and Buildable Land.

[638] See Chapter 10. Geologic Hazards. Finding 3: Storm Surge and Coastal Flooding.

[639] Climate Central and Zillow. 2019. Ocean at the Door: New Homes and the Rising Sea. Research brief of Climate Central.https://ccentralassets.s3.amazonaws.com/pdfs/2019Zillow_report.pdf.

[640] Four Twenty Seven. 2018. Assessing Exposure to Climate Change in U.S. Munis. http://427mt.com/wp-content/uploads/2018/05/427-Muni-Risk-Paper-May-2018-1.pdf.

[641] Surging Seas Risk Finder. 2019. Seattle, Washington, USA: Future flood risk to homes. https://riskfinder.climatecentral.org/place/seattle.wa.us?comparisonType=place&forecastType=NOAA2017_int_p50&level=4&unit=ft&zillowPathway=RCP85.

[642] Bichard & Kazmierczak. 2012. Are homeowners willing to adapt to and mitigate the effects of climate change? *Climatic Change*. 112(3-4): 633-654.

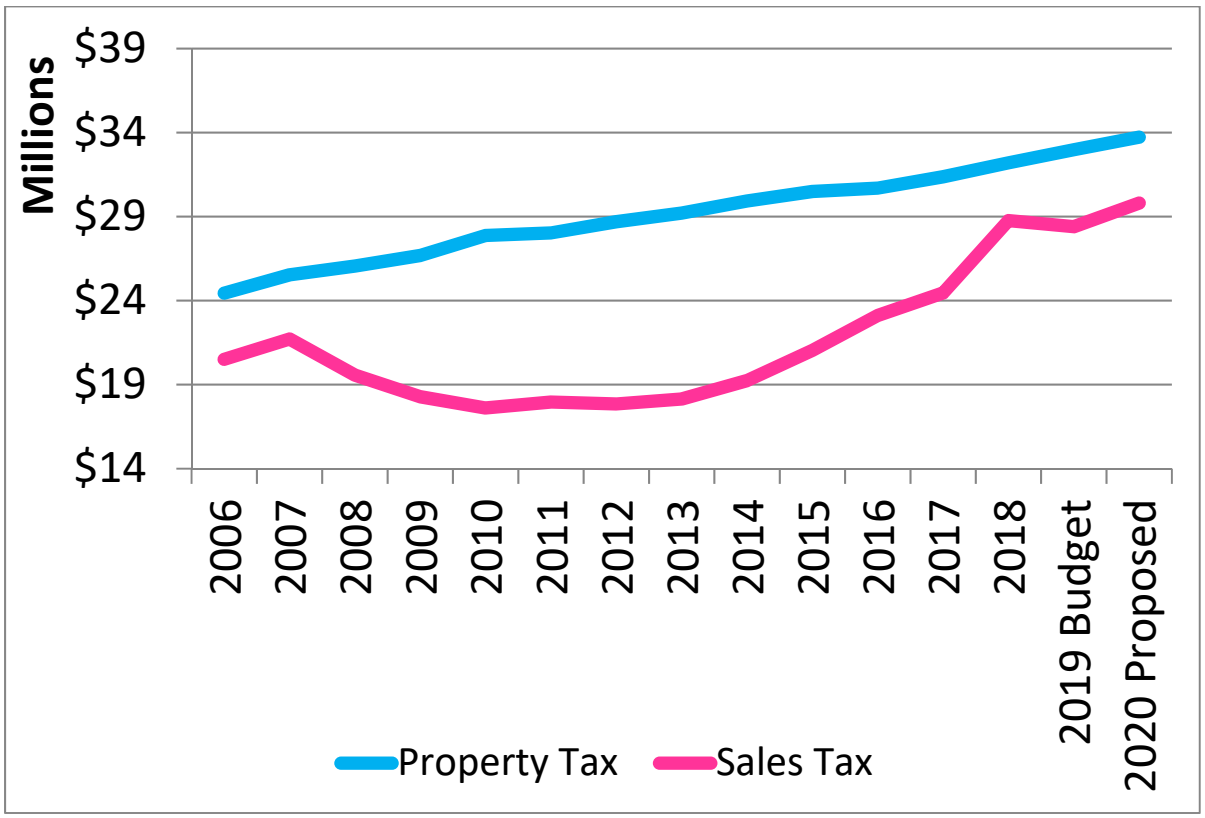
[643] Thistlethwaite *et al.*. 2018. How Flood Experience and Risk Perception Influences Protective Actions and Behaviours among Canadian Homeowners. *Environmental Management*. 61(2): 197-208.

[644] Gorte, R. 2013. The Rising Cost of Wildfire Protection. http://headwaterseconomics.org/wildfire/fire-costs-background/.

[645] Lout *et al.* 2012.

significantly by area, with Bainbridge Island achieving a two-fold value over other areas within and near Kitsap County.[646] This variation indicates that any impact to property values (climate change or other) may differ between areas. Further, although tax revenues and total County revenues are expected to increase through 2025, both 2019 and 2020 budget projections indicate that expenses are likely to outpace revenues. That suggests the inability to meet all budgetary needs if additional costs are incurred due to climate change or other factors. The 2019 and 2020 budgets both indicate 31% of all county revenues are due to property taxes. If this source of revenue declines, as presented above, it could be a big concern for the County's annual budget. Figure 42 shows the historical (2006-2018), 2019 budget, and 2020 proposed budget projection for sales and property taxes. Figure 43 depicts the 2019 budget projected revenues, expenses, net revenues, and tax revenues.

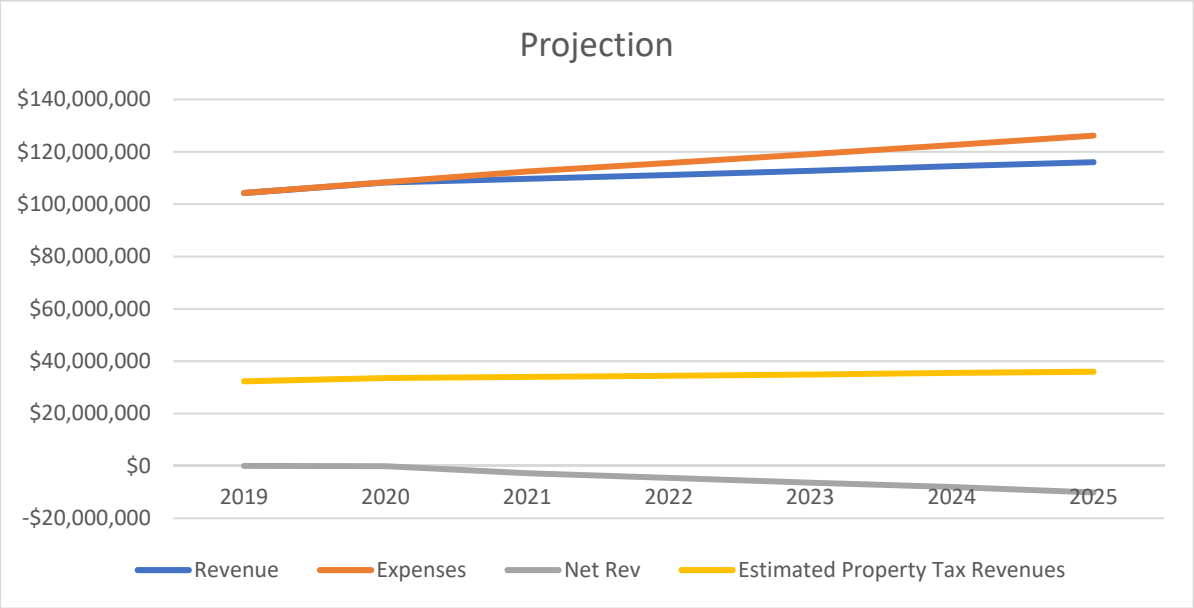
Figure 42. Kitsap County Property Sales Tax (2006-2020)[647]



[646] See: Chapter 4. Economy. Finding 1: Property Values and Buildable Land.

[647] Kitsap County. 2020. Budget Town Hall Presentation. Figure created by Greene Economics.

Figure 43. Future Projections of Net Revenue for Kitsap County[648]



After 2020, the projected net revenues (revenues minus expenses) begin to go negative, meaning expenses are greater than revenues, even without climate change considerations. If climate change impacts are introduced, the gap is increased.

Compared to other U.S. regions, the Northwest is projected to have the highest damages to urban drainage when looking at 10-year storms. Further, economic damages from climate impacts on roads in the Pacific Northwest will rise from $360 million per year in 2050 to $950 million per year by 2090 under RCP8.5.[649] These costs could be another potential strain on the local economy.

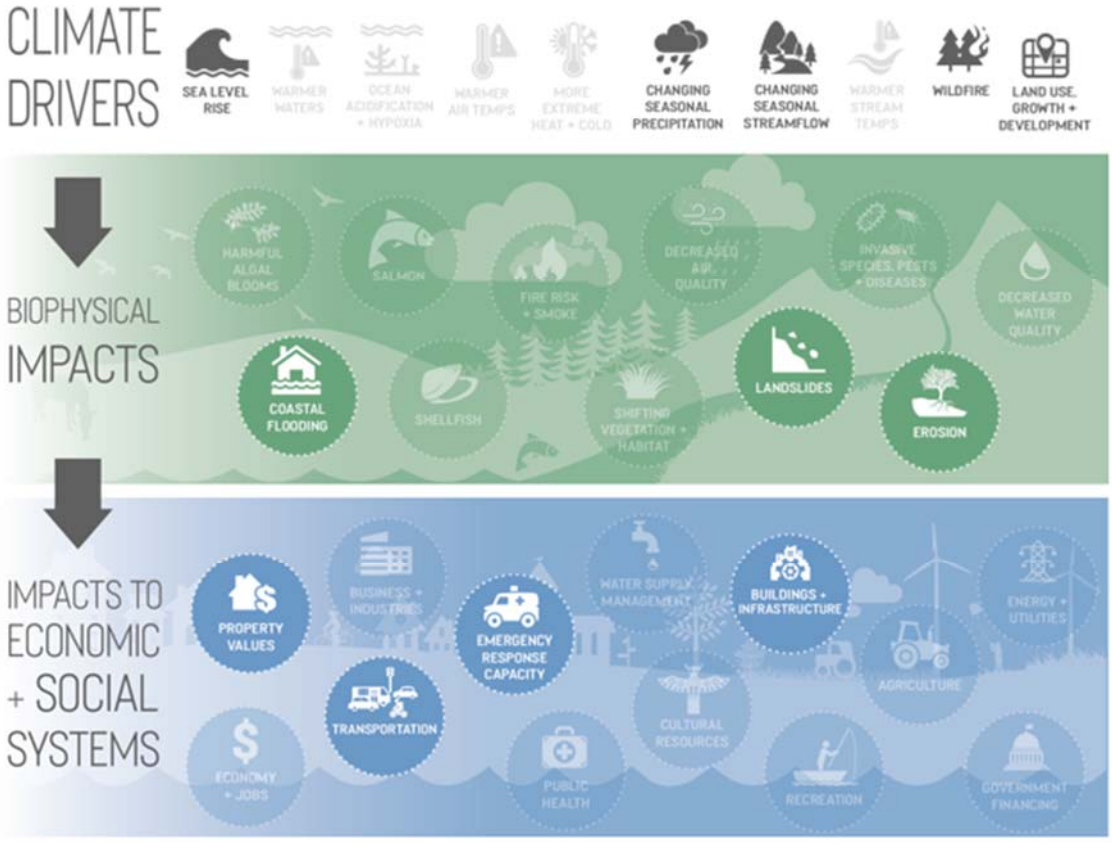
[648] Kitsap County. Performance Across Kitsap. www.kitsapgov.com/PerformanceCenter. Figure calculated and developed by Greene Economics based on data from Kitsap County Budget.
[649] EPA. 2017.

Chapter 10. Geologic & Natural Hazards

Summary of Findings

Kitsap County has had a history of geologic hazards, including landslides, erosion, storm surges, and flooding that has led to disruption of services and damage to infrastructure and residences. Though evidence for connecting climate change and certain hazards, such as landslides and storm surge flooding, has been previously absent, the underlying factors and conditions that contribute to the frequency and magnitude of these hazards will change under future climate scenarios. Rising sea levels and increased winter storm intensity will likely increase risk for winter storm surge flooding. Winter rain and heavy rain events will increase the landslide risk of certain areas in Kitsap County during the winter and early spring. Sea level rise, storm events, and heavy rain events will likely increase the erosion rates for coastal bluffs. Collectively, the changing landscape of risk for these natural geologic hazards will very likely result in future damage and loss of infrastructure and residences and disruption of transportation routes and infrastructure, potentially presenting challenges for emergency response services during extreme hazard and weather events.[650]

Figure 44. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Geologic and Natural Hazards



[650] See: Chapter 3. Public Health. Finding 3: Acute Injuries from Extreme Weather.

Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Landslides and sediment processes	**Medium-High** • Landslides will likely increase in frequency in the winter and early spring due to soil erosion, heavy rain events, and sediment transport patterns [*high confidence*].	**Near-term** • Landslides already naturally occur in Kitsap County, but more frequent landslides will likely happen in the near term [*low confidence*].
2. Bluff erosion	**Medium-High** • Coastal bluffs may erode at faster rates due to heavy rain events, sea level rise, and storm surges [*medium confidence*]. • Coastal bluff erosion may mitigate sea level rise impacts by supplementing beaches with sediment [*low confidence*].	**Near-term to long-term** • Coastal erosion rates are likely to increase by mid-century and could double by end of the century [*medium confidence*].
3. Storm surge and coastal flooding	**Very High** • Coastal flooding impacts from a combination of sea level rise and winter storms can result in substantial physical, ecological, and infrastructure damage [*very high confidence*].	**Already happening** • Annual coastal flooding events are already happening in Kitsap County [*very high confidence*]. **Long-term** • By the end of the century, extreme flooding will very likely happen on an annual basis [high confidence].

Finding 1: Landslides and Sediment Processes

Though few studies link landslide risk directly to climate change, many of the natural processes that cause landslides have clear linkages to climate change, such as soil erosion, precipitation, and sediment transport. Future climate change will significantly alter these processes, which will very likely increase the likelihood of landslides in the winter and early spring, likely impacting public infrastructure and human health.

Though few studies link landslide risk directly to climate change, many of the natural processes that cause landslides have clear linkages to climate change, such as soil erosion, precipitation, and sediment transport.[651] There has been a history of landslides in Kitsap County over the past 20 years that have caused deaths, property damage, and infrastructure damage (Table 15). One notable incident is the 1996 Bainbridge Island landslide, which came during a severe winter storm. It led to the death of a family of four and destroyed millions of dollars of public and private property.[652]

[651] Mauger *et al.* 2015. Section 5: Landslides, Erosion, and Sediment Transport. https://cig.uw.edu/resources/special-reports/ps-sok/.
[652] Kitsap County Department of Emergency Management. 2015.

Landslides are a major sediment source in Kitsap County.[653] In Kitsap County, landslides are much more likely to happen in coastal areas or along coastal bluffs due to slope steepness, slope stability, underlying geology, and hydrological processes that facilitate soil erosion, sediment transport, and beach nourishment.[654,655]

Table 15. LIDAR-defined Landslides in Kitsap County[656]

Jurisdiction	Number of Landslides	% of Total Landslides	Affected Area per Jurisdiction (sq. miles)
Unincorporated Kitsap County	137	76.5	24.5
Bainbridge Island	27	15	4.8
Bremerton	6	3.4	1.1
Port Orchard	3	1.7	0.54
Poulsbo	0	0	0
Port Madison Suquamish Reservation	4	2.2	0.7
Port Gamble S'Klallam Reservation	2	1.1	0.35
Totals	**179**	**100%**	**32**

Future climate change will significantly alter these processes, which will likely increase the likelihood of landslides in the winter and early spring, likely impacting public infrastructure and human health. Though it is difficult to precisely predict where landslides will occur, projected increases in heavy rainfall, storm intensity, and hydrological changes will increase the risk and likelihood of landslides in the winter and early spring while decreasing risk and likelihood in the summer.[657,658,659] Warmer temperatures, increased fire risk, and shifting vegetation type can lead to greater slope instability.[660,661] Thus, landslide risks on bluffs or other steeper slope areas will increase during periods of heavy rains and higher winter streamflow.[662,663,664]

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[653] Gerstel *et al.* 2012. Restoration Feasibility and Prioritization Analysis of Sediment Sources in Kitsap County. From Kitsap Regional Shoreline Restoration Feasibility and Prioritization Study Demonstration Project.www.kitsapgov.com/dcd/PEP%20Documents/Qwg_Kitsap_Sediment_Source_Analysis_FINAL.pdf.

[654] Mauger *et al.* 2015, Section 5: Landslides, Erosion, and Sediment Transport.

[655] McKenna *et al.* 2008. Landslides mapped from LIDAR imagery, Kitsap County, Washington. *U.S. Geological Survey Open File Report 2007-1292.* 81 pp. https://pubs.usgs.gov/of/2008/1292/downloads/OF08-1292.pdf.

[656] Kitsap County Department of Emergency Management. 2015.

[657] Mauger *et al.* 2015. Section 5: Landslides, Erosion, and Sediment Transport.

[658] Pike *et al.* 2010. Climate Change Effects on Watershed Processes in British Columbia. In: *Compendium of forest hydrology and geomorphology in British Columbia Land Management Handbook*. pp. 699-747. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66/Lmh66_ch19.pdf.

[659] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment. http://nr.pgst.nsn.us/wp-content/uploads/2017/08/PGST_climate-impact-assessment_report_0518-FINAL.pdf.

[660] Schmidt. *et al.* 2001. The variability of root cohesion as an influence on shallow landslide susceptibility in the Oregon Coast Range. *Canadian Geotechnical Journal*. 38: 995-1024.

[661] Crozier, M.J. 2010. Deciphering the effect of climate change on landslide activity: A review. *Geomorpohology*. 124: 260-267.

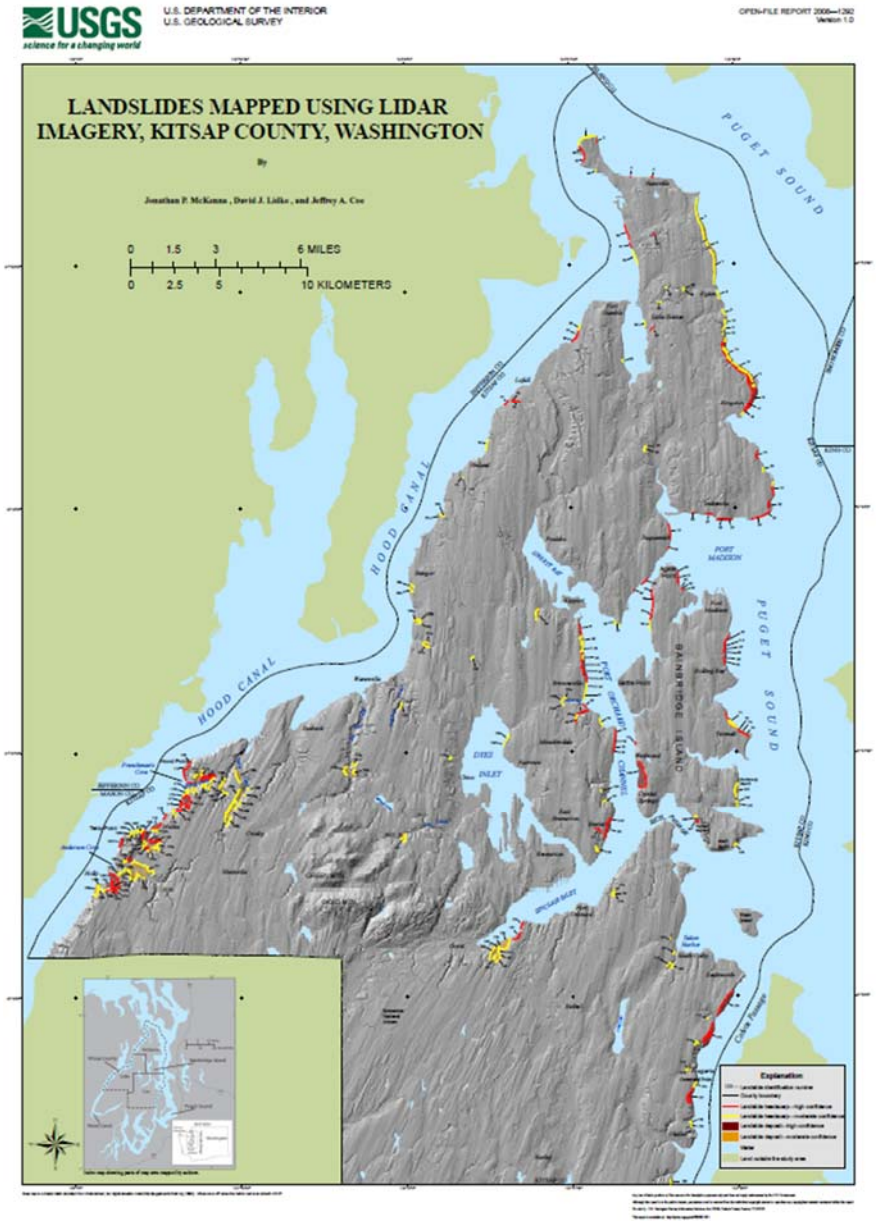
[662] Huggel, C. *et al.* 2012. Is climate change responsible for changing landslide activity in high mountains? *Earth Surface Processes and Landforms*. 37: 77-91.

[663] Huppert *et al.* 2009. Chapter 8: Impacts of climate change on the coasts of Washington State. In *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate*.

[664] Mauger *et al.* 2015. Section 5: Landslides, Erosion, and Sediment Transport.

In Kitsap County, landslide risk is most likely to happen near coastal areas, coastal bluffs, or areas near river channels (Figure 45).[665] This could potentially affect up to 8.7% of Kitsap County's residents and 7.9% of building stock in landslide prone areas.[666] Though no critical facilities lie within landslide prone areas, landslides may disrupt the roads and utilities necessary for access and services, presenting additional challenges for healthcare access for acute injuries during extreme events.[667]

Figure 45. Landslides Mapped from LIDAR Imagery, Kitsap County[668]



[665] McKenna *et al.* 2008.

[666] Kitsap County Department of Emergency Management. 2015.

[667] See: Chapter 3 Health. Finding 3: Acute Injuries from Extreme Weather

[668] USGS. 2008. Landslides mapped using LIDAR imagery, Kitsap County, Washington. https://pubs.usgs.gov/of/2008/1292/downloads/OF08-1292_map.pdf.

Table 16. Kitsap County Residents Affected by Land Shift Hazards[669]

Jurisdiction	Total Population	Population Density	Population in Hazard Area	% Population Affected
Unincorporated Kitsap County	164,595	642	15,729	9.5
Bainbridge Island	22,010	735	3,528	1.6
Bremerton	37,729	1,644	1,808	4.8
Port Orchard	11,144	1,910	1,031	9.4
Poulsbo	9,200	2,121	0	0
Port Madison Suquamish Reservation	5,600	590	413	7.3
Port Gamble S'Klallam Reservation	1,200	461	161	1.3
Totals	**258,278**		**22,670**	**8.7%**

Finding 2: Bluff Erosion

Coastal bluffs are important features of Kitsap County, serving as a sediment source and contributing to sediment transport. Although past trends between bluff erosion rates and climate change are not clearly established, many of the physical factors affecting bluff erosion will likely be impacted by future climate change, with implications for habitat, sedimentation, and infrastructure.

Coastal bluffs are important features of Kitsap County, and they serve as a sediment source and contribute to sediment transport. Coastal bluffs are prominent features of Puget Sound's shoreline, including Kitsap County, covering approximately 17.7 miles of Kitsap County's shorelines, with 8.5 miles of coastal bluffs being armored (Figure 46).[670] Bluff erosion is a natural geologic process that provides sediment to shores and nearshore systems and habitats.[671] Bluff erosion is often influenced by bluff height, the erosion rate, and bluff composition.[672] Kitsap County's bluff characteristics are naturally variable, though many mapped bluffs are low to medium height.[673] Although it is extremely difficult to measure bluff erosion rates and correlate those rates to climate change, major erosion episodes often occur during storm events or the coincidence of storm events and high tides.[674,675] In Port Gamble Bay, surface water erosion and subsurface sediment seepage has caused slope failures.[676]

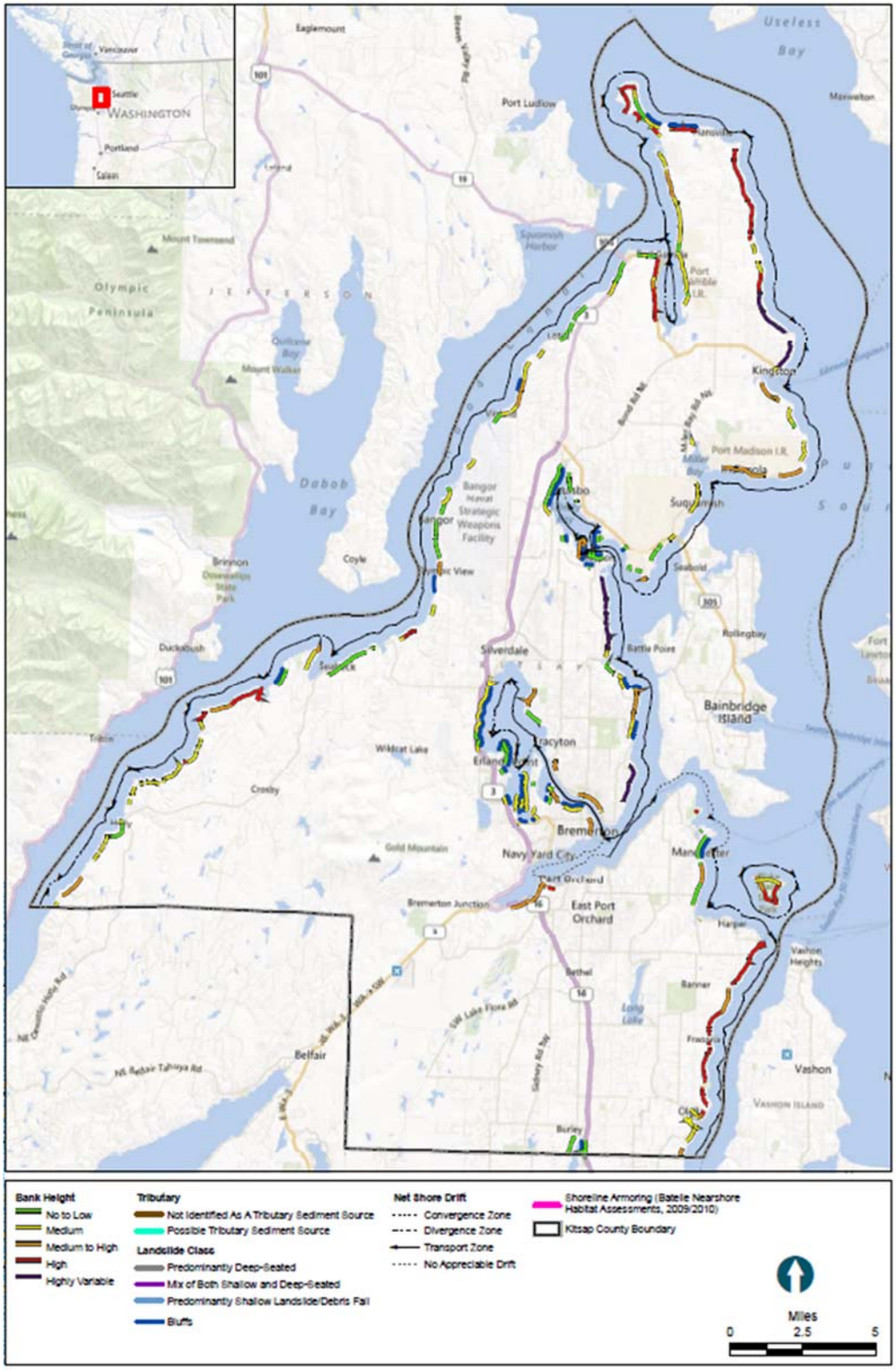
[669] Kitsap County Department of Emergency Management. 2015.
[670] Gerstel *et al.* 2012.
[671] Shipman *et al.* 2014. Puget Sound Feeder Bluffs: Coastal Erosion as a Sediment Source and its Implications for Shoreline Management. Publication #14-06-016.
[672] Shipman *et al.* 2014.
[673] Gerstel *et al.* 2012.
[674] Shipman *et al.* 2014.
[675] Huppert *et al.* 2009.
[676] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment.

Although past trends between bluff erosion rates and climate change are not clearly established, many of the physical factors affecting bluff erosion will likely be impacted by future climate change, with implications for habitat, sedimentation, and infrastructure. Increased winter rain precipitation, higher intensity winter storms, more heavy rainfall events, and sea level rise will very likely accelerate bluff erosion rates, though it is unclear the increase in the magnitude of erosion rates.[677,678,679] Furthermore, future bluff erosion increases and associated risks will vary based on bluff geology and location.[680] One study from San Juan County found that coastal bluffs could recede 75 to 100 feet by the end of the century, doubling current recession rates.[681] Another study in Clallam County projected that erosion rates could increase up to +4 inches per year by 2050.[682]

Increased bluff erosion has multiple implications for habitat, houses, infrastructure, and long-term climate resilience. Future increases of bluff erosion may transport additional sediment to bluff-fed beaches, potentially mitigating sea level rise impacts, although there is still uncertainty about long-term impacts of bluff erosion as a means to mitigate sea level rise as the sediment may be transported off-shore.[683,684] Furthermore, many residences and infrastructure along bluffs face long-term risk from bluff erosion, although they will likely remain safe in the short term.[685,686,687] Potential long-term impacts from bluff erosion include property or residence abandonment, engineered mitigation strategies, managed retreat, and rerouting of roads and transportation routes.[688]

[677] Shipman *et al.* 2014.
[678] Mauger *et al.* 2015. Section 5: Landslides, Erosion, and Sediment Transport.
[679] May *et al.* 2018.
[680] Ladd *et al.* 2017. Port Gamble S'Klallam Tribe Geotechnical Assessment and Shoreline Management Study.
[681] MacLellan. *et al.* 2013. Sea Level Rise Vulnerability Assessment for San Juan County, Washington.
[682] Kaminsky *et al.* 2014. Mapping and Monitoring Bluff Erosion with Boat-based LIDAR and the Development of a Sediment Budget and Erosion Model for the Elwha and Dungeness Littoral Cells, Clallam County, Washington.
[683] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[684] Shipman *et al.* 2014.
[685] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[686] Ladd *et al.* 2017.
[687] Petersen *et al.* 2015. Climate Change Preparedness Plan for the North Olympic Peninsula. A Project of the North Olympic Peninsula Resource Conservation & Development Council and the Washington Department of Commerce. www.noprcd.org.
[688] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

Figure 46. Sediment Source Map of Kitsap County[689]



[689] Kitsap County. 2012. Regional Shoreline Restoration Feasibility and Prioritization Study. www.kitsapgov.com/dcd/PEP%20Documents/Fig1_Sediment%20Source%20Data.pdf.

Finding 3: Storm Surge and Coastal Flooding

Though there is a lack of an evidence base on changes in storm surge height and intensity in the Puget Sound region due to climate change, Kitsap County is already susceptible to storm surges and flooding. Future sea level rise and changing storm activity will directly affect storm surges and associated flooding for Kitsap County.

Though there is a lack of an evidence base on changes in storm surge height and intensity in the Puget Sound region due to climate change, Kitsap County is already susceptible to storm surges and flooding. Though long-term trends of storm surge heights have not been comprehensively studied, studies have found that extreme high-water levels in the Pacific Northwest are associated with sea level rise.[690,691] Flooding is the most repetitive and damaging hazard occurring in Kitsap County, with nine emergency or disaster declarations from severe flooding events between 1990 and 2007.[692] From FEMA and U.S. Census, flood damages and insurance claims have totaled $15 million for Bremerton, $64 million for Bainbridge Island, $6.8 million for Port Orchard, $8.7 million for Poulsbo, and $155 million for unincorporated Kitsap County areas (dollar year not reported).[693]

Washington Sea Grant's King Tides Program has enlisted community residents to take photos of Puget Sound's shoreline during king tide events, or extremely high tides (Figure 47). King tides are considered events that reflect future sea level rise conditions, which coupled with winter storms, often produce extreme coastal flooding.[694]

[690] Mauger *et al.* 2015. Section 4: Sea Level.

[691] Woodworth & Blackman. 2004. Evidence for systematic changes in extreme high waters since the mid-1970s. J*ournal of Climate*. 17(6): 1190-1197.

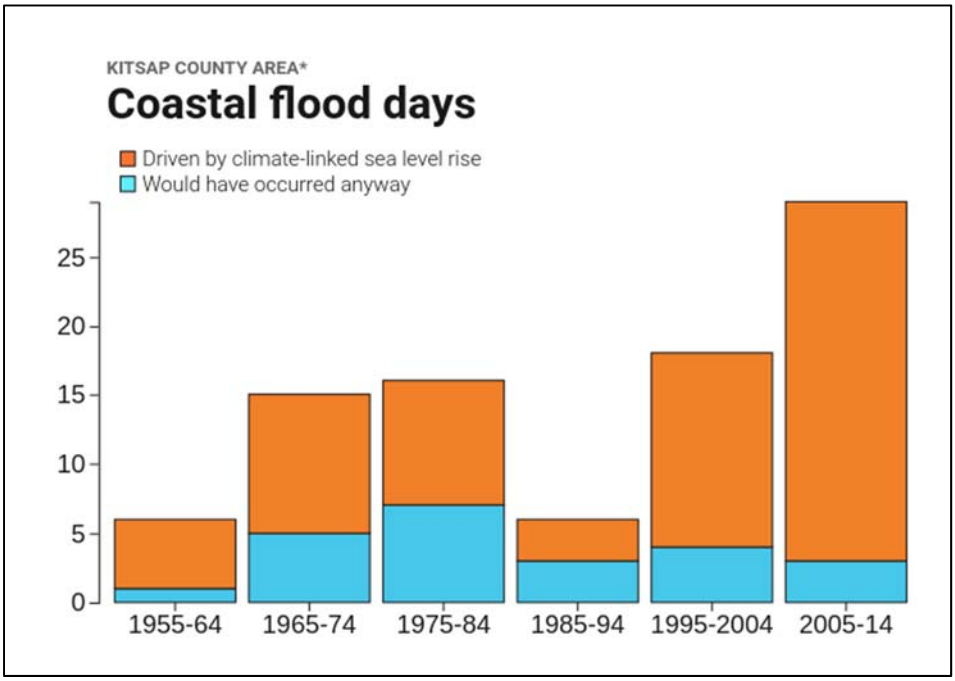
[692] Kitsap County Department of Emergency Management. 2015.

[693] FEMA. 2015. Risk Report: For Kitsap County, including the Cities of Bremerton, Bainbridge, Port Orchard, Poulsbo, the Port Gamble S'Klallam Indian Reservation, the Suquamish Tribe, and Unincorporated Kitsap County. https://fortress.wa.gov/ecy/gispublic/AppResources/SEA/RiskMAP/Kitsap/Kitsap_Project_Docs/Risk%20Report%20-%20Kitsap%20County%20-%20Final.pdf.

[694] Miller *et al.* 2018. Leveraging King Tides and Citizen Science to Prepare for Coastal Flooding in Puget Sound, Washington State. https://ui.adsabs.harvard.edu/abs/2018AGUFMPA51A..02M/abstract.

Figure 47. Coastal Flooding Photos, *from left to right and top to bottom, are from Bainbridge Island (credit: @cberg); Bucklin Hill Bridge in Silverdale (@ClearCreekTrail); and Lion's Park in Bremerton (@klmckaybevers)*[695]

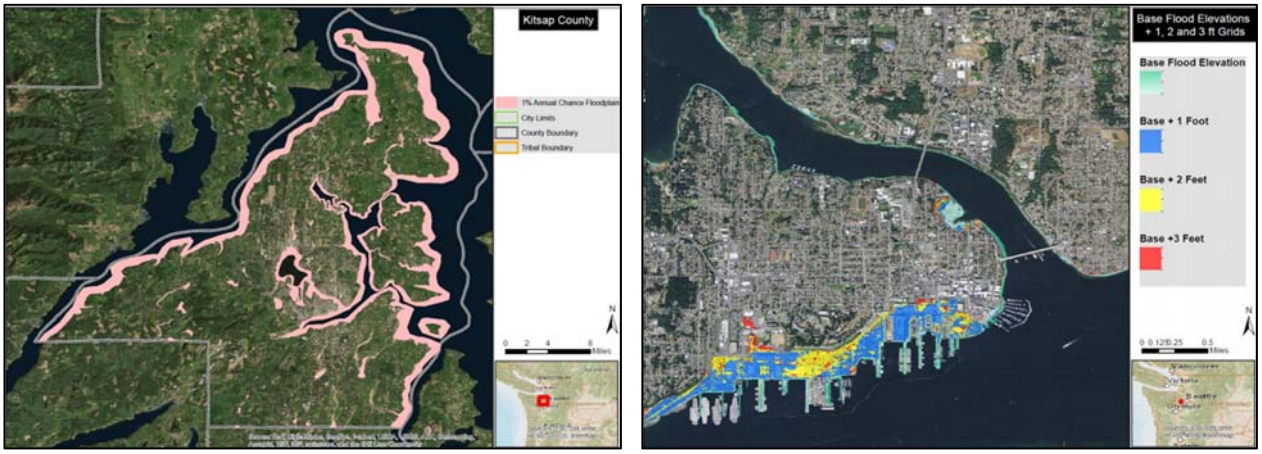
Figure 48. Kitsap County Coastal Flood Days per Decade, 1955-2014[696] *(The nearest water level station is in Seattle, approximately 15 miles from Kitsap County and is used a proxy for sea level rise and flooding data.)*



[695] AnecData. Washington King Tides Project. www.anecdata.org/explore/map?project_id=62&images=0&direction=desc
[696] Climate Central. 2016. Sea level rise and coastal flood exposure: Summary for Kitsap County, WA.

Future sea level rise and changing storm activity will directly affect storm surges and associated flooding for Kitsap County. Multiple publications by County departments and climate scientists project that storm surge and coastal flooding hazard will intensify under future climate conditions due to sea level rise and increasing storm frequency and intensity.[697,698,699] Kitsap County's sea level rise is projected to rise under both low- and high-emissions scenarios, which will likely increase the exposure of the county's coastline to more intense future storm surges and flooding events.[700,701] Figure 49 shows the 1%-annual change floodplain, or the base flood elevation. Future impacts of sea level rise coupled with storm surge will likely result in increased flooding risks above this base flood elevation.[702,703,704]

Figure 49. 1% Annual Change Floodplains for Kitsap County (left); Future Risk if Flooding Occurs at 1 Foot, 2 Feet, and 3 Feet for Bremerton (right)[705]



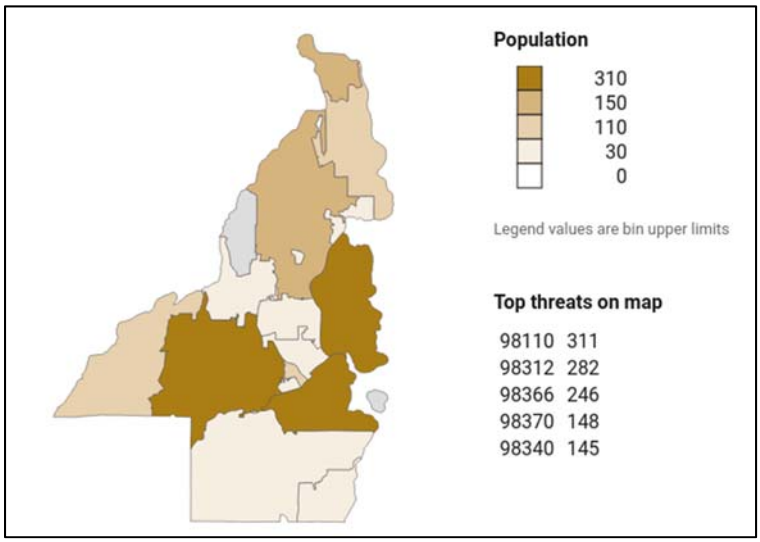
Cities and communities in Kitsap County have approximately $13.4 million of building value within the 1% annual base floodplain, which does not account for additional inundation expected from storm surge, sea level rise, and wave action, with Bainbridge Island having the greatest number of buildings and potential value lost within the community.[706,707]

[697] Kitsap County Department of Emergency Management. 2015.
[698] Mauger *et al.* 2015. Section 4: Sea Level.
[699] Rahmstorf, S. 2017. Rising hazard of storm-surge flooding. *PNAS*. 114(45): 11806-11808. https://doi.org/10.1073/pnas.1715895114.
[700] See: Chapter 2. Climate Change Overview, Future Climate Change Projections. Sea Level Rise.
[701] FEMA. 2015.
[702] FEMA. 2015.
[703] Reeder *et al.* 2013. Chapter 4. Coasts: Complex Changes Affecting the Northwest's Diverse Shorelines. In *Climate change in the Northwest: Implication for our Landscapes, Waters, and Communities*. 271 pp. http://cses.washington.edu/db/pdf/daltonetal678.pdf.
[704] Port Gamble S'Klallam Natural Resource Department. 2016.
[705] FEMA. 2015.
[706] See Chapter 6. Public Infrastructure.
[707] FEMA. 2015.

For Kitsap County, the "100-year" flood height is approximately 3.3 feet above local mean higher high water (MHHW), or the high tide line. Between 1899 and 2015, the largest observed flood in Kitsap County reached 3.1 feet MHHW and occurred in 1983. In Kitsap County, the number of days of coastal flooding occurs has increased from 5 days per decade between 1955-1964 to over 25 days between 2005-2014 (Figure 48). Sea level rise projections indicate a 51% and a 98% risk of at least one flood over 4 feet occurring in Kitsap County between 2020 and 2050 under low- and high-emissions scenarios, respectively (Figure 50).[708] An analysis completed by Climate Central's Surging Seas Risk Finder anticipates that local seal level rise has a 1% likelihood of at least one flood over 4 feet occurring in Kitsap County by 2030, a 9% risk by mid-century, and a 100% risk by 2100. [709]

These risks may lead to detrimental impacts to Kitsap County's local economies, public infrastructure, water supply, and the health of residents. Coastal infrastructure is likely to experience more problems with saltwater intrusion, corrosion, flooding, and inundation as a result of sea level rise.[710,711] In addition, bus, and rail services located in or near current floodplains are likely to experience increases in the number of delays due to projected increases in heavy rainfall and river flooding. This includes homes, businesses and critical infrastructure.[712,713,714] In Kitsap County, 2 square miles of land are projected to be at risk of being impacted by a flood exceeding 4 feet. Within those 2 square miles are located 1,521 individuals, 940 homes, 10 miles of public roads, and an estimated property value of over $300 million at risk of a flood exceeding 4 feet. These impacts are anticipated to increase in severity under higher emissions scenarios.[715]

Figure 50. Total Population below 4 Feet in Kitsap County, by Zip Code



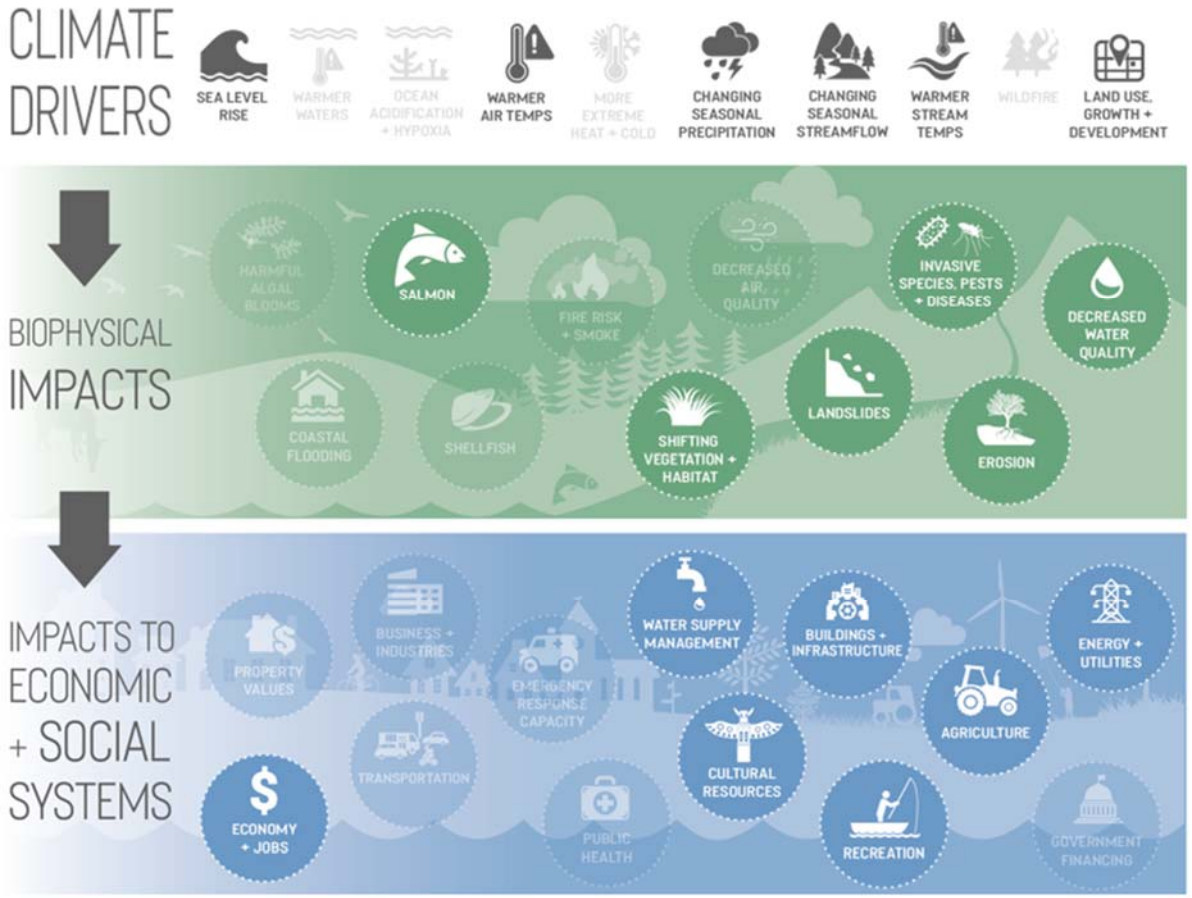
[708] Climate Central. 2016. Sea level rise and coastal flood exposure: Summary for Kitsap County, WA.
[709] Climate Central. 2016.
[710] Hansen *et al.* 2016. Bainbridge Island Climate Impact Assessment. EcoAdapt, Bainbridge Island, WA. www.cakex.org/sites/default/files/documents/BICIA%20Final%2028%20July%202016.pdf.
[711] Mauger *et al.* 2015. Section 12: Built Environment.
[712] Mauger *et al.* 2015. Section 4: Sea Level.
[713] Mauger *et al.* 2015. Section 7: Water Quality.
[714] Mauger *et al.* 2015. Section 12: Built Environment.
[715] Climate Central. 2016.

Chapter 11. Hydrology & Hydrogeology

Summary of Findings

Significant evidence links climate change to changes in hydrology, including larger precipitation events, changes in seasonal precipitation patterns, higher water temperatures, changing streamflow patterns, less groundwater recharge, and declining water quality. These impacts have implications for ecosystems, infrastructure, agriculture, and local communities in Kitsap County and Puget Sound. Future climate change projections will continue to stress water resources in Kitsap County and increase uncertainty in the region's water supply because there may be less groundwater recharge and greater demand because of increased temperatures, which may increase irrigation demand, and larger population. Climate change impacts are expected to increase the frequency that Puget Sound rivers exceed thermal tolerance for cold-water fish species. Projections indicate that climate change will continue to stress marine ecosystems, and it may become more difficult to maintain an adequate water supply. Certain sectors and groups of people are of concern due to their close relationship with water.

Figure 51. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Hydrology and Hydrogeology



Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Hydrological Changes	**High** • Increasing water temperatures, sea level rise, flooding, and declining summer flows will have impact on groundwater recharge and freshwater ecosystems and species [*very high confidence*]. • Hydrological impacts to these ecosystems and species will have significant effects for the industries and communities that use them for their livelihoods, recreation, and/or harvesting [*high confidence*].	**Already happening** • Changes to hydrological systems are already happening in Kitsap County and impacting local ecosystems and infrastructure [*medium confidence*]. **Near-term** • There may be near-term impacts affecting ecosystems and communities [*high confidence*]. **Long-term** • These changes are projected to have long-term implications for people, infrastructure, and ecosystems [*high confidence*].
2. Stream and Riverine Flooding	**Medium-High** • Changes in temperature and streamflow characteristics lead to increased rates of flooding which can have widespread implications to people, infrastructure, and ecosystems [*high confidence*].	**Near-term** • Flooding is already happening in Kitsap County and will likely impact people, infrastructure, and ecosystems in the near term [*medium confidence*]. **Near-term & Long-term** • There may be direct and indirect impacts to Kitsap County in the future [*medium confidence*].
3. Hydropower	**Low-Medium** • Anticipating the impacts on hydropower is challenging due to the variable nature of energy markets, energy demand, water quality/quantity, and policy [*high confidence*]. • Hydropower production is projected to reflect the seasonal shifts in streamflow, with increased production in the winter and decreases in the summer. However, these do not fully encompass all factors, including PSE's changes in fuel mix [*medium confidence*].	**Near term & Long-term** • PSE supplies electricity in Kitsap County and with mandates requiring carbon-free electricity, there may be an increased dependence on hydropower in the near term [*high confidence*]. • Hydropower may be strained in the long term due to low summer flows and increased summer energy demand as a result of climate change [*medium confidence*].
4. Agriculture	**Low-Medium** • It is anticipated that agriculture in the Puget Sound region will be adaptable to climate change, and that changes in water management and land use (crop rotation) can reduce the impacts felt by decreased summer water availability [*medium confidence*].	**Near-term & Long-term** • Depending on water management techniques used, there may be near-term and long-term effects to Kitsap County [*low confidence*].

Finding 1: Hydrologic Changes

Puget Sound hydrologic systems have been experiencing increasing stream temperatures, earlier peak streamflow, and declining summer streamflow. Future climate projections will continue these trends and have impacts on hydrologically linked ecosystems and human resources in Kitsap County and the Puget Sound region. These impacts will affect communities that rely on those habitats and species for economy, sustenance, and/or recreation.

Puget Sound hydrologic systems have been experiencing increasing stream temperatures, higher peak streamflow, and declining summer streamflow. These changes have been impacting aquatic and marine habitats and cold-water species.[716,717,718] Across the Puget Sound region, annual snowpack, glaciers, snow-water equivalent, and seasonal streamflow patterns affect Puget Sound's complex hydrological system. The observed changes in snowpack, glacial ice, and streamflow correlate with the impacts seen on Puget Sound's hydrology.[719] The local salinity of the water in Puget Sound is closely connected to the freshwater inflows from streams.[720] Increasing temperatures shift precipitation patterns in the Puget Sound basin, resulting in more precipitation falling as rain instead of snow during the wintertime.[721,722] These changes cause increased freshwater inflow into Puget Sound during the winter and decreased freshwater inflows in the summer.[723,724] These patterns that drive water exchange between Puget Sound and the ocean are responding to climate change and its impacts on hydrology.

Recent years have seen warmer winters causing both earlier snowmelt and reduced spring and summer flows from snowmelt. Declines in Puget Sound area glaciers may have indirect impacts to Kitsap County since 10% to 44% of total Puget Sound summer streamflow can originate from glaciers depending on the watershed.[725] Snowpack in the Cascades has been decreasing by a rate of nearly 4% each decade between the 1900s and 2006.[726] Increasing temperatures, decreased snowpack, and earlier spring melt have shifted streamflow timing to occur earlier in the year for many snow-dominant basins. These impacts have led to reduced ocean water renewal, warmer stream temperatures, and has further exacerbated human impacts on hydrological

[716] Mauger *et al.* 2015. Section 3, Water Cycle.
[717] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[718] Hansen *et al.* 2016. Bainbridge Island Climate Impact Assessment. EcoAdapt, Bainbridge Island, WA. www.cakex.org/sites/default/files/documents/BICIA%20Final%2028%20July%202016.pdf.
[719] Mauger *et al.* 2015. Section 3: Water Cycle.
[720] Krembs *et al.* 2018. Recent and projected seasonal changes to river flows combine with human pressures to restructure the base of the marine food web in Puget Sound. Salish Sea Ecosystem Conference. https://cedar.wwu.edu/ssec/2018ssec/allsessions/31.
[721] Vynne & H. Harguth. 2015. Hood Canal Climate Change Projections Summary. Prepared by the Hood Canal Coordinating Council. http://hccc.wa.gov/sites/default/files/resources/downloads/Hood_Canal_Climate_Projection_Summary_May_2015.pdf.
[722] Mauger *et al.* 2015, Section 7: Water Quality.
[723] Mauger *et al.* 2015, Section 7: Water Quality.
[724] Vynne & Harguth. 2015.
[725] Mauger *et al.* 2015, Section 3: Water Cycle.
[726] Mauger *et al.* 2015, Section 3: Water Cycle.

systems during summer.[727,728] Between 1980-2009, the Olympic Mountains saw a 34% decline in glacier volume and a 31% decrease in the number of glaciers.[729] Changes in water quality and quantity from increasing temperatures, declining glaciers, and the ongoing shift to more rain-dominant basins directly and indirectly influence salmon, an ecologically important and iconic species in the Northwest.[730]

In the Puget Sound region, increases in the variability of freshwater flows result in more negative impacts for salmon than any other climate indicator-species studied. The lifecycle of cold-water species like Chinook salmon more sensitive to hydrological and climatic changes than other species.[731] In the summer of 2015, multiple hatcheries operated by the Washington Department of Fish and Wildlife experienced low summer streamflow, which resulted in increased water temperatures and a subsequent loss of nearly 1.5 million juvenile salmon.[732] Streamflow volume and temperature directly impact salmon during the freshwater stage of their lifecycle. Furthermore, alterations in ocean chemistry force marine species to spend more energy to control their internal chemistry, leading to less energy available for growth, reproduction, and managing other climate-driven impacts.[733]

These collective impacts have also affected groundwater recharge rates for the Puget Sound region, which are important because groundwater and aquifer sources provide water for human consumption, irrigation, and ecosystem uses. Changes in precipitation and snowpack have had impacted aquifer recharge rates in British Columbia, though there is substantial variability in how groundwater recharge feedback loops will be affected under different climate scenarios, most scenarios predict that groundwater recharge rates will decline under future climate conditions.[734] Most notably, there will be impacts in how surface and sub-surface hydrological processes interact, with timing and quantity of groundwater discharge decreasing during the summer months. Furthermore, increasing development and population growth can lead to additional reductions in groundwater settings, especially for areas reliant on groundwater such as Kitsap County.[735]

Future climate projections will have impacts on hydrologically linked ecosystems and human resources in Kitsap County and the Puget Sound region.[736,737] An increase of 1.8°F in sea surface temperatures, which the Hood Canal is already halfway to reaching, is projected to cause a 1-4% decrease in salmon survival.[738] Puget Sound rivers are projected to exceed thermal tolerances more frequently for cold-water fish species. By the 2040s, current projections anticipate summer streamflow to decrease 16% to 19% under low-and high-emissions scenarios, respectively. By the end of the century, streamflow is projected to decrease even further,

[727] Krembs *et al.* 2018. Recent and projected seasonal changes to river flows combine Recent and projected seasonal changes to river flows combine with human pressures to restructure the base of the marine food with human pressures to restructure the base of the marine food web in Puget Sound web in Puget Sound.
[728] See Chapter 12. Finding 3: Marine and Coastal Habitat.
[729] Mauger *et al.* 2015. Section 3: Water Cycle.
[730] Vynne & Harguth. 2015.
[731] Vynne & Harguth. 2015.
[732] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment. http://nr.pgst.nsn.us/wp-content/uploads/2017/08/PGST_climate-impact-assessment_report_0518-FINAL.pdf.
[733] Vynne & Harguth. 2015.
[734] Alexander & Palmer. 2007. Technical Memorandum #8: Impacts of Climate Change on Groundwater Resources: A Literature Review. A report prepared by the Climate Change Subcommittee of the Regional Water Supply Planning Process, Seattle, WA.
[735] Pitz. 2016. Predicted Impacts of Climate Change on Groundwater Resources of Washington State. Washington Department of Ecology, Publication No. 16-03-006. https://fortress.wa.gov/ecy/publications/documents/1603006.pdf.
[736] Vynne & Harguth. 2015.
[737] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[738] Mauger *et al.* 2015. Section 11: Marine Ecosystems.

with projections anticipating a decrease of 24% to 31% under low- and high-emissions scenarios, respectively.[739] Decreasing summer streamflow are anticipated to reduce marine and aquatic habitat health, and survival of cold-water species.[740] However, increases in sea surface temperature is projected to increase survival rates in Dungeness crabs, though other climate impacts such as ocean acidification may offset any potential benefits.[741,742]

These impacts will affect communities that rely on those habitats and species for economy, sustenance, and/or recreation.[743,744,745] The projected changes may directly and indirectly impact local communities in Kitsap County, such as the Port Gamble S'Klallam Tribe.[746] Warming stream temperatures, decreasing summer streamflow, and declining snowpack and glaciers affect the lifecycles and habitats of salmon, shellfish, and foraging fish. Impacts to hydrology present a major threat to marine health and commercial fisheries. It is estimated that closures to shellfish industries combined with fish deaths can cost nearly $108 million per year (dollar year not reported).[747] Hydrology plays an important role in aquatic and terrestrial ecosystems, and future hydrological changes will have direct and indirect consequences, including alterations to the food web, increased susceptibility to pests and diseases, increased pollution from nutrient runoff, reduced spawning for salmon, changes in habitat availability, and decreased forest productivity.[748] As climate impacts manifest, it will require adaptive management of water related resources, though future water management conflicts may emerge with future competing uses between sectors (e.g., decreasing water availability for hatcheries to fuel hydropower generation).[749]

Finding 2: Stream and Riverine Flooding

Heavier rainfall events, more winter precipitation, and sea level rise will very likely increase flooding risks. These risks will have detrimental impacts to Kitsap County's local economies, public infrastructure, water supply, and the health of residents.

Heavier rainfall events, more winter precipitation, and sea level rise will very likely increase flooding risks. More frequent and intense winter precipitation will lead to more frequent flooding events.[750] Intensity of precipitation also negatively affects groundwater recharge rates, as faster-moving runoff water has less time to infiltrate the surface. Additionally, flooding can lead to decreases in surface water quality because heavier, fast moving rains can pick up more pollutants, excess nutrients and sediments, and infiltrate new locations.[751]

[739] Mauger *et al.* 2015. Section 3: Water Cycle.
[740] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[741] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[742] See Chapter 12: Habitat. Finding 2: Freshwater and Aquatic Habitat and Finding 3: Marine and Coastal Habitat.
[743] Mauger *et al.* 2015. Section 3: Water Cycle.
[744] Mauger *et al.* 2015. Section 7: Water Quality.
[745] Vynne & Harguth. 2015.
[746] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[747] Mauger *et al.* 2015. Section 7: Water Quality.
[748] See Chapter 12. Habitat.
[749] Mauger *et al.* 2015. Section 3: Water Cycle.
[750] Mauger *et al.* 2015. Section 12: Built Environment.
[751] Hansen *et al.* 2016.

These risks will have detrimental impacts to Kitsap County's local economies, public infrastructure, water supply, and the health of residents. In addition, bus and transportation infrastructure located in or near current floodplains are likely to experience increases in the number of delays due to projected increases in heavy rainfall and river flooding. This includes homes, businesses and critical infrastructure.[752] In Kitsap County, 2 square miles of land are projected to be at risk of a flood exceeding 4 feet from extreme precipitation and storm surges. Within those 2 square miles are located 1,521 individuals, 940 homes, 10 miles of public roads, and an estimated property value of over $300 million at risk of a flood exceeding 4 feet. These impacts are anticipated to worsen in severity under higher emissions scenarios.[753]

Finding 3: Hydropower

Climate change has direct influences on hydrology, including decreasing snowpack and reduced peak streamflow. With hydropower's direct relationship to water, negative impacts to hydrology impact Washington State's water supply and energy generation. Kitsap County currently receives electricity from Puget Sound Energy, including electricity produced from hydropower. Increasing summer temperatures, and decreased precipitation are projection to decrease summer hydropower production in Washington State. In contrast, increases in winter and spring precipitation are anticipated to increase hydropower generation during those seasons.

Climate change has already affected the region's hydropower electricity generation. Increasing temperatures, decreasing precipitation, and impacts to snowpack and seasonal streamflow have already placed stress on Washington's water resources, including hydropower.[754,755] Climate change increases the uncertainty of water supply, making it more difficult to allocate water supply across habitats and users such as utilities and agriculture.

Kitsap County currently receives electricity from Puget Sound Energy (PSE), including electricity produced from hydropower. [756] **Increasing summer temperatures and decreased summer precipitation are projected to decrease summer hydropower production in Washington State. In contrast, increases in winter and spring precipitation are anticipated to increase hydropower generation during those seasons.** Hydropower serves as an important resource for Washington State, and Kitsap County receives electricity from PSE.[757] In 2018, hydropower made up 32% of PSE's fuel generation mix (Table 17).[758] Projected changes in temperature, precipitation, and hydrological patterns are anticipated to affect the seasonal generation of hydropower in the Puget Sound region. The Columbia River basin is a critical source for hydropower for the region and projections anticipate an increase of 5% in winter hydropower production and a decrease of 12-15% in summer hydropower production by 2040 (relative to 1970-1999). By the 2080s, hydropower production is projected to increase 8-11% in the winter and decrease 12-21% in the summer (relative to 1970-

[752] Mauger *et al.* 2015. Section 12: Built Environment.
[753] Climate Central. 2016. Sea level rise and coastal flood exposure: Summary for Kitsap County, WA.
[754] Mauger *et al.* 2015. Section 3: Water Cycle.
[755] Washington State Department of Ecology. 2020. Impacts of climate change on water resources. https://ecology.wa.gov/Air-Climate/Climate-change/Climate-change-the-environment/Water-supply-impacts
[756] Kitsap Economic Development Alliance. 2020. Infrastructure & Utilities. http://kitsapeda.org/business-programs-and-incentives/infrastructure-utilities/.
[757] Kitsap Economic Development Alliance. 2020.
[758] PSE Electricity Supply. 2018. www.pse.com/pages/energy-supply/electric-supply.

1999).[759] Increasing summer temperatures and population are anticipated to increase summer energy demand and therefore increase stress on managing shared water resources.[760] Additionally, Kitsap County is a winter peak power use area, though higher temperatures will increase summer power use for cooling. These impacts may result in utilities seeking alternative energy sources that are likely more expensive than hydropower.[761]

In 2019, Washington State passed Senate Bill 5116, mandating for Washington's electricity to be 100% carbon-free by 2045.[762] Carbon-free electricity may require a heavier reliance on hydropower and other carbon-free energy sources. PSE's fuel mix currently generates over 50% of its electricity from carbon sources, with 36% of that originating from coal. Replacing those energy sources with carbon-free sources will require a continued shift in infrastructure and investments. This includes a potential increased dependence on hydropower. This increase demand in hydropower may be further stressed by low summer flows and increased summer energy demand as a result of climate change.

Table 17. Puget Sound Energy Fuel Mix in 2018 [763]

Fuel	Percentage
Coal	36%
Hydroelectric	32%
Natural Gas	20%
Wind	10%
Nuclear	<1%
Other*	<1%

**Other fuel mix contains biomass, non-biogenic, and petroleum.*

Finding 4: Irrigated Agriculture

Climate changes impact on hydrology impact water quality and availability for crop irrigation. Increasing water stress and flood risk is projected to damage agriculture infrastructure and cause decreases in crop production in the Puget Sound region. The impacts of climate change on the agricultural industry in Kitsap County are contingent on local circumstances, including crops grown, and adaptive strategies adopted, as well as how climate change impacts agricultural production on a national scale. Hydrological impacts due to climate change may cause challenges to farmers, ranchers, and Tribes that rely on irrigation and have limited adaptive capacity; however, agriculture in the Puget Sound region is projected to be resilient to some climate impacts.

[759] Mauger *et al.* 2015. Section 3: Water Cycle.
[760] Washington State Department of Ecology. 2020.
[761] Mauger *et al.* 2015. Section 3: Water Cycle.
[762] Washington State. 2019. LegiScan: Washington Senate Bill 5116. https://legiscan.com/WA/text/SB5116/2019.
[763] PSE Electricity Supply. 2018.

Climate impacts on hydrological patterns, water quality, and water availability will affect crop irrigation. Increasing temperatures and decreasing precipitation have already placed stress on Washington's water resources, including irrigation used for agriculture.[764,765] In Kitsap County, crops account for 73% of all agricultural sales, many of which rely heavily on irrigation (e.g., melons, fruits, berries, tree nuts, grains). In Kitsap County, 245 farms use irrigation, covering approximately 465 acres of land.[766] During the 2015 drought, the combination of water stress and high temperatures in irrigation districts in western Washington led to significant reductions in yield and quality of berry crops.[767]

Hydrological impacts due to climate change are anticipated to cause challenges to Kitsap County farmers, ranchers, and Tribes that rely on irrigation.[768] The impacts of climate change on agricultural livelihoods in Kitsap County are contingent on local circumstances, including crop diversity and adaptive strategies adopted. Water availability, supply, and quality will almost certainly be impacted by future climate conditions.[769,770] Future sea level rise and reduced summer water supply can increase the risk of saltwater intrusion, exacerbating expected future water availability challenges.[771,772] Warmer spring and summer temperatures will increased the demand for water and irrigation, potentially increasing conflicts over limited water supply. [773,774] Efficiency improvements in farming equipment and irrigation systems have the ability to significantly increase agricultural productivity while simultaneously decreasing its water consumption.[775] The adaptive capacity of the agricultural sector in the Puget Sound region is projected to be high, as regional agriculture will be adaptable to future climate change, especially with more efficient irrigation and land use management.[776]

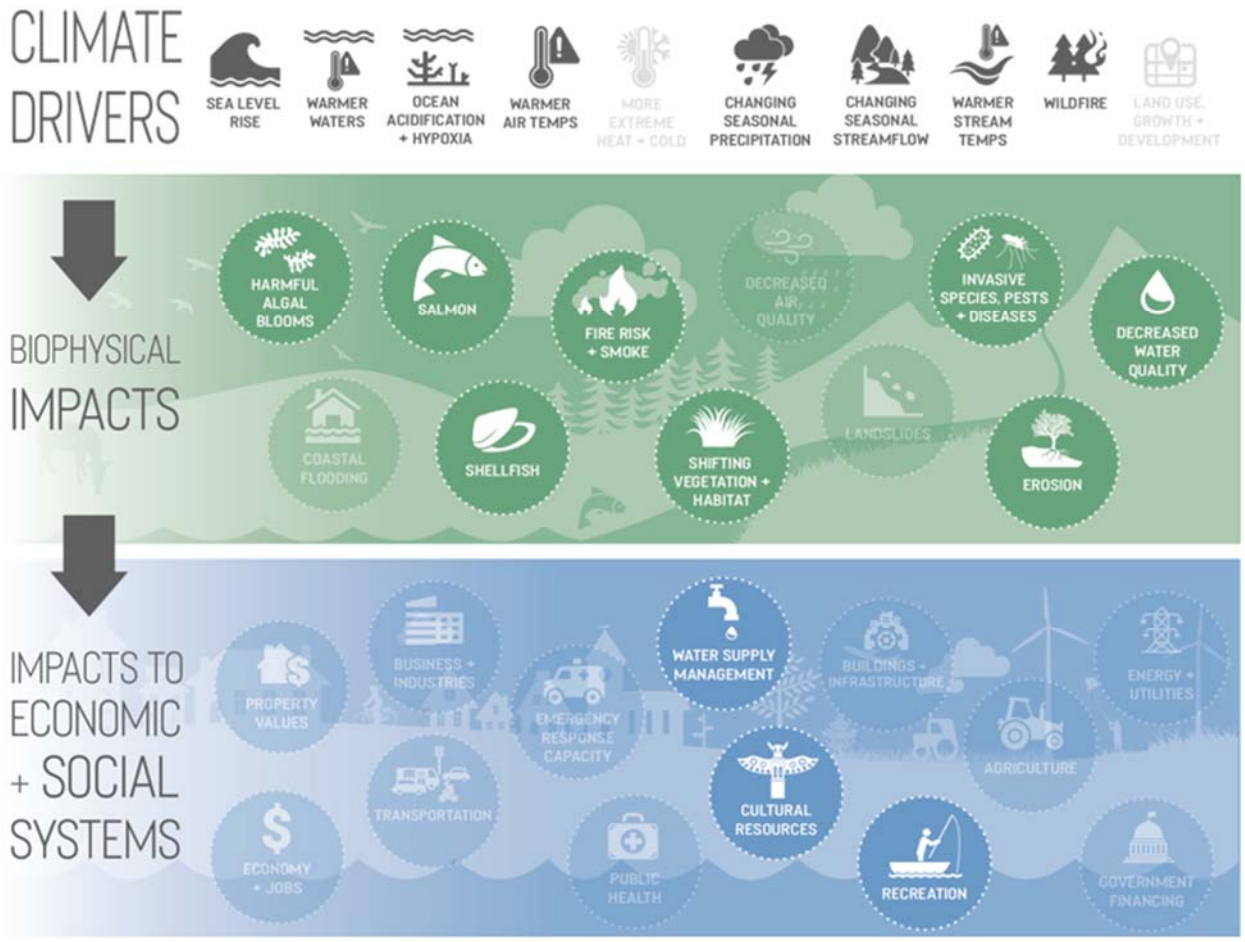
[764] Mauger *et al.* 2015. Section 3: Water Cycle.
[765] Washington State Department of Ecology. 2020.
[766] USDA, National Agricultural Statistics Service. 2017. County Profile: Kitsap County, Washington. www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Washington/cp53035.pdf.
[767] McLain *et al.* 2017. 2015 Drought and Agriculture: A Study by the Washington State Department of Agriculture. Washington State Academy of Sciences. 15 pp. https://agr.wa.gov/getmedia/d814e329-dde6-4034-a878-8b6ba1b3f9b7/495-2015droughtreport.pdf.
[768] Casola *et al.* 2005. Climate Impacts on Washington's Hydropower, Water Supply, Forests, Fish, and Agriculture. https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/34555/14.pdf?sequence=1&isAllowed=y
[769] May *et al.* 2018. Chapter 24: Northwest. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment.* Volume II: 1036–1100. https://nca2018.globalchange.gov/chapter/24/
[770] Gowda *et al.* 2018: Agriculture and Rural Communities. *In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*. Volume II: pp. 391–437. doi: 10.7930/NCA4. 2018.CH10.
[771] Mauger *et al.* 2015. Section 8: Agriculture.
[772] Tibbot, E.B. 1992. Seawater intrusion control in coastal Washington. Department of Ecology Policy and Practice. EPA.
[773] Hansen *et al.* 2016.
[774] May *et al.* 2018.
[775] Kitsap County Board of Commissioners. 2011. Kitsap County Strategic Agricultural Plan and Inventory. https://s3.wp.wsu.edu/uploads/sites/2074/2016/12/Kitsap-Strategic-Ag-Plan-and-Inventory-2011.pdf.
[776] Mauger *et al.* 2015. Section 8: Agriculture.

Chapter 12. Habitat

Summary of Findings

Natural ecosystems provide various services for Kitsap County and its residents and communities. Many of these natural systems will be affected by future climate change. Warmer air temperatures, wildfire risk, and changing precipitation patterns will alter forest and vegetation habitat and species distribution. Sea level rise, warmer water temperatures, dissolved oxygen, and ocean acidification will affect coastal and nearshore habitats, sensitive species (such as shellfish), and water quality. Changing seasonal precipitation, streamflow patterns, and stream temperatures will affect water supply, freshwater habitats, and cold-water species like salmon. Across all systems, invasive species, pests, and diseases will become more prevalent in the future as temperatures and water conditions allow them to reach areas previously unsuitable. Cumulatively, these impacts will alter the County's fire risk, recreational opportunities, key cultural resources, iconic species, resource-based industries, and regional water management and conservation measures—with long-term implications for Kitsap County's economy, ecosystems, and the wellbeing of its residents.

Figure 52. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Habitat



Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Terrestrial Habitats	**Medium** • Climate change impacts such as increasing temperatures and more frequent and extended droughts are altering the lifecycles and the geographic distribution of various insects, diseases, invasive species, and sensitive species within terrestrial ecosystems [*high confidence*]. • The most significant impacts to terrestrial habitat are projected to occur areas east of the Cascade Range. However, impacts to species distribution, forest growth and productivity, wildfire regimes, and infectious diseases are anticipated in western Washington and the lower elevation areas of the Puget Sound region [*high confidence*].	**Near-term** • There may be near-term impacts affecting ecosystems and communities [*medium confidence*]. **Long-term** • There may be long-term impacts to Kitsap County, but they are challenging to determine due to the individual responses of species to climate change [*medium confidence*].
2. Freshwater and Aquatic Habitat	**Medium-High** • Increasing water temperatures, sea level rise, decreasing snowpack and glaciers, shifting streamflow, declining summer flows, and flooding will affect freshwater ecosystems and aquatic species [*very high confidence*]. • Climate impacts will significantly affect species using freshwater for critical life stage development (e.g., salmon, bull trout, amphibian species) and will have downstream impacts to ecosystems and the freshwater food system [*high confidence*].	**Already happening** • Impacts to freshwater ecosystems and freshwater species are already happening in the Puget Sound region and Kitsap County and will likely impact people, infrastructure, and ecosystems in the near term [*high confidence*]. **Near-term & Long-term** • The number of stream miles exceeding the thermal tolerance of cold-water species (e.g., salmon, trout) are projected to increase in the near and long term [*high confidence*]. • Impacts to freshwater ecosystems and aquatic species are projected to have long-term implications [*high confidence*].
3. Marine and Coastal Habitat	**Low-Medium** • Changes in the ocean environment, such as warmer waters, altered water chemistry, and sea level rise, will significantly alter marine ecosystems and the communities that use them [*very high confidence*]. • Changes to wetland composition and biodiversity can have direct impacts on available area for habitat and recreation and can negatively impact Kitsap County's water resources [*medium confidence*].	**Already happening** • Changes to marine and coastal habitats are already happening in Kitsap and impacting local ecosystems [*very high confidence*]. **Near-term & Long-term** • Future climate conditions are anticipated to continue long-term and will likely continue to alter marine and coastal habitats in Puget Sound [*high confidence*]. • These impacts will likely have near- and long-term consequences for communities that rely on those habitats and species for economy, sustenance, and/or recreation [*high confidence*].

Key Findings	Magnitude of Impact & Key Metrics	Timeline
4. Invasive Species and Diseases	**Medium** • Climate impacts are projected to further increase the range and intensity of invasive species, pests, and diseases in Kitsap County terrestrial, freshwater, and marine ecosystems [*high confidence*].	**Already happening** • Invasive species, pests, and diseases are already a problem that Kitsap County faces [*very high confidence*]. **Near-term & Long-term** • Projected changes in the frequency and deadliness of invasive species, pests, and diseases will likely impact native ecosystems; however, specific impacts to Kitsap County are difficult to generalize due to the intricacies of host and species interactions [*high confidence*].

Finding 1: Terrestrial Habitat

Terrestrial ecosystems in the Puget Sound region are sensitive to increasing air temperature, reduced snowpack, decreasing summer precipitation, and changing risks from invasive species and diseases. Alterations in the geographic distribution of tree species, forest growth and productivity, wildfire activity, and pest and disease outbreaks are expected in Kitsap County and the Puget Sound region as a result of climate change. Changes in terrestrial habitat composition, structure, and species interaction are expected to impact local organizations, agencies, municipal activities, and Tribes.

Terrestrial ecosystems in the Puget Sound region are sensitive to increasing air temperature, reduced snowpack, decreasing summer precipitation, and changing risks from invasive species.[777,778] Throughout Kitsap County, there are large amounts of maintained forested area, including Kitsap Forest Natural Preserve area (125 acres), Coulter Creek Heritage Park (1,200 acres), and over 1,500 acres on the Port Gamble S'Klallam reservation.[779,780,781] These sites are important habitats for mature and old-growth Douglas-firs and western hemlock, rhododendron, evergreen huckleberry, and sword fern. Many of these sites also provide critical support to salmon and chum habitats, blue heron rookery, and nesting osprey.[782] Observed local climate impacts to Kitsap County forests are lacking sufficient data, though the Port Gamble S'Klallam Tribe has found that past fire records show a strong correlation between warmer and drier summers and higher

[777] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[778] Whitely Binder *et al.* 2017. Preparing Washington State Parks for Climate Impacts: A Climate Change Vulnerability Assessment for Washington State Parks. https://doi.org/10.7915/CIG6B27QV.
[779] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment. http://nr.pgst.nsn.us/wp-content/uploads/2017/08/PGST_climate-impact-assessment_report_0518-FINAL.pdf.
[780] Washington State Department of Natural Resources. Kitsap Forest Natural Area Preserve. www.dnr.wa.gov/kitsap-forest-natural-area-preserve.
[781] Kitsap County. Forest Stewardship. www.kitsapgov.com/parks/Pages/ForestStewardship.aspx
[782] Washington State Department of Natural Resources. Kitsap Forest Natural Area Preserve. www.dnr.wa.gov/kitsap-forest-natural-area-preserve.

rates of wildfire activity, specifically among hemlock and Douglas-fir trees.[783] Wildfires have caused temporary park closures and have damaged park infrastructure throughout Washington State.[784]

Within the last ten years, increasing temperatures and drought have extended the habitat for various insects and pests, including the mountain pine beetle, leading to significant forest destruction.[785] Insects and disease damage to Washington's forests doubled from 600,000 acres in the 1980s to over 1.2 million acres in the 2000s.[786] Laminated root rot is a significant issue for Kitsap County terrestrial habitats and projected increases in temperatures and declines in summer water supply are expected to increase the impact and prevalence of root diseases.[787] Furthermore, the amount of forest area damage has continuously increased in Washington State, with projections anticipating damage from insects, wildfires, and disease to continue in the future.

Alterations in the geographic distribution of tree species, forest growth and productivity, wildfire activity, and pest and disease outbreaks are expected in Kitsap County and the Puget Sound region as a result of climate change.[788,789,790] The most significant impacts to terrestrial habitat are projected to occur east of the Cascade Range.[791] However, impacts to species distribution, forest growth and productivity, wildfire regimes, and infectious diseases are anticipated in western Washington and lower elevations in the Puget Sound region.[792]

Climate change will likely alter the geographic distribution of various terrestrial species in the Puget Sound region, but there is little evidence of local impacts to Kitsap County from the individual responses of species to climate change. Earlier seasonal snowmelt coupled with warmer temperatures can extend growing seasons and indirectly increase forest and vegetation growth of some species, while simultaneously decreasing productivity for other species, such as Douglas-firs.[793] The geographic distribution of forests is anticipated to change due to increasing air temperatures and drier conditions. These impacts are likely to reduce the amount of habitat suitable for Douglas-firs and western hemlocks by the 2060s, specifically in low-elevation areas like Kitsap County.[794]

Wildfire activity is expected to increase in the Puget Sound region and Kitsap County.[795] Wildfire activity is important to maintain a healthy ecosystem, although increased fire risk from a combination of climate change and legacy of forest management practices (e.g., fire suppression, overharvesting) can harm ecosystems.[796] Projected increases in wildfire frequency and intensity is anticipated to drive significant environmental changes in the region's forests.[797,798] Forest composition could shift to favor vegetation that is more fire-

[783] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[784] Whitely Binder *et al.* 2017.
[785] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[786] Whitely Binder *et al.*2017.
[787] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[788] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[789] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[790] Whitely Binder *et al.* 2017.
[791] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[792] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[793] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[794] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[795] See: Chapter 13. Fire. Finding 1: Wildfires.
[796] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[797] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[798] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

tolerant.[799,800] In the event of wildfires, significant changes to terrestrial habitat is expected to alter forest management practices, the accessibility of timber resources, and wildlife habitat.[801,802]

Changes in terrestrial habitat composition, structure, and species interaction are expected to affect local organizations, agencies, municipal activities, and Tribes.[803] Climate change is not the only significant driver to forest health, as indirect impacts from population growth, urban growth, logging, and management of natural resources will also contribute to the long-term resilience of terrestrial ecosystems and habitat.

Finding 2: Freshwater and Aquatic Habitat

Impacts to freshwater and aquatic habitats are driven by increasing air temperatures, declines in snowpack, and decreasing summer precipitation. Future climate projections are expected to impact local wetlands and increase the frequency of Puget Sound watersheds exceeding thermal tolerance for cold-water fish species. Future climate conditions are anticipated to continue to alter the freshwater ecosystem in the Puget Sound region, affecting communities that rely on those habitats and species for their economic livelihoods, sustenance, and/or recreation.

Impacts to freshwater habitats and cold-water species are driven by increasing air temperatures, declines in snowpack, and decreasing summer precipitation.[804] Increasing air temperatures are driving the transition from snow-dominant basins and rain/snow-mixed basins to rain-dominant basins, changing streamflow patterns and stream temperatures in the Puget Sound region.[805] Decreases in streamflow increase streamflow temperature and affect stream water quality, harming anadromous species like salmon. Low streamflow and elevated water temperature limit the ability of adult salmon to travel upstream for spawning and make it difficult for juvenile salmon to travel downstream to reach Puget Sound.[806]

Juvenile salmon growth and development depends on cool freshwater temperatures and available macroinvertebrates for food supply. Before salmon migrate to marine habitat, they undergo smoltification, a series of physiological changes to adapt from living in freshwater to seawater. This process of smoltification and the timing of seaward migration are highly dependent on streamflow temperatures; thus, changes to streamflow and temperature may directly affect smolt timing and the survival rates of juvenile and out-migrating salmon. Increased stream temperature and decreased summer flows also hinder adult upstream migration, creating fish passage barriers and restricting adult salmon from their natal spawning grounds.[807]

[799] Vose *et al.* 2018. *Forests. In Impacts Risks, and Adaptation in the United States: Fourth National Climate Assessment.*
[800] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[801] May *et al.* 2018. Chapter 24: Northwest. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment. Volume II: 1036–1100. https://nca2018.globalchange.gov/chapter/24/
[802] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[803] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[804] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[805] See Chapter 2. Climate Change Overview. Future Climate Projections: Streamflow and Stream Temperature
[806] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[807] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

Inland wetlands are composed of freshwater located at or near the surface, which are highly sensitive to changes in snowpack and summer precipitation. Both climate drivers contribute and combine with increased evaporation rates and decreased water quality to reduce the area of wetlands and threaten amphibian species residing in wetland habitats.[808] Wetland amphibians are cold-blooded and therefore highly sensitive to changes in water temperatures; changes to water quality and quantity will likely increase mortality rates and decrease habitat availability for these species.[809,810] Wetlands provide a variety of beneficial ecological and economic benefits to Kitsap County, including flood control, filtering contaminants, recharging groundwater, providing fish and wildlife habitats (especially for salmonids), and recreation.[811] Changes to the composition and available area of wetlands can reduce the benefits they provide.

Future climate projections are expected to impact local wetlands and increase the frequency that Puget Sound Rivers exceed thermal tolerance for cold-water fish species.[812] The Port Gamble S'Klallam Tribe anticipates restricted access of 0 to 3 river miles in the Dungeness and Skokomish rivers during August due to stream temperatures exceeding thermal tolerances for salmon (>64°F), and 32 to 120 miles with August stream temperatures exceeding thermal tolerances for char (>54°F). When salmon or char are exposed to warm water temperatures, they become more susceptible to diseases, experience higher mortality rates, and slow or stop their migration.[813] Temperature-sensitive aquatic species like bull trout, salmon, and amphibians, are also extremely susceptible to mortality and sensitive to habitat destruction, increased frequency and severity of extreme weather events, and pollutant runoff, which will likely drive local extirpation of some aquatic species.[814] Projections in decreased stream flows during migration periods are expected to alter migration timing and further reduce migration success. As spring and summer streamflow decreases, the amount of available habitat will decline and subsequently altering increased fish densities in the stream, changing species-to-species interactions, and increase disease prevalence and likelihood of infection.[815]

Kitsap County is home to the Stavis Natural Resources Conservation Area, protecting habitat and ecosystems for Douglas-firs, western hemlocks, evergreens, huckleberries, Pacific rhododendrons, and sword ferns. Large native trees and shrubs along stream shorelines provide a riparian buffer that provides water quality treatment, increased rainfall infiltration to reduce streamflow during storm events, and shading to reduce water temperatures. Nutrient input from urban activities, such as landscaping, pet activity, and lawn maintenance increase phosphorus and nitrogen in freshwater streams. Excess nutrients, combined with increase sunlight and temperatures, may lead to harmful algal blooms (HABs) such as blue-green algae. HABs can produce extremely dangerous toxins that can sicken people and animals and create dead zones in the water. Areas such as the Stavis Natural Resource Conservation Area are expected to be impacted from projected changes in precipitation, water quality and quantity, and HABs.[816]

[808] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[809] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[810] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[811] Kitsap County. 2017. Critical Areas Ordinance Fact Sheet. www.kitsapgov.com/dcd/FormsandBrochures/Wetlands%20Brochure.pdf.
[812] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[813] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[814] May *et al.* 2018.
[815] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[816] Mauger *et al.* 2015. Section 11: Marine Ecosystems.

Future climate conditions are anticipated to continue to alter the freshwater ecosystem in the Puget Sound region, affecting communities and other ecosystems that rely on those habitats and species for their economic livelihoods, sustenance, and/or recreation.[817] Warming stream temperatures, decreased streamflow, and increasing peak winter flows are projected to significantly impact species like Chinook, coho, and sockeye salmon, steelhead and bull trout, and amphibians. Climate projections anticipate increased mortality of these species, impacting downstream ecosystems and the marine food system.[818,819] Furthermore, changes to wetland compositions and biodiversity can have direct impacts on available area for habitat and recreation and can negatively impact Kitsap County's water resources as a result of decreased groundwater recharge.[820,821]

Finding 3: Marine and Coastal Habitat

Coastal and marine ecosystems in Puget Sound are sensitive to changes in snowpack, ocean acidification, local fauna/flora composition, sea level rise, streamflow, and stream temperature in the Puget Sound region. Future climate conditions are anticipated to continue to alter the coastal and marine ecosystem in Puget Sound, affecting communities that rely on those habitats and species for economy, sustenance, and/or recreation.

Coastal and marine ecosystems in Puget Sound are sensitive to changes in snowpack, ocean acidification, local fauna/flora composition, sea level rise, streamflow, and stream temperature in the Puget Sound region.[822] Climate observations show a strong warming trend in seawater temperatures. Warmer, less oxygenated water stresses some cold-water fish and shellfish and promotes HAB growth. Increasing water temperatures has been observed throughout Puget Sound, with water temperatures increasing from 0.9°F to 1.6°F in Admiralty Inlet and in Hood Canal from 1950 to 2009.[823] Admiralty Inlet has shown consistent decreasing dissolved oxygen concentrations, which may imply similar trends throughout Kitsap County (Figure 53).[824,825] Puget Sound is experiencing the effects of increasing ocean acidification on ecosystems and commercial fishing. Ocean acidification occurs when the excess carbon dioxide from the atmosphere is absorbed by the ocean, which leads to decreasing pH levels or increasing ocean acidity. Ocean acidification directly affects marine species ability to create shells and skeletons, decreasing shellfish populations, reducing benthic invertebrate and crustacean prey sources, and altering marine food webs (Figure 54).[826]

[817] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[818] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[819] Vynne & H. Harguth. 2015.
[820] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[821] Clifton *et al.* 2018. Effects of climate change on hydrology and water resources in the Blue Mountains, Oregon, USA. Climate Services. www.sciencedirect.com/science/article/pii/S2405880717300158.
[822] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[823] Mauger *et al.* 2015, Section 7.
[824] Mauger *et al.* 2015, Section 7: Water Quality.
[825] Washington State Department of Ecology. 2014. Nitrogen in Puget Sound – A Story Map. https://waecy.maps.arcgis.com/apps/MapSeries/index.html?appid=907dd54271f44aa0b1f08efd7efc4e30
[826] Mauger *et al.* 2015. Section 11: Marine Ecosystems.

It is important to consider that non-climatic factors can be drivers of change for hydrology in the Puget Sound region, including changes to land use and vegetative cover.[827] Marine habitat quality is significantly impacted by pollution runoff. For example, stormwater runoff from commercial, industrial, and residential land continues to cause erosion and sedimentation of streams and degrade water quality and causes eutrophication, which impacts critical juvenile salmonid habitat for fish in Kitsap County.[828]

Figure 53. Excess Nitrogen in Puget Sound, Kitsap County[829] *(This map highlights areas in Puget Sound where measured dissolved oxygen levels are either below the water quality standard (impaired) or close to being at this minimum threshold (areas of concern) based on the 2014 Water Quality Assessment. The minimum dissolved oxygen water quality standard in most of Puget Sound is set to 7.0 milligrams per liter.)*

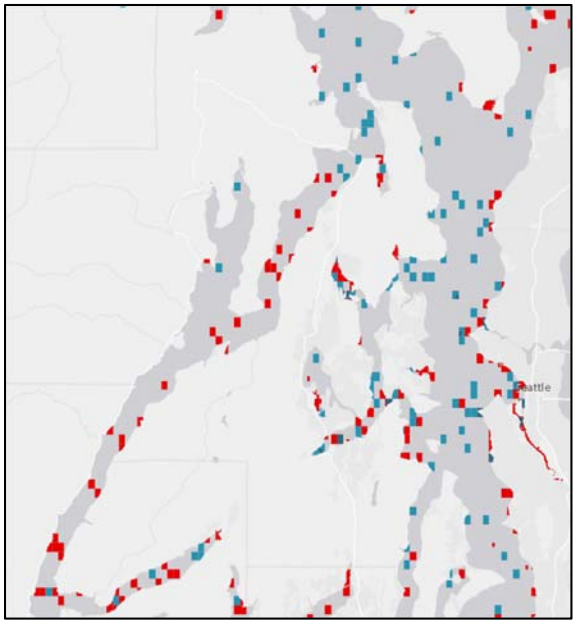
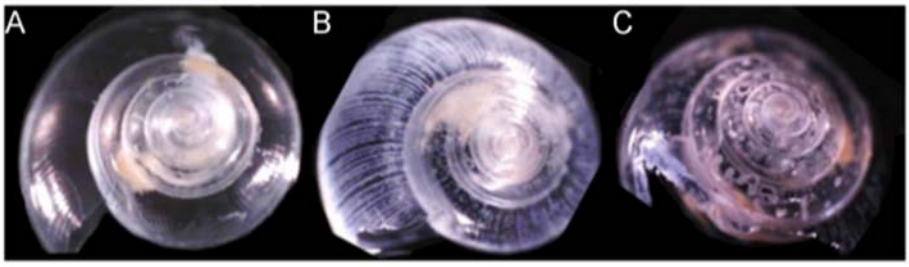


Figure 54. Ocean Acidification Reduces Shell Formation and Increases the Likelihood of Shell Dissolution [830] *Pictured below is the sea snail (Pteropod) in three different aragonite saturation state levels. State (A) is 1.59 (current summer surface conditions), (B) 0.56 (current summer surface conditions during upwelling), and (C) 0.28 (anticipated future surface conditions during upwelling). Both (B) and (C) show corrosion and holes forming in the shells. Sea snails are an important prey species in the Puget Sound marine food chain.*



[827] Mauger *et al.* 2015. Section 3: Water Cycle.
[828] Kitsap County. 1997. Initial Basin Assessment. https://test-fortress.wa.gov/ecy/publications/documents/oftr974.pdf
[829] Nitrogen in Puget Sound visualization tool created by the Washington State Department of Ecology.
[830] Mauger *et al.* 2015. Section 11: Marine Ecosystems.

Future climate projections are expected to increase the frequency that Puget Sound rivers exceed thermal tolerance for marine fish species during juvenile and mating lifecycles, and increased likelihood of HAB formation. Nearly all climate models anticipate continued increases in sea surface temperatures, ocean acidification, and sea level rise within Puget Sound. Sea level rise is projected to increase throughout Puget Sound, which will likely increase land inundation rates and alter nearshore and coastal habitats in Kitsap County.[831] A mixture of increased carbon dioxide in the atmosphere, coastal upwelling, and excess nutrient runoff have acidified the region's waters, including Hood Canal.[832] Ocean acidification is projected to harm the commercial shellfish industry by increasing shell dissolution and reducing or preventing shell formation for mollusks and other calcifying species.[833,834] Ocean acidification is projected to cause a 17% decline in mollusk growth, and a 34% decline in their survival rates by 2100.[835] It is projected that when atmospheric carbon dioxide (CO_2) concentration doubles, 49-82% of the acidification of Hood Canal's deep waters can be attributed to human-caused ocean acidification (relative to 1986-2005 levels).[836] Increasing sea surface temperatures expands the window of time for harmful algal species to develop by nearly 30 days. Furthermore, ocean acidification may lead to toxicity increases of HABs.[837]

Estuary productivity may increase from changes in nutrients and increases in CO_2 levels as well as sea surface temperatures.[838] Climate impacts to coastal areas such as sea level rise and erosion can lead to loss of coastal wetlands and other habitats, impacting a wide array of coastal wildlife that depend on those places such as fish, birds, shellfish and other animals.

Future climate conditions are anticipated to continue to alter the marine ecosystem in Puget Sound, affecting communities that rely on those habitats and species for economy, sustenance, cultural identity, and/or recreation. Changes in the ocean environment, such as warmer waters, altered chemistry, and sea level rise, are expected to alter marine ecosystems, potentially limiting their productivity. These projected changes affect the Puget Sound region's natural resource economy, heritage, recreation, and the health and livelihoods of residents.[839,840]

[831] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[832] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment.
[833] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[834] Hansen *et al.* 2016. Bainbridge Island Climate Impact Assessment. EcoAdapt, Bainbridge Island, WA. www.cakex.org/sites/default/files/documents/BICIA%20Final%2028%20July%202016.pdf.
[835] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[836] Mauger *et al.* 2015. Section 7: Water Quality.
[837] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[838] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[839] May *et al.* 2018.
[840] See Chapter 4. Economy and Chapter 5. Cultural Resources.

Finding 4: Invasive Species and Diseases

Invasive species and diseases are already a problem facing the Puget Sound region and Kitsap County. Increasing temperatures, changing precipitation rates, and food web disruptions are projected to further increase the range and intensity of invasive species, pests, and diseases in Kitsap County and the region. Projected increases in frequency and intensity of invasive species, pests, and diseases will impact native habitats and have direct and indirect impacts on communities and major industries in Kitsap County. However, specific projections on impacts to the county can be difficult to generalize due to the intricacies of host and species interactions.

Invasive species and diseases are already a problem in the Puget Sound region and Kitsap County. Invasive species are non-native animal and plant species that have been introduced accidentally or have been forced to a novel area or habitat type. They can reduce crop yields, displace native plant and animal species, damage native habitat, limit recreational opportunities, and impact local food webs. Prominent invasive plant species in Kitsap County include giant hogweed, tansy ragwort, purple loosestrife, hydrilla, and parrotfeather. Many of these invasive plant species threaten salmon habitat, damage wetland habitats, and require expensive control strategies.[841] Kitsap County has experienced invasive species to marine habitats as well, with invasive tunicates (sea squirts) being found in the Hood Canal and Puget Sound region. Invasive tunicates are extremely resilient to increasing water temperatures and impede shellfish harvesting by suffocating oysters and clams (Figure 55). Warmer waters have allowed for other invasive species to find suitable habitat in the Puget Sound region, including European green crabs, the New Zealand mud snail, and varnish clams. European green crabs, which drove the collapse of the soft-shell clam industry in parts of the East Coast, have been spotted in the Olympic Peninsula and have disrupted local eelgrass and shellfish habitats.[842] However, further research is needed to determine the impact these invasive species will have in Kitsap County.[843]

Figure 55. Invasive Tunicate Growth on Oysters in Puget Sound[844]

[841] Kitsap County. Noxious Weed Control. www.kitsapgov.com/treas/Documents/NoxiousWeedFAQ.pdf
[842] SeaGrant Washington. European Green Crab. https://wsg.washington.edu/crabteam/greencrab/
[843] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[844] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

Figure 56. Invasive European Green Crabs Found off Olympic Peninsula[845] *(Seattle Times photo)*

Various habitats in the Puget Sound region have experienced impacts from pests and diseases. For aquatic habitats, water temperature plays a critical role in regulating biological and physiological processes related to disease vulnerability in fish. Across the Puget Sound region, diseases such as *Ichthyophonus hoferi* have caused liver and heart damage to several fish species, including the Pacific herring and surf smelt. Furthermore, *Heterosigma akashiwo,* a toxic species of algae found in HABs, has killed millions of salmon in the Puget Sound region within the last 50 years. These toxic species have been found to flourish in areas in Puget Sound that contain high concentrations of dissolved carbon dioxide. HABs have additional impacts on shellfish, with *Alexandrium catenella* causing paralytic shellfish poisoning (PSP). Although this poisoning has not been found to harm shellfish, PSP has direct health impacts on humans and animal species that consume contaminated shellfish. Clams and oysters, which make up a majority of commercial shellfish harvesting and subsistence harvesting in Kitsap County, are two of the most common carriers of HAB-related toxins.[846]

Within the last decade, rising temperatures and decreasing precipitation rates have expanded the available habitat and allowed for earlier occurrences of various terrestrial pests and diseases across the western United States.[847] Rising temperatures have allowed pests like the mountain pine beetle, the spruce beetle, and the Douglas-fir beetle to move further north, affecting tree species throughout Kitsap County. Climate change impacts have also allowed for diseases, like the Swiss needle cast, to establish and increase infection rates and prevalence (Figure 57). Pest and diseases degrade terrestrial health by decreasing forest productivity and making them more vulnerable to droughts and wildfires.[848] Nonetheless, rising temperatures and longer periods of drought have allowed for numerous other insects and diseases to infect tree species found in Washington State and Kitsap County (Table 18).

[845] Associated Press. 2017. Invasive green crabs found off Olympic Peninsula. *Seattle Times.* www.seattletimes.com/seattle-news/invasive-green-crabs-found-off-olympic-peninsula/

[846] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

[847] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.

[848] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.

Table 18. Insects, Diseases, and Their Most Common Host Trees Found in Washington State[849]

Insects	Host
Mountain pine beetle	Lodgepole, ponderosa, white pines
Spruce beetle	All species of spruce
Douglas-fir beetle	Douglas-fir (average age of 120)
Western hemlock looper	Western hemlock, Douglas-fir, western redcedar
Western spruce budworm	Douglas-fir, subalpine fir
Diseases	**Host**
Swiss needle cast	Douglas-fir
White pine blister rust	All North American white pines
Cedar leaf blight	Western redcedar
Rhabdocline needle cast	Douglas-fir

Figure 57. Swiss Needle Cast Effect on Douglas-Fir Trees[850]

[849] Table adapted from Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment.
[850] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.

Increasing temperatures, changing precipitation rates, and food web disruptions are projected to further increase the range and intensity of invasive species and diseases in Kitsap County and the Puget Sound region.[851] Climate change is projected to affect the survival rates, distribution, and effect of pathogens and species that are currently and potentially invasive. Projected increases in air temperatures and changes in precipitation rates are likely to allow invasive species to establish themselves in regions of Puget Sound that historically were unsuitable, particularly in areas of higher elevation.[852,853]

The frequency and severity of aquatic pests and diseases are projected to increase with decreasing streamflow and rising air and water temperatures.[854] Rising stream temperatures can shift the distribution of pathogens, increasing the rate of infection among salmon and other fish species and compromising their ability to fight infections.[855] Rising air and water temperatures allow disease and pathogens to multiply at much faster rates. Combined with thermal stress and reduced fish resistance to diseases, this leads to a substantial increase in fish mortality.[856] Rivers in the Puget Sound basin and Kitsap County are projected to exceed the thermal tolerances of various fish species, and it has been found that freshwater above 60°F increases the risk of mortality related to infection.[857,858]

Eelgrass beds are a key component of Kitsap County ecosystems, offering food and shelter for a variety of species, including salmon and crabs. Historically, eelgrass beds have been resilient to diseases and climate impacts, but they are sensitive to impacts from development and nutrient and pollution runoff.[859]

The effect of Swiss needle cast, sudden oak death, and bark beetles are expected to decline due to projected increase in air temperature and decreases in summer water resources. In contrast, impacts from *Armillaria* root disease, which affect conifer and hardwood trees in the Puget Sound region, is projected to increase as a result of warming air temperatures and decreasing summer water availability.[860] Climate change projections are anticipated to change host-pathogen relationships in a way that will increase the impact of diseases and pathogens and altering local phenology—that is, plant and animal lifecycles, like flowering, pollinator cycles, and migration. Furthermore, changes in climate are likely to make conditions more habitable for invasive species and pests, driving native terrestrial species to higher elevations and to new regions.[861] The impacts climate change will have on the interactions of these new invasive species, pests, and diseases with local ecosystems is currently uncertain.[862]

[851] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[852] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[853] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[854] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[855] Mauger *et al.* 2015. Section 10: Freshwater Ecosystems.
[856] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[857] See Chapter 12. Habitat. Finding 2: Freshwater and Aquatic Habitat.
[858] McCullough, D.A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. Environmental Protection Agency, Region 10, Seattle, WA. www.critfc.org/wp-content/uploads/2012/11/EPAreport_2.pdf.
[859] Mauger *et al.* 2015. Section 11: Marine Ecosystems.
[860] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.
[861] Port Gamble S'Klallam Tribe Natural Resources Department. 2016.
[862] Mauger *et al.* 2015. Section 9: Terrestrial Ecosystems.

Projected increases in frequency and intensity of invasive species, pests, and diseases will impact native habitats and have direct and indirect impacts on communities and major industries in the Puget Sound region. However, specific projections on impacts to Kitsap County are unavailable and difficult to specify due to the intricacies of host and species interactions. Projected increases in the frequency and severity of invasive species and disease will likely damage both commercially and culturally important wildlife and traditional plants, berries, roots, seeds, shellfish, and fish species.[863,864] Communities including the Port Gamble S'Klallam Tribe, Suquamish Tribe, and local commercial fishing fleets are expected to be most at risk from associated impacts of invasive species, pests and diseases. Impacts to shellfish and salmon can have economic, cultural, and subsistence consequences, and in the case of the Port Gamble S'Klallam and the Suquamish Tribes, can cause significant losses to Tribal identity and culture.[865] As climate change impacts continue to be felt, fisheries will need to practice active management to maintain fish and aquatic habitats and populations.[866] Furthermore, it is important to note that invasive species, pests, and diseases may have indirect impacts to those who use those resources for food, recreation, or both.[867,868]

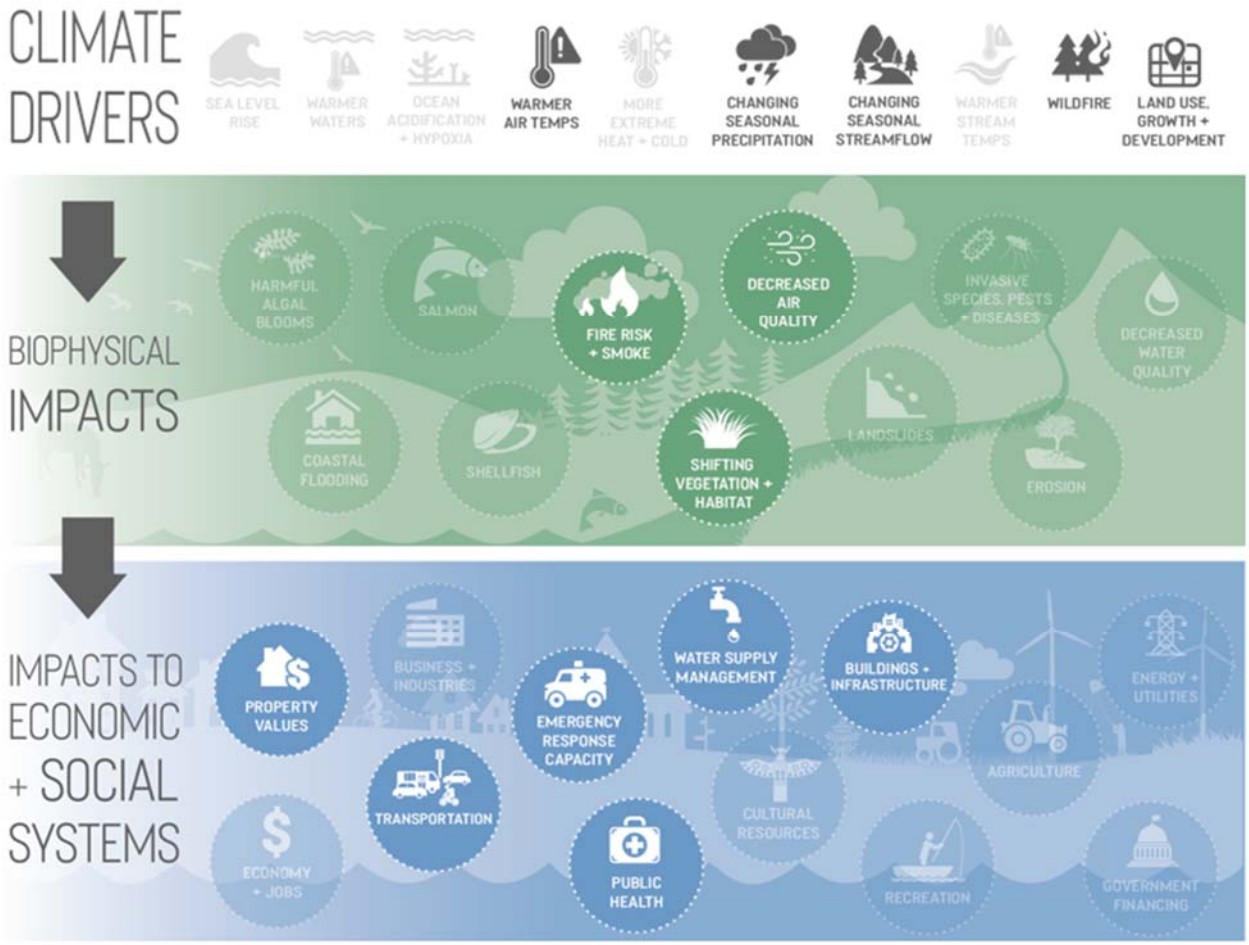
[863] May *et al.* 2018.
[864] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment.
[865] Port Gamble S'Klallam Tribe Natural Resources Department. 2016. Climate Change Impact Assessment.
[866] May *et al.* 2018.
[867] May *et al.* 2018.
[868] See: Chapter 3. Health. Finding 4: Vector-borne Diseases.

Chapter 13. Fire

Summary of Findings

Large wildfires have been a naturally occurring event in Kitsap County's historical fire regime, though these events are rare. Due to the lack of historical data, confident projections are not available for future wildfire risk in Kitsap County, although warmer and drier projections suggest that drier fuel sources create conditions that lead to increased fire risk. If future growth mirrors the historical population growth and the concurrent development of wildlands, fire risk will increase as development expands adjacent to wildland areas. Additionally, the collective increase of fire risk in Washington and the Pacific Northwest due to regional warming, more frequent droughts, reduced snowpack, and limited summer water supply may lead to negative externalities for Kitsap County residents and businesses, such as health risks due to poor air quality. Though uncertainty remains, there may likely be increased future demand for Kitsap County's fire response services. Future climate impacts that reduce summer water supplies may also hinder firefighting capacity.

Figure 58. Relationship between Changes in Climate, Associated Biophysical Impacts, and Impacts to Economic and Social Systems, Highlighting Links to Fire Risk



Key Findings	Magnitude of Impact & Key Metrics	Timeline
1. Wildfires	**Medium** • Confident projections for future wildfire frequency and intensity are not available for Kitsap County, although warmer and drier conditions in the future will likely increase the risk of moderate and small fires [*medium confidence*].	**Near-term & Long-term** • Fire risk and wildfire seasons will increase due to warmer temperatures, less summer precipitation, and less snowpack [*high confidence*]. • Western Washington is projected to experience 43 very high fire danger days for the 2020s and 48 very high danger days annually by the 2050s [*high confidence*]. • Increased fires can reduce Kitsap County's air quality and affect Puget Sound's salmon populations in the near and long term [*medium confidence*].
2. Wildland-Urban Interface (WUI)	**Medium** • The increase in wildland-urban interface area has not been linked to future increased wildfire risk; however, warmer and drier conditions in addition to population growth and development may increase wildfire risk [*medium confidence*].	**Near-term & Long-term** • WUI growth may increase fire risk due to compounding impacts of climate change, development, and the choices of individual residents [*medium confidence*].
3. Emergency Response Demand	**Medium** • It is uncertain how climate change will affect future emergency response demand; however, it is important to consider climate impacts to emergency response demand such as wildfires blocking transportation routes [*medium confidence*].	**Long-term** • Kitsap County already has a strong capacity to respond to fires. Long-term uncertainty remains on the additional future demand for fire emergency response services [*medium confidence*].

Finding 1: Wildfires

Wildfires are a natural part of Kitsap County's forests and wildlands, though major wildfires have been rare in Kitsap County. Due to insufficient historical data, confident projections are not available for future wildfire frequency and intensity for Kitsap County, although warmer and drier conditions in the future will likely increase the risk of moderate and small fires. Increased wildfire risk across the Western Cascades may have spillover impacts for county residents.

Wildfires are a natural part of the county's forests and wildlands, though major wildfires have been rare in Kitsap County. Wildfires are a natural part of the ecological and cultural ecosystem in western Washington, though causative associations between western Washington fires and climate change are less clear.[869]

[869] Morgan *et al.* 2019. Managing Washington Wildfire Risk in a Changing Climate. Workshop summary report prepared by the Northwest Climate Adaptation Science Center and the Climate Impacts Group, University of Washington, Seattle.

Documentation is limited about the history of wildfires in Kitsap County, though evidence suggests that there were major fires approximately 450, 480, 540, and 670 years ago.[870,871] On Bainbridge Island, fire conditions have been defined as moderately different than historic fire regimes.[872] Western Washington fire regimes suggest that major fires occur approximately every 100-150 years, although medium-size fires occur every few decades and small fires (a few acres) occur every year in parts of Kitsap County.[873,874] Though large wildfires (100,000 to 1,000,000 acres) west of the Cascades are much rarer than in eastern Washington, examples of large wildfires include the 1933 Tillamook fire and the 1902 Yacolt fire.[875]

Though wildfire trends are not as clearly established within Kitsap County, wildfire frequency and intensity have increased since the 1980s due to warmer and drier conditions across the western United States.[876,877] Though most of these fires have not occurred within the county's borders, recent fires have caused smoky conditions in western Washington, including Kitsap County.[878]

Due to insufficient historical data, confident projections are not available for future wildfire frequency and intensity for Kitsap County, although warmer and drier conditions in the future will likely increase the risk of moderate and small fires. Kitsap County, and much of the Puget Sound area, has not been known historically to have frequent wildfires.[879] Across Washington and the western United States, fire risk and wildfire seasons will increase due to warmer temperatures, less summer precipitation, and less snowpack.[880] Projections, on average, indicate that western Washington will experience 43 very high fire danger days for the 2020s and 48 very high danger days by the 2050s, up from 36 days from the 1971–2000 period.[881]

Cumulatively, these climate conditions will likely lead to interconnected impacts of increased wildfire risk and increased risk of pests and diseases.[882] Data are currently insufficient for the Puget Trough ecosection (Figure 59), where Kitsap County resides, to make confident projections for future fire frequency and intensity. However, there may likely be an increase in fire risk for Kitsap County, especially moderate and small fires, due to warmer temperatures and drier conditions and a growing area of wildland-urban interface.[883,884,885,886]

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[870] Bainbridge Island Fire Department. 2010. Bainbridge Island Community Wildfire Protection Plan. Prepared by the Bainbridge Island Fire Department and Peninsula College. www.dnr.wa.gov/publications/rp_burn_cwpp_bainbridgeIsland.pdf?jjjhnj.
[871] Kitsap County Department of Emergency Management. 2015. Kitsap County, Washington Hazard Identification and Vulnerability Assessment. www.kitsapdem.org/pdfs/kc_plans/Kitsap%20County%20HIVA%202015.pdf.
[872] Bainbridge Island Fire Department. 2010.
[873] Kitsap County Department of Emergency Management. 2015.
[874] Bainbridge Island Fire Department. 2010.
[875] Morgan *et al.* 2019.
[876] Westerling, A.L. 2016. Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring. *Philosophical Transactions of the Royal Society B.* 371: 20150178. http://dx.doi.org/10.1098/rstb.2015.0178.
[877] Wehner *et al.* 2017. Droughts, floods, and wildfires. In: *Climate Science Special Report: Fourth National Climate Assessment.* Volume II: pp. 231-256 doi: 10.7930/J0CJ8BNN.
[878] See Chapter 3. Public Health. Finding 2: Respiratory Illnesses.
[879] Morgan *et al.* 2019.
[880] Wehner *et al.* 2017.
[881] Morgan *et al.* 2019.
[882] Mote *et al.* 2014.Ch. 21: Northwest. Climate Change Impacts in the United States: The Third National Climate Assessment. pp. 487-513. doi:10.7930/J04Q7RWX.
[883] Hansen *et al.* 2016.
[884] Morgan *et al.* 2019.
[885] See: Chapter 13. Fire. Finding 2: Wildland-Urban Interface (WUI)
[886] Bainbridge Island Fire Department 2010.

Increased wildfire risk across the Western Cascades may have spillover impacts for Kitsap County residents. Within western Washington, the future area burned in the Western Cascades ecosection (Figure 59) is projected to triple by 2040 (from 2,700 acres to 8,000 acres per year).[887] Though Kitsap County is not located within this ecosection, increased fires may have implications for the county's air quality and affect Puget Sound's salmon populations.[888]

Figure 59. Ecosections Used for Subregional Fire Modeling[889]

Finding 2: Wildland-Urban Interface (WUI)

The area of Kitsap County that is considered part of the wildland-urban interface (WUI) has been growing since the 1990s, mirroring national trends of decentralized urbanization. Although the increased Kitsap WUI area has not been specifically linked to future increased wildfire risk, warmer and drier conditions coupled with population growth and development will increase relative wildfire risk for Kitsap County.

The area of Kitsap County that is considered part of the wildland-urban interface (WUI) has been growing since the 1990s, mirroring national trends of decentralized urbanization. Much of the U.S. population is becoming less concentrated in urban areas and moving to suburban, exurban, or rural areas.[890] Decentralized

[887] Morgan *et al.* 2019.
[888] May *et al.* 2018. Chapter 24: Northwest. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment. Volume II: 1036–1100. https://nca2018.globalchange.gov/chapter/24/.
[889] Littell *et al.* 2013. Chapter 5: Forest Ecosystems: Vegetation, Disturbance, Economics. In *Climate Change in the Northwest: Implication for our Landscapes, Waters, and Communities*. 271 pp. http://cses.washington.edu/db/pdf/daltonetal678.pdf.
[890] Martinuzzi, S., S.I. Stewart, D.P. Helmers, M.H. Mockrin, R.B. Hammer, and V.C. Radeloff. 2015. The 2010 wildland-urban interface of the conterminous United States. Research Map NRS-8. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 124 pp.

growth has resulted in development of areas on the fringe of urban metropolitan areas, resulting in the conversion of land to residential development and an increase of areas considered to be part of the WUI, or areas where human development meets and mixes with undeveloped wildland.[891,892] Kitsap County's population growth has grown 7.4% between 2010 and 2018 (251,143 to 269,805), mirroring national growth, as many people have moved to Kitsap County over the past decade because of its proximity to Puget Sound urban centers, subsequently expanding the area that is considered part of the WUI (Figure 60).[893,894]

Although the increased Kitsap WUI area has not been linked to future increased wildfire risk, warmer and drier conditions coupled with population growth and development will likely increase relative wildfire risk for Kitsap County. WUI expansion increases the risk of wildfires to rapidly spread across the wildland to urban landscape, potentially resulting in significant costs and damages to infrastructure and result in the loss of human life.[895,896] The increased risk is often due to the land use changes associated with increasing population growth and development as well as higher probability of fires spreading across a landscape due to the additional fuel loads from residences.[897,898] Although there have not been scientific studies in the Puget Sound area on WUI expansion and fire risk, regional and national trends suggest an association between WUI growth and fire risk due to compounding impacts of climate change, development, and individual residents' choices.[899,900] For example, all of Bainbridge Island and parts of Port Orchard has been defined as "at-risk" areas because it is considered to be part of the WUI, as defined by the Healthy Forest Restoration Act.[901,902] Expanding development and WUI areas are partially correlated to increasing fire suppression and response costs, suggesting that Kitsap County and its municipalities and towns may carry additional cost burden of firefighting in the future.[903,904]

[891] Martinuzzi *et al.* 2015.

[892] Radeloff, V.C., R.B. Hammer, S.I. Stewart, J.S. Fried, S.S. Holcomb, J.F. McKeefry. 2005. The wildland-urban interface in the United States. *Ecological Applications*. 15: 799-805.

[893] U.S. Census Bureau. 2019. QuickFacts: Kitsap County, Washington; United States. www.census.gov/quickfacts/fact/table/WA,kitsapcountywashington/PST045219.

[894] Martinuzzi *et al.* 2015.

[895] Bar Massada *et al.* 2009. Wildfire risk in the wildland-urban interface: A simulation study in northwestern Wisconsin. *Forest Ecology and Management*. 258: 1990-1999.

[896] Bar Massada *et al.* 2014.

[897] Bar Massada *et al.* 2014.

[898] Warziniack *et al.* 2019. Responding to Risky Neighbors: Testing for Spatial Spillover Effects for Defensible Space in a Fire-Prone WUI Community. *Environmental and Resource Economics*. 73: 1023-1047. Doi:10.1007/s10640-018-0286-0.

[899] Liu *et al.* 2015. Climate change and wildfire risk in an expanding wildland-urban interface: a case study from the Colorado Front Range Corridor. *Landscape Ecology*. 30(10): 1943-1957. Doi: 10.1007/s10980-015-0222-4.

[900] Morgan *et al.* 2019.

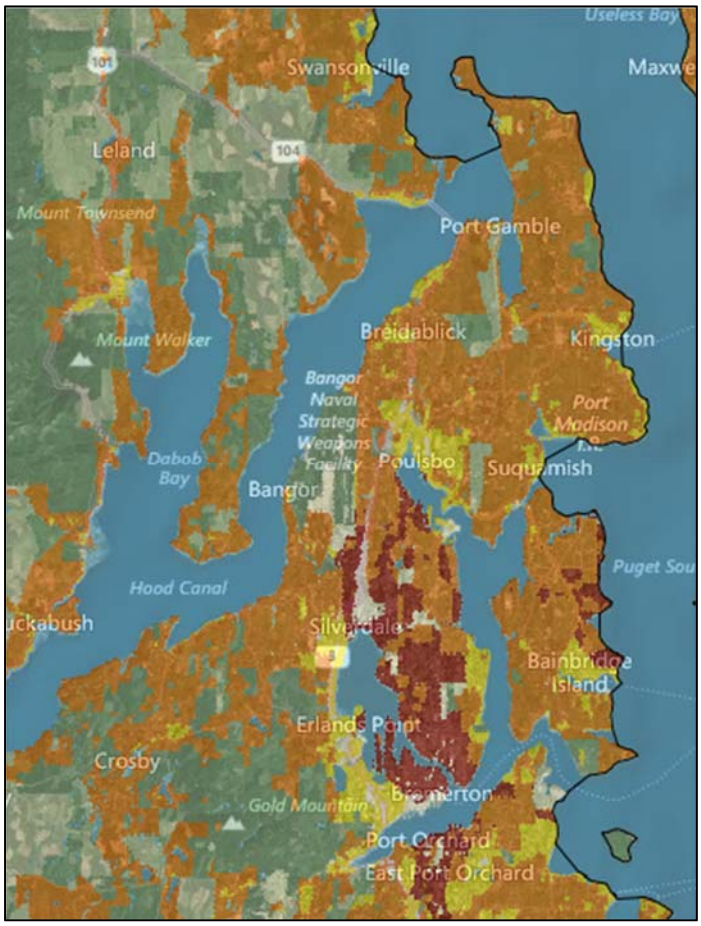
[901] Silvis Lab. Wildland-urban interface (WUI) change 1990-2010. University of Wisconsin-Madison. Accessed 9 January 2020. http://silvis.forest.wisc.edu/data/wui-change/.

[902] Bainbridge Island Fire Department. 2010.

[903] Bainbridge Island Fire Department. 2010.

[904] Gude *et al.* 2013. Evidence for the effect of homes on wildfire suppression costs. *International Journal of Wildland Fire.* 22: 537-548. https://doi.org/10.1071/WF11095.

Figure 60. Wildland-Urban Intermix or Wildland-Urban Interface in Kitsap County[905]
(Yellow areas indicate wildland-urban interface and orange areas indicate wildland-urban intermix. Green areas are non-WUI vegetated areas with no or very low housing density. Gray areas are non-vegetated areas with low housing density, and red areas are non-vegetated areas with medium and high housing density.)



[905] Silvis Lab. Wildland-urban interface (WUI) change 1990-2010.

Finding 3: Emergency Response Demand

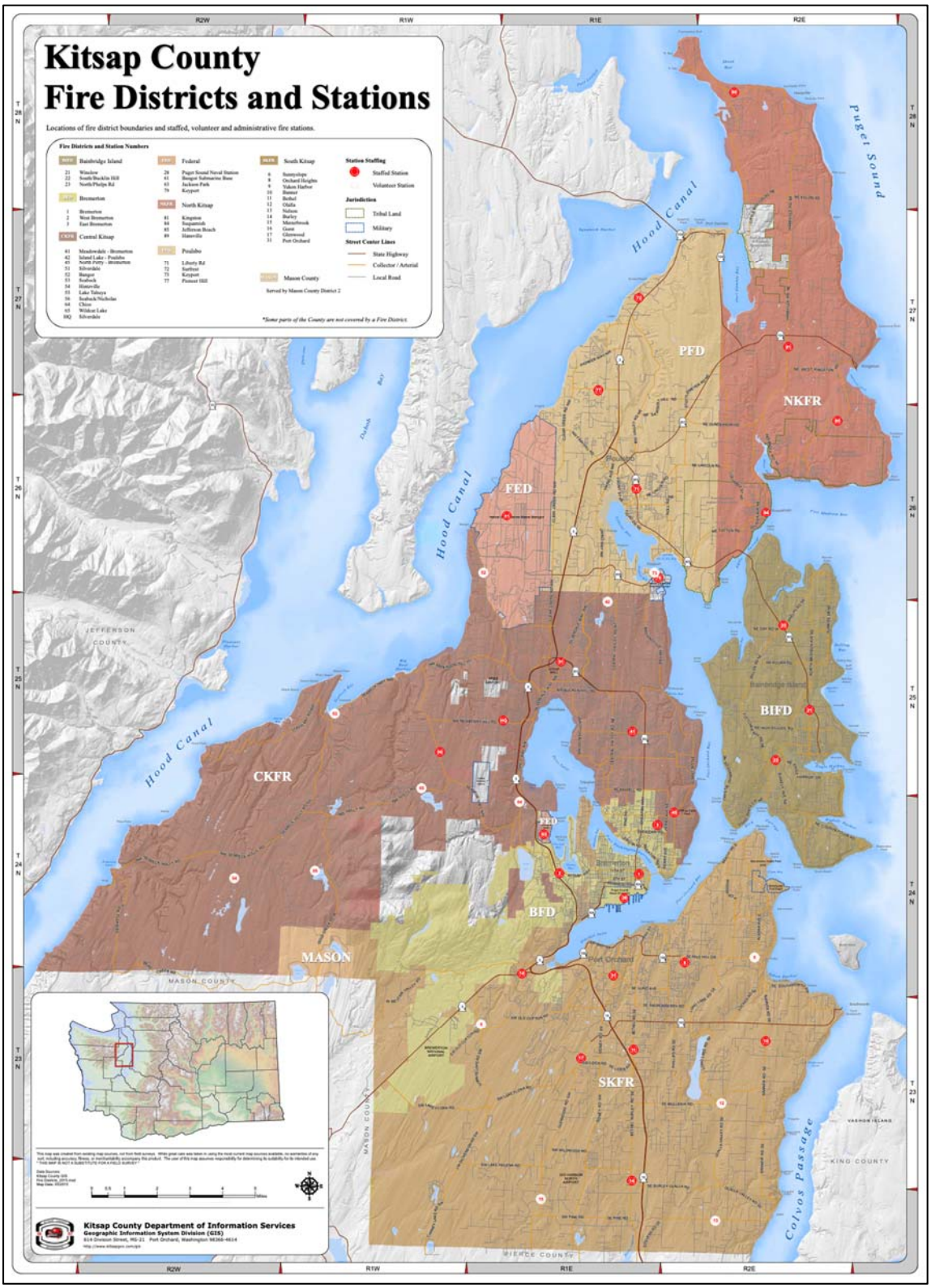
Kitsap County currently has a robust capacity to respond to fires. There is still some uncertainty on the additional future demand for fire emergency response services.

Kitsap County currently has a robust capacity to respond to fires. Kitsap County has multiple fire districts and staffed firefighters based out of 29 fire stations and multiple other volunteer firefighting units that covers most areas of the county (Figure 61).[906] The Bremerton Fire District services the City of Bremerton and some surrounding areas and the South Kitsap Fire and Rescue serves the City of Port Orchard. The Bainbridge Island Fire District has 3 fire stations, 21 response vehicles, 80 members, and special service firefighting vehicles, including engines, boats, ladder truck, rescue truck, special operations vehicle, brush truck.[907] In 2009, the Bainbridge Island Fire District received 2,652 calls, with 73% of the calls (1,995) being emergency medical service calls. Fires have sometimes blocked transportation evacuation routes for response vehicles and residents.[908]

There is still some uncertainty on the additional future demand for fire emergency response services. Despite a robust firefighting response capacity, it is still unclear how climate change will affect future fire emergency response demand, though it is imperative to consider the full range of climate impacts to firefighting. Expanding WUI areas is partly associated with increasing firefighting costs, and it is generally expected that with warmer and drier conditions will lead to an associated cost increase for fire preparedness and firefighting services.[909] If fires affect energy grids, this may affect people's ability to call for emergency response services, especially in rural areas.[910] Additionally, there may be inadequate water supply to respond to fires due to future climate change conditions exacerbating summer water deficits and extending the fire season. [911,912] More understanding is needed on how future fire risk will affect areas in Kitsap County that are currently not covered by fire districts or are located further away from current fire hydrants or water tenders.

[906] Kitsap County Department of Information Services. Kitsap County Fire Districts and Stations. Geographic Information System (GIS) Division, Kitsap County Department of Information Services. www.kitsapgov.com/dis/Documents/fire_districts_stations.pdf.
[907] Bainbridge Island Fire Department. 2010.
[908] Bainbridge Island Fire Department. 2010.
[909] Gude *et al.* 2013.
[910] See Chapter 6. Public Infrastructure. Finding 6: Power and Energy.
[911] Littell *et al.* 2013.
[912] Morgan *et al.* 2019.

Figure 61. Kitsap County Fire Districts and Stations[913]



[913] Kitsap County. 2015. Fire District Stations Map. www.kitsapgov.com/dis/Documents/fire_districts_stations.pdf.

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Appendix A. Port Orchard Climate Impacts

Introduction

This appendix highlights projected impacts of climate change for the City of Port Orchard. Port Orchard is a small but growing city in Kitsap County that is located near other major urban centers in the Puget Sound region. The small city has a strong community spirit and maritime history. This appendix is organized to mirror the organization of the main assessment report, with specific impacts to Port Orchard highlighted.

Figure A-1. Map of Port Orchard