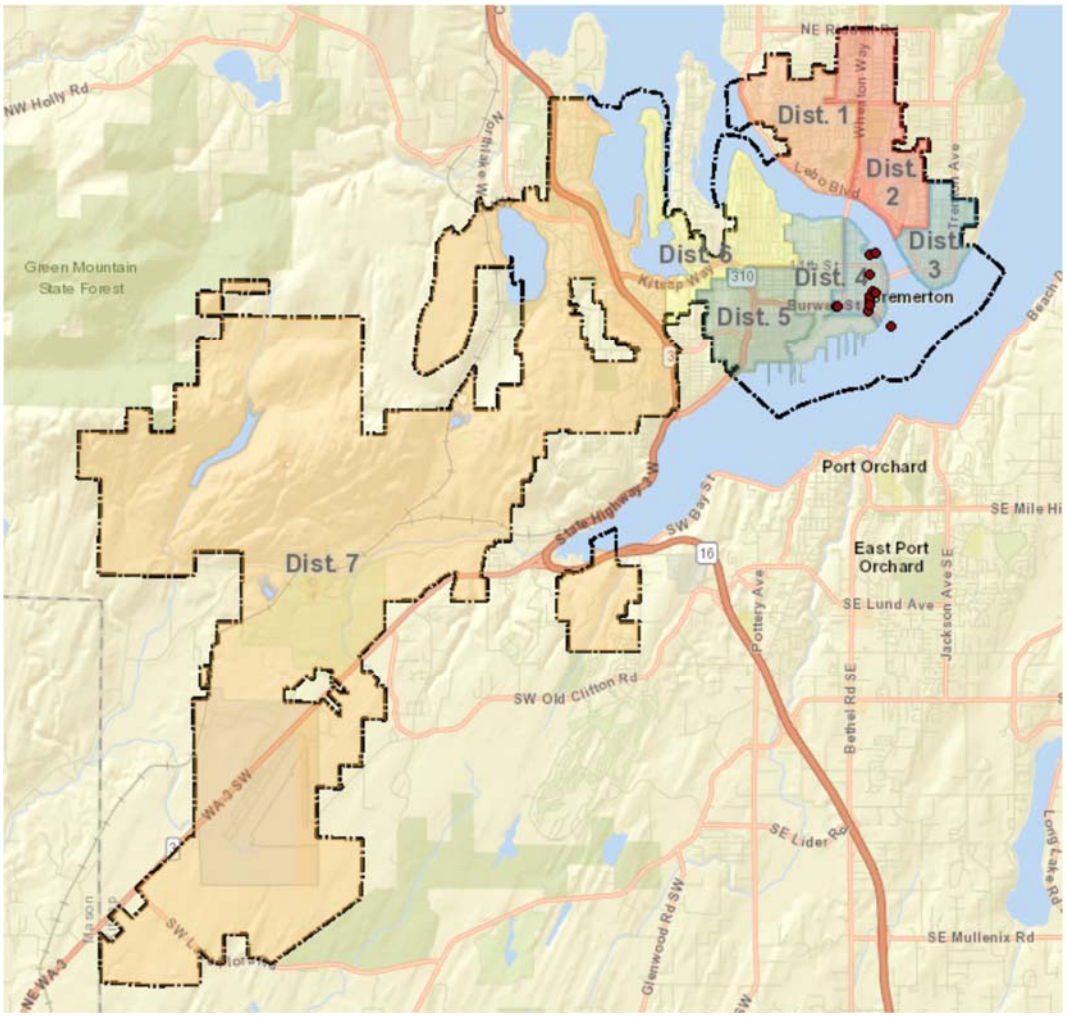
Appendix B. Bremerton Climate Impacts

Introduction

This appendix highlights projected impacts of climate change for the City of Bremerton. Bremerton is the largest city in Kitsap County and serves as a major urban center for western Puget Sound. Bremerton serves as a transition point and transportation gateway between the Olympic Peninsula and eastern Puget Sound, where most major urban centers in the Puget Sound region are located. The city has a strong maritime legacy and naval influence, past and present. This appendix is organized to mirror the organization of the main assessment report, with specific impacts to Bremerton highlighted.

Figure B-1. Map of Bremerton



Future Climate Change Projections

Sea Level Rise

Under the low-emissions scenario (RCP4.5), 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 (RCP8.5), 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 B-1. Probabilistic Sea Level Rise Projections for Bremerton[931]

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 and Bremerton
	90%	47.6°N	122.6°W	0.1	0.3	0.7	SW Bainbridge Island and Bremerton
	95%	47.6°N	122.6°W	0	0.2	0.5	SW Bainbridge Island and Bremerton
	99%	47.6°N	122.6°W	-0.1	-0.1	0	SW Bainbridge Island and 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 and Bremerton
	90%	47.6°N	122.6°W	0.1	0.3	1.1	SW Bainbridge Island and Bremerton
	95%	47.6°N	122.6°W	0.1	0.2	0.8	SW Bainbridge Island and Bremerton
	99%	47.6°N	122.6°W	-0.1	0	0.3	SW Bainbridge Island and 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

[931] See all Kitsap County sea level rise projections in Appendix D. Sea Level Rise Projections, Likelihood Maps, and Graphs.

Other Future Climate Projections

In addition to localized sea level rise projections, Bremerton is likely to experience climate impacts comparable to other parts of the Puget Sound region. These impacts include the following:

- **Warmer surface and subsurface marine waters**. Regional models project a 2.2°F temperature increase by mid-century (2030-2059) under moderate emissions scenarios.
- **More acidic oceans** and **more intense and frequent low dissolved oxygen events** and dead zones.
- **Warmer air temperatures**, with expected warming of 4.9°F by end of century under RCP4.5 and 8.5°F by end of century under RCP8.5.
- An **increase in the number of extreme heat days** during the summer and **decrease in freeze-free days** during the winter.
- **Increased intensity of maximum 24-hour precipitation events**.
- **Changes in seasonal precipitation patterns,** with **increased winter precipitation** and **decreased summer precipitation**.

Climate Impacts

Public Health

Many of the public health impacts associated with future climate change in Bremerton are likely to reflect countywide health impacts. Health impacts include:

- **More heat-related illnesses and deaths** from more frequent heat waves. This will particularly affect **outdoor laborers, elderly people, and youth**.
- The **urban heat island effect**, or the tendency of buildings and pavement to absorb and emit heat leading to a higher ambient temperature in urban areas, is likely to be more of an challenge for Bremerton, given its urban density, than other areas in Kitsap County.
- **More acute and chronic respiratory illnesses** with air quality degradation from regional wildfires and longer pollen seasons.
- **More acute injuries directly associated with extreme events**, such as flooding, winter storms, and landslides. There may also be additional injuries or deaths associated with disruption of medical services and communication channels.
- **Increased prevalence of vector-borne diseases**, such as West Nile virus, Lyme diseases, paralytic shellfish poisoning, and *C. gattii*.
- **Increased food insecurity**, especially for those who are reliant on natural resources for jobs and wages.
- **Potential increases in mental health illnesses** (e.g., post-traumatic stress disorder, anxiety, depression). Children and people dependent on natural resources face a higher risk of mental health illnesses linked to climate change.
- 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.**
- Long-term climate impacts will likely continue **stress the regional health and social safety net**.

Economy

Bremerton's industries are diverse, and include healthcare and social assistance, retail trade, accommodation and food services, manufacturing, and public administration. Additionally, there are some industries related to natural resources (farming, fishing, and forestry), firefighting and prevention, and grounds cleaning and maintenance operations.[932] Though this latter group of industries represents a smaller percentage of the industries and workforce in Bremerton, many of these workers may be more vulnerable to economic disruption from climate change. Outdoor laborers are likely to experience lost labor hours due to extreme heat and poor air quality during the summer. Lost labor hours from future climate change is the biggest economic damage from future climate change across the Pacific Northwest.

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.[933] Impacts to that facility will ripple through the rest of the county's 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 approximately 45,500 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 include the maritime services and transportation industries, such as shipbuilding and maintenance, shipyard workers, and ferry and boat workers that also contribute much to the regional Puget Sound maritime economy.[934]

Climate change may also affect housing values and buildable land for Bremerton, especially for many of its low-lying coastal residences. The average housing sales value for Bremerton is $232,430 (reported in 2019).[935] Future sea level rise, storm surges, and flooding events could lead to decreased values for these properties.

Cultural Resources

There are 21 nationally registered historic places and 201 archaeological sites in Kitsap County. In Bremerton, places and districts listed in the National Register of Historic Places include the following locations:

- Bremerton Elks Temple Lodge No. 1181 Building (285 Fifth Street).
- Coder-Coleman House (904 Highland Avenue).
- Hospital Reservation Historic District (roughly bounded by Mahan Avenue, Hoogewerf Road, Decatur Avenue, and Dewey Street).
- Marine Reservation Historic District (bounded by Cole Street, Dewey Street, Decatur Avenue, and Doyen Street).
- Navy Yard Puget Sound (also known as Bremerton Navy Yard and Puget Sound Naval Shipyard, located along the north shore of Sinclair Inlet).

[932] https://datausa.io/profile/geo/bremerton-wa/.
[933] Kitsap County. 2019. Budget Book. Available at Kitsapgov.com. page 35.
[934] Kitsap Economic Development Alliance. Maritime.
[935] Kitsap County Assessor Single Family Residence Sales History. 2020

- Officers' Row Historic District (roughly bounded by Mahan Avenue, Decatur Avenue, and Coghlan Road).
- Port Washington Narrows Bridge (also known as Bridge Number 303/12, located on State Route WA-303 over Washington Narrows).
- Puget Sound Radio Station Historic District (roughly bounded by Mahan Avenue, Coghlan Road, and Cottman Road).
- Shelbanks (also known as Kean Cabin, located at 1520 Shorewood Drive)—see Figure B-2.
- U.S. Post Office—Bremerton Main (602 Pacific Avenue).
- U.S.S. Hornet (also known as CVS-12, located in the Puget Sound Naval Shipyard on Sinclair Inlet).

Historic places in or near the floodplain will likely face future damages from flooding, storm surges, and sea level rise. Maintenance costs and operations of these historical buildings may be affected due to future climate change. Similarly, recreational opportunities, parks, and monuments may face similar impacts.

Figure B-2. Shelbanks (Kean Cabin) in Bremerton[936] *(photo from Kitsap County Historical Society & Museum)*

Public Infrastructure

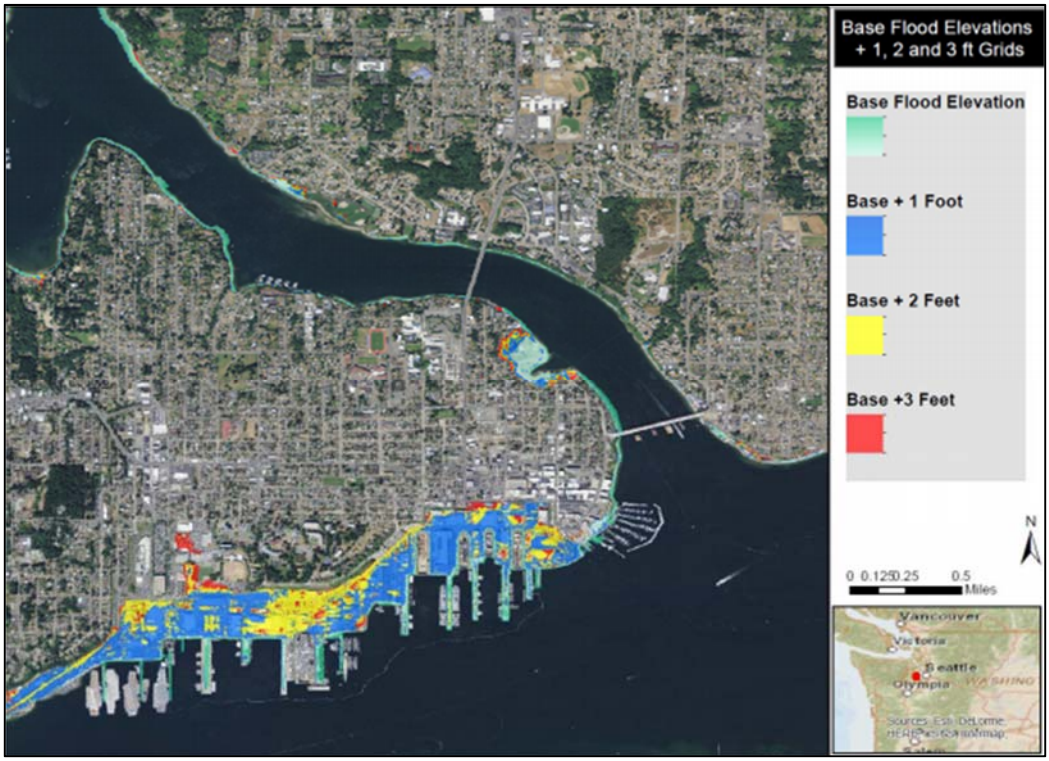
Climate impacts to public infrastructure in Bremerton is salient to understand because of Bremerton's importance as a regional hub for western Puget Sound. Specific impacts could include:

- **Potential disruption of transportation routes and damage to ferry terminal**. Any damage to transportation infrastructure will affect local and regional connectivity.
    - Heavy rains, sea level rise, flooding events, and heat waves could affect the Bremerton Airport, state highways, and ferry infrastructure and operations.
    - Bremerton's ferry terminal operates ferries from Kitsap Transit (ferries between Bremerton/Port Orchard, Bremerton/Annapolis, and Bremerton/Seattle) and Washington State Ferries (Bremerton/Seattle).

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

- Potential **overload and damage of stormwater and wastewater infrastructure** from flood inundation and/or saltwater intrusion.
    - Current observed trends have shown that stormwater outfalls in Bremerton have been inundated from sea level rise and heavy precipitation.[937]
    - In recent years, Bremerton has dealt with higher than normal saltwater concentrations in its wastewater systems resulting in additional operating costs and implications for water quality compliance.[938]
- More **frequent flooding of low-lying coastal infrastructure**, including roads, structures, and public facilities.
    - This could disrupt access for Bremerton residents. For example, State Route 3 through Gorst frequently floods during heavy rain events and storms.
    - Naval Base Kitsap in Bremerton will likely be affected by future sea level rise and flooding events.[939]
    - There have been 5 flood insurance claims through FEMA's National Flood Insurance Program, with an estimated flood insurance coverage of $15 million.[940]
- **Degradation of public infrastructure** from flooding, saltwater intrusion, and extreme heat.
- **Disruption of power and energy** to residents and businesses during extreme events.

Figure B-3. 1% Annual Change Floodplains for Bremerton at 1 Foot, 2 Feet, and 3 Feet[941]



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

[938] 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/.

[939] 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.

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

[941] FEMA. 2015.

Land Use and Development

Climate change is likely to affect future land use development. Future development in Bremerton may be impacted by future sea level rise, storm surges, and flooding. Anticipated major developments include the Harbor Square mixed-use development; 100,000-square-foot industrial warehouse for Puget Sound Industrial Center; and new developments at Port of Bremerton. Future climate change may also affect buildable land, zoning, land cover types, and vegetation cover for Bremerton. However, land use decisions can worsen or mitigate future climate change. For example, increasing green spaces can offset heat island effects and provide natural flood control.

Agriculture

There are several working farms and nurseries in and around Bremerton. Any negative impact of climate change will have detrimental effects for agricultural economics and livelihoods. Future climate change impacts to crops, nurseries, and livestock include the following:

- Potential competing interests of future irrigation demand and limited summer water availability.
- Benefits to some crops that will thrive in warmer temperatures and increased carbon dioxide concentrations, which could extend growing seasons.
- Expansion of pest and disease ranges, which could lead to decreased agricultural productivity.
- More frequent flooding, which could lead to decreased yields.

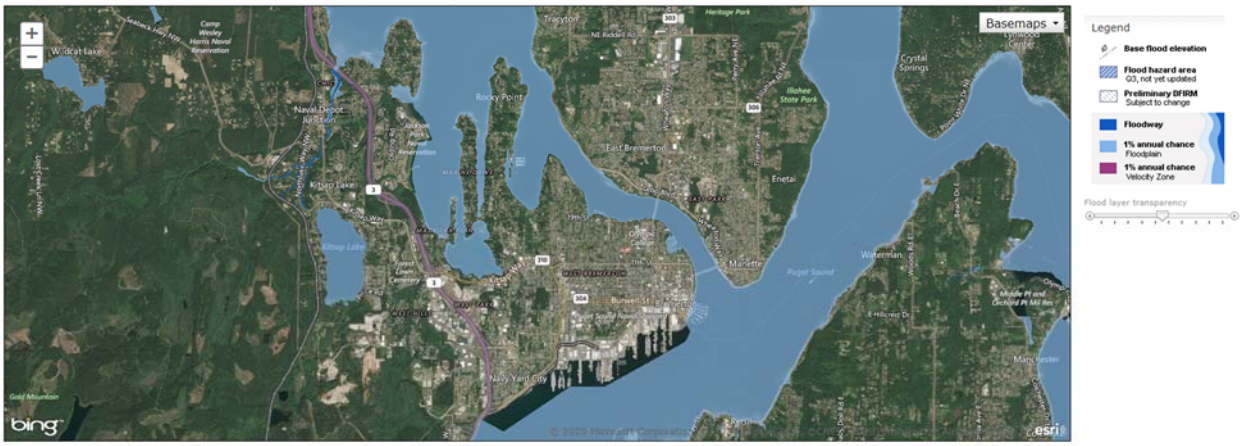
Local Government Finance

Insurance premiums could increase in the future due to climate change. In particular, insurance costs for structures and buildings within the flood zone is likely to increase as the risk of damages from flooding will increase due to sea level rise and storm surges (Figure B-4).

In 2019, Bremerton received a credit rating upgrade to Aa2 from Moody's Investors Service.[942] Although municipal bonds for Kitsap County and Puget Sound are relatively resilient compared to other urban areas in the U.S., municipal bonds for Kitsap County localities may also be adversely affected in the future, especially if future extreme weather events increase in frequency and intensity. Furthermore, tax revenue may be affected from future climate change and regional growth trends, especially if developers and potential residents are deterred from investing in Bremerton properties due to perceived climate-related risks.

[942] 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.

Figure B-4. FEMA Flood Insurance Maps for the 1% Annual Chance Floodplain for Bremerton
(Flood insurance rate maps outline flood hazards in a community and includes flood insurance risk zones, 1% and 0.2% annual chance floodplains.)



Geologic and Natural Hazards

There is a range of geologic and natural hazards that will increase due to future climate change. Landslide risk will likely increase due to heavier rain events, soil erosion and destabilization, and sediment transport patterns. There have been 6 LIDAR-defined landslides in Bremerton, affecting about 1.1 square miles. Approximately 1,800 people, or about 4.8% of Bremerton's population, live in landslide hazard areas. Additionally, about 4.5% of Bremerton's building stock, or 625 structures, and 64 critical facilities are located within the landslide hazard area.[943]

Furthermore, there is very high likelihood that coastal flooding from sea level rise and storm surges will increase in frequency and intensity. From FEMA and U.S. Census data, flood damages and insurance claims have totaled $15 million for Bremerton (dollar year not reported).[944] Future flooding will result in more damages, which will subsequently affect insurance rates and property values.

Hydrology and Hydrogeology

Bremerton is likely to see similar climate impacts to hydrologic and hydrogeologic systems as Kitsap County. Key impacts could include:

- **Groundwater recharge** may be affected by hydrologic changes, including from increasing water temperatures, sea level rise, and declining summer flows.
- **Stream and riverine flooding** will become more frequent, which can have widespread health, infrastructure, and habitat impacts.

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

[944] 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.

- **Regional hydropower production** will decrease in the summer months, which may create a mismatch in energy supply and demand with expected increases in energy demand during the summer due to cooling demands.
- **Summer water availability** may affect irrigation capacity for agriculture.

Habitat

Climate change will affect all types of habitat in Kitsap County. Key climate impacts include the following:

- **Terrestrial habitats**
  - Some impacts to vegetation distribution and composition, forest growth and productivity and wildfire regimes are expected to change in lower elevation areas in the Puget Sound region.
  - Prevalence of invasive species and pests will increase, altering habitat types and vegetation distribution.
- **Freshwater and aquatic habitats**
  - Regionally, warmer stream temperatures and lower spring and summer flows will affect cold-water fish species across multiple life-cycle stages.
  - Wetland habitats are likely to contract, threatening habitats for a variety of species and shelter for juvenile fish.
  - Climate impacts to aquatic benthic invertebrates, amphibians, and salmonids will have downstream ecosystem and food-web impacts.
- **Marine and coastal habitats**
  - Marine waters around Kitsap County will likely experience increased acidification, more frequent growth of harmful algal blooms (HABs), and more frequent low dissolved oxygen events and dead zones. This will have impacts to shellfish populations, reduce benthic invertebrate and crustaceans, and alter marine food webs.
- **Increased prevalence of invasive species and diseases** across all habitat types. Novel and new species and diseases could emerge in the future. Currently known invasive species and diseases known include:
  - Invasive tunicates
  - European green crabs
  - New Zealand mud snail
  - Varnish clams
  - Giant hogweed
  - Tansy ragwort
  - Purple loosestrife
  - Hydrilla
  - Parrotfeather
  - *Ichthyophonus hoferi*
  - Harmful algae
  - *Alexandrum catanella*
  - Mountain pine beetle
  - Spruce beetle
  - Swiss needle cast

Fire

Kitsap County's wildland-urban interface (WUI) area has not been linked to future increased wildfire risk. However, 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.[945,946] 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.[947,948]

Although there has been no scientific studies in the Puget Sound area on WUI expansion and fire risk, regional and national trends are suggesting that there is an association between WUI growth and fire risk due to compounding impacts of climate change, development, and individual residents' choices.[949,950] For example, **parts of Bremerton have been defined as "at-risk" areas because the area is considered to be part of the WUI, as defined by the Healthy Forest Restoration Act**.[951,952] Expanding development and WUI areas are partially correlated to increasing fire suppression and response costs, suggesting that Kitsap County and its municipalities may carry additional cost burden of firefighting in the future.[953,954]

Kitsap County already 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 County area.[955] The Bremerton Fire District provides services to the City of Bremerton and some surrounding areas.

[945] 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.
[946] Bar Massada *et al.* 2014.
[947] Bar Massada *et al.* 2014.
[948] 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.
[949] 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.
[950] Morgan *et al.* 2019.
[951] 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/.
[952] Bainbridge Island Fire Department. 2010.
[953] Bainbridge Island Fire Department. 2010.
[954] 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.
[955] 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.