Climate Conditions Report

City of Olympia Climate Risk and Vulnerability Assessment

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Abbreviations

CMIP	Coupled Model Intercomparison Project
CMRW	Climate Mapping for a Resilient Washington
EPA	Environmental Protection Agency
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
NCCV	National Climate Change Viewer
NCEI	National Centers for Environmental Information
NOAA	National Oceanic and Atmospheric Administration
ORCAA	Olympic Region Clean Air Agency
PM	Particulate matter
RCP	Representative Concentration Pathway
SLR	Sea Level Rise
SRES	Special Report on Emission Scenarios
SSP	Shared Socio-economic Pathway
USGS	U.S. Geological Survey
WUI	Wildland urban interface

Introduction

This Climate Conditions Report provides a summary view of the City of Olympia's exposure to climate-related hazards by synthesizing research and data about current hazards and possible future conditions. Data points from climate projections are included, when available.

Where relevant, this report synthesizes analysis completed as part of other local assessments and planning efforts, including:

- Thurston Climate Adaptation Plan (2018), Science Summary (2016), and Vulnerability Assessment (2016)
- Thurston Region Hazards Mitigation Plan (2017) and The City of Olympia Annex to the Hazards Mitigation Plan for the Thurston Region (2017)
- Olympia Sea Level Rise Response Plan (2019) and Science Review (2017)

Further information was drawn from scientific reports and academic articles, which are referenced in the text.

Definitions

The definitions used in this report are adapted from multiple sources, including the U.S. Climate Resilience Toolkit glossary, Intergovernmental Governmental Panel on Climate Change (IPCC) Annex II 2014 and 2022 glossaries, and other sources as cited [1]–[3]. Note that some definitions have been adapted for readability and relevance.

Atmospheric river: The relatively narrow streams of moisture transport that often occur within and across midlatitudes, so-named in part because they often transport as much water as in the Amazon River [4].

Baseline: The baseline, which may also be referred to as a reference period, is the state against which change is measured [3]. In this report, the baseline typically refers to the average across a modeled historical period.

Climate change: 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 [4].

Climate models: Mathematical models that simulate the physical, chemical, and biological processes that influence the climate system [5]. To learn more about climate models, see: [6].

Climate projections: Simulated responses of the climate system to a scenario of future concentrations of greenhouse gases (GHGs) and aerosols, along with changes in land use, generally derived using climate models. Climate projections vary based on the emission/concentration/radiative forcing scenario used; these scenarios in turn are based on assumptions concerning, for example, future emissions and socioeconomic and technological developments that may or may not be realized [2].

El Niño-Southern Oscillation (ENSO): Basin-wide warming of the tropical Pacific Ocean east of the dateline associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with time scales of 2 to about 7 years, is known as the El Niño-Southern Oscillation (ENSO). ENSO strongly impacts wind, sea surface temperature, and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world through global teleconnections. The cold phase of ENSO is called La Niña [3].

Ensemble modeling: Using a collection of climate model simulations to characterize a climate projection [3].

Exposure: The presence of people, assets, and ecosystems in places where they could be adversely affected by hazards [1].

Extreme weather event: An extreme weather event is an event that is rare at a particular place and time of year. By definition, the characteristics of what is considered an extreme weather event vary from place to place [3].

Greenhouse gases (GHGs): Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth's ocean and land surface, by the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapor, carbon dioxide, nitrous oxide, methane and ozone are the primary GHGs in the Earth's atmosphere [3].

Hazard: An event or trend that may cause injury, illness, or death to people or damage to community assets. In this report the term "hazard" primarily refers to climate-related physical events or trends [1], [3].

King Tide: A non-scientific term used to describe exceptionally high tides that occur several times each year [7].

Pathway: The temporal evolution of natural and/or human systems towards a future state. Pathway concepts range from sets of quantitative and qualitative scenarios or narratives of potential futures to solution-oriented decision making processes to achieve desirable societal goals [8]. Examples include the Representative Concentration Pathways and Shared Socio-economic Pathways.

Radiative forcing: The change in the net, downward minus upward, radiative flux at the tropopause or top of the atmosphere due to a change in an (external) driver of climate change, such as a change in the concentration of carbon dioxide, the concentration of volcanic aerosols or the output of the sun [2].

Representative Concentration Pathway (RCP): Scenarios that include time series of emissions and concentrations of the full suite of GHGs and aerosols and chemically active gases, as well as land use/land cover. Four RCPs are used in the IPCC Fifth Assessment Report, which span the range from approximately below 2°C warming to high (>4°C) warming best-estimates by the end of the 21st century: RCP2.6, RCP4.5, RCP6.0, and RCP8.5 [2]. In 2023, the IPCC released the Sixth Assessment Report, which adopts Shared Socio-economic Pathways (SSPs) to complement the RCPs.

Shared Socio-economic Pathway (SSP): Socioeconomic scenario families that reflect different social, economic, and environmental development trajectories. There are five SSP families, SSP1–SSP5, which reflect different levels of challenge for mitigation and adaptation. Each SSP family is associated with multiple emissions scenarios to provide an indication of warming associated with different development pathways [8]. Some of the SSPs roughly correspond to the RCPs, including: SSP1-2.6 (RCP2.6), SSP2-4.5 (RCP4.5), and SSP5-8.5 (RCP8.5), though warming associated with the SSPs tends to be higher than for the linked RCP [9]. For an overview of the SSPs, see: [10].

Wildland urban interface (WUI): The zone of transition between unoccupied land and human development. It is the line, area or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels [11].

100-year storm tide: A severe, rarely occurring flood event that is a combination of a high astronomical tide and storm surge [12]. The 100-year storm tide has a 1% annual chance of occurring.

About Climate Models and Projections

Climate projections are the outputs of climate models, which are built on a series of assumptions about the earth system and future GHG emissions. Climate projections are not predictions for the future, but should instead be considered as an approximation of the range of possible future conditions. This is why it is important to view them in terms of multi-year averages, ranges, and trends. Climate projections are helpful tools that can be used to inform future planning; however, it is not appropriate to use them as the sole foundation for decision-making [13]. In this report, climate projections are compiled from the National Climate Change Viewer (NCCV), Climate Mapping for a Resilient Washington (CMRW), and Risk Factor platforms [14]–[16].

Most of the projections used in this report are derived from climate models of the Coupled Model Intercomparison Project Phase 5 (CMIP5) developed for the IPCC Fifth Assessment

Report.[1] Stream temperature data uses Coupled Model Intercomparison Project Phase 3 (CMIP3) models, as these are the latest available.

CMIP model output typically has a coarse spatial resolution. To produce finer resolution, locally relevant data, various statistical downscaling techniques are applied. In this report, projection data is provided on the county level. This is because most climate models do not operate at fine-enough scales to yield insights on intra-county variations. For more information about models and downscaling techniques, refer to the data platform technical documentation in the Data Platforms section.

Climate data included in this report uses an ensemble modeling approach. In ensemble modeling, a collection of climate model simulations are used to characterize a climate projection, instead of one model or scenario alone [3]. Using an ensemble approach has been shown to increase the reliability and skill of model projections and help to characterize the level of confidence and uncertainty of results [17].

Except where noted, future projections are compared to the baseline, which is a simulation of historical climate, not historical observations. These historical simulations can also be referred to as modeled history. Projections are presented as averages over 25- or 30-year periods (e.g. 2025-2049), which is standard for analyzing future climatological values. The range of projections (10th to 90th percentiles) is shown in addition to the model median in cases where data platforms make this information available.

Modeling Extreme Events

Modeling risk of extreme events like flooding and wildfire is complex due to the variety of factors at play in these hazards [4]. For flooding, climatic changes in rainfall and snowmelt are key drivers; however, other human and natural factors, including seasonality, urbanization, land use change, dams, and stormwater and agricultural management practices are also highly relevant. Wildfires are also influenced by a myriad of factors, including temperature, soil moisture, humidity, wind, fuel characteristics, land management, and topography.

Extreme storms are particularly challenging to incorporate in climate models because they occur relatively randomly, are rare, and only last for a short period of time [4]. Another

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[1] In March of 2023, the IPCC published the Sixth Assessment Report, which introduced Shared Socio-economic Pathways (SSPs) to complement the RCPs [8]. Many of the tools and resources that make downscaled climate data available have yet to adopt the relatively novel SSPs, which is why the Fifth Assessment RCPs are used in this report. See Table 1 in the "GHG Scenarios" section for a comparison of the RCPs and SSPs.

challenge is that modeling storms requires capturing highly localized, small-scale elements of the climate system [4]. Because storms are compound events that can include wind, precipitation, and flooding, they cannot be represented by “single-indicator” projections.

Risk Factor, a platform that provides community-level data on flood, fire, heat, and wind, uses probabilistic models developed by nonprofit First Street Foundation that take some of these factors into account. This report uses First Street Foundation wildfire models to project how wildfire risk could increase in Olympia in the future. These wildfire models consider fuels (e.g. trees, vegetation, structures), forest and fuel management, probability of ignition (based on historic fires), and weather patterns that support ignition (e.g. dryness) and help fires spread (e.g. wind), as well as future climate projections [18].

GHG Scenarios

GHG scenarios consider GHG emission concentration and land use change based on a set of assumptions about future conditions. Three GHG scenarios are used in this report: RCP4.5 and RCP8.5 (both from CMIP5) and AB1 (CMIP3). See Table 1 to see how the RCPs align with the SSPs and warming associated with each scenario.

Four RCPs are used in the IPCC Fifth Assessment Report, which span the range from approximately below 2°C warming to high (>4°C) warming best-estimates by 2100: RCP2.6, RCP4.5, RCP6.0, and RCP8.5 [2]. Each RCP represents a distinct level of total radiative forcing (or warming effect) on the atmosphere. Climate projections made using RCP4.5 and RCP8.5 are the most commonly available:

- RCP4.5 (sometimes referred to as the “lower emissions pathway”): a moderate stabilization scenario under which emissions peak around 2040, then decline.
- RCP8.5 (sometimes referred to as the “higher emissions pathway”): a high emissions scenario under which emissions continue rising through 2100.

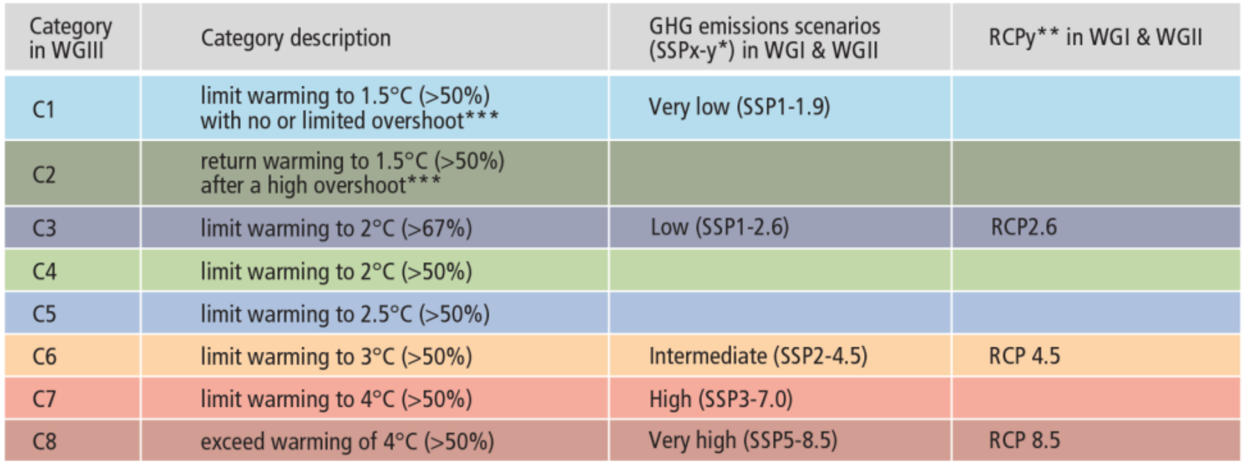
The A1B scenario was created for the 2000 Special Report on Emission Scenarios (SRES) [19]. It is used for projections based on CMIP3 models on CMRW. It is described as a balanced, moderate emission scenario [19]. Stream temperature is the only indicator based on scenario A1B.

This report includes projections from both RCP4.5 and RCP8.5, though projections from RCP8.5 are more frequently referenced in the text and included in the appendix. This decision was made because awareness of—and preparedness for—RCP8.5 reflects a more risk-averse approach (i.e. more of a “worst case” scenario). RCP8.5 is associated with over 4°C of warming by 2100 (Table 1). Note that when considering near-term (2050 and earlier) planning and policy, the choice of scenario (RCP4.5 or RCP8.5) is less important, as projections under RCP4.5 and RCP8.5 do not substantially diverge until after 2050 [20].

Updated models used in the recently published IPCC Sixth Assessment Report indicate (with medium confidence) that pathways linked to >4°C by 2100 (including RCP8.5) now appear to be less likely [9]. Assuming continuation of 2020 policy and technology trends indicates warming in the range of 2.2-3.5°C by the end of the 21st century. However, the report cautions that >4°C could still occur in the case of, for example, global reversals in mitigation policies or greater than anticipated warming-amplifying carbon cycle feedbacks [9].

Some of the RCPs roughly align with the SSPs adopted under the Sixth Assessment Report (Table 1). It is important to note, however, that warming associated with the SSPs "tends" to be higher than the linked RCP [9].

Table 1. Warming trends associated with different scenarios, showing some SSPs and most closely aligned RCPs [9, p. 31]. "Limited overshoot" means exceeding 1.5°C global warming by up to about 0.1°C while "high overshoot" indicates exceedance by about 0.1°C-0.3°C. Notation >50% denotes greater than 50% likelihood for the associated warming outcome.



Category in WGIII	Category description	GHG emissions scenarios (SSPx-y*) in WGI & WGII	RCPy** in WGI & WGII
C1	limit warming to 1.5°C (>50%) with no or limited overshoot***	Very low (SSP1-1.9)	
C2	return warming to 1.5°C (>50%) after a high overshoot***		
C3	limit warming to 2°C (>67%)	Low (SSP1-2.6)	RCP2.6
C4	limit warming to 2°C (>50%)		
C5	limit warming to 2.5°C (>50%)		
C6	limit warming to 3°C (>50%)	Intermediate (SSP2-4.5)	RCP 4.5
C7	limit warming to 4°C (>50%)	High (SSP3-7.0)	
C8	exceed warming of 4°C (>50%)	Very high (SSP5-8.5)	RCP 8.5

Navigating Uncertainty

Human-caused climate change is scientific consensus. However, the precise nature of these changes, including their magnitude, timeline, and local impacts, is less certain. Numerous factors contribute to this uncertainty, including the natural variability of Earth's climate (for example, due to semi-cyclical phenomena such as El Niño), climate model uncertainty, evolving knowledge on the Earth system, and uncertainty around future emissions and land development [21]. The possibility of reaching "tipping points" that trigger major shifts in the Earth's climate system is another contributor. For example, rapid, irreversible loss of the West Antarctic and Greenland ice sheets is a tipping point that could lead to significantly higher sea level rise than currently anticipated [22].

Climate modeling and uncertainty remain an area of active research. Scientific understanding of the Earth system is constantly improving, as are models used to project future climate. Studying historical trends, evaluating multiple climate models (ensemble modeling), considering the range of possible outcomes, and adopting flexible, adaptive management techniques can help planners navigate amidst uncertainty [21].

Regional Summary: The Northwest and Washington State

The Northwest is a geographically and climatologically diverse region of the continental US that includes the states of Washington, Oregon, and Idaho. Climate change—which manifests through both extreme events and gradual shifts in prevailing conditions—is already having profound impacts on the natural environment, built assets, and quality of life in the Northwest. New and growing threats in the region include increasing temperatures, extreme heat, water scarcity, reductions in snowpack, extreme precipitation, flooding, rising seas, and wildfires [23].

Since 1900, recorded temperatures in Washington state have increased by almost 2°F (1.1°C), and warming trends are projected to continue under both the lower (RCP4.5) and higher emissions (RCP8.5) pathways (Figure 1). The annual and seasonal time series panel (Figure 2) shows how mean temperature is projected to change over time. The projections indicate temperature increases across all seasons, with more marked increase occurring under RCP8.5.

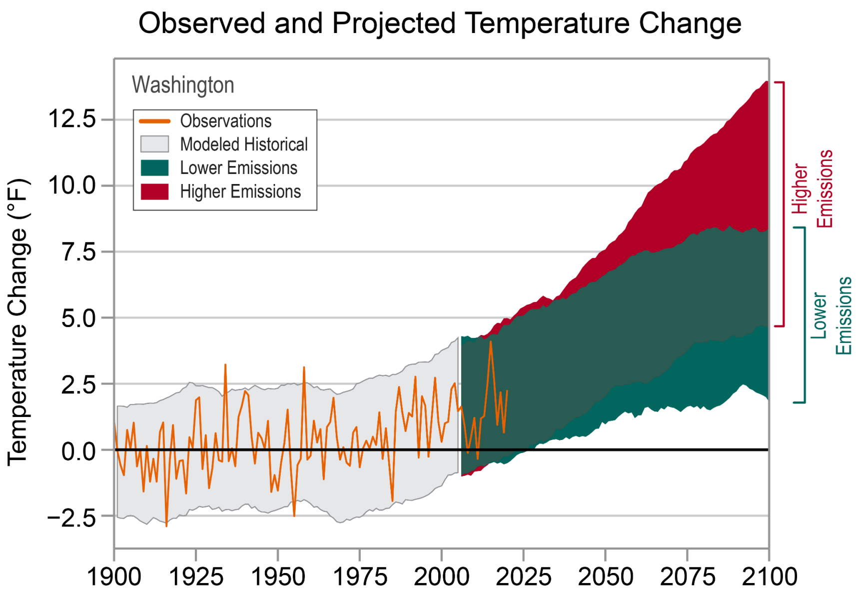


Figure 1. Observed and projected temperature change in Washington state [24]. The lower and higher emissions pathways refer to RCP4.5 and RCP8.5, respectively.

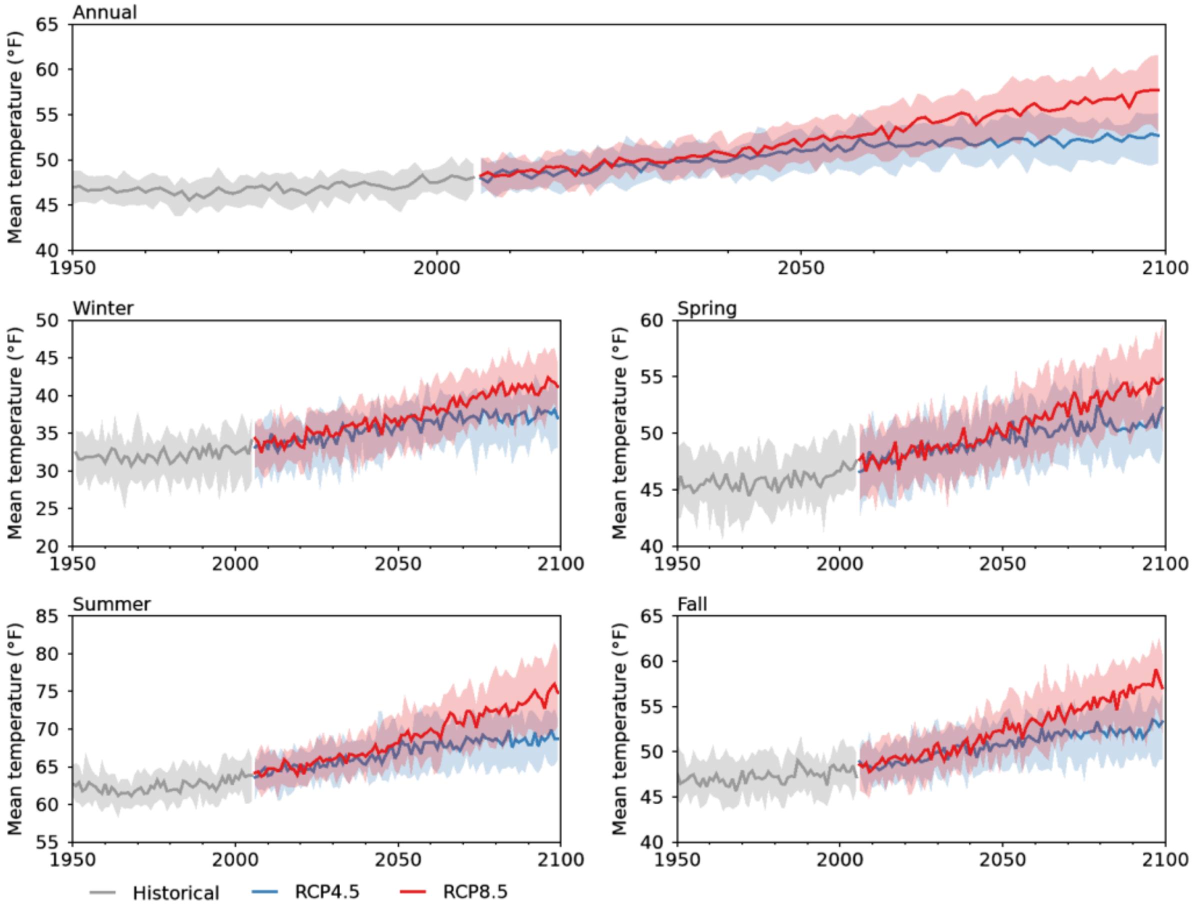


Figure 2. Annual and seasonal time series of mean temperature for baseline (gray), RCP4.5 (blue) and RCP8.5 (red) for Washington State [25]. The historical period ends in 2005 and the future periods begin in 2006. The solid lines show the ensemble median. Shaded areas show the 10th to 90th percentile range of projections.

Though overall precipitation trends in Washington state are considered highly variable, precipitation models project a decrease in summer precipitation across the state (approximately 5%) in 2050 compared to the late 20th century under RCP8.5 (Figure 3). Increased intensity and frequency of rainfall events, considered one of the clearest observed precipitation trends in the US, is expected to continue in the future [4]. By 2100, parts of Western Washington, including Puget Sound, could receive 30-39% more of total annual precipitation in the heaviest 1% of events under RCP4.5 (Figure 4). Under RCP8.5, most of the state is projected to receive ≥40% more of its total precipitation in the heaviest 1% of rainfall events.

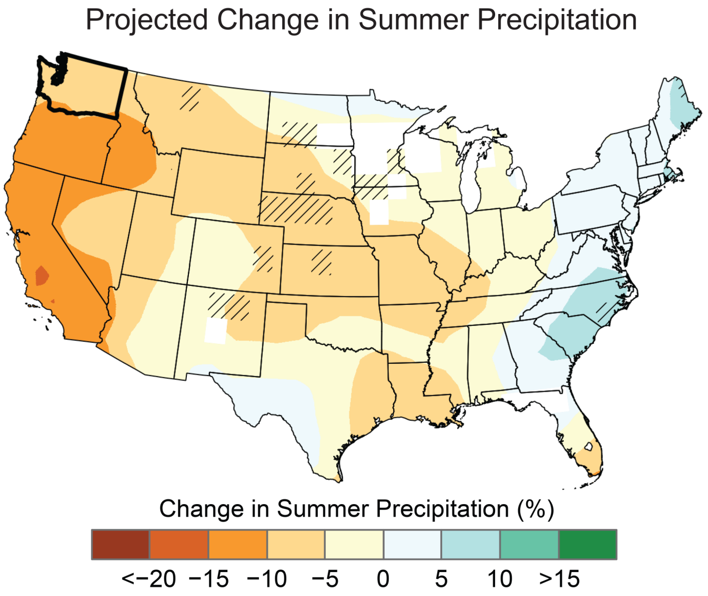


Figure 3. Projected changes (%) in total June-August precipitation for 2050 compared to the late 20th century under RCP8.5. Hatched areas indicate that the majority of models show statistically significant change [24].

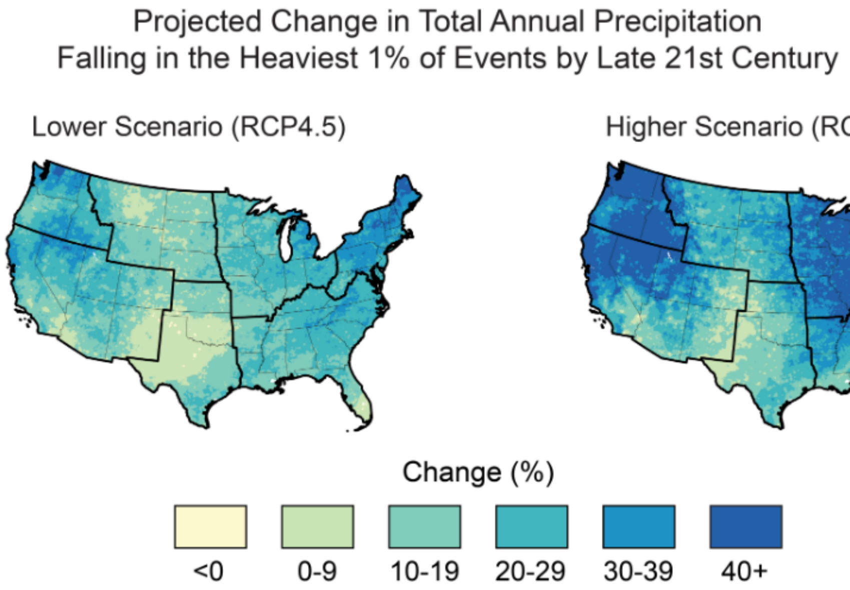


Figure 4. Projected change in total annual precipitation falling in the heaviest 1% of rainfall events by the late 21st century under RCP4.5 and RCP8.5 [23].

Atmospheric rivers, an important source of water on the west coast, can create extreme weather and precipitation conditions lasting up to several days. Climate models indicate that atmospheric rivers may become more frequent and intense in the future [4].

Higher temperatures are linked to early melting of snowpack, an important factor for water availability during spring and summer months in the Northwest [24]. Around 80% of watersheds in Washington state are projected to experience reduced water flow in summer [24]. These reductions pose a threat to the state's freshwater ecological systems, and also have implications for water availability for irrigation and hydropower.

With summers projected to become hotter and drier, wildfire risk is increasing in Washington; the 2015 wildfire season was the most destructive on record in the state's history [24]. Areas that are not directly affected by wildfire can still be exposed to wildfire smoke. Between 2016 and 2020, Washington residents were exposed to wildfire smoke for as many as 8-10 weeks, on average, each year [26].

In coastal areas, sea level rise increases nuisance (minor) and acute flood risk and land loss due to coastal erosion [24]. Ocean warming and acidification have altered Pacific marine environments, causing shifts and disruptions to underwater ecosystems. Changing conditions can be conducive to harmful algal blooms, such as the coast-wide bloom event that occurred in 2015 in confluence with an Pacific ocean heat wave nicknamed "the blob" [23].

Local Summary: Climate-Related Hazards in Olympia and Thurston County

ICLEI USA reviewed available resources and climate projections to learn more about the climate-related hazards the City of Olympia is exposed to in the present day, as well as how those hazards could change in a future of higher GHG emissions. Findings and associated climate projections (when available) on these hazards are summarized in the following section. Note that all climate projections are for the entirety of Thurston County, with the exception of 1) all sea level rise projections and 2) wildfire exposure projections, which are Olympia-specific.

Rising Temperatures

At baseline, temperatures in Olympia are several degrees warmer than the state average, though average annual mean temperatures are projected to follow a similar warming trajectory to those of the state. Under RCP8.5, annual mean temperatures are projected to increase by 2.8°F in 2025-2049, 5.3°F in 2050-2074, and 7.9°F by 2075-2099 compared to baseline (Table A1).

Winter minimum temperatures are projected to follow a similar warming trend to the annual average, increasing by 2.9°F in 2025-2049, 5.2°F in 2050-2074, and 7.9°F by 2075-2099 compared to baseline under RCP8.5 (Table A1). Summer maximum temperatures, however, are projected to rise at a faster rate than the annual mean (Table A1). In the 2030-2059 period, the average maximum summer temperature is projected to be 79.8°F (compared to the baseline of 75.4°F) under RCP8.5. In the 2050-2079 period, the summer maximum temperature is projected to rise to 82.4°F, and to 85.1°F in 2070-2099.

There is less variation in temperature projections across models and more agreement as to the directionality of change, as shown by the model ranges below, which include only positive values. Therefore, confidence in these trends is relatively high.

Were global GHG emissions to stabilize along a lower emissions trajectory (RCP4.5), temperatures in Olympia would increase at a more moderate rate (Table A2).

RCP8.5 Climate Projections Snapshot: Rising Temperatures

Annual Mean Temperature [14]	**Winter Minimum Temperature [14]**
Baseline: 51.3°F 2025-2049: +2.8°F (+1.0 to +4.7°F) 2050-2074: +5.3°F (+2.8 to +7.9°F) 2075-2099: +7.9°F (+4.9 to +10.8°F)	Baseline: 33.8°F 2025-2049: +2.9°F (-0.7 to +5.9°F) 2050-2074: +5.2°F (+1.5 to +8.6°F) 2075-2099: +7.9°F (+4.3 to +11.5°F)
Summer Maximum Temperature [15] Baseline: 75.4°F 2030-2059: +4.4°F (+2.96 to +6°F) 2050-2079: +7.0°F (+5.2 to +8.9°F) 2070-2099: +9.7°F (+6.9 to +11.9°F)	

RCP4.5 Climate Projections Snapshot: Rising Temperatures	
Annual Mean Temperature [14] Baseline: 51.3°F 2025-2049: +2.2°F (+0.4 to +4.2°F) 2050-2074: +3.7°F (+1.5 to +6.0°F) 2075-2099: +4.3°F (+2.1 to +6.7°F)	**Winter Minimum Temperature [14]** Baseline: 33.8°F 2025-2049: +2.2°F (-1.6 to +5.4°F) 2050-2074: +3.8°F (+0.6 to +6.9°F) 2075-2099: +4.5°F (+0.7 to +8.0°F)
Summer Maximum Temperature [15] Baseline: 75.4°F 2030-2059: +3.4°F (+1.6 to +4.7°F) 2050-2079: +4.7°F (+3 to +7.1°F) 2070-2099: +5.2°F (+3.4 to +7.8°F)	

Jump to the data on annual mean temperature, winter minimum temperature, and summer maximum temperature.

Stream Temperatures

Increasing stream temperatures have implications for aquatic ecosystems and species that depend on cold water (including salmon) as well as for water quality [15]. Under scenario A1B, projections for August—when stream temperatures tend to be at their highest—indicate potential increases (Figure A15).[2] In the 1993-2011 baseline period, the majority of stream

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[2] Note that stream temperature is the only indicator in this report to use the moderate emission CMIP3 scenario A1B, as no other scenarios are available for these indicators on CMRW.

lengths in Thurston County (65%) were 14-16°C or cooler. In the 2030-2059 period, 43% of streams are projected to be 14-16°C, with 46% even warmer (16-18°C). By the 2070-2099 period, 65% of streams could be 16-18°C, with 14% even warmer (18 to >20°C).

Hotter Summers and Extreme Heat Events

The definition of what is considered an extreme heat event varies by location. Historically, "hot days" (defined as days on which the maximum temperature is greater than 100°F) were rare in Olympia. However, as the climate changes, these events are projected to become more likely (Figure A3). Under RCP8.5, Olympia could experience one or two such days each year by the 2050-2075 period; by the 2070-2099 period, some models predict as many as five hot days each year.

Humidex is a measure that considers temperature and humidity to approximate "felt" temperature. 90°F Max Humidex Days—which have a dangerous combination of hot weather and humidity—are expected to increase significantly in Olympia. The 1980-2009 baseline indicates that Olympia could expect to experience 90°F Max Humidex, on average, 14 days annually in past years. As the climate changes, 90°F Max Humidex days are projected to occur more often: as early as the 2030-2059 period, Olympia could have around 24.2 additional 90°F Max Humidex days each year under RCP8.5 (Figure A5).

The annual number of Cooling Degree Days (a unitless measure indicative of air conditioning use) is projected to rise alongside temperatures (Figure A7).

RCP8.5 Climate Projections Snapshot: Hotter Summers and Extreme Heat Events [15]	
Hot Days Baseline: 0 days per year 2030-2059: +0.5 days/yr (+0.1 to +0.8 days/yr) 2050-2079: +0.9 days/yr (+0.3 to +2.2 days/yr) 2070-2099: +1.9 days/yr (+1.3 to +5.1 days/yr)	**90°F Max Humidex Days** Baseline: 14.1 days per year 2030-2059: +24.2 days/yr (+11.2 to +35 days/yr) 2050-2079: +45.3 days/yr (+23.3 to +58 days/yr) 2070-2099: +62 days/yr (+36.4 to +80.3 days/yr)
Cooling Degree Days (CDD) Baseline: 152 CDD per year	

2030-2059: +238 CCD/yr (+137 to +368 CCD/yr) 2050-2079: +452 CCD/yr (+268 to +673 CCD/yr) 2070-2099: +685 CCD/yr (+412 to +1071 CCD/yr)	

RCP4.5 Climate Projections Snapshot: Hotter Summers and Extreme Heat Events [15]	
Hot Days Baseline: 0 days per year 2030-2059: +0.2 days/yr (+0.1 to +0.4 days/yr) 2050-2079: +0.3 days/yr (+0.1 to +0.9 days/yr) 2070-2099: +0.4 days/yr (+0.1 to +1.3 days/yr)	**90°F Max Humidex Days** Baseline: 14.1 days per year 2030-2059: +17 days/yr (+6.5 to +25.3 days/yr) 2050-2079: +25.3 days/yr (+11.8 to +40.4 days/yr) 2070-2099: +29.5 days/yr (+17.5 to +44.9 days/yr)
Cooling Degree Days (CDD) Baseline: 152 CCD per year 2030-2059: +174 CCD/yr (+77 to +268 CCD/yr) 2050-2079: +243 CCD/yr (+125 to +467 CCD/yr) 2070-2099: +282 CCD/yr (+176 to +512 CCD/yr)	

Jump to the data on Hot Days, 90°F Max Humidex Days, and Cooling Degree Days.

Shifting Precipitation Patterns

Total precipitation may increase somewhat this century, with a 2.6% average increase (range -2.6% to +8.0%) in the 2030-2059 period, and a 4.1% average increase (range -2.6% to +17.9%) in the 2070-2099 period (Figure A9). However, precipitation projections have a high degree of variation across models. This is evident in the ranges shown in parentheses in the climate projections snapshot below. The ranges, which include zero, indicate that some precipitation models project decreased precipitation, while others project increased precipitation.[3] Similar uncertainty is also evident in statewide annual precipitation projections for Washington state [24].

Decreases in late summer precipitation (July 15-September 15) are possible. Climate projections indicate an average decrease of 14.2% in the 2030-2059 period and 20.4% in the 2050-2079 period (Figure A10). It must be noted, however, that these projections also span a large range, and some models project increased summer precipitation. This means that the directionality of expected precipitation changes is uncertain and confidence in these assumptions is low [15]. Reduced summer rainfall has implications for water availability during what is typically a dry period; it is also a time when fuel moisture may be low, and could increase fire risk.

RCP8.5 Climate Projections Snapshot: Shifting Precipitation Patterns [15]	
Total Annual Precipitation	**Late Summer Precipitation**
Baseline: 51 inches annually 2030-2059: +2.60% (-2.6 to +8.0%) 2050-2079: +3.70% (-3.7 to +11.7%) 2070-2099: +4.10% (-2.6 to +17.9%)	Baseline: 1 inch annually 2030-2059: -14.20% (-29.3 to +3.8%) 2050-2079: -20.40% (-41.1 to +21.4 %) 2070-2099: -16.70% (-59.5 to +9.3%)

Jump to the data on Total Annual Precipitation and Late Summer Precipitation.

Flooding

Flooding is linked to multiple causal factors, including heavy precipitation, stream dynamics, storms, sea level rise, coastal processes, land cover and development patterns.

Heavy Precipitation Events

Heavy precipitation can directly cause flooding, such as urban flash flooding and rainfall-induced riverine flooding. In Olympia, heavy rainfall events can also interact with tides to worsen tidal flooding [12] and contribute to instability and landslides in susceptible areas [27]. Due to the interconnectivity of water systems, even heavy rainfall events outside of Olympia can worsen flooding; for example, heavy rain in the Deschutes River watershed can cause flooding on the shoreline of Capitol Lake [12].

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[3] Note that local precipitation projections often have a higher level of uncertainty than temperature projections. This stems from the fact that it is more difficult to represent complex, locally variable precipitation processes in climate models [13].

The maximum total amount of precipitation (or magnitude) that falls during heavy and extreme precipitation events in Olympia appears likely to increase in the future. A heavy precipitation event is defined as the 24-hour rain storm that occurred every two years, on average, in the 1980-2009 period. Modeled precipitation magnitude for heavy rainfall varies widely; some models project a small decrease in the magnitude of this type of storm event. Still, it appears to be more likely than not that the magnitude of precipitation during 2-year rainfall events will increase, particularly towards the end of the century (Figure A12). RCP8.5 projections for 2030-2059 indicate a 7% increase (range of -1% to +21%) and a 15% increase (range of +7% to +27%) in heavy rainfall magnitude for 2070-2099.

Extreme precipitation events are defined as the 24-hour rain storm that occurred every 25 years, on average, in the 1980-2009 period. These relatively rare events cause extremely heavy rainfall and flooding. Projected magnitude for extreme rainfall events (RCP8.5) also shows significant model spread; still, it appears to be more likely than not that the magnitude of 25-year rainfall events will increase, particularly towards the end of the century (Figure A13). The top of the model range indicates the possibility for significant increases in magnitude for this already extreme event (for example, a 32% increase in the 2030-2059 period), which would pose a significant hazard.

Increases in heavy and extreme precipitation magnitude align with historical trends in Olympia [27], increasing confidence in these assumptions despite model uncertainty. Possible increases in frequency and intensity of atmospheric rivers discussed in the regional summary section is an additional factor relevant to heavy precipitation in Olympia.

According to the NOAA Climate Summary for Washington State, more than 2 inches of precipitation on a single day is considered an extreme precipitation event in western Washington [24]. Increases in the number of days with more than 2 inches of precipitation is an indicator of rainfall-induced flooding. Under RCP8.5, model range for these events spans zero until the 2050-2079 period (Figure A14). This means that there is less certainty in the direction of change (increase/decrease) and overall confidence is low. Starting in the 2050-2079 period, however, and continuing until the end of the century, most models indicate at least some increase in the frequency of these heavy rainfall days under RCP8.5.

RCP8.5 Climate Projections Snapshot: Heavy Precipitation Events [15]	
Heavy Precipitation Magnitude	**Extreme Precipitation Magnitude**

Baseline: N/A (2-year event magnitude) 2030-2059: +7% (-1 to +21%) 2050-2079: +12% (-1 to +30%) 2070-2099: +15% (+7 to +27%)	Baseline: N/A (25-year event magnitude) 2030-2059: +13% (-8 to +32%) 2050-2079: +17% (-3 to +31%) 2070-2099: +31% (+5 to +44%)
2-Inch Precipitation Days Baseline: 1 day 2030-2059: +0.3 days (-0.1 to +0.6 days) 2050-2079: +0.4 days (+0 to +0.7 days) 2070-2099: +0.5 days (+0.2 to +0.6 days)	

Jump to the data on Heavy Precipitation Magnitude, Extreme Precipitation Magnitude, and 2-Inch Precipitation Days.

Streamflow

Peak streamflow and return interval of 25-year peak streamflow both have implications for flooding in Olympia. “Peak streamflow” is the highest-magnitude streamflow to occur each year. Peak streamflow in Olympia may be getting higher. In the 2030-2059 period, 90% of stream lengths in Thurston County could experience a 10-30% increase in maximum stream flow compared to baseline highs (Figure A20). These increases are projected to continue, and may even increase, later in the century.

In Thurston County, high streamflows that once occurred, on average, every 25 years, are projected to occur more often (Figure A21). In the 2020-2049 period, 93.4% of streamflows could have a return period of historical high streamflow levels every 10-20 years instead of every 25 years; around 6% could experience return intervals of 0-10 years for these high flows. This trend toward shorter return periods has implications for frequency of flood events.

Sea Level Rise and Coastal Flooding

Sea level rise projections and insights on coastal flooding are drawn from the Olympia Sea Level Rise Response Plan (2019) and Science Review Appendix (2017).[4] These sources tailor projections to Olympia's unique natural geography, built environment, and development patterns.

Coastal flooding is a complex phenomenon influenced by local wave and wind dynamics, coastal geography (e.g. subsidence), naturally occurring high-tide events (e.g. King Tides), and semi-cyclical climate variability (e.g. El Niño). Sea level rise projections must be considered in confluence with these factors (i.e. added "on top") to understand how different rates of sea level rise could impact a particular location, as was done in Olympia's sea level rise response plan.

Olympia has long been subject to coastal flooding. Downtown areas face frequent flooding during storm events or when high water levels in Capitol Lake coincide with high tides in Budd Inlet. All it takes is the "the right mix of tides, river flows, and weather" [12]. Twelve inches of sea level rise—which projections indicate is likely to occur as soon as 2050, or even 2030 (high range), is enough to increase the frequency of severe flooding (100-year storm tide) to as often as every other year (Figure A22 and Table A3) [12].[5] Sea level rise exceeding 24 inches would expose an extensive part of Olympia to both King Tide and 100-year storm tide flooding [12].

Climate Projections Snapshot: Sea Level Rise [12]	
Most-Likely Sea Level Rise 2030: 5-7 inches 2050: 11-13 inches 2100: 32-36 inches	**High-Range Sea Level Rise** 2030: 11-13 inches 2050: 23-25 inches 2100: 64-68 inches

Jump to the data on Sea Level Rise.

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[4] In 2018, after Olympia-specific modeling for the 2017 Science Review Appendix was completed, the Washington Coastal Resilience Project developed new sea level rise projections for Washington State. The Sea Level Rise Response Plan team reviewed these new projections and found them to be "generally consistent" with the Olympia-specific projections, aside from one exception. Under the new projections, the "worst-case" (0.1% probability of exceedance) estimate for 2100 is up to 9 feet (108 inches), which exceeds the worst-case scenario in the Sea Level Rise Response Plan of 68 inches (5.7 feet). The Olympia-specific projections are retained in this report in the interest of using the same projections used to calculate exposure (Table A4).

[5] Note: These SLR projections assume a moderate level of GHG emissions and continued acceleration of land ice melt [28].

Severe Storms

Large coastal storm events are common occurrences in the Puget Sound region in wintertime. These storms are associated with high wind speeds and low atmospheric pressure, which can raise shoreline water levels in and around Olympia by as much as 6 inches to 3 feet above normal [12]. Though Olympia's location in southern Budd Inlet is somewhat protective against wave action, locally generated wind waves may still reach 2-5 feet in height, risking structural damage to built assets [12].

Because storms are compound events that can include wind, waves, storm surge, and rainfall, they are challenging to represent in "single-indicator" projections. In Puget Sound, "storminess" can refer to storm frequency and intensity, storm surge magnitude, storm tracks, and changes to wave heights and wind speed (thunderstorms are rare in the region) [29]. In general, future climate conditions have been interpreted as pointing to an increase in storminess, though there is low confidence in these findings (particularly in the Pacific) [4]. Research on storm frequency and intensity does not point to an increase in storminess in the Puget Sound region specifically [29]. Even without increased frequency and intensity of storm events, it is important to note that sea level rise will magnify storm-related inundation [12].

Water Availability and Drought

Along with declines in summer precipitation, the annual chance of a precipitation drought can be indicative of future drought conditions. The chance of a precipitation drought occurring in any given year (defined as the likelihood that summer precipitation falls below 75% of the historical normal) may increase slightly, from 25% at baseline to around 30-35% in the middle and end of the century under RCP8.5 (Figure A11). Some models, however, put the odds of a precipitation drought occurring at 50% or greater by the middle and end of the century.

Aside from precipitation levels, streamflow can also serve as an indicator of water availability. Rising temperatures, decreased snowpack, and reduced warm season rainfall contribute to reduced streamflow in the Puget Sound area [29]. Projections for warm season (April-September) streamflow indicate that an increasing percentage of streams could experience 10% and 30% declines in flow in the 2020-2049 period, with declines growing through the end of the century (Figure A16). Larger declines are evident in summer stream flow (June-September). Starting in the 2030-2059 period, over 20% of stream lengths could decline by as much as 30 to 50% compared to the historical baseline (Figure A17). Duration of low streamflow (how long low streamflow lasts compared to baseline) may increase by 10 to 20 days for some streams as the climate warms (Figure A18).

Changing stream characteristics are associated with water availability, drought, flooding, and ecosystem impacts. Projections indicate that prevailing stream patterns and flows may change in Thurston County, influenced by temperature and precipitation changes.

One indicator showing signs of change is winter to spring streamflow timing. The winter to spring streamflow timing ratio indicates the timing of higher/lower streamflows during the year. Figure A19 indicates that Olympia may experience increased winter streamflow and decreased spring stream flow. These changes have implications for water availability for agriculture and hydropower, as well as for migration timing and survival rates of species like salmon [15].

Despite projected drops in streamflow, duration of low streamflow (i.e. how long it lasts) is not projected to change significantly from baseline for the majority of stream lengths in Thurston County (Figure A18).

RCP8.5 Climate Projections Snapshot: Water Availability and Drought [15]	
Precipitation Drought Baseline: 25% chance 2030-2059: 30% (24 to 41%) 2050-2079: 33% (22 to 50%) 2070-2099: 36% (24 to 58%)	

Jump to the data on Precipitation Drought and Streamflow.

Wildfire

Wildfire projections for Olympia should be interpreted with caution, as wildfires have historically been limited in the city due to its urban development character and lack of wildland-urban interface (WUI) zones [27]. The city's hazard mitigation plan annex indicates that some areas on the west side of the city, as well as Watershed and Priest Point Parks, may be vulnerable. Urban growth trajectories are expected to further reduce vulnerable areas [27]. However, fire modeling conducted by First Street Foundation noted areas on the east side of Olympia have some annual chance of being impacted by wildfire [30] (Figure A27 and Figure A28).

Increases in high fire danger days and wildfire likelihood point to possible increased occurrence of wildfire near Olympia in surrounding wildland areas. High fire danger days are defined as a day during which the 100-hour fuel moisture is less than the historic 20th percentile. The baseline (1971-2000) value for Thurston county is 56 days (Figure A23). RCP8.5 projections indicate an average of 7 additional days in the 2010-2039 period (range +0 to +9 days) and 9 days (+2 to +16 days) in the 2040-2069 period.

Wildfire likelihood is defined as the likelihood of climate and fuel conditions favorable for wildfire. The 1980-2009 baseline for Thurston County is 0%, indicating low wildfire likelihood (Figure A25). However, under RCP8.5, the average for 2030-2059 rises slightly to an average 3% likelihood by 2030-2059, with higher increases possible in the 2050-2079 (range 2% to 24%) and 2070-2099 (1% to 34%) periods. Note that the large range across models reduces confidence in these projections.

RCP8.5 Climate Projections Snapshot: Wildfire [15]	
Wildfire Danger Baseline: 56 days 2010-2039: +7 days (+0 to +9 days) 2040-2069: +9 days (+2 to +16 days)	**Wildfire Likelihood** Baseline: 0% 2030-2059: 3% (0 to 5%) 2050-2079: 8% (2 to 24%) 2070-2099: 12% (1 to 34%)

RCP4.5 Climate Projections Snapshot: Wildfire [15]	
Wildfire Danger Baseline: 56 days 2010-2039: +4 days (+0 to +8 days) 2040-2069: +7 days (+1 to +15 days)	**Wildfire Likelihood** Baseline: 0% 2030-2059: 1% (0 to 3%) 2050-2079: 4% (1 to 9%) 2070-2099: 13% (4 to 27%)

Jump to the data on Wildfire Danger and Wildfire Likelihood.

Air Quality

Aside from the direct risk wildfires pose to life and property, wildfires both near and far can cause poor air quality in the Pacific Northwest. The Olympic Region Clean Air Agency (ORCAA) notes that wildfires as far away as Oregon, Montana, British Columbia, and Alaska have been linked to air pollution in Olympia [31].

Wildfire smoke contains a mix of harmful pollutants including carbon monoxide and particulate matter (PM) [32]. Most of the pollution that comes from wildfire smoke is fine particulate matter pollution (referred to as PM2.5). Fine particle pollution is particularly hazardous to health because it is small enough to reach the lungs; this type of pollution has been linked to respiratory and cardiovascular health risks [32].

As the climate changes, particulate pollution from wildfire activity is projected to rise in the western US. A study that modeled wildfire-induced PM2.5 concentration projected that increased wildfires under SSP2-4.5 and SSP5-8.5 (CMIP6 scenarios roughly equivalent to RCP4.5 and RCP8.5, respectively) could cause PM2.5 concentration in the Pacific Northwest to double or even triple in August and September in the mid to late 21st century [33].

Extreme heat is known to worsen air quality. This effect has been documented locally: ORCAA air quality monitoring conducted during a June 2021 heat wave showed spikes in harmful PM2.5 concentration as temperatures rose (Figure A29). Co-occurrence of wildfires and extreme heat has proved to be a deadly combination. A recent study of mortality rates in California showed that co-occurrence of extreme heat and air pollution led to higher mortality rates than exposure to either hazard in isolation [34].

Appendix

Data Platforms

Platform	Description
National Climate Change Viewer (NCCV)	The NCCV, created by the US Geological Survey (USGS) allows users to visualize and download data on projected climatic changes across climate indicators (mean, minimum, and maximum air temperature and precipitation) as well as simulated water balance indicators (snow water equivalent, runoff, soil water storage, and evaporative deficit) for states and counties in the US. See technical documentation for more information.
Climate Mapping for a Resilient Washington (CMRW)	The CMRW, created by the University of Washington Climate Impacts Group, provides climate projections across 28 indicators at the county level in Washington state. The tool provides a wide range of indicators for temperature, precipitation, sea level rise, streamflow, and wildfire. Projections can be displayed and downloaded in map, graph, or table form. Technical documentation can be viewed under the “About Climate Data” tab on the tool webpage.
Risk Factor	Risk Factor is an online platform created by the nonprofit First Street Foundation that provides data on climate hazards and exposure. As of March 2023, Risk Factor provides free access to high-level information and data on exposure to flooding, wildfires, extreme heat, and severe wind at the city, county, zip code and address level. Detailed property-level information is available for purchase. See Risk Factor’s About page for more information.

Indicators

Note: projections for all available scenarios are included in the appendix with the exception of RCP4.5 projections for streamflow indicators, which can only be viewed on the CMRW platform. CMRW does not provide precipitation projections for RCP4.5.

Indicator (Unit)	Description	Available Scenarios	Source
Temperature			
Mean Temperature (°F)	The average of minimum and maximum annual or seasonal air temperature	RCP4.5, RCP8.5	NCCV
Maximum Temperature (°F)	The maximum annual or seasonal air temperature	RCP4.5, RCP8.5	NCCV
Minimum Temperature (°F)	The maximum annual or seasonal air temperature	RCP4.5, RCP8.5	NCCV
Summer Maximum Temperature (°F)	Average daily summer (June-August) maximum temperature	RCP4.5, RCP8.5	CMRW
Hot Days (°F)	Days per year with maximum daily temperature greater than 100°F	RCP4.5, RCP8.5	CMRW
90°F Max Humidex Days (°F)	Days per year with a maximum humidex value over 90°F. Humidex is a measure of "experienced" temperature, and includes measures of both temperature and humidity	RCP4.5, RCP8.5	CMRW
Cooling Degree Days (CCDs)	Total annual cooling degree days (threshold of > 65°F). Cooling degree days are a unitless measure used to approximate air conditioning use	RCP4.5, RCP8.5	CMRW
Precipitation			
Total Annual Precipitation	Average total accumulated precipitation in inches over a year	RCP8.5	CMRW

(in)			
Late Summer Precipitation (%)	Change in average July 15 - September 15 total precipitation, relative to the average for 1980-2009	RCP8.5	CMRW
Precipitation Drought (%)	Likelihood that summer (June-August) precipitation in any given year is below 75% of average precipitation, the historical normal for the period 1980-2009	RCP8.5	CMRW
Heavy Precipitation Magnitude (%)	Percent change in the maximum amount of water from the 24-hour rain storm that occurs on average once every 2 years relative to the average for 1980-2009	RCP8.5	CMRW
Extreme Precipitation Magnitude (%)	Percent change in the maximum amount of water from the 24-hour rain storm that occurs on average once every 25 years relative to the average for 1980-2009	RCP8.5	CMRW
2 Inch Precipitation Days (days)	Change in days with more than 2 inches total precipitation relative to 1980-2009	RCP8.5	CMRW
Streamflow			
August Stream Temperature (°C)	Average August stream temperature	A1B	CMRW
Warm Season Streamflow (%)	Percent change in total warm season (April-September) streamflow relative to the period 1980-2009	RCP4.5, RCP8.5	CMRW
Summer Streamflow (%)	Percent change in total summer (June-September) streamflow relative to the period 1980-2009	RCP4.5, RCP8.5	CMRW
Duration of Low Streamflow (days)	Change in days with streamflow less than the historical (1980-2009) summer (June-September) 7Q2, or the lowest 7-day average streamflow that occurs every 2 years on average	RCP4.5, RCP8.5	CMRW
Streamflow Timing (n/a)	Ratio of total streamflow in winter (November-February) to total streamflow in spring (May-June)	RCP4.5, RCP8.5	CMRW
Peak	Percent change in the magnitude of streamflow on the	RCP4.5,	CMRW

Streamflow (%)	day of the year with the most streamflow	RCP8.5	
Return Interval of 25-Year Peak Streamflow (years)	Return interval of the historical high streamflow that occurs every 25 years on average	RCP4.5, RCP8.5	CMRW
Sea Level Rise			
Most-Likely Sea Level Rise (in)	Most likely sea level rise (higher probability, lower impact scenario)	N/A	Olympia SLR Plan
High-Range Sea Level Rise (in)	High-range sea level rise (lower probability, higher impact scenario)	N/A	Olympia SLR Plan

Seasons

Months falling under each season, unless otherwise specified in the text.

Season	Months
Winter	December, January, February
Spring	March, April, May
Summer	June, July, August
Fall	September, October, November

Climate Data and Projections Detailed View

All projections and data points refer to Thurston County, unless otherwise noted.

Temperature

Minimum, Mean, and Maximum Temperature

Table A1. Projected minimum, mean, and maximum air temperatures (°F) annually and by season averaged across three 25-year climatology periods for Thurston County under RCP8.5 [14]. 1981-2010 baseline provided for comparison.

RCP 8.5												
	Baseline (1981-2010)			**2025-2049**			**2050-2074**			**2075-2099**		
Season	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Annual	41.8	51.3	60.8	44.5	54.1	63.7	47.1	56.6	66.2	49.7	59.2	68.8
Winter	33.8	40.4	46.9	36.7	43.2	49.7	39.0	45.5	51.9	41.7	48.0	54.3
Spring	40.0	50.1	60.1	42.4	52.5	62.5	44.4	54.5	64.6	46.6	56.6	66.7
Summer	51.1	63.3	75.5	54.0	66.4	78.9	56.9	69.5	82.0	59.9	72.5	85.1
Fall	42.4	51.6	60.9	45.1	54.4	63.6	47.8	57.2	66.5	50.5	59.7	69.0

Table A2. Projected minimum, mean, and maximum air temperatures (°F) annually and by season averaged across three 25-year climatology periods for Thurston County under RCP4.5 [14]. 1981-2010 baseline provided for comparison.

RCP 4.5												
	Baseline (1981-2010)			**2025-2049**			**2050-2074**			**2075-2099**		
Season	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Annual	41.8	51.3	60.8	44.0	53.6	63.1	45.4	55.0	64.6	46.1	55.7	65.3
Winter	33.8	40.4	46.9	36.0	42.5	49.1	37.6	44.1	50.6	38.3	44.7	51.1
Spring	40.0	50.0	60.0	42.0	52.1	62.2	43.2	53.4	63.5	43.8	53.9	64.1
Summer	51.1	63.2	75.4	53.5	65.8	78.2	55.0	67.5	80.0	55.7	68.2	80.6
Fall	42.5	51.7	60.9	44.6	53.8	63.0	45.9	55.2	64.4	46.6	55.9	65.2

Summer Maximum Temperature

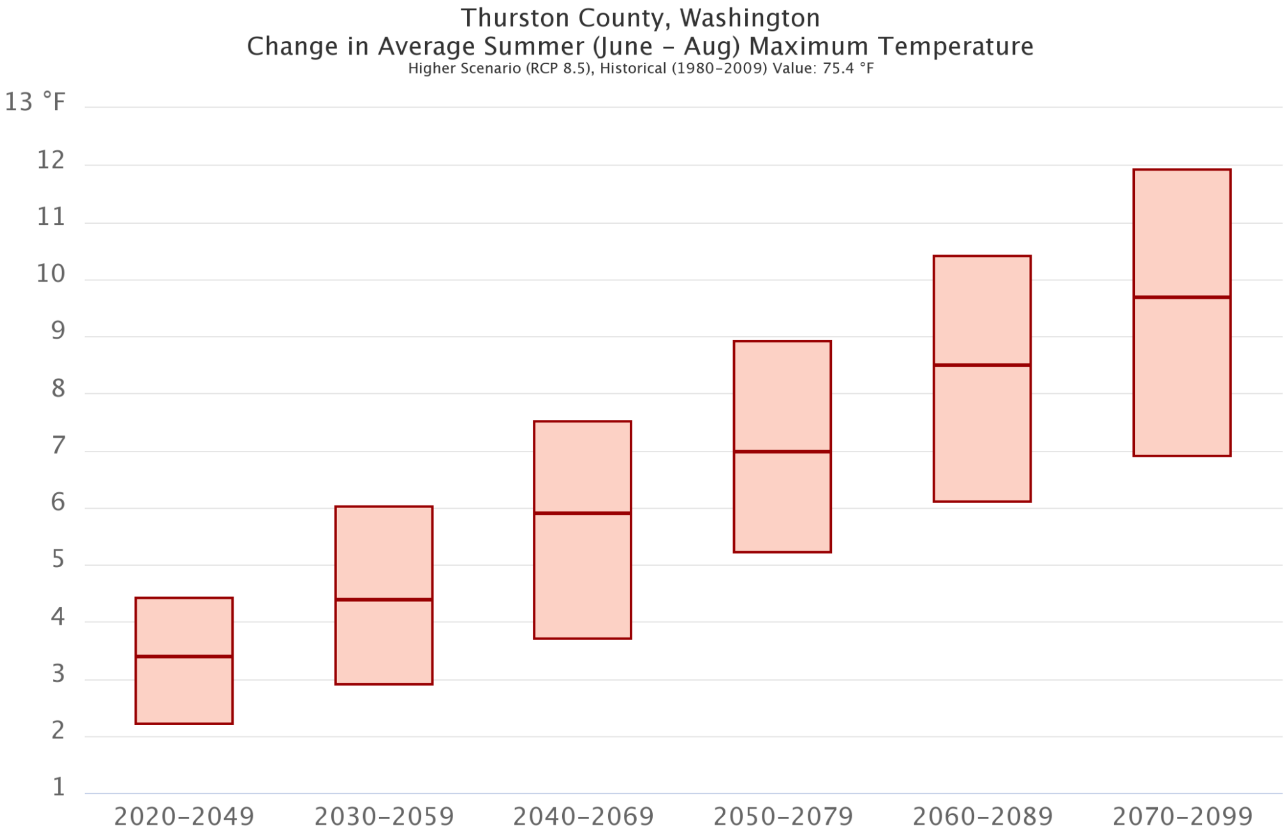


Figure A1. Change in the annual summer maximum temperature (°F) in Thurston County for future 30-year periods under RCP8.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

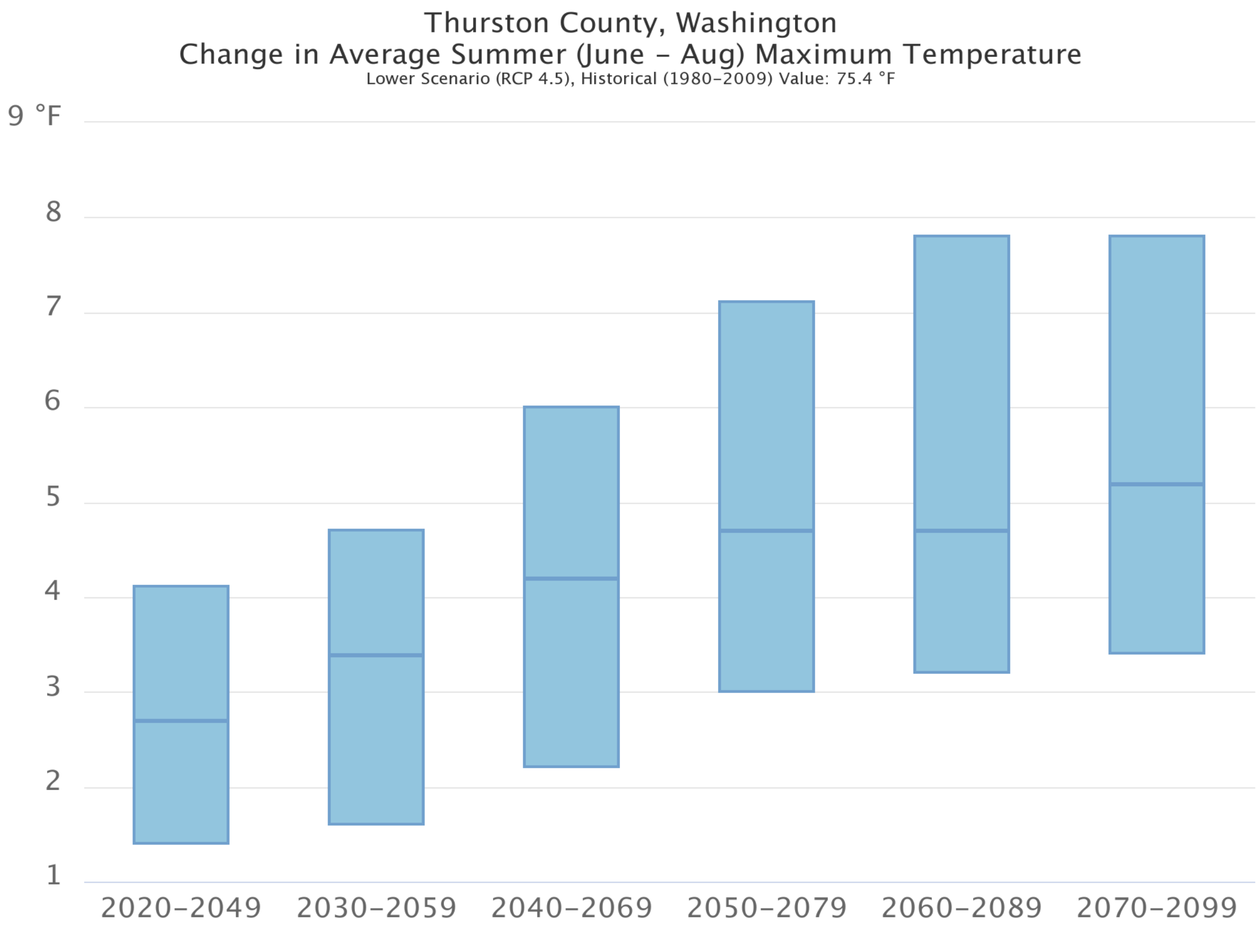


Figure A2. Change in the summer maximum temperature (°F) in Thurston County for future 30-year periods under RCP4.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six blue bars show the 10th to 90th percentile range of projections; the dark blue line contained within each bar is the ensemble median.

Hot Days

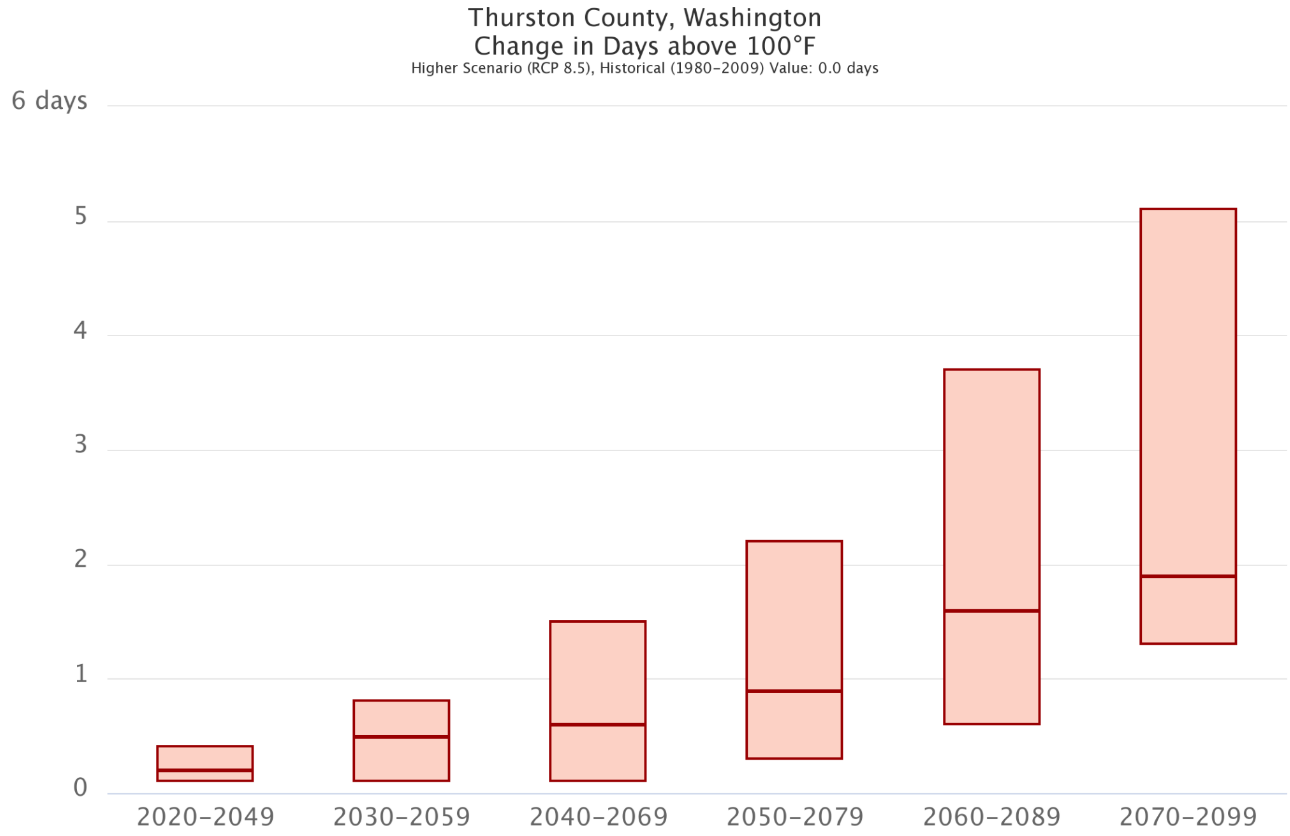


Figure A3. Change in the number of days per year with a maximum temperature > 100°F in Thurston County for future 30-year periods under RCP8.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

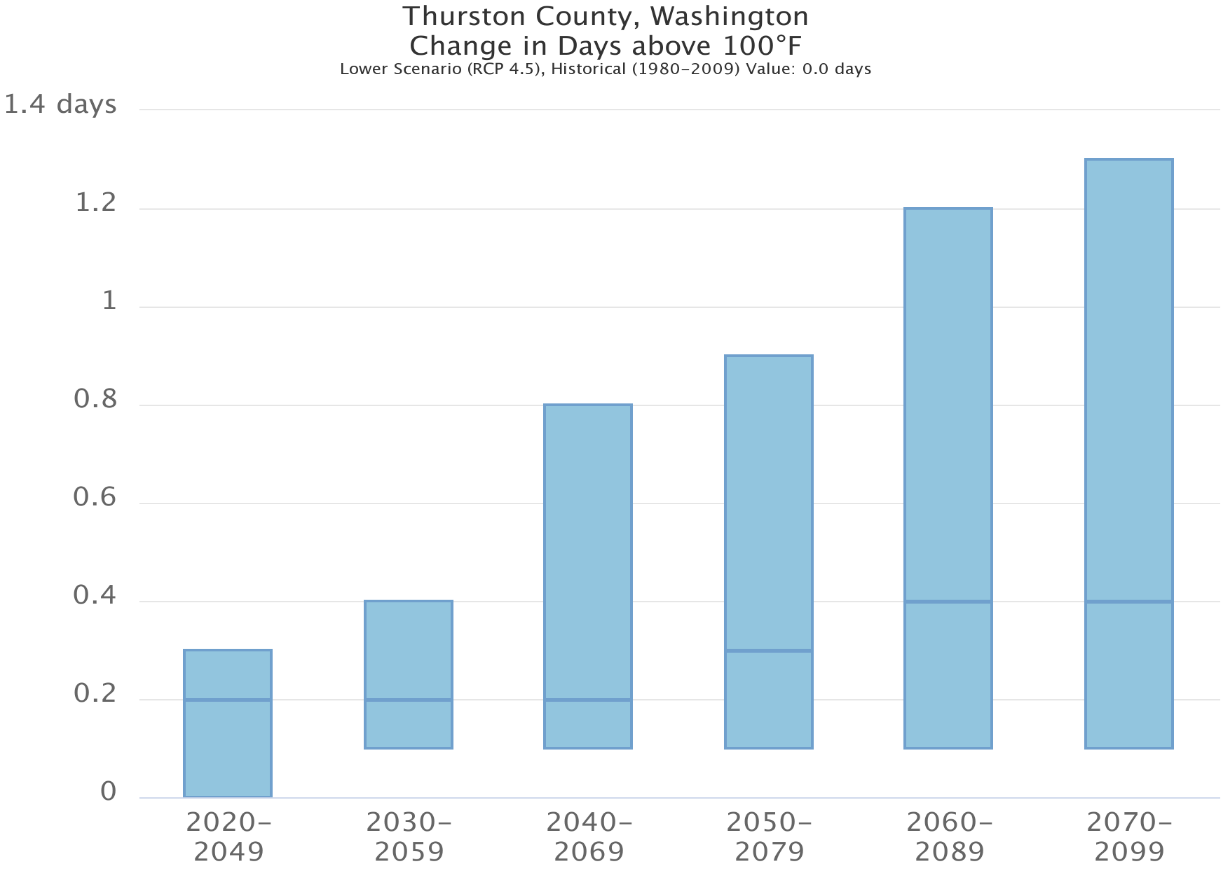


Figure A4. Change in the number of days per year with a maximum temperature > 100°F in Thurston County for future 30-year periods under RCP4.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six blue bars show the 10th to 90th percentile range of projections; the dark blue line contained within each bar is the ensemble median.

90°F Max Humidex Days

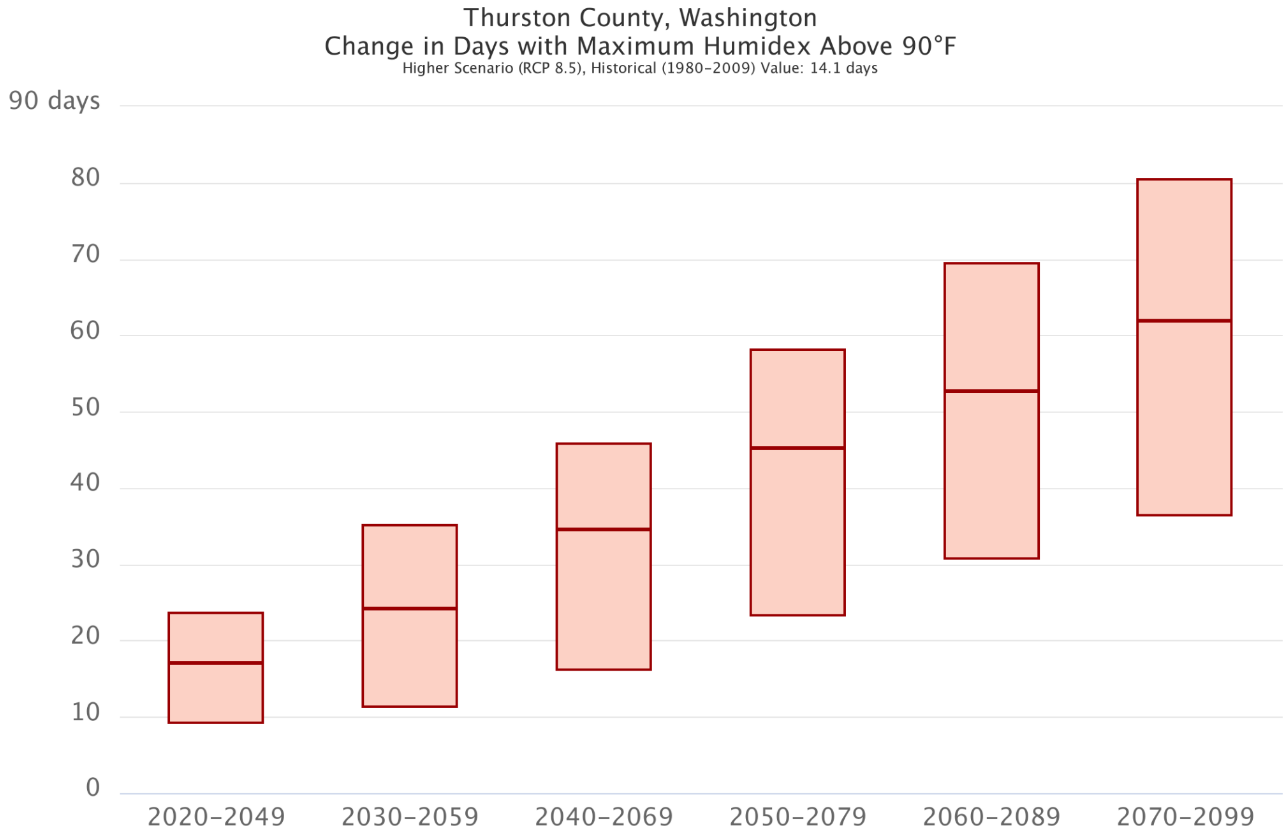


Figure A5. Change in the number of days per year with a maximum humidex value > 90°F in Thurston County for future 30-year periods under RCP8.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

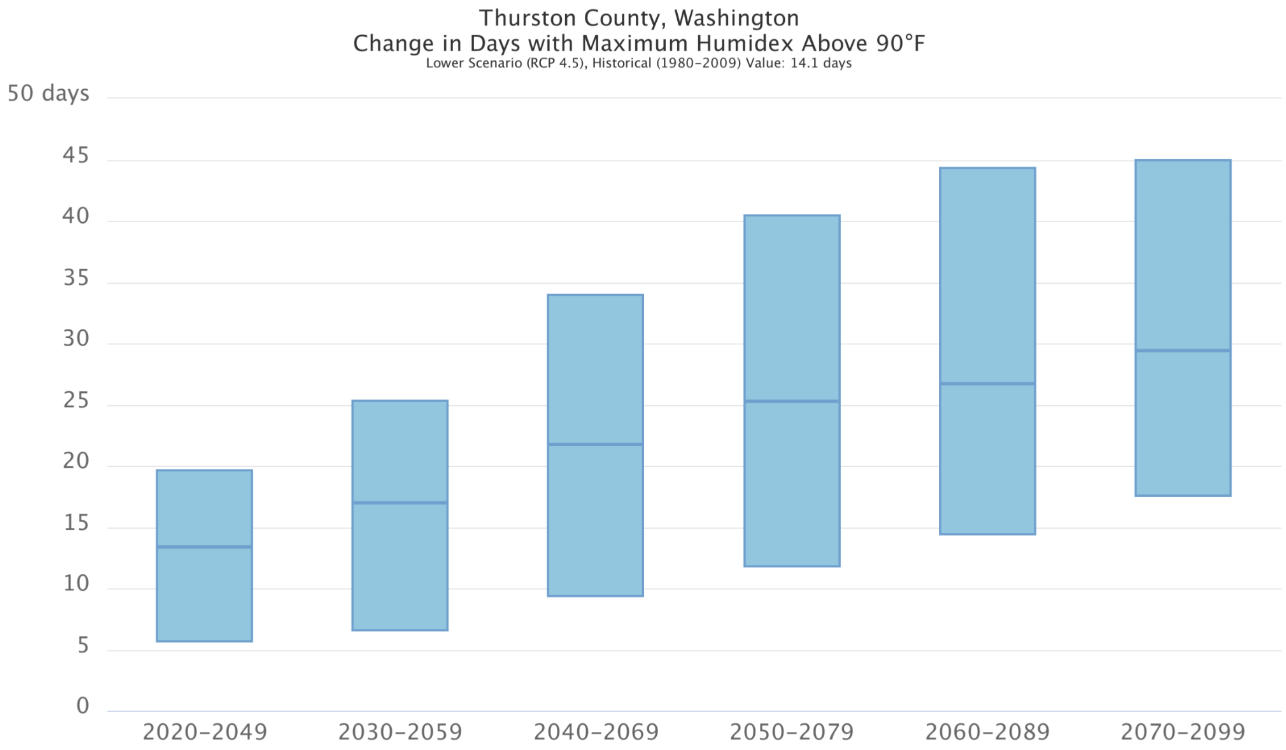


Figure A6. Change in the number of days per year with a maximum humidex value > 90°F in Thurston County for future 30-year periods under RCP4.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six blue bars show the 10th to 90th percentile range of projections; the dark blue line contained within each bar is the ensemble median.

Cooling Degree Days

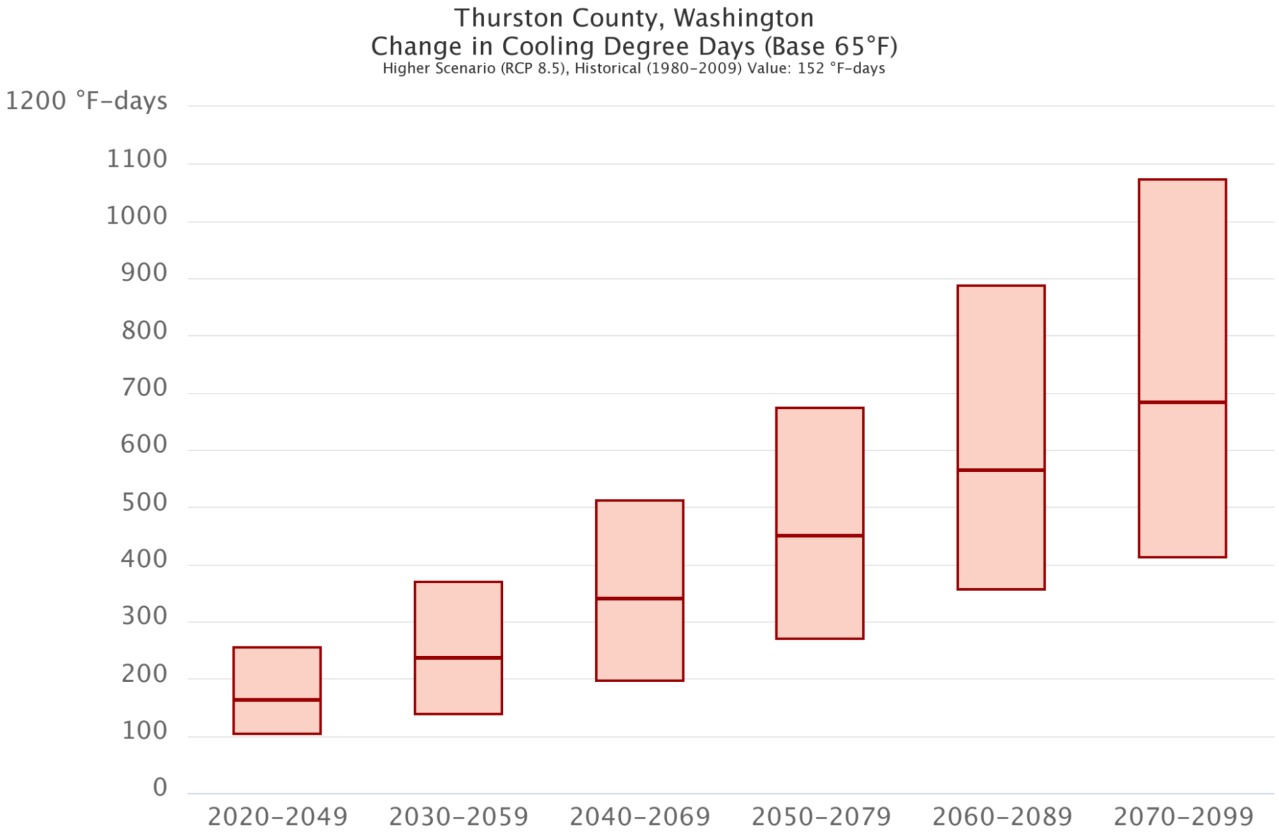


Figure A7. Change in the number of Cooling Degree Days (a unitless measure indicative of air conditioning use) in Thurston County for future 30-year periods under RCP8.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

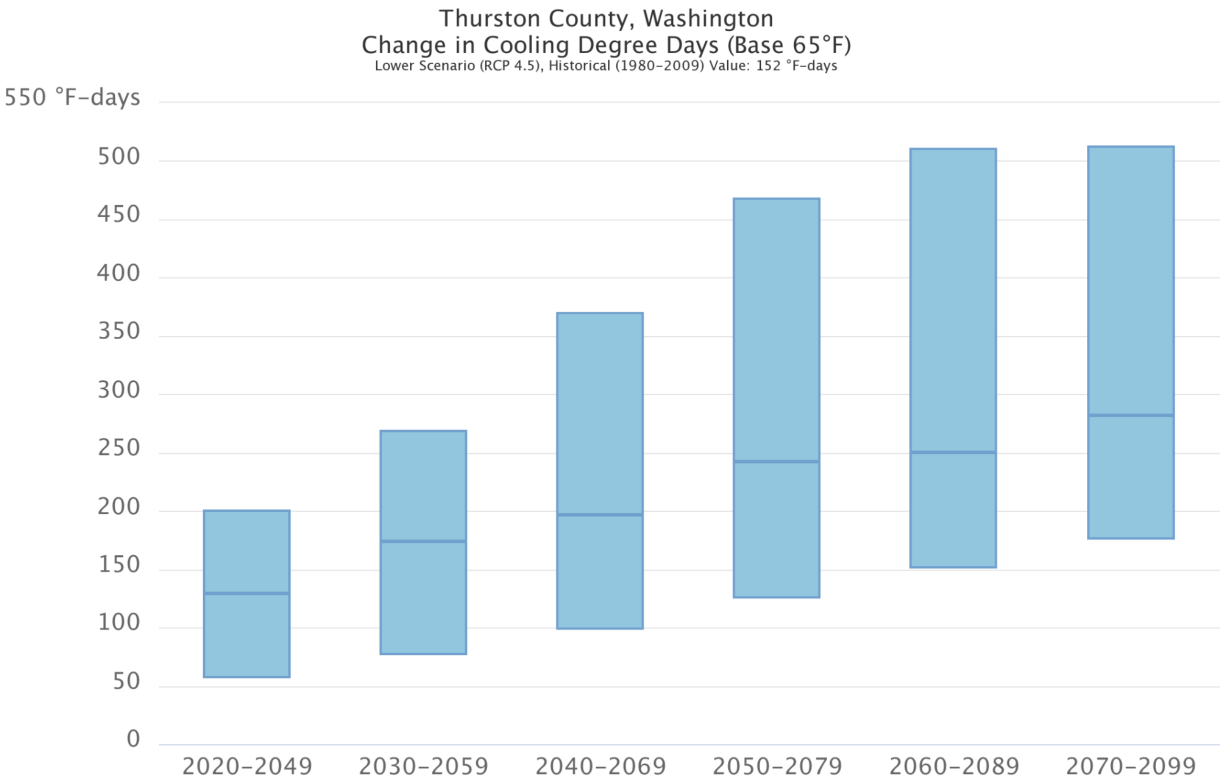


Figure A8. Change in the number of cooling degree days (a unitless measure indicative of air conditioning use) in Thurston County for future 30-year periods under RCP4.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six blue bars show the 10th to 90th percentile range of projections; the dark blue line contained within each bar is the ensemble median.

Precipitation

Total Annual Precipitation

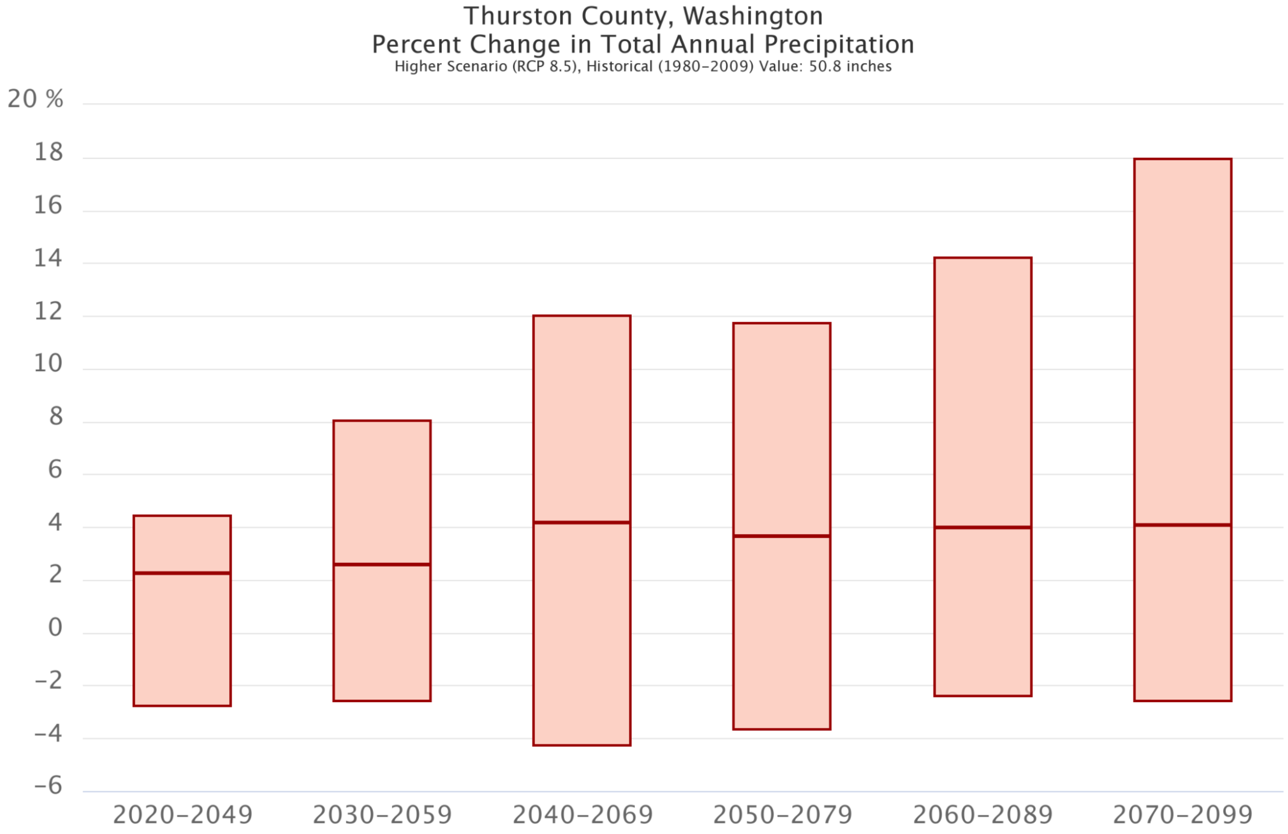


Figure A9. Percent change in total annual precipitation in Thurston County for future 30-year periods under RCP8.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

Late Summer Precipitation

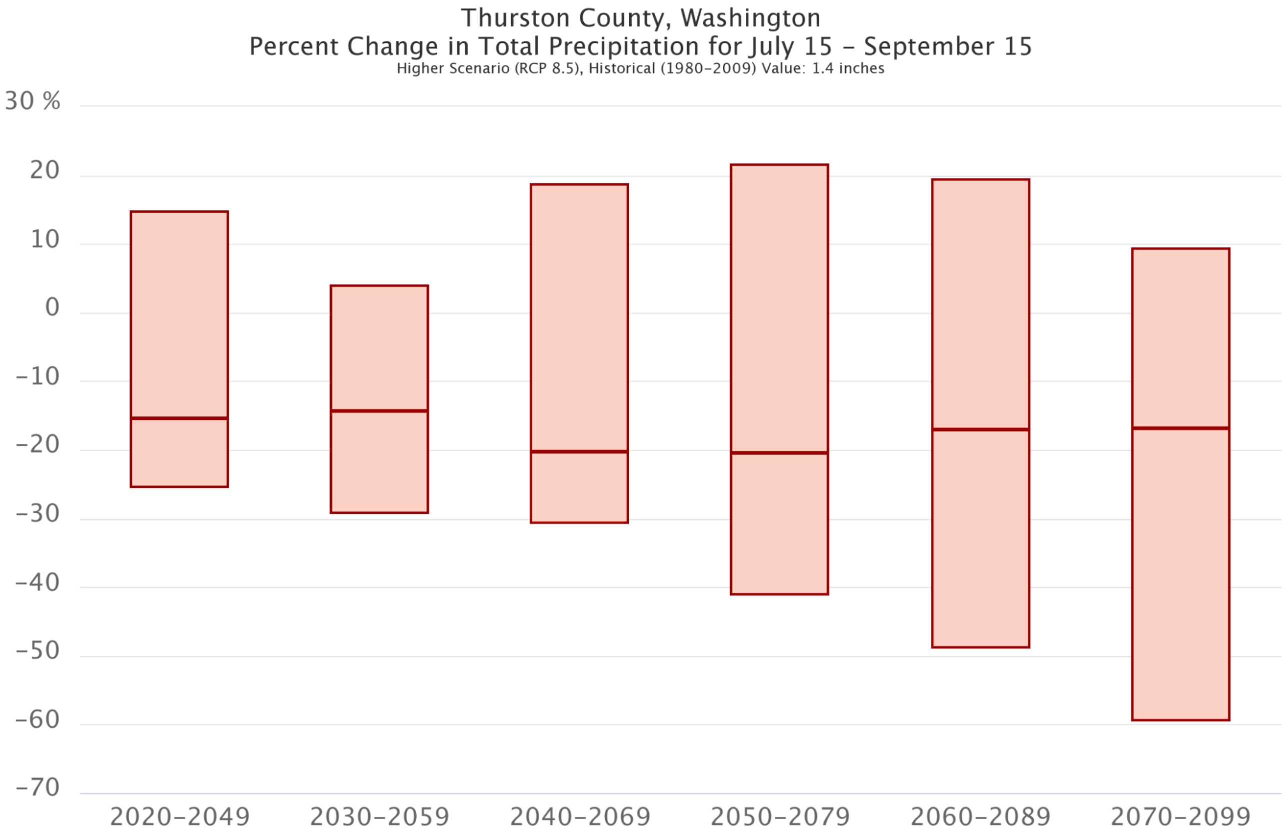


Figure A10. Percent change in total late summer (July 15 – September 15) precipitation in Thurston County for future 30-year periods under RCP8.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

Precipitation Drought

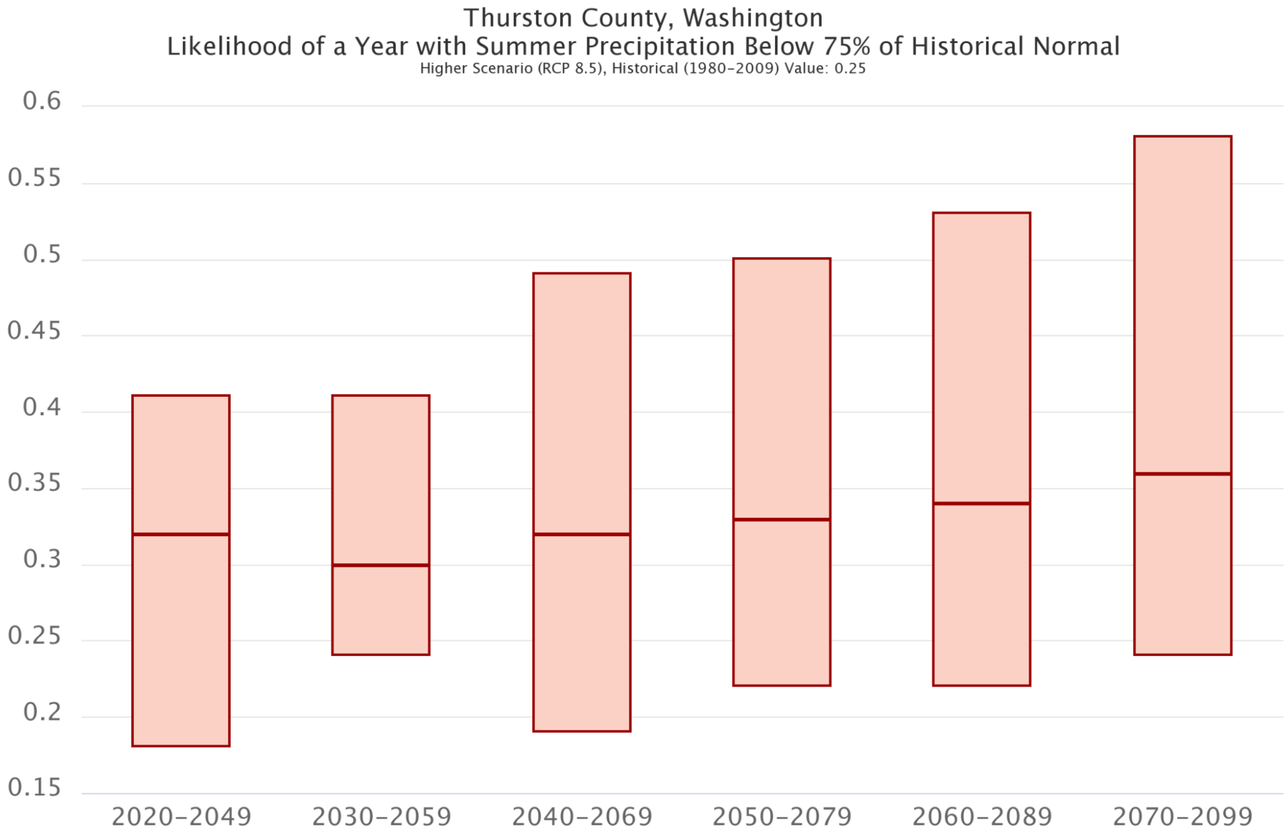


Figure A11. Likelihood of a year with summer precipitation < 75% of normal in Thurston County for future 30-year periods under RCP8.5 [15]. Percent change is in comparison to the historical baseline normal (1980-2009). The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

Heavy Precipitation Magnitude

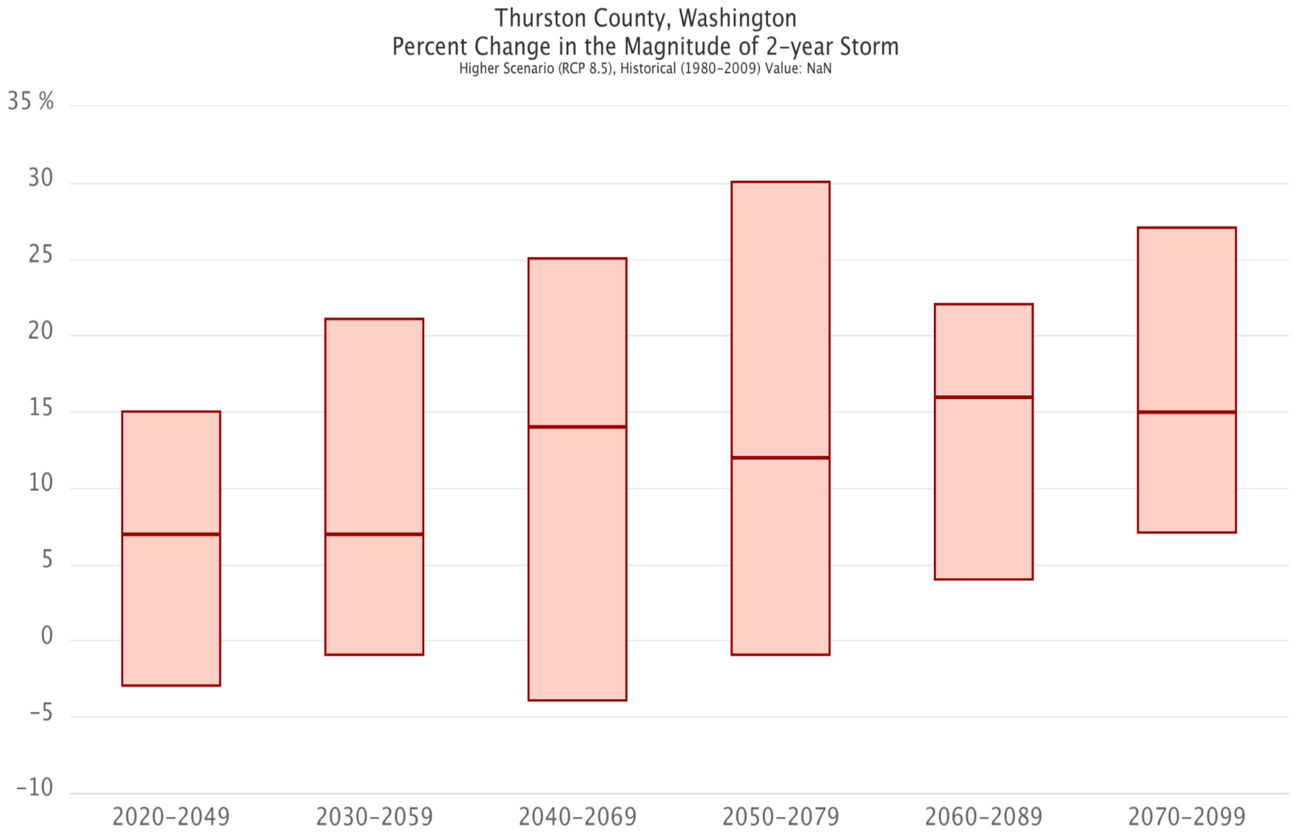


Figure A12. Percent change in the magnitude of the 2-year storm in Thurston County for future 30-year periods under RCP8.5 [15]. Percent change is in comparison to the historical baseline (1980-2009) 2-year storm magnitude. The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

Extreme Precipitation Magnitude

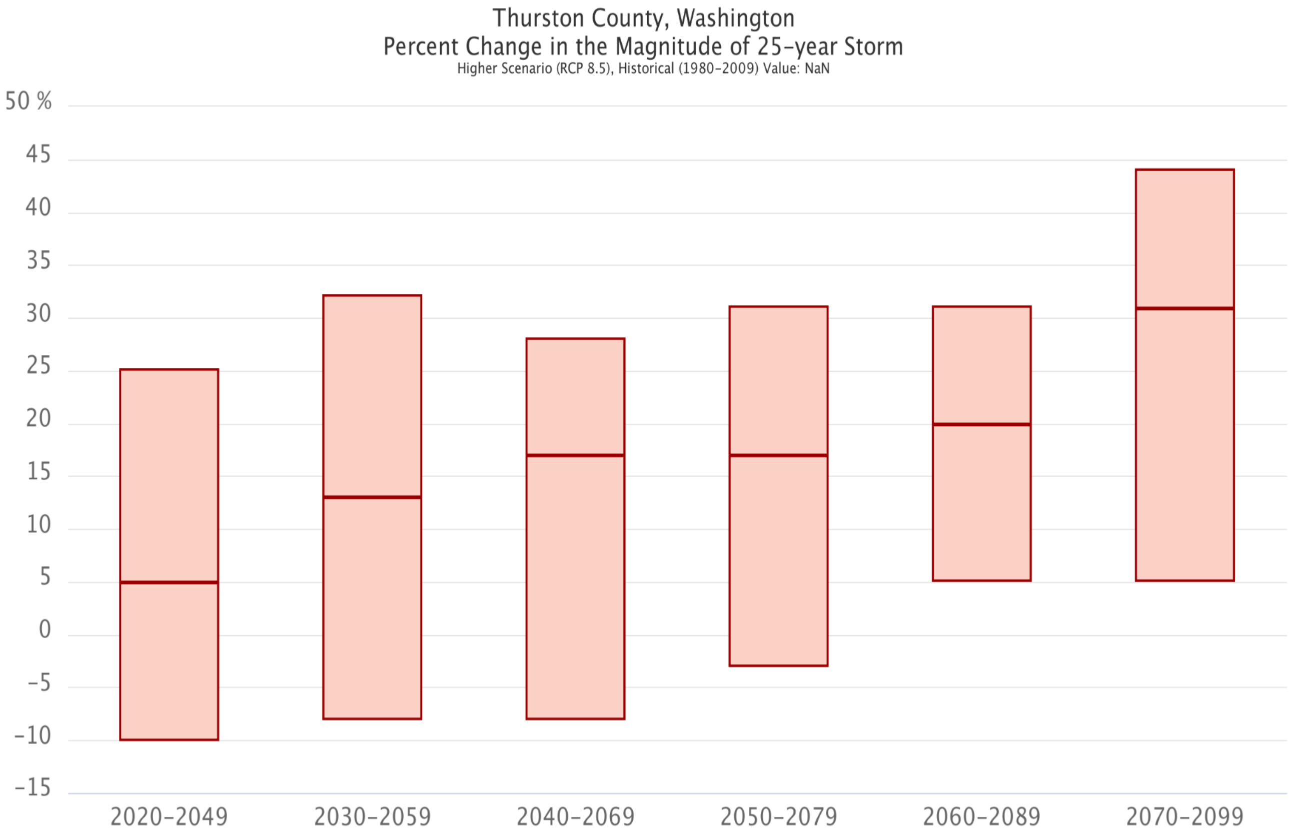


Figure A13. Percent change in the magnitude of the 25-year storm in Thurston County for future 30-year periods under RCP8.5 [15]. Percent change is in comparison to the historical baseline (1980-2009) 25-year storm magnitude. The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

2-Inch Precipitation Days

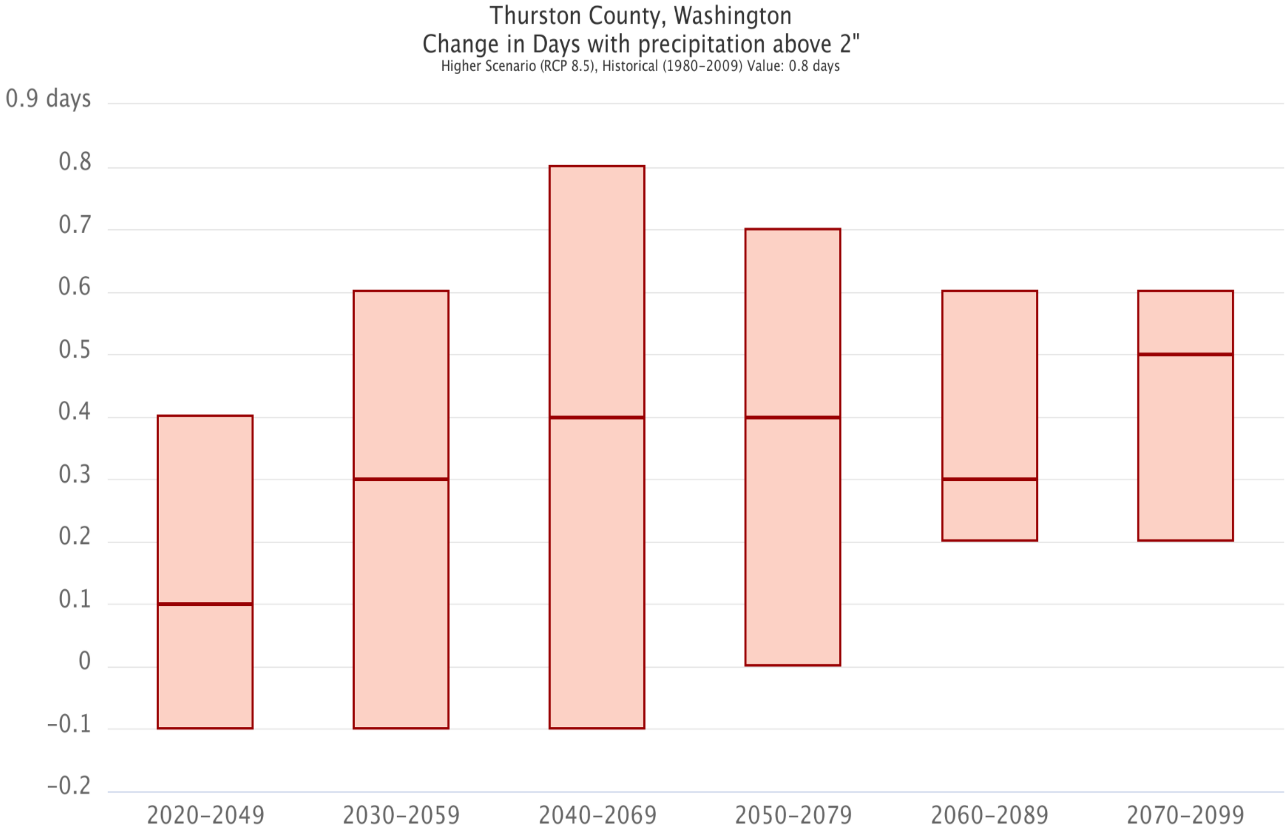


Figure A14. Change in the number of days when total precipitation is > 2 inches in Thurston County for future 30-year periods under RCP8.5 [15]. Change is in comparison to the historical baseline (1980-2009). The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

Streamflow

August Stream Temperature

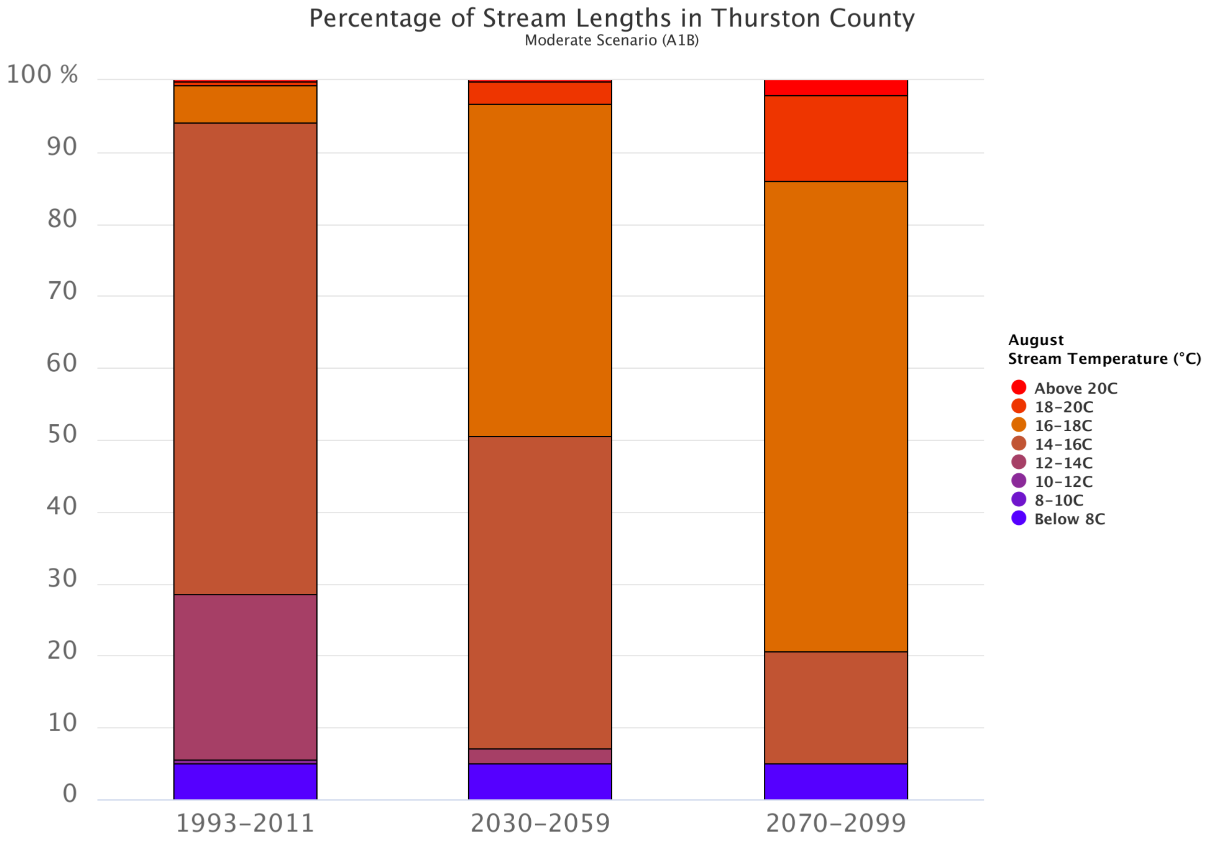


Figure A15. Percentage of stream lengths classified by category of stream temperature in August in Thurston County for three 30-year periods under the A1B scenario [15]. 1993-2011 is the historical baseline. The size of the area taken up by each colored section of the three bars corresponds to the percentage of stream lengths that are projected to fall within the associated temperature range.

Warm Season Streamflow

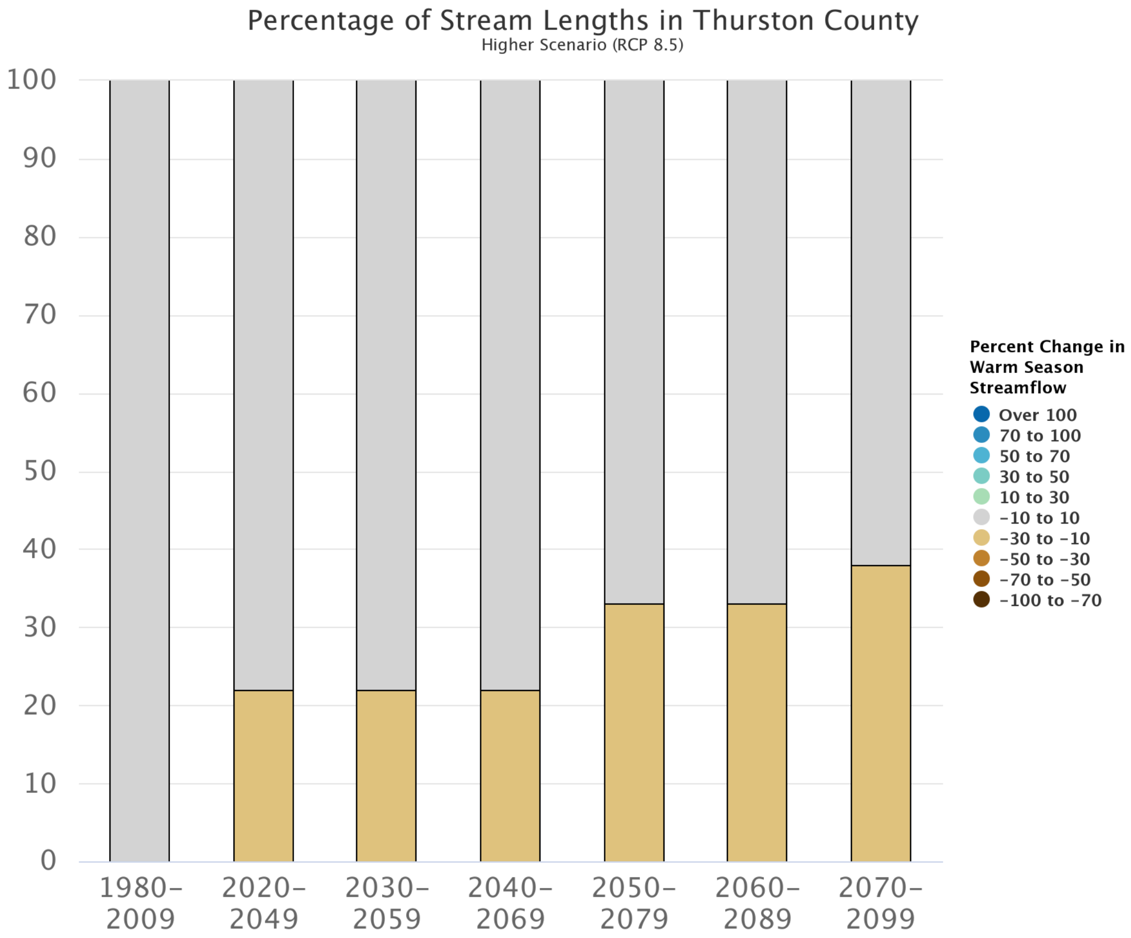


Figure A16. Percentage of stream lengths classified by category of flow change during the warm season (April-September) in Thurston County for future 30-year periods under RCP8.5 [15]. Flow change is in comparison to the historical baseline (1980-2009). The size of the area taken up by each colored section of the seven bars corresponds to the percentage of stream lengths that are projected to fall within the associated range of flow change. Note that these projections do not consider anthropogenic withdrawals (e.g. for irrigation).

Summer Streamflow

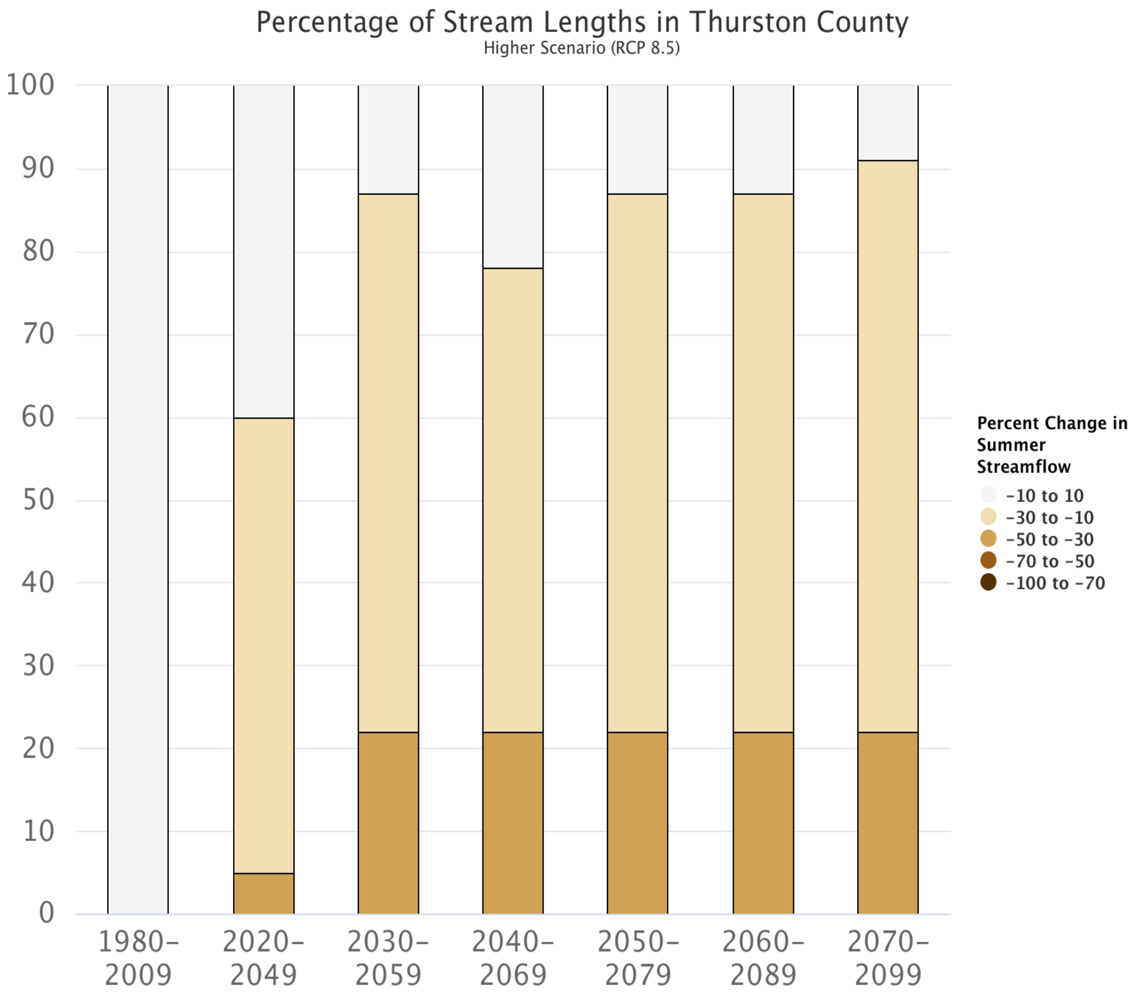


Figure A17. Percentage of stream lengths classified by category of flow change during summer (June-September) in Thurston County for future 30-year periods under RCP8.5 [15]. Flow change is in comparison to the historical baseline (1980-2009). The size of the area taken up by each colored section of the seven bars corresponds to the percentage of stream lengths that are projected to fall within the associated range of flow change. Note that these projections do not consider anthropogenic withdrawals (e.g. for irrigation).

Duration of Low Streamflow

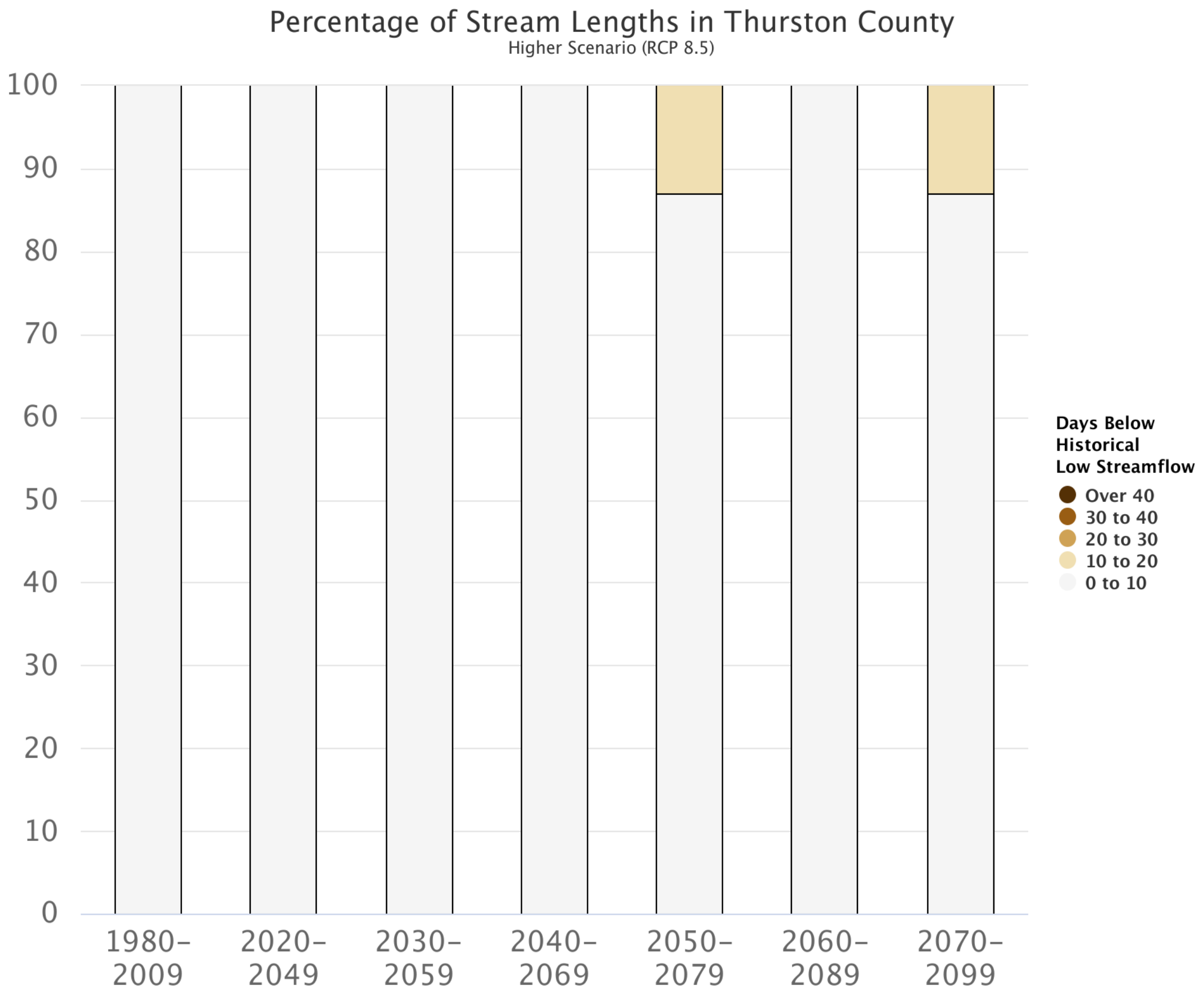


Figure A18. Percentage of stream lengths classified by change in the number of days streamflow is projected to fall below the baseline summer (June-September) low streamflow threshold in Thurston County for future 30-year periods under RCP8.5 [15]. Flow change is in comparison to the historical baseline (1980-2009). The size of the area taken up by each colored section of the seven bars corresponds to the percentage of stream lengths that are projected to experience historical low streamflow for the associated period of time (e.g. for 0-10 days). Note that these projections do not consider anthropogenic withdrawals (e.g. for irrigation).

Streamflow Timing

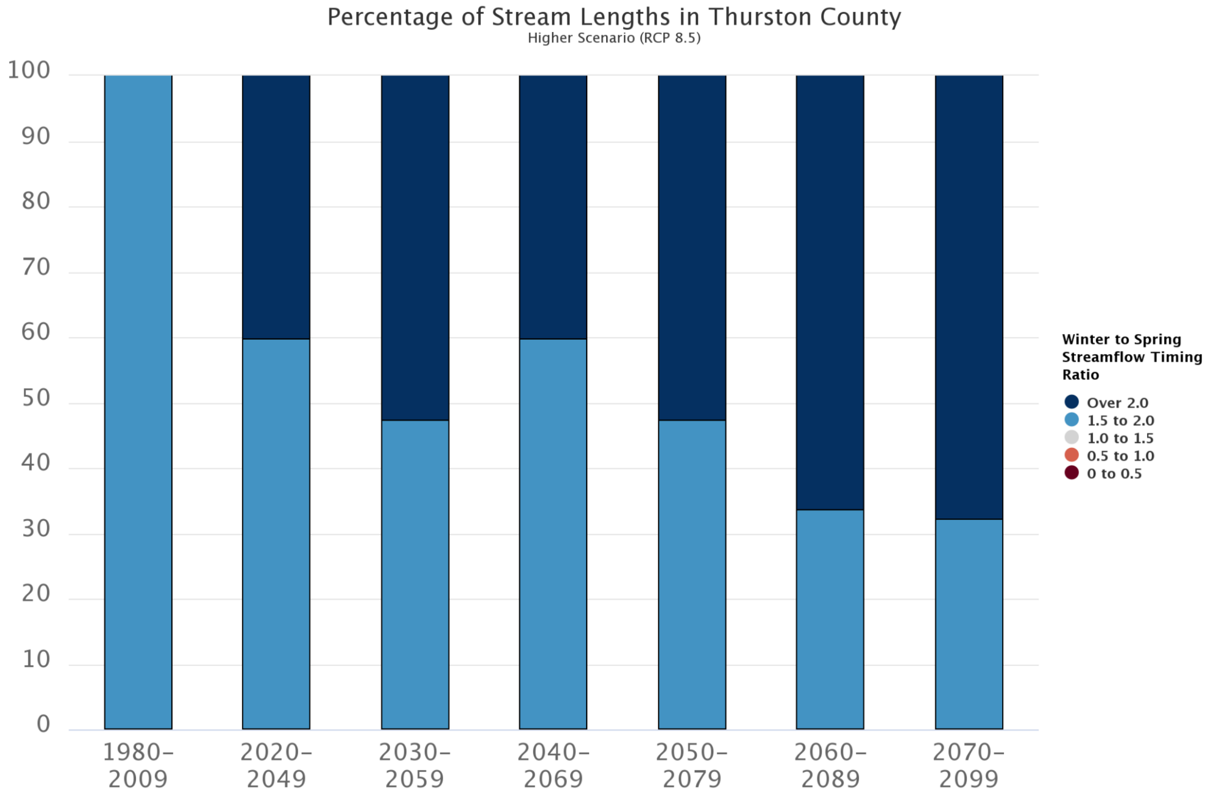


Figure A19. Percentage of stream lengths classified by category of change in winter to spring streamflow timing ratio in Thurston County for future 30-year periods under RCP8.5 [8]. Winter to spring streamflow timing ratio is calculated by dividing the average winter streamflow by average spring streamflow. The size of the area taken up by each colored section of the seven bars corresponds to the percentage of stream lengths that are projected to fall within the associated streamflow timing ratio. Note that these projections do not consider anthropogenic withdrawals (e.g. for irrigation).

Peak Streamflow

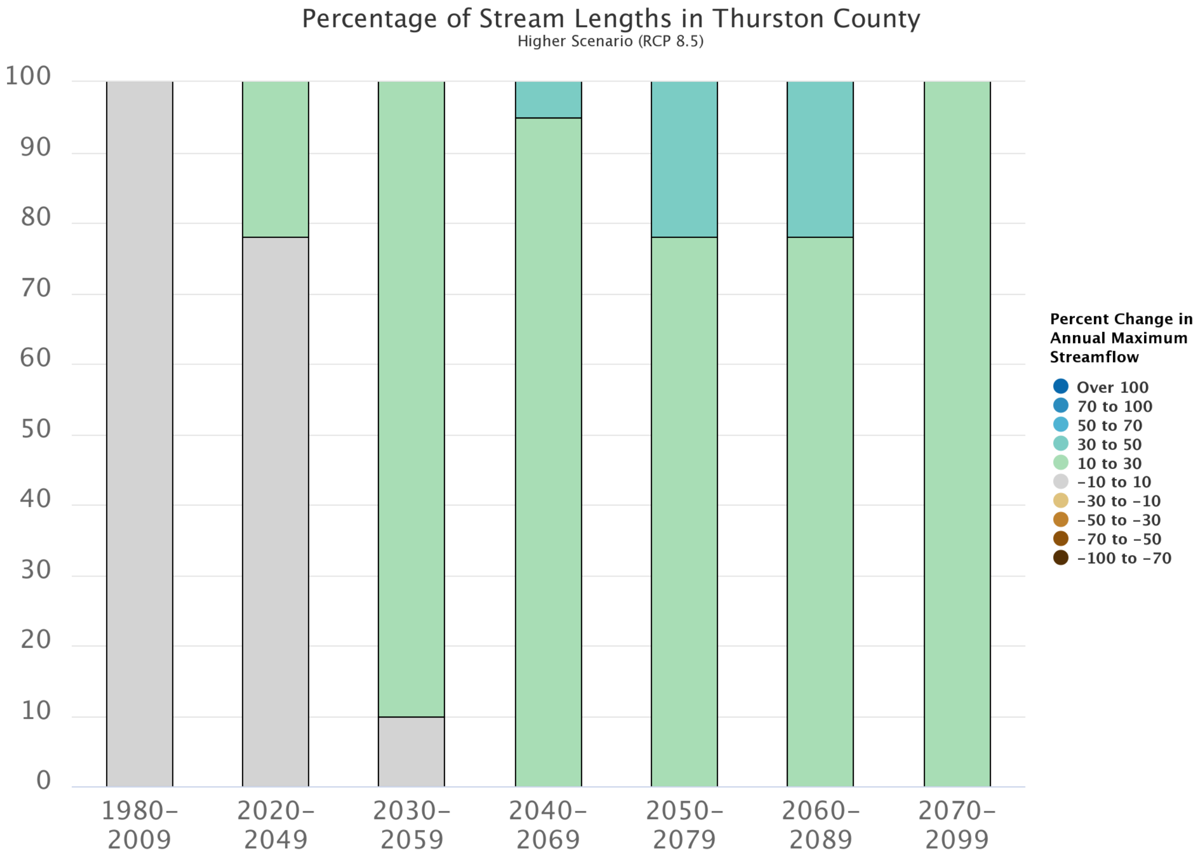


Figure A20. Percentage of stream lengths classified by category of percent change in peak (annual maximum) streamflow in Thurston County for future 30-year periods under RCP8.5 [15]. Peak streamflow is the highest magnitude streamflow to occur at any point in a given year. Flow change is in comparison to the historical baseline (1980-2009). The size of the area taken up by each colored section of the seven bars corresponds to the percentage of stream lengths that are projected to fall within the associated range of flow change. Note that these projections do not consider anthropogenic withdrawals (e.g. for irrigation).

Return Interval of 25-Year Peak Streamflow

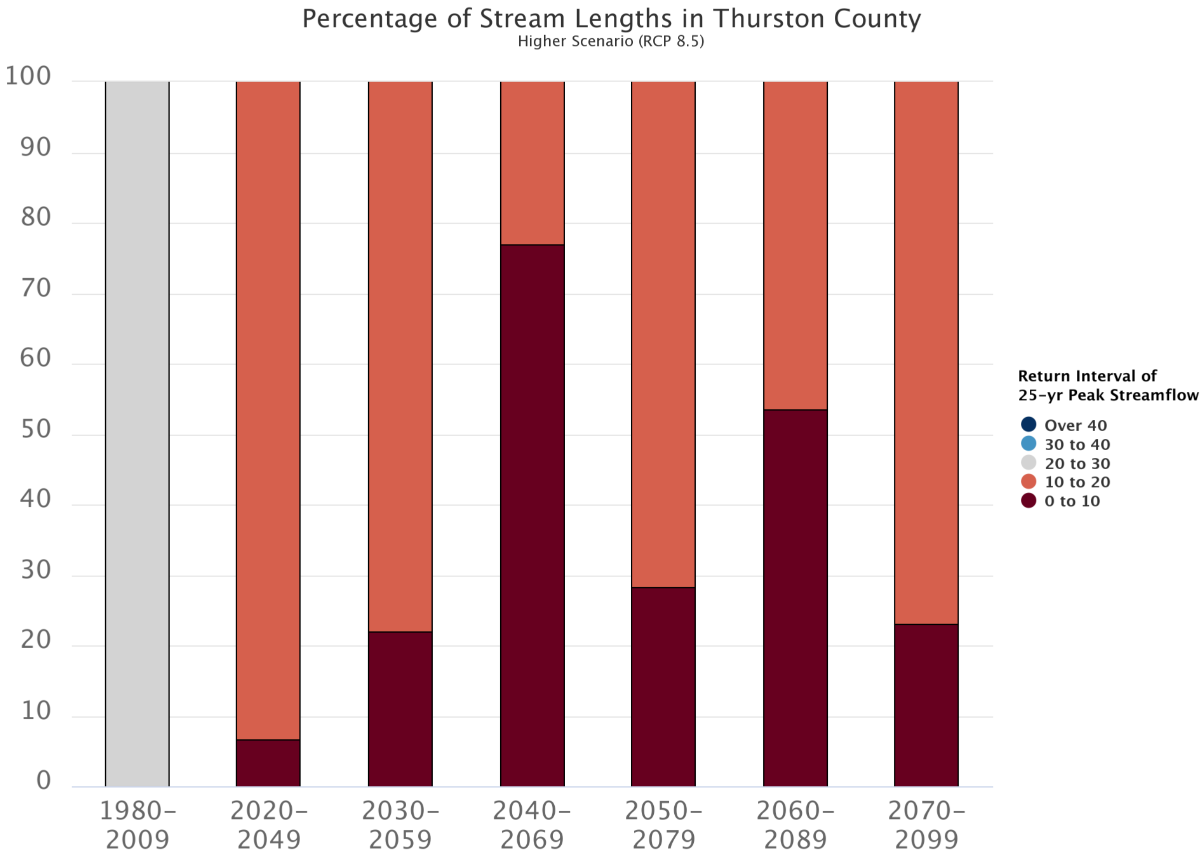


Figure A21. Percentage of stream lengths classified by return interval of 25-year peak streamflow in Thurston County for future 30-year periods under RCP8.5 [15]. Return interval is in comparison to the historical baseline (1980-2009) 25-year peak streamflow. The size of the area taken up by each colored section of the seven bars corresponds to the percentage of stream lengths that are projected to fall within the associated return interval range (e.g. stream lengths classified 1 to 10 are projected to have 25-year historical peak streamflow recur every 0 to 10 years). Note that these projections do not consider anthropogenic withdrawals (e.g. for irrigation).

Sea Level Rise

Most-Likely and High-Range Sea Level Rise

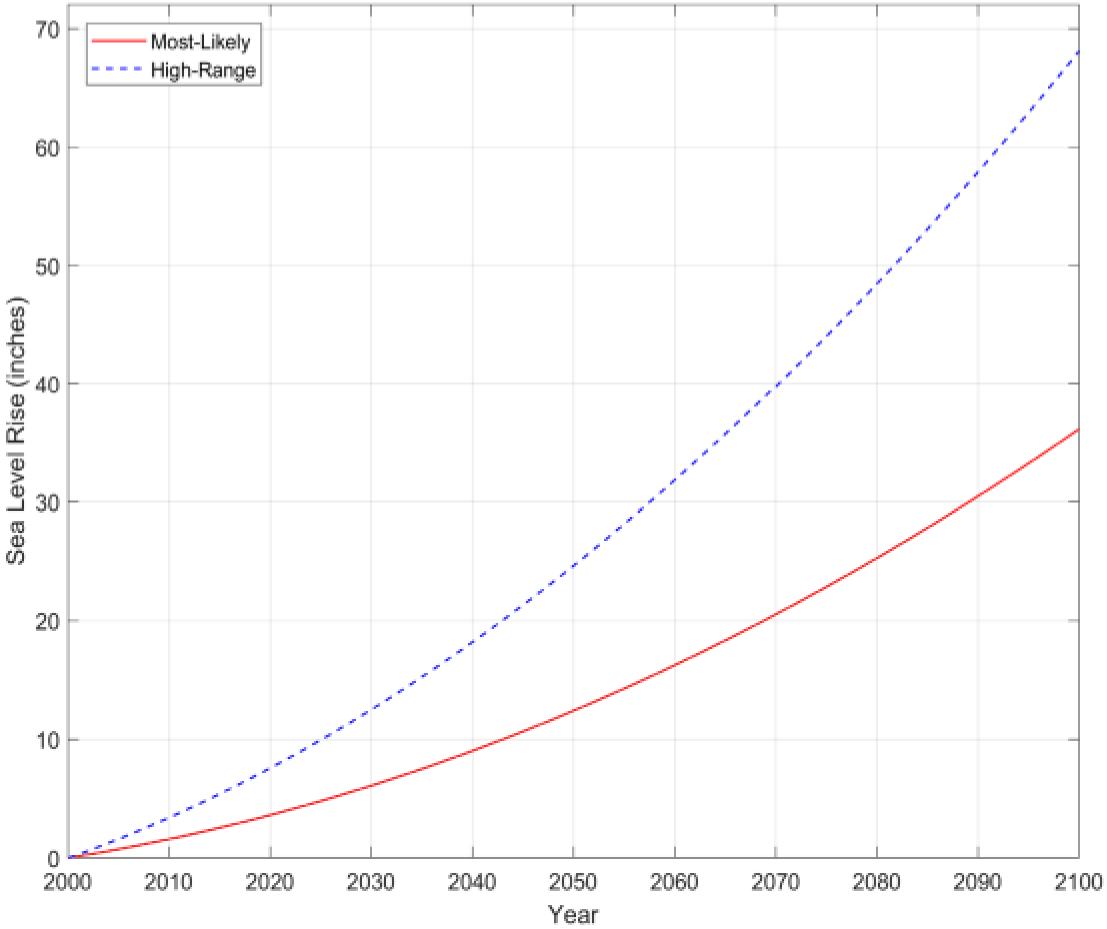
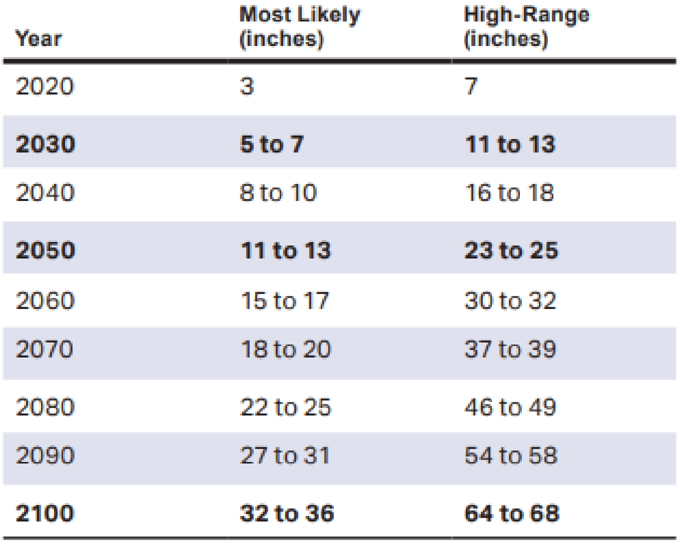


Figure 6. Sea Level Rise Projections at Olympia

Figure A22. Graphic representation of most-likely and high-range sea level rise projections for Olympia [12].

Table A3. Table representation of most likely and high-range sea level rise projections for Olympia [12].



Year	Most Likely (inches)	High-Range (inches)
2020	3	7
2030	**5 to 7**	**11 to 13**
2040	8 to 10	16 to 18
2050	**11 to 13**	**23 to 25**
2060	15 to 17	30 to 32
2070	18 to 20	37 to 39
2080	22 to 25	46 to 49
2090	27 to 31	54 to 58
2100	**32 to 36**	**64 to 68**

Sea Level Rise Exposure

Table A4. Olympia's exposure to sea level rise, with associated notes from the source retained [12]. The table summarizes exposure of land inundated, employment, residential population, buildings, and roads for sea level rise of up to 4 feet higher than the 100-Year Storm Tide in Budd Inlet.

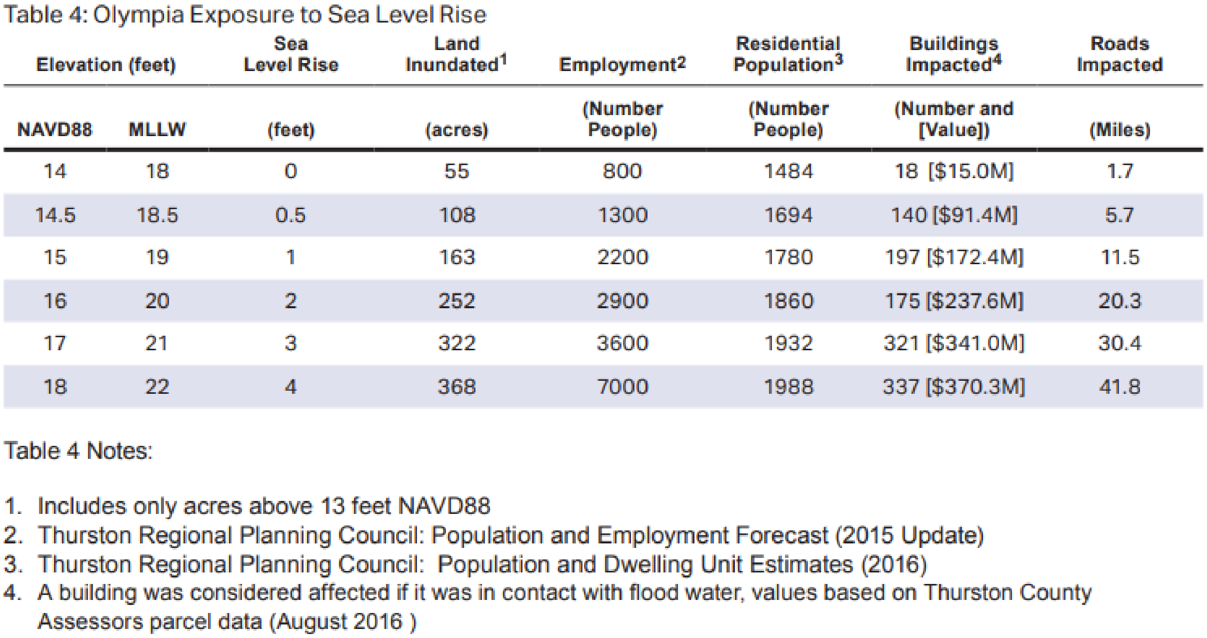


Table 4: Olympia Exposure to Sea Level Rise

Elevation (feet)		Sea Level Rise	Land Inundated[1]	Employment[2]	Residential Population[3]	Buildings Impacted[4]	Roads Impacted
NAVD88	MLLW	(feet)	(acres)	(Number People)	(Number People)	(Number and [Value])	(Miles)
14	18	0	55	800	1484	18 [$15.0M]	1.7
14.5	18.5	0.5	108	1300	1694	140 [$91.4M]	5.7
15	19	1	163	2200	1780	197 [$172.4M]	11.5
16	20	2	252	2900	1860	175 [$237.6M]	20.3
17	21	3	322	3600	1932	321 [$341.0M]	30.4
18	22	4	368	7000	1988	337 [$370.3M]	41.8

Table 4 Notes:

1. Includes only acres above 13 feet NAVD88
2. Thurston Regional Planning Council: Population and Employment Forecast (2015 Update)
3. Thurston Regional Planning Council: Population and Dwelling Unit Estimates (2016)
4. A building was considered affected if it was in contact with flood water, values based on Thurston County Assessors parcel data (August 2016)

Wildfire

Wildfire Danger

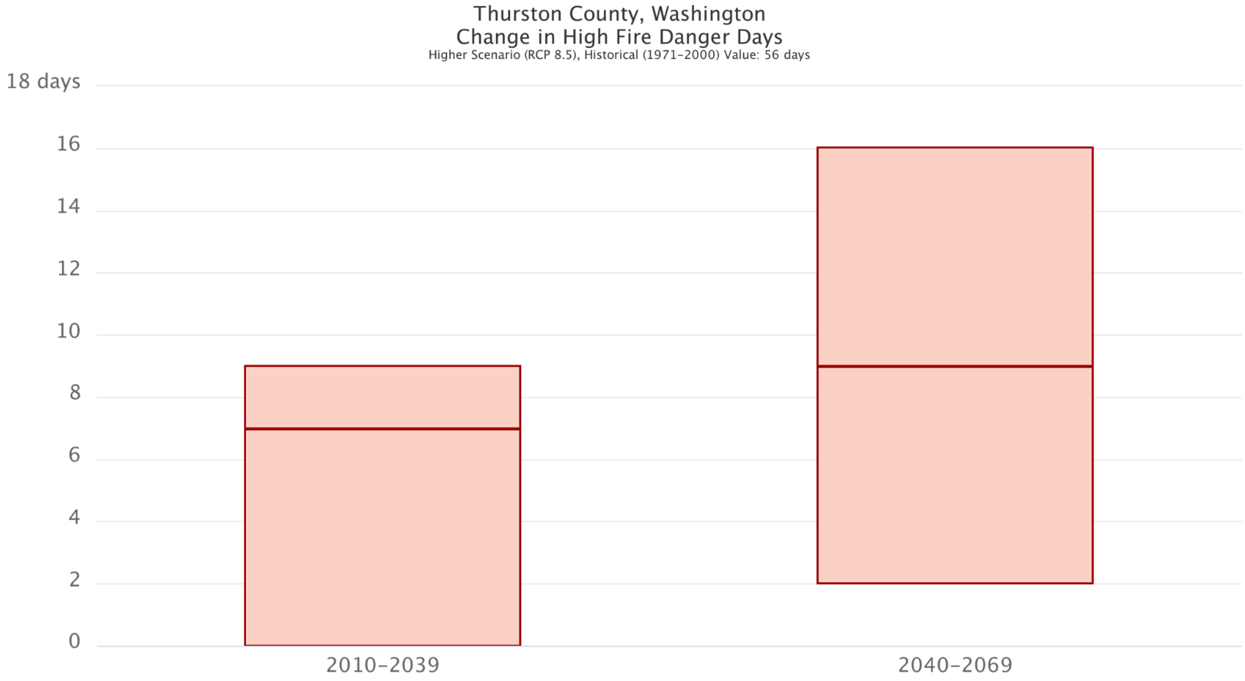


Figure A23. Change in the number of high wildfire danger days in Thurston County for two 30-year periods under RCP8.5 [15]. Change is in comparison to the historical baseline (1971-2000). The two red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

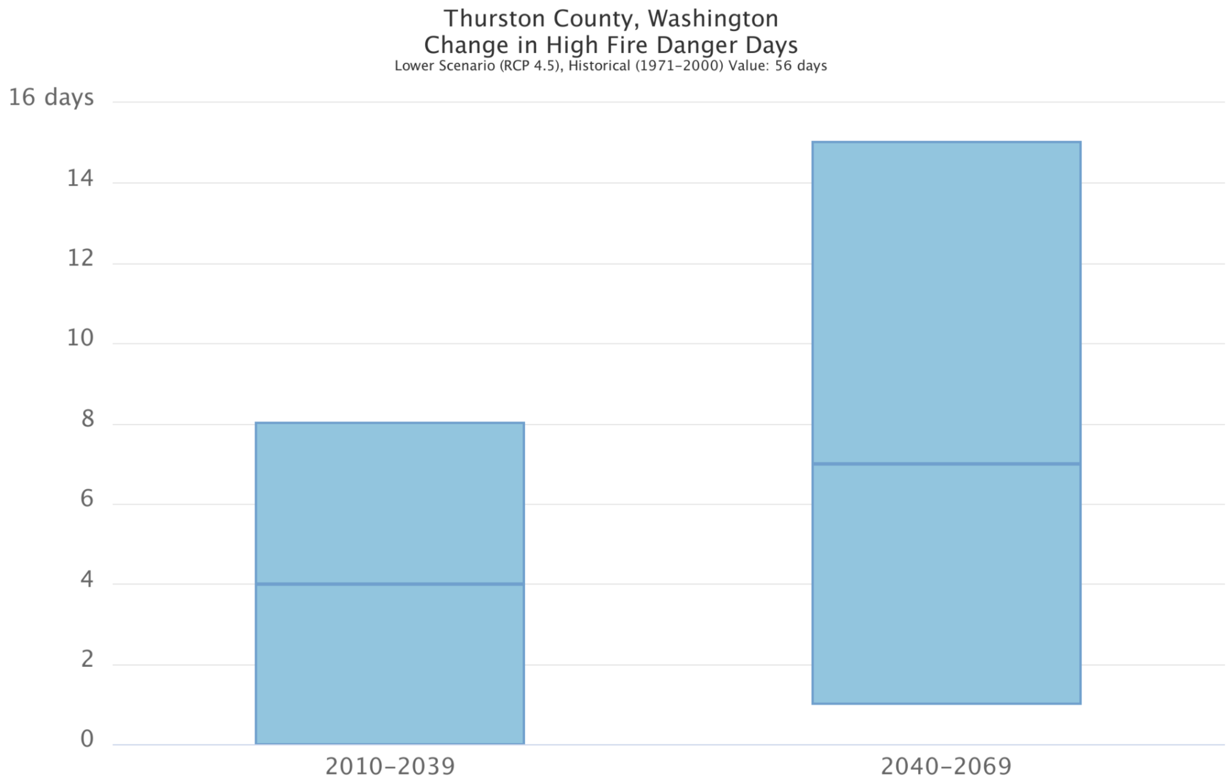


Figure A24. Change in the number of high wildfire danger days in Thurston County for two 30-year periods under RCP4.5 [15]. Change is in comparison to the historical baseline (1971-2000). The six blue bars show the 10th to 90th percentile range of projections; the dark blue line contained within each bar is the ensemble median.

Wildfire Likelihood

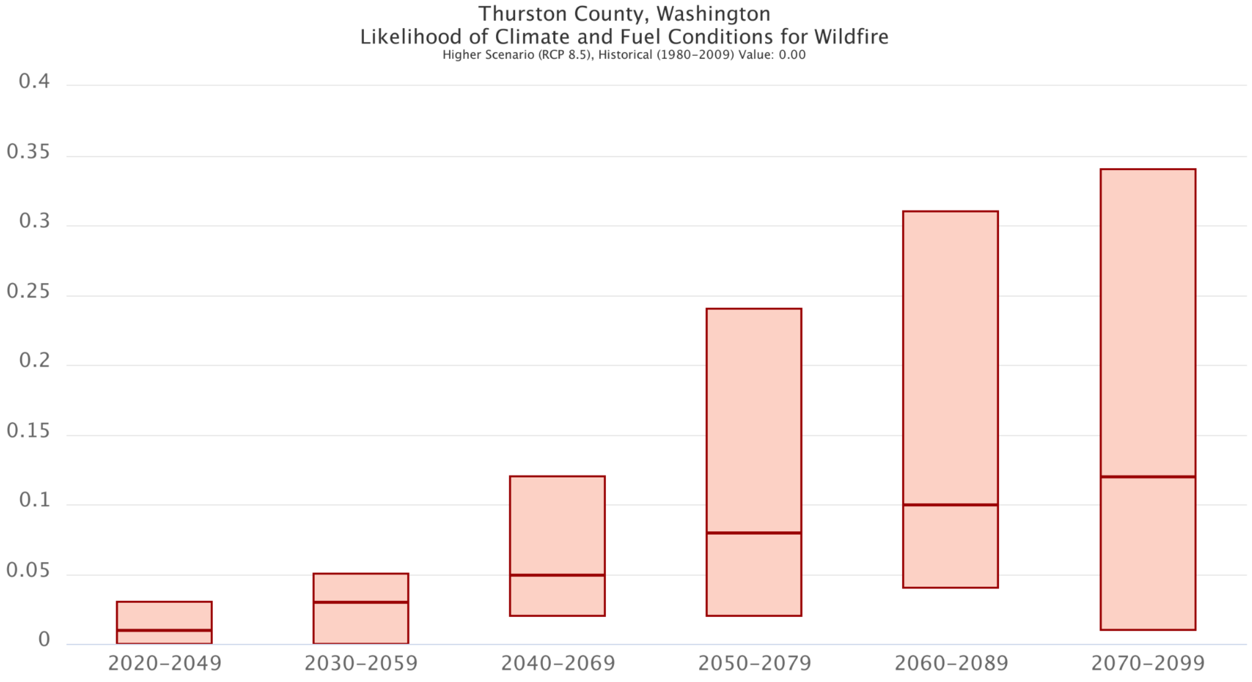


Figure A25. Likelihood of a year with climate and fuel conditions favorable for wildfire in Thurston County for future 30-year periods under RCP8.5 [15]. The six red bars show the 10th to 90th percentile range of projections; the dark red line contained within each bar is the ensemble median.

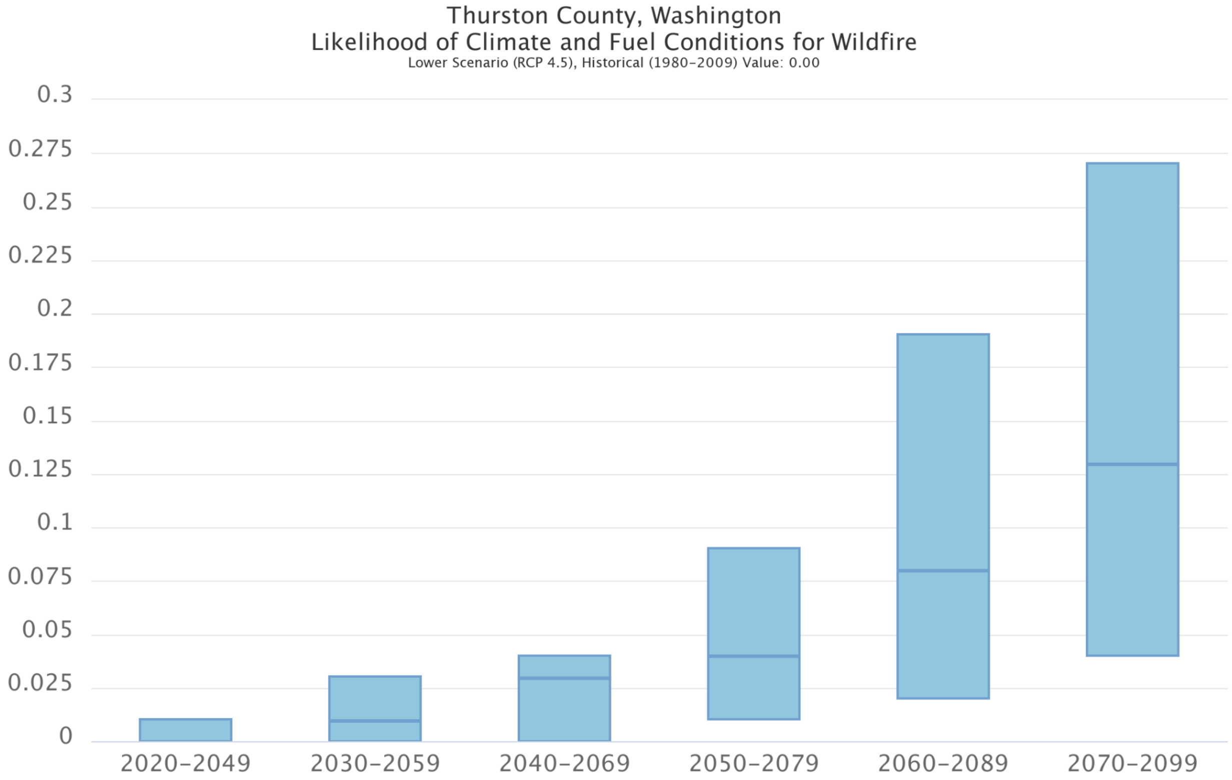
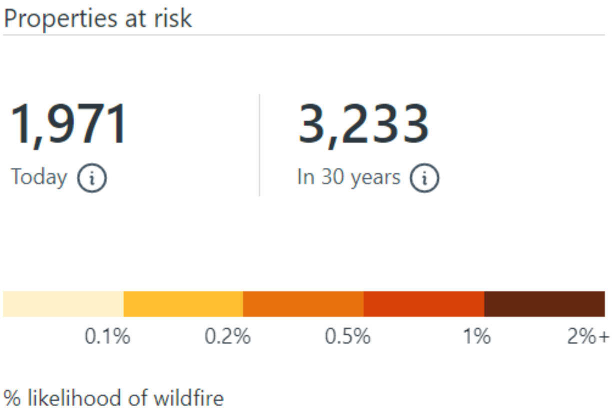


Figure A26. Likelihood of a year with climate and fuel conditions favorable for wildfire in Thurston County for future 30-year periods under RCP4.5 [15]. The six blue bars show the 10th to 90th percentile range of projections; the dark blue line contained within each bar is the ensemble median.

Wildfire Exposure



Properties at risk

1,971
Today

3,233
In 30 years

% likelihood of wildfire

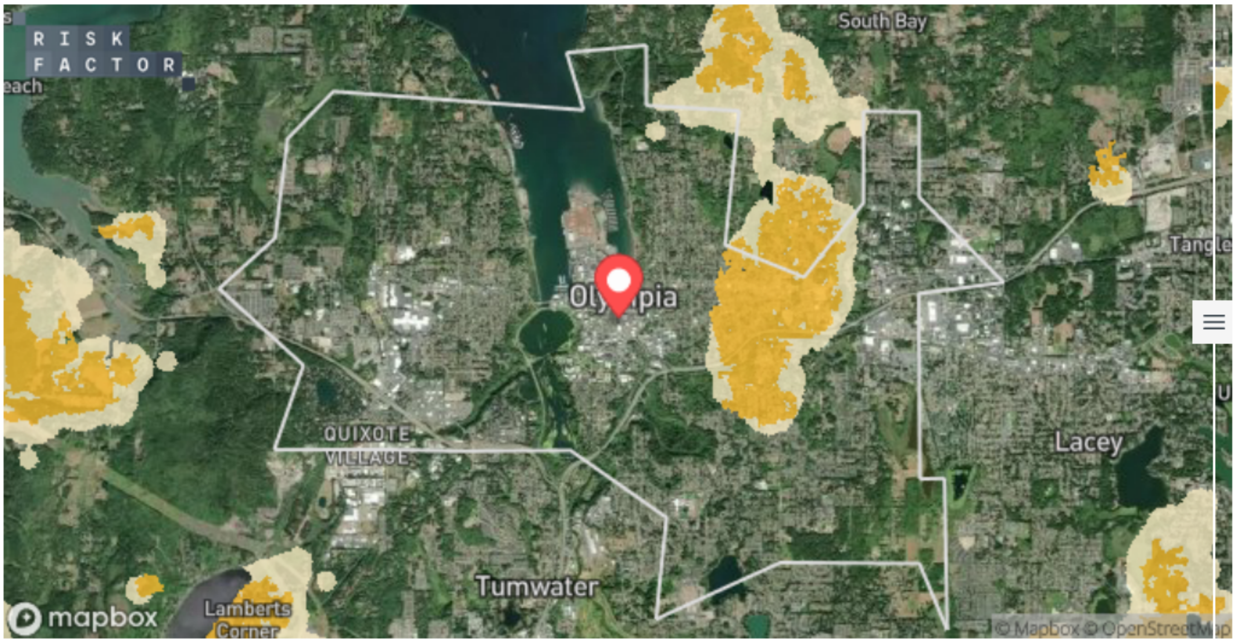


Figure A27. Baseline (2011-2021) wildfire exposure in Olympia under RCP4.5 [30], [35]. Shaded areas have some risk of wildfire occurring in that area in the given year. Light yellow areas have a 0.1% chance of a wildfire occurring in a given year, dark yellow areas have a 0.2% chance. Source modeling for wildfire exposure is only provided for RCP4.5.

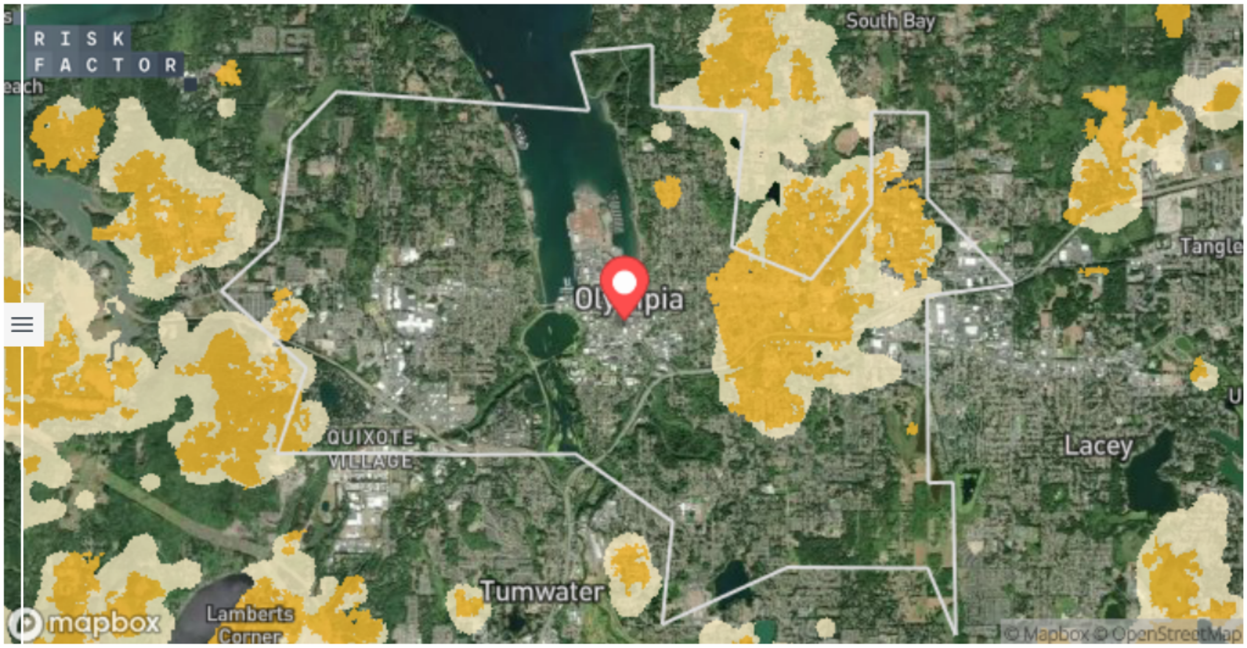


Figure A28. Projected (2041-2050) wildfire exposure in Olympia under RCP4.5 [30], [35]. Shaded areas have some risk of wildfire occurring in that area in the given year. Light yellow areas have a 0.1% chance of a wildfire occurring in a given year, dark yellow areas have a 0.2% chance. Source modeling for wildfire exposure is only provided for RCP4.5.

Air Quality

Air Quality and Temperature

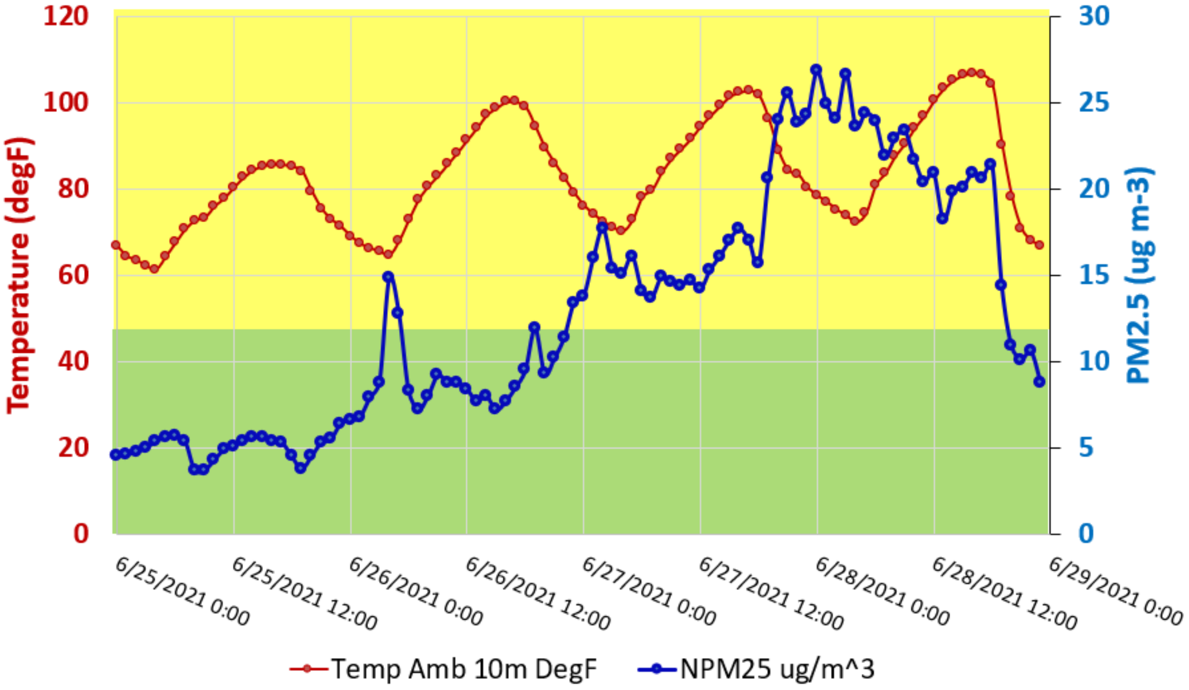


Figure A29. A comparison of temperature and PM2.5 (fine particle air pollution) concentrations measured at ORCAA site in Lacey, WA, during a heatwave in June of 2021.

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