Land Use & Economic Development Committee Agenda

Mukilteo City Hall - 11930 Cyrus Way

Tuesday, June 1, 2021

5:30 PM - 7:00 PM

Zoom Virtual Meeting

Join Zoom Meeting
https://us02web.zoom.us/j/84006796607?pwd=MDIyQi9HQmRNMzF6eDFhVmMyMGR3Zz09

BY PHONE:
+1 253 215 8782 US (Tacoma)
+1 669 900 9128 US (San Jose)

Meeting ID: 840 0679 6607
Passcode: 066151

CALL TO ORDER - 5:30 PM

Meeting Objectives:

1. Economic Recovery
2. Climate Action Planning (Councilmember Emery)
3. Development Projects/Proposals
4. Schedule July Meeting (due to 4th of July Holiday Weekend and Tuesday, July 6, 2021 conflict with Council meeting)

ADJOURNMENT - 7:00 PM

Next Meeting Date: Time to be determined
Preliminary July Agenda Topics: Economic Recovery, Ordinance - Source Control

- For accessibility information and for accommodation requests, please call the ADA Coordinator at (425) 263-8005 *(or TRS (800) 833-6384 or dial 711)*, or visit https://mukilteowa.gov/departments/executive/ada-program/.

LAND USE & ECONOMIC DEVELOPMENT COMMITTEE AGENDA REPORT	
SUBJECT TITLE: Climate Action Planning	**FOR AGENDA OF:** June 1, 2021
Contact Staff: David Osaki, Community Development Director **Department Director:** David Osaki	**EXHIBITS:** 1. Thurston County Climate Adaptation Plan 2. City of Mukilteo Climate Action Committee Final Report, October 2020

Background

At its April 5, 2021 Preliminary Docket Public Hearing, the Mukilteo City Council moved certain climate change Comprehensive Plan text amendments to the 2021 Final Docket. This means that Comprehensive Plan text amendments pertaining to climate change will undergo further study and eventually be brought to the Planning Commission for a public hearing and recommendation to the City Council.

The general framework for the 2021 final docket climate change Comprehensive Plan text amendments is as follows.

General Comprehensive Plan Text/Narrative To:

- Summarize the federal, state, regional and county framework of laws, policies, and actions related to climate change, as applicable, including greenhouse gas and/or vehicle miles traveled reduction targets set by other agencies.
- Acknowledge the work of the City Climate Action Committee/prior City Council action(s) related to reduction of greenhouse gas and/or vehicle miles traveled.

Policy Amendments To:

- Retain/Update Comprehensive Plan Policy TR4 and TR4A related to air quality and the City increasing the percentage of its vehicle fleet comprised of hybrid, all-electric or other non CO_2-emitting vehicles.
- Using the draft Countywide Planning Policies (CPP) amendments as a guide, propose new Mukilteo Comprehensive Plan policies such as:
  - The City will pursue efforts to realize state and/or regional targets related to the reduction of greenhouse gas emissions and vehicle miles traveled.
  - Participate in/cooperate in regional efforts to address climate change.
  - The City will coordinate with programs that work to reduce greenhouse gas emissions and increase energy conservation, including the retrofit of existing buildings, expansion of alternative/clean energy within the public and private sector, and the use of environmentally sustainable building techniques and materials.
  - Using natural systems to reduce carbon in the atmosphere such as open space, vegetative cover, wetlands, and estuaries.

Specific Comprehensive Plan text amendment language is to be developed through the final docket process.

DISCUSSION

Since the April 5, 2021 City Council Preliminary Docket Public Hearing, Councilmember Emery has noted work done by Thurston County on its 2018 Climate Adaptation Plan. The Thurston County Climate Adaptation Plan is attached **(See Exhibit 1)** for Councilmember Emery to present to the LU&ED Committee.

As additional information, in May 2019 the City Council approved a resolution (Resolution 2019-02) creating a Climate Action Committee to advise the City Council on energy goals for the City and residents. The Climate Action Committee's work culminated with a Final Report to the City Council on October 19, 2020 (**See Exhibit 2).**

EXHIBIT 1

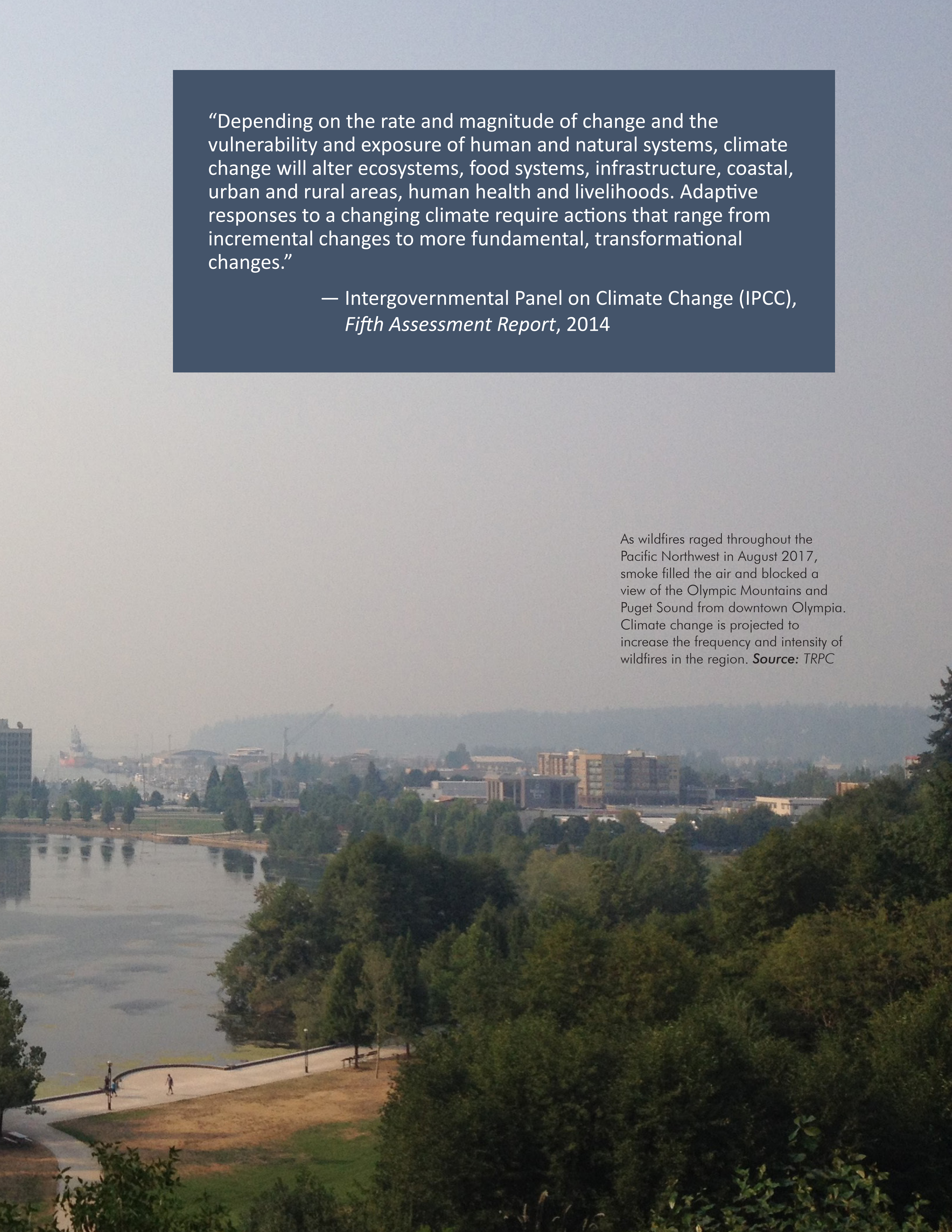
THURSTON CLIMATE ADAPTATION PLAN

Climate Resilience Actions for
Thurston County and South Puget Sound

2018

thurston regional planning council

> “Depending on the rate and magnitude of change and the vulnerability and exposure of human and natural systems, climate change will alter ecosystems, food systems, infrastructure, coastal, urban and rural areas, human health and livelihoods. Adaptive responses to a changing climate require actions that range from incremental changes to more fundamental, transformational changes.”
>
> — Intergovernmental Panel on Climate Change (IPCC), *Fifth Assessment Report*, 2014



As wildfires raged throughout the Pacific Northwest in August 2017, smoke filled the air and blocked a view of the Olympic Mountains and Puget Sound from downtown Olympia. Climate change is projected to increase the frequency and intensity of wildfires in the region. ***Source:*** *TRPC*

Suggested Citation

Thurston Regional Planning Council (2018). Thurston Climate Adaptation Plan: Climate Resilience Actions for Thurston County and South Puget Sound: TRPC, 2018. Print.

Acknowledgments

The Thurston Regional Planning Council (TRPC) prepared the Thurston Climate Adaptation Plan — which recommends actions to help Thurston County and the broader South Puget Sound region prepare for and adjust to adverse climate change impacts (adaptation) and bolster resilience. The U.S. Environmental Protection Agency (EPA) provided a National Estuary Program grant for the project. The Washington Department of Commerce administered the funding, and TRPC hired Thurston County and Earth Economics as subcontractors. TRPC is grateful for the support of these organizations and the thousands of area residents who served on the project's advisory committees, attended meetings, and otherwise contributed to the plan's development. For more information, please visit www.trpc.org/climate.

Thurston Regional Planning Council (TRPC) is a 22-member intergovernmental board made up of local governmental jurisdictions within Thurston County, plus the Confederated Tribes of the Chehalis Reservation and the Nisqually Indian Tribe. The Council was established in 1967 under RCW 36.70.060, which authorized creation of regional planning councils.

TRPC's mission is to "Provide Visionary Leadership on Regional Plans, Policies, and Issues."

To Support this Mission:

A. Support regional transportation planning consistent with state and federal funding requirements.

B. Address growth management, environmental quality, economic opportunity, and other topics determined by the Council.

C. Assemble and analyze data that support local and regional decision making

D. Act as a "convener" to build regional consensus on issues through information and citizen involvement.

E. Build intergovernmental consensus on regional plans, policies, and issues, and advocate local implementation.

Contributors

Project Team

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Nathaniel Jones (Vice Chair), City of Olympia

Everett Gage, City of Rainier

David Watterson, City of Tenino

Tom Oliva (Chair), City of Tumwater

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Jeanne Rynne, The Evergreen State College

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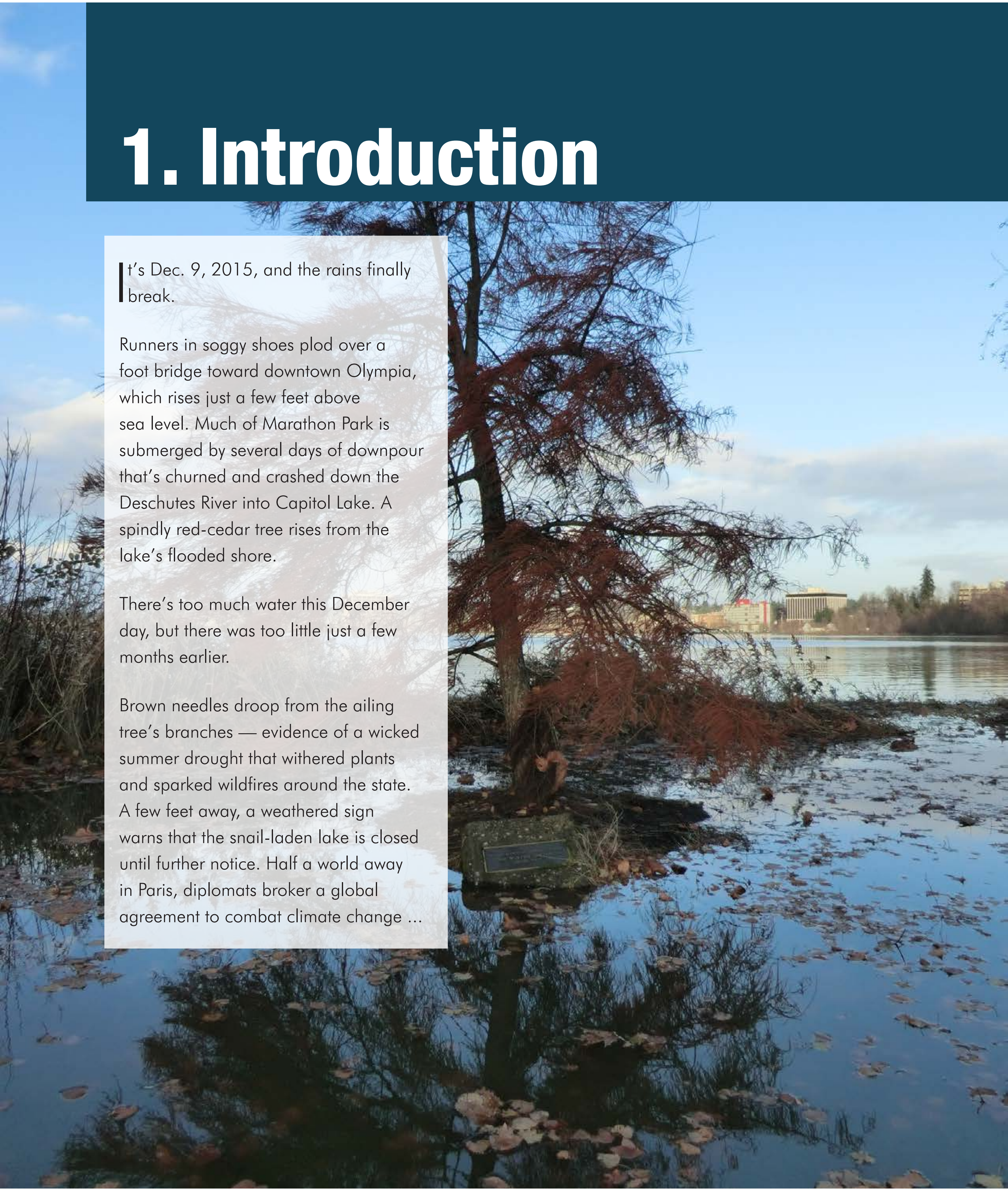
1. Introduction



It's Dec. 9, 2015, and the rains finally break.

Runners in soggy shoes plod over a foot bridge toward downtown Olympia, which rises just a few feet above sea level. Much of Marathon Park is submerged by several days of downpour that's churned and crashed down the Deschutes River into Capitol Lake. A spindly red-cedar tree rises from the lake's flooded shore.

There's too much water this December day, but there was too little just a few months earlier.

Brown needles droop from the ailing tree's branches — evidence of a wicked summer drought that withered plants and sparked wildfires around the state. A few feet away, a weathered sign warns that the snail-laden lake is closed until further notice. Half a world away in Paris, diplomats broker a global agreement to combat climate change ...

It's a scene rich with symbolism, a scene set in the context of extremes: 2015 marked Washington's most severe wildfire year in modern history — with more than 1 million acres burned by summer's end — but December's deluge still made the year one of wettest on record (USDA, 2015).

Such seasonal extremes are perhaps a preview of our future.

Burning fossil fuels in automobiles and other human activities are increasing emissions of carbon dioxide and other gases that trap heat in the atmosphere like a greenhouse. Even as we strive to slow our emissions, adaptation is essential to address unavoidable warming due to past emissions. Our temperate region of snowy peaks, rocky shores, and evergreen forests is not immune to change.

Climate models project progressively warmer, wetter winters and hotter, drier summers for the Puget Sound region through the end of the 21st century. The warming is projected to shift the timing, type, and intensity of precipitation — all of which have a trickle-down effect on snowpack, runoff, streamflow, groundwater, and other crucial components of the hydrologic cycle: Picture winters in the 2050s with less snow across our highlands and more flooding along our rivers. And while our summers might feel more Californian, such warmer and drier days will raise the risk of algal blooms, wildfires, disease outbreaks, heat illnesses, and other hazards.

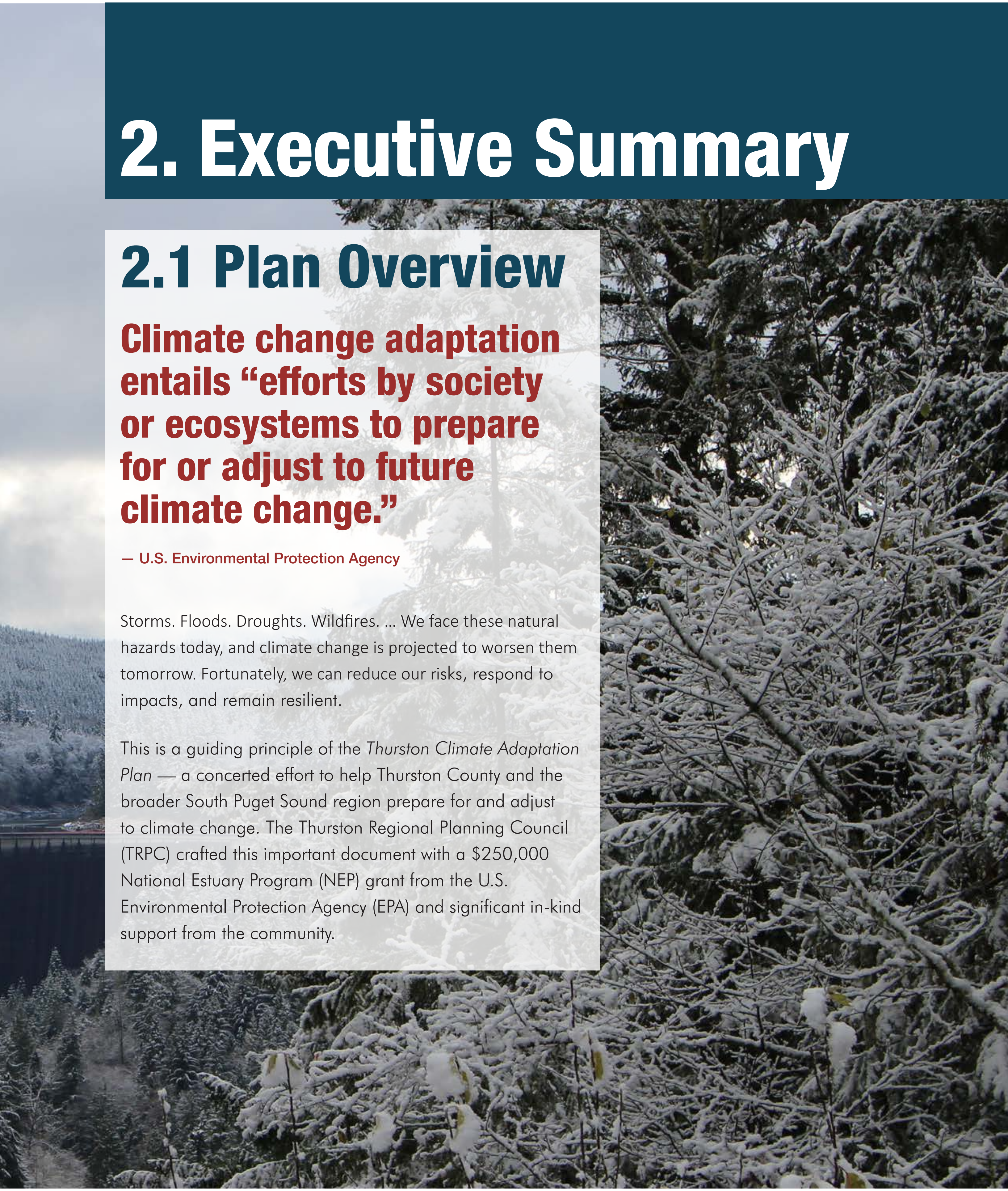
The takeaway: Climate change will continue to affect our human and natural systems in myriad ways tomorrow, so we must begin adapting today. It's the socially, economically, and environmentally responsible thing to do.

The plan you're reading includes a menu of actions to help the Thurston County, Washington region (Thurston Region) and broader South Puget Sound prepare for and adjust to climate impacts — the very definition of adaptation. Many actions are new to the region, while other actions build on work we're already doing. Please read on to learn what you can do personally and what your community can do collectively to become more resilient.

We have one planet but many climate solutions, so let's get to work.

Low-lying buildings and roads where McLane Creek meets Eld Inlet are among built assets vulnerable to sea-level rise. ***Source:*** *Washington State Department of Ecology*

Fresh snow blankets the forest surrounding the Alder Dam, in southeastern Thurston County. ***Source:*** *TRPC*



2. Executive Summary

2.1 Plan Overview

Climate change adaptation entails "efforts by society or ecosystems to prepare for or adjust to future climate change."

— U.S. Environmental Protection Agency

Storms. Floods. Droughts. Wildfires. ... We face these natural hazards today, and climate change is projected to worsen them tomorrow. Fortunately, we can reduce our risks, respond to impacts, and remain resilient.

This is a guiding principle of the *Thurston Climate Adaptation Plan* — a concerted effort to help Thurston County and the broader South Puget Sound region prepare for and adjust to climate change. The Thurston Regional Planning Council (TRPC) crafted this important document with a $250,000 National Estuary Program (NEP) grant from the U.S. Environmental Protection Agency (EPA) and significant in-kind support from the community.

Partners included representatives from tribes, municipalities, universities, nonprofits, businesses, and other entities within the project area: three geographically diverse watersheds (Nisqually, Deschutes and Kennedy-Goldsborough) within Thurston County that drain into Puget Sound [See *Figure 01*]. The watersheds are dynamic — encompassing beaches, rivers, lakes, wetlands, highlands, forests, farms, ranches, cities, towns, and tribal reservations.

The Chehalis River Basin covers southwestern Thurston County and drains into the Pacific Ocean, so this area is outside of the NEP grant's estuary boundary. That said, many of this adaptation plan's actions may be applied effectively across Thurston County's entire 774-square-mile area. Indeed, it is TRPC's hope that other communities throughout the Puget Sound region, state, and nation will replicate this project's science-based assessments, innovative public-engagement efforts, collaborative planning processes, economic analyses, and comprehensive actions.

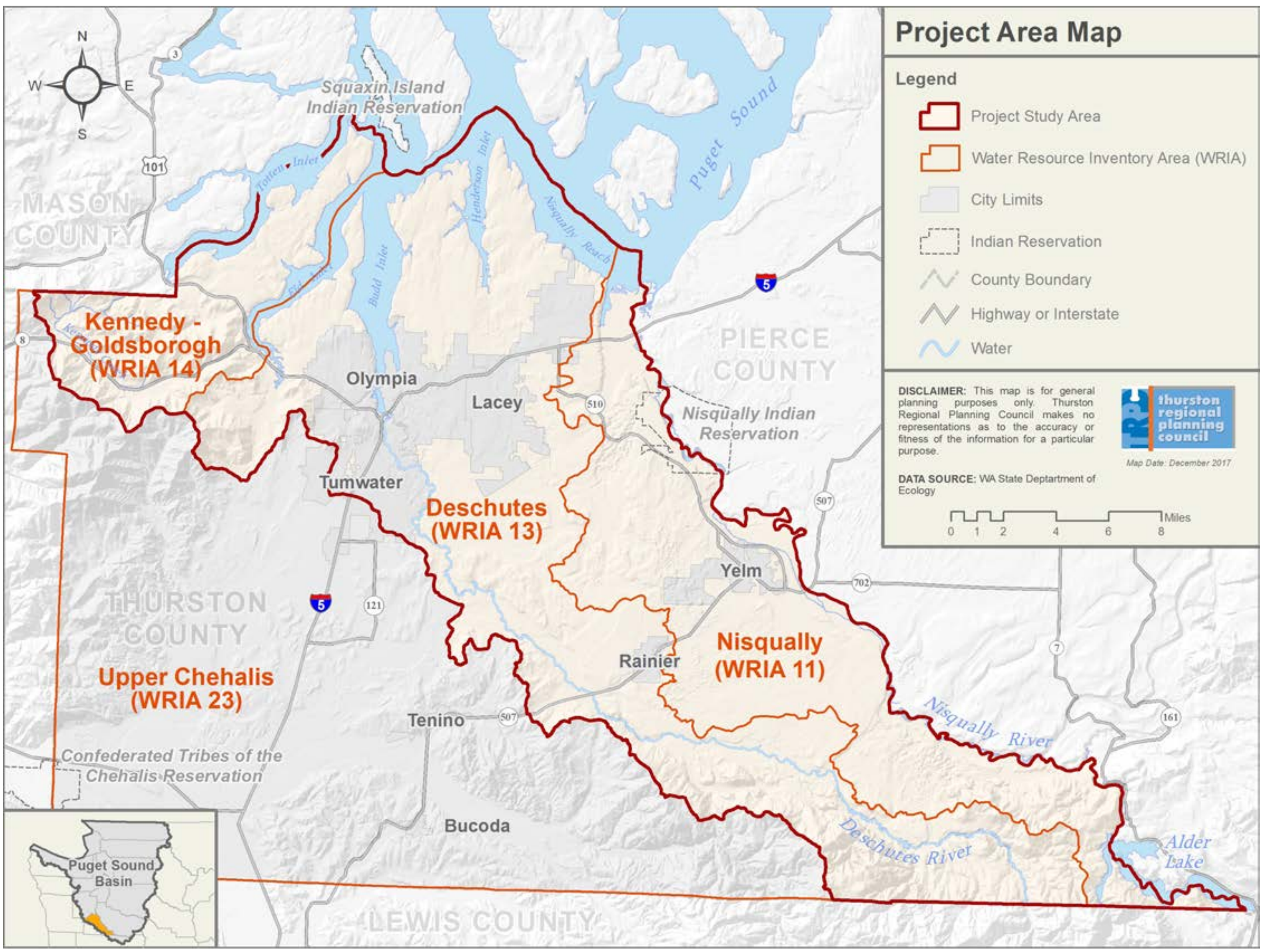


Figure 01: The *Thurston Climate Adaptation Plan* project area included parts of the Puget Sound-draining Nisqually (WRIA 11), Deschutes (WRIA 13) and Kennedy-Goldsborough (WRIA 14) watersheds that are within Thurston County. The full Nisqually Watershed straddles Thurston, Pierce and Lewis counties and begins on the flanks of Mount Rainier; the Deschutes Watershed straddles Lewis and Thurston Counties and begins in the Mount Baker-Snoqualmie National Forest, southwest of Alder Lake; the Kennedy-Goldsborough Watershed (WRIA 14) straddles Mason and Thurston counties and includes Kennedy and Goldsborough creeks, as well as Totten, Hammersley and Little Skookum inlets. The Upper Chehalis Watershed (WRIA23) is not within the project area, so climate modeling for southwestern Thurston County is limited to streamflow (Mauger et al., 2016). ***Source:*** *TRPC*

2.2 Plan Components

The *Thurston Climate Adaptation Plan* is the sum of many parts completed over a more than two-year period. Below is a project timeline and summary of these components, which are featured in this plan's body and appendices.

Science Summary

In spring 2016, the project team — composed of TRPC and Thurston County staff members — completed a science summary of observed and projected climate change impacts at the global, national, and regional scales [*See Section 4.1 and Appendix A*]. The document also explored the emissions scenarios and computer models used in Intergovernmental Panel on Climate Change (IPCC) and University of Washington Climate Impacts Group (CIG) reports that provided the scientific foundation for this project's vulnerability and risk assessments.

Plan Goals & Advisors

In summer 2016, the project team formed the Stakeholder Advisory Committee — a group composed of more than 20 public- and private-sector people with technical expertise and policy influence [*See pg. 5*]. The Stakeholder Advisory Committee, which met 13 times through fall 2017, began its work by choosing a vision statement, 12 goals, and nine guiding principles for the adaptation plan [*See Section 3*]. Members of TRPC's ad hoc Science Advisory Committee also reviewed project materials, as needed, to ensure technical accuracy.

Vulnerability Assessment

In fall 2016, the project team completed work on a 100-page vulnerability assessment [*See Section 4.2 and Appendix B*], which used maps and other tools to explain how the region's climate has changed historically, how it is projected to change during the 21st century, and how such changes affect the vulnerability of our human and natural systems. Building on the science summary, the vulnerability assessment describes how human health and welfare, as well as highways, municipal water systems, estuaries, and other built and natural "assets" within the project area are vulnerable to the collective impacts of natural hazards (e.g., wildfires, landslides, floods) and human-caused stressors (e.g., water pollution) exacerbated by climate change.

Risk Assessment

In winter 2017, the project team and Stakeholder Advisory Committee used a U.S. EPA methodology to evaluate how 85 risks identified in the vulnerability assessment affect the region's ability to achieve the 12 project goals. The Stakeholder Advisory Committee selected a strategy for each risk — either Take Action or Accept — based on the risk's likelihood and consequence of occurrence [*See Section 4.3 and Appendix C*].

Public Engagement

In early spring 2017, the project team began executing a public-engagement strategy to communicate the region's climate risks and elicit adaptation action ideas from the community [*See Section 4.4 and Appendix D*]. Members of the project team met with more than 20 local organizations, hosted a community forum, and administered an online survey. TRPC promoted the project via an online video, newspaper editorial, social media, and other multimedia tools that reached more than 50,000 community members.

Action Evaluation & Prioritization

In late spring 2017, the project team drafted actions to respond to the region's most severe climate risks. The Stakeholder Advisory Committee then modified the actions, as needed, and prioritized them using common criteria (effectiveness, durability, equity, etc.) [See *Section 5.1*]. This collaborative exercise yielded a list of 91 adaptation actions, including 25 priority actions, across six thematic categories: General; Drought & Water Quality; Flood & Erosion; Plants & Animals; Transportation & Energy; and, Wildfire & Extreme Heat. Priority actions in this plan include:

General:

G-01: Direct government staff members to develop their technical expertise and skills to prepare for and respond to climate change impacts.

G-02: Create hazard recovery plans and prioritize the restoration of vital public safety facilities and other essential community assets (e.g., hospitals and major bridges).

G-03: Pursue funding to implement highest-priority actions identified in the adopted Hazards Mitigation Plan for the Thurston Region.

G-04: Factor climate impacts into the planning of operations and the coordination of disaster response and recovery activities among first-responders, including public health, law enforcement, fire, and emergency medical services personnel.

Drought & Water Quality:

D-01: Develop and implement a comprehensive drought-response strategy that sets action levels for different drought stages.

D-02: Evaluate and secure sustained funding to support long-term monitoring of ground and surface water quality and quantity.

D-03: Increase reuse of reclaimed water for irrigating plants, supplementing low streamflow, and other purposes.

D-04: Conduct benefit-cost analyses of adaptation actions that conserve water resources.

Flood & Erosion:

F-01: Evaluate and secure sustained funding to restore and protect riparian vegetation along freshwater and marine shorelines.

F-02: Incorporate projected sea-level rise and flooding information into the designation of regulatory hazard areas.

F-03: Design new and replacement stream culverts and other drainage infrastructure to accommodate projected higher peak flows associated with more frequent and intense heavy precipitation events.

F-04: Install flood gates and pumps on stormwater outfalls connected to Puget Sound to mitigate back-ups during high tides and heavy rains exacerbated by rising seas.

F-05: Build floodwalls or other protective structures around critical facilities located in areas vulnerable to flooding as a result of sea-level rise and heavy precipitation.

F-06: Require that new or renovated buildings utilize flood-protection measures (such as raised finished-floor levels and temporary flood barriers) to accommodate projected sea-level rise over the structures' lifespan.

Plants & Animals:

P-01: Increase funding, education, and incentives for private landowners to manage lands in ways that enhance ecological and economic resilience (e.g., protecting and restoring forests, prairies, and shoreline/riparian areas).

P-02: Use best-management practices, such as installing large woody debris in rivers, to improve water temperature, streamflow, and channel conditions.

P-03: Create/Update basin plans that integrate climate impacts, and include goals and targets for protecting natural resources and habitat.

Transportation & Energy:

T-01: Expand and retrofit the region's energy distribution, monitoring, and storage infrastructure to support more on-site renewable energy generation.

T-02: Provide additional utility incentives to support energy efficiency and renewable energy investments in buildings.

T-03: Offer additional utility rebates or bill credits to induce residents to buy and install energy-efficient appliances and other equipment.

T-04: Evaluate strategies to protect important electrical equipment that is within critical areas at risk of flooding and/or landslides.

T-05: Map transportation infrastructure that is vulnerable to repeated floods and/or landslides, and designate alternative travel routes for critical transportation corridors when roads must be closed because of natural hazards.

Wildfire & Extreme Heat

W-01: Create and maintain a map of the region's high-risk Wildland Urban Interface (WUI) communities and locations of wildfires.

W-02: Require new developments in high-risk wildfire areas to submit a fire-protection plan during site plan review.

W-03: Provide private forestland owners and residents living in Wildland-Urban Interface (WUI) areas information about fire prevention/Firewise practices, and encourage application of such practices.

Tables with all 91 actions, as well as recommended leads and partners, conclude Section 5.2.

Benefit-Cost Analyses

The Tacoma-based consulting firm Earth Economics conducted benefit-cost analyses (BCAs) of plan actions that call for protecting and expanding vegetative buffers along shorelines and incentivizing infill development in urban areas [*See Section 5.3 and Appendix F*]. The economic analyses, which incorporate the value of local ecosystem services (e.g., forests, grasslands, and riparian shorelines), include data that are applicable to a wide range of climate adaptation and mitigation actions and can aid decision-making efforts.

Next Steps

Effective plans don't sit on shelves and collect dust, so this document's first action and final section underscore that TRPC and its partners should consult the *Thurston Climate Adaptation Plan* frequently and update it periodically. This work should include evaluating the plan's climate modeling and implementation progress, taking and amending actions where necessary, and enhancing the community's understanding of climate change causes, impacts, and responses.

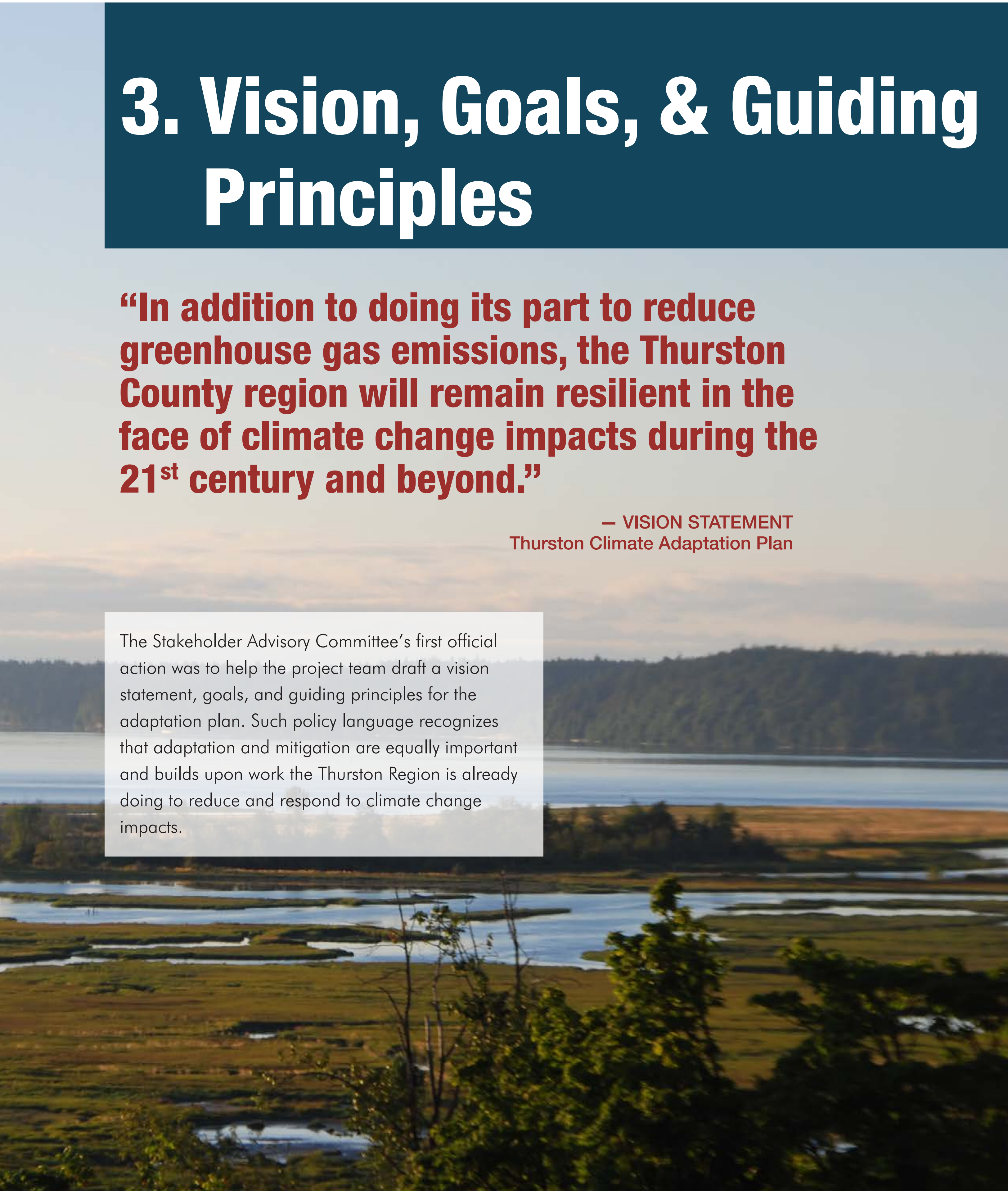
To this end, the final section [*See Section 6*] directs readers to TRPC's online climate "Resilience Toolkit" and points to innovative ways TRPC and its partners are working to increase the community's climate literacy. Such efforts include a climate change board game, pop-up library, and public art.

Climate change mitigation is just as important as adaptation, so the plan concludes by explaining how TRPC and its partners will continue working to reduce the region's carbon footprint. Such efforts include commissioning an "energy map" of Thurston County's energy sources and end uses, and commissioning "carbon wedge" analyses that show pathways to hit the region's 2050 emissions-reduction target.

TRPC developed the "Resilience Road" board game to encourage residents to learn about climate stressors and response actions in this plan. Visit trpc.org/climate to download and play the game.

The sun begins to set over the Nisqually estuary during summer 2017. The low-lying marshes and woodlands are vulnerable to sea-level rise. ***Source:*** *TRPC*

3. Vision, Goals, & Guiding Principles



"In addition to doing its part to reduce greenhouse gas emissions, the Thurston County region will remain resilient in the face of climate change impacts during the 21st century and beyond."

— VISION STATEMENT
Thurston Climate Adaptation Plan

The Stakeholder Advisory Committee's first official action was to help the project team draft a vision statement, goals, and guiding principles for the adaptation plan. Such policy language recognizes that adaptation and mitigation are equally important and builds upon work the Thurston Region is already doing to reduce and respond to climate change impacts.

3.1 Vision Statement

This plan's vision statement recognizes that our region must do its part to shrink its carbon footprint [*Also see Section 6.2*] while adapting to climate impacts in the years ahead.

The award-winning Sustainable Thurston plan, which TRPC policymakers adopted in late 2013 and subsequently integrated into local policies, set the following targets for reducing the Thurston Region's greenhouse gas emissions:

- Achieve 25 percent reduction of 1990 levels by 2020;
- Achieve 45 percent reduction of 1990 levels by 2035; and,
- Achieve 80 percent reduction of 1990 levels by 2050

The 2050 emissions target — which also has been adopted by California, King County, and many other state and local governments — provides a medium chance of preventing the global average temperature from rising more than 2° Celsius (3.6° Fahrenheit) above pre-industrial levels (Luers et al., 2007). The United Nations Framework Convention on Climate Change's "Paris Agreement," which was brokered by more than 150 nations in late 2015, includes the 2°C target but also stresses the importance of pursuing a more aggressive 1.5°C (2.7°F) target to mitigate the most dangerous climate change risks (Figueres, 2015).

3.2 Project Goals

The Stakeholder Advisory Committee selected Sustainable Thurston's 12 priority goals, which are regional in scope and comprehensive in nature, as the adaptation plan's regional goals [*right*]. The subsequent risk assessment [*See Section 4.3*] considered how climate change risks compromise the Thurston Region's ability to achieve these goals.

REGIONAL GOALS

1 Create vibrant centers, corridors and neighborhoods while accommodating growth;

2 Preserve environmentally sensitive lands, farmlands, forest lands, prairies, and rural lands, and develop compact urban areas;

3 Create a robust economy;

4 Protect and improve water quality, including groundwater, rivers, streams, lakes and Puget Sound;

5 Plan and act toward zero waste in the region;

6 Ensure that residents have the resources to meet their daily needs;

7 Support a local food system to increase community resilience, health and economic prosperity;

8 Ensure that the region's water supply sustains people in perpetuity while protecting the environment;

9 Move toward a carbon-neutral community;

10 Maintain air quality standards;

11 Provide opportunities for everyone in the Thurston Region to learn about and practice sustainability;

12 Make strategic investments to advance sustainability regionally.

3.3 Guiding Principles

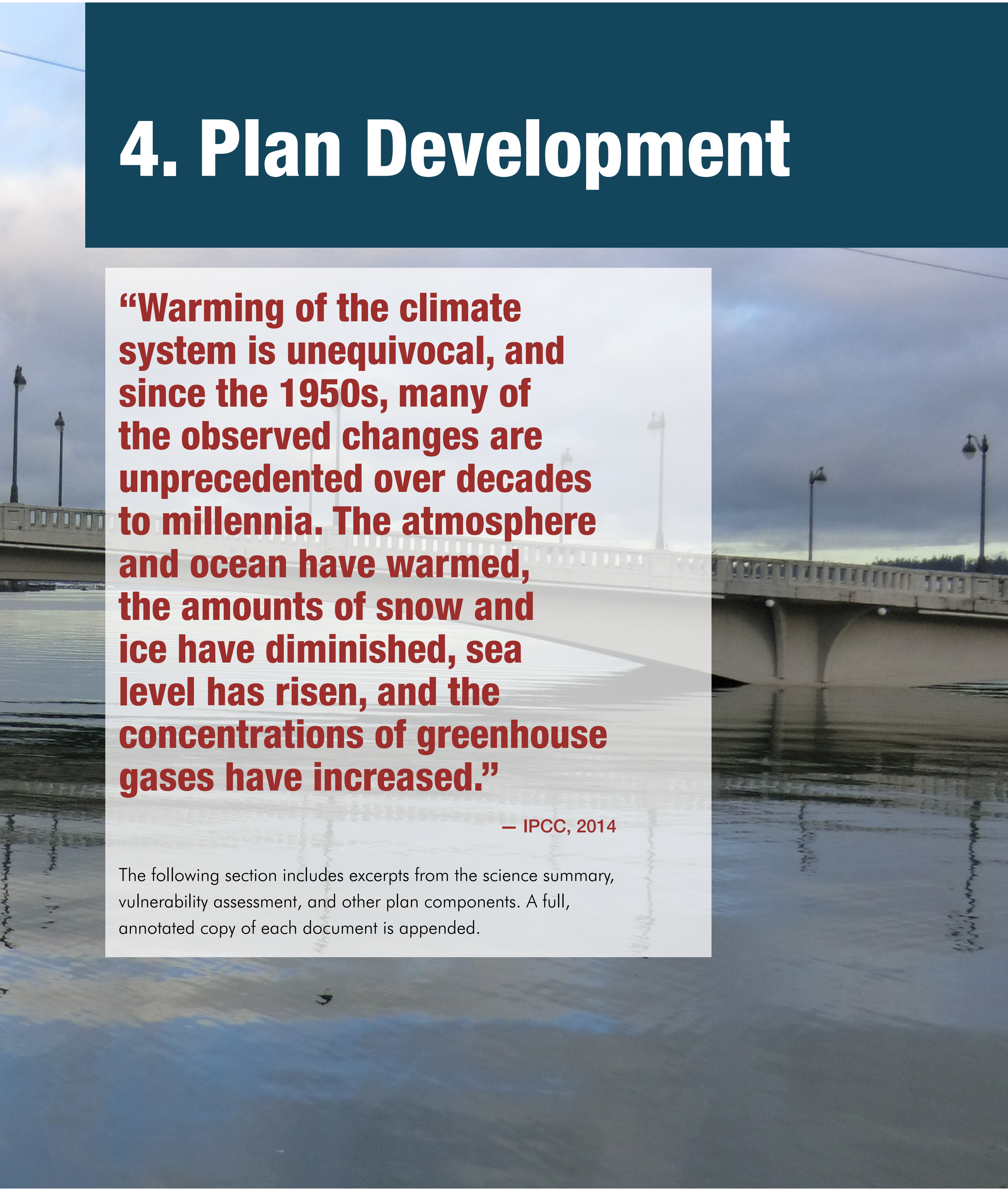
Lastly, the Stakeholder Advisory Committee crafted nine guiding principles to shape the adaptation plan's development and outcomes. These principles are reflected throughout the plan's components [*See Section 4*] and actions [*See Section 5*].

GUIDING PRINCIPLES

1. Think in terms of multiple generations and connected built and natural systems, as well as view local and regional decisions through the lens of social, economic, and environmental sustainability;
2. Increase resiliency through achievable, flexible — and, where possible, measurable and replicable — adaptation strategies and actions that will help the region prepare for and cope with climate change impacts;
3. Be responsive to immediate and long-term climate impacts — both emergencies and opportunities;
4. Identify and leverage climate change adaptation strategies and actions with mitigation co-benefits, such as reducing, capturing, and storing greenhouse gas emissions;
5. Utilize sound scientific research, scenarios modeling, economic analysis, and other tools to analyze regional and local climate change vulnerabilities, risks, and solutions;
6. Incorporate and complement work produced by others, including the Natural Hazards Mitigation Plan for the Thurston Region, Sustainable Thurston, Thurston Thrives, and Olympia sea-level rise analyses;
7. Consider the impacts of climate change adaptation recommendations on the region's economy, environment, and society; this includes all urban and rural communities — especially vulnerable residents — and the ecosystem benefits provided by natural systems;
8. Recognize and strive to protect local indigenous tribes' community health and well-being, including natural resources security and self-determination;
9. Seek broad community input, as well as educate residents about climate change and inspire them to take action.

Downtown Olympia's 4th Avenue bridge rises above lower Budd Inlet during high tide in spring 2016. ***Source:*** *TRPC*

4. Plan Development



> **“Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.”**
>
> — IPCC, 2014

The following section includes excerpts from the science summary, vulnerability assessment, and other plan components. A full, annotated copy of each document is appended.

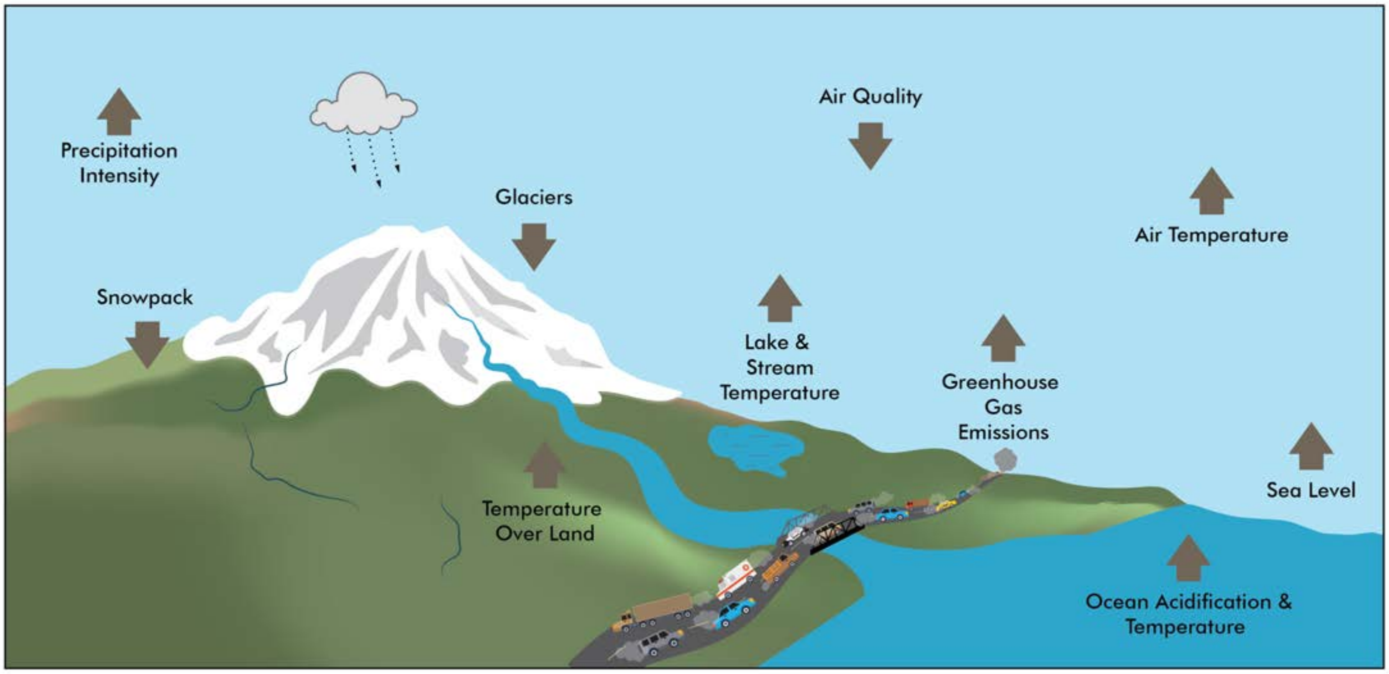


Figure 02: Pictured above are key indicators of the region's changing climate. Arrows show increasing or decreasing trends, based on empirical data and modeling. ***Source:*** *TRPC, adapted from image in U.S. Global Change Research Program's (USGCRP) 2014 National Climate Assessment*

4.1 Science Summary

Our individual actions affect our collective carbon footprint — whether we drive a car, charge a cellphone, or catch a plane. Emissions from burning all those gallons of fuel and generating all those watts of electricity are adding up and changing the climate in significant ways.

Consider the science: The IPCC concluded in a recent global climate change synthesis report, it is "extremely likely" that human influence was the "dominant cause" of observed planetary warming between 1951 and 2010 (IPCC, 2013). Such warming of the air, land, and water has caused a reduction in snow and ice, rise in sea level, and other changes [*See Figure 02*] (USGCRP, 2014).

Shortly after calendars flipped to 2017, scientists reported that 2016 was the warmest year since modern record-keeping began in 1880: The global average temperature was 58.69°F — more than 1.8°F (1°C) warmer than it was in pre-industrial times (NOAA, 2017). Just as noteworthy, 2016 marked the fifth new record annual temperature this century and the 40th consecutive year that the annual temperature was above the 20th century average (57°F).

There's no crystal ball that shows what the future holds, so scientists run plausible scenarios of future greenhouse gas emissions — also known as Representative Concentration Pathways (RCPs) — through models that simulate global climate. Local researchers can then downscale these scenarios to project changes in temperature, precipitation, and other climate indicators for the Pacific Northwest, Puget Sound region, and individual watersheds.

The IPCC's 2013 report included an "extremely low" scenario (RCP 2.6), involving aggressive emissions reductions, all the way up to a "high" scenario (RCP 8.5), involving continued substantial greenhouse gas emissions through 2100 [*See Figure 03*]. The UW Climate Impacts Group's 2015 *State of Knowledge* report (Mauger et al., 2015) — the primary source of watershed-scale modeling for TRPC's vulnerability assessment — included the low and high scenarios in its projections for the Puget Sound region.

Weather vs. Climate

Weather is atmospheric conditions over the short term (e.g., minutes to days). Climate is the average of weather over longer periods of time and space (e.g., years and decades). … A good way to remember the difference is that climate is what you expect — like a long and hot summer; weather is what you get — like a dry and sunny day.

— NASA, 2015

Science isn't static, of course. The climate scenarios reflect the scientific community's current understanding of complex and dynamic natural systems, coupled with informed assumptions about future human behaviors, economies, and technologies. Understanding of these various components will continue to evolve over time, as will the climate projections developed on the basis of these components. Additionally, natural variability (e.g., El Niño) has and will continue to play a role in shaping the Pacific Northwest's climate. Some weather events and seasons may deviate temporarily from long-term climate trends.

All of this to say, the Thurston Region should monitor how modeled projections track with actual climate impacts in the years ahead. To this end, the Thurston Climate Adaptation Plan's first action (A-01) recommends that TRPC update the document periodically with new information, evaluate implementation efforts, and amend strategies and actions as necessary.

A May 2017 microburst caused heavy rain and overflowing gutters in Lacey. ***Source:*** *Mollie Selstrom*

Greenhouse gas scenarios	Scenario characteristics	Amount of carbon dioxide in the atmosphere, 2100	Qualitative description, as used by UW CIG
RCP 2.6	A very low emissions scenario that assumes ambitious greenhouse gas emissions reductions (50% reduction in global emissions by 2050 relative to 1990 levels, and near or below zero net emissions in the final decades of the 21st century)	400 parts per million (ppm)	"Very Low"
RCP 4.5	A low scenario in which greenhouse gas emissions stabilize by mid-century and fall sharply thereafter	538 ppm	"Low"
RCP 6.0	A medium scenario in which greenhouse gas emissions increase gradually until stabilizing in the final decades of the 21st century	670 ppm	"Medium"
RCP 8.5	A high scenario that assumes continued increases in greenhouse gas emissions until the end of the 21st century	936 ppm	"High"

Figure 03: This table shows the greenhouse gas emissions scenarios (RCPs) used in the IPCC's 2014 synthesis report.

Source: *UW Climate Impacts Group (Mauger et al., 2015)*

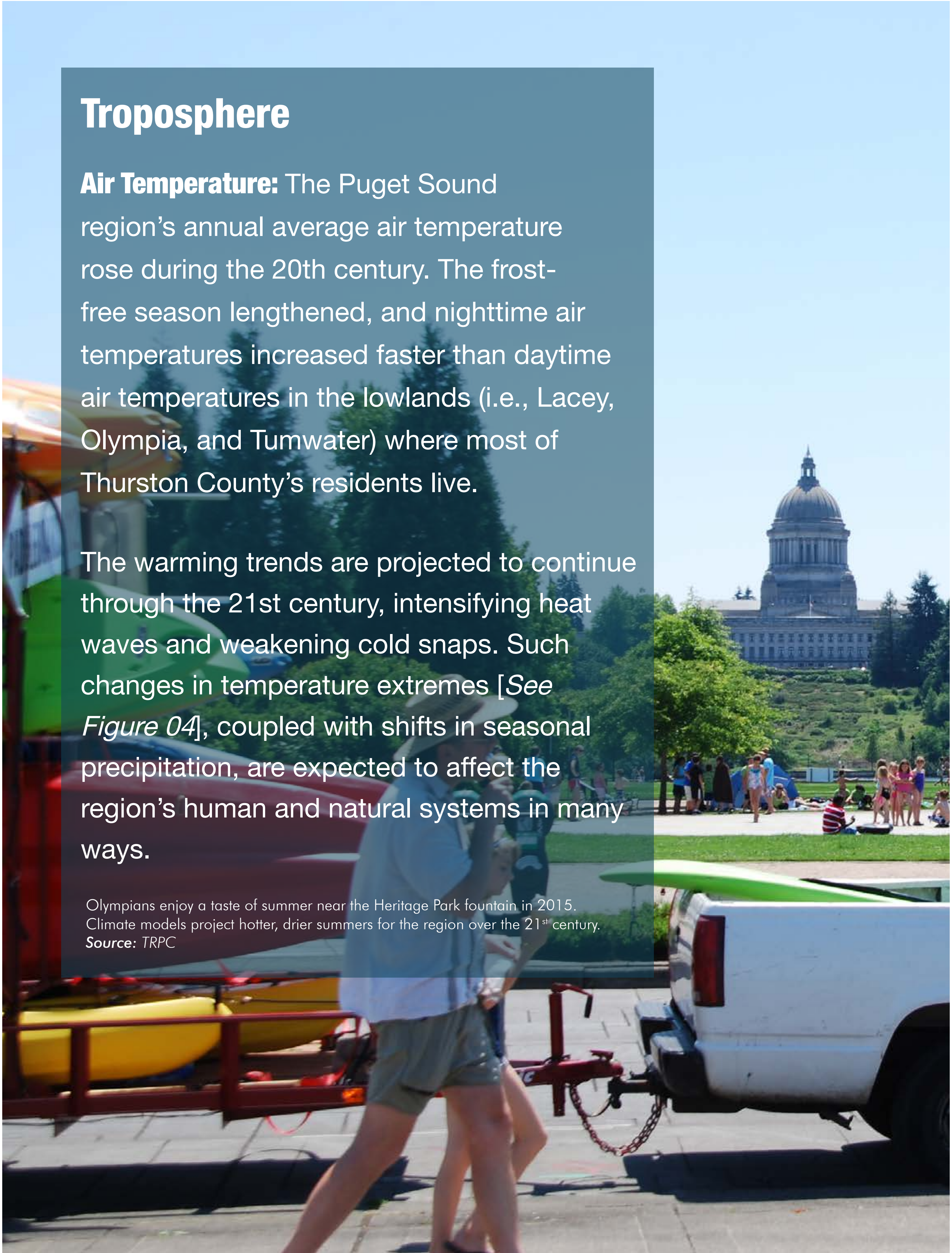
4.2 Vulnerability Assessment

Building on the science summary [See Appendix A], the vulnerability assessment [See Appendix B] uses empirical data and modeling to produce text, tables, and maps that explain how the South Puget Sound region's climate has changed historically, how it is projected to change during the 21st century, and how such changes affect the vulnerability of our human and natural systems. The 100-page document (TRPC, 2016) is organized into five sections — Troposphere, Freshwater Ecosystems, Marine Ecosystems, Terrestrial Ecosystems, and Human Health & Welfare — each of which is summarized on the following pages.

Troposphere

Air Temperature: The Puget Sound region's annual average air temperature rose during the 20th century. The frost-free season lengthened, and nighttime air temperatures increased faster than daytime air temperatures in the lowlands (i.e., Lacey, Olympia, and Tumwater) where most of Thurston County's residents live.

The warming trends are projected to continue through the 21st century, intensifying heat waves and weakening cold snaps. Such changes in temperature extremes [*See Figure 04*], coupled with shifts in seasonal precipitation, are expected to affect the region's human and natural systems in many ways.



Olympians enjoy a taste of summer near the Heritage Park fountain in 2015. Climate models project hotter, drier summers for the region over the 21st century.
Source: *TRPC*

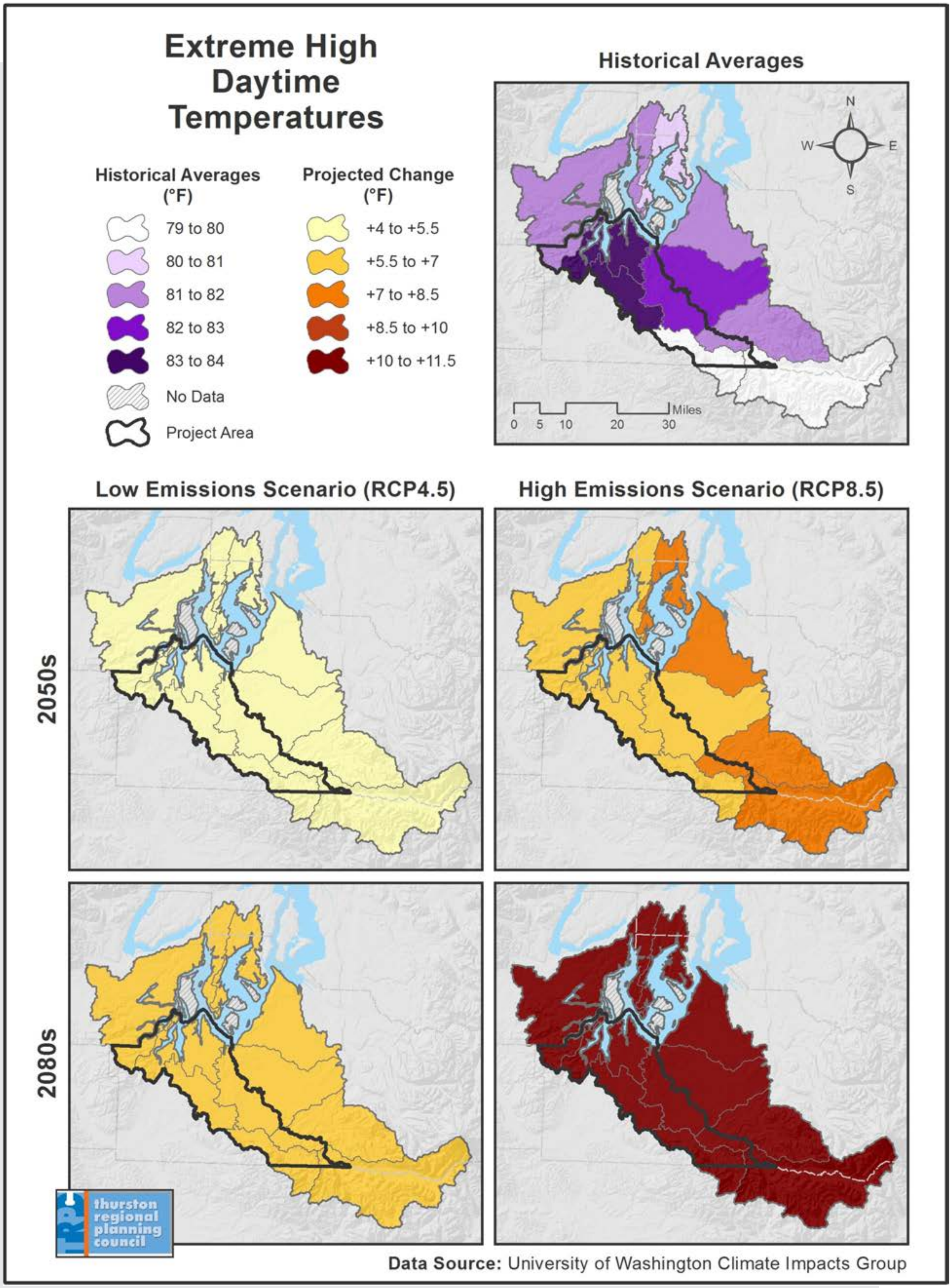
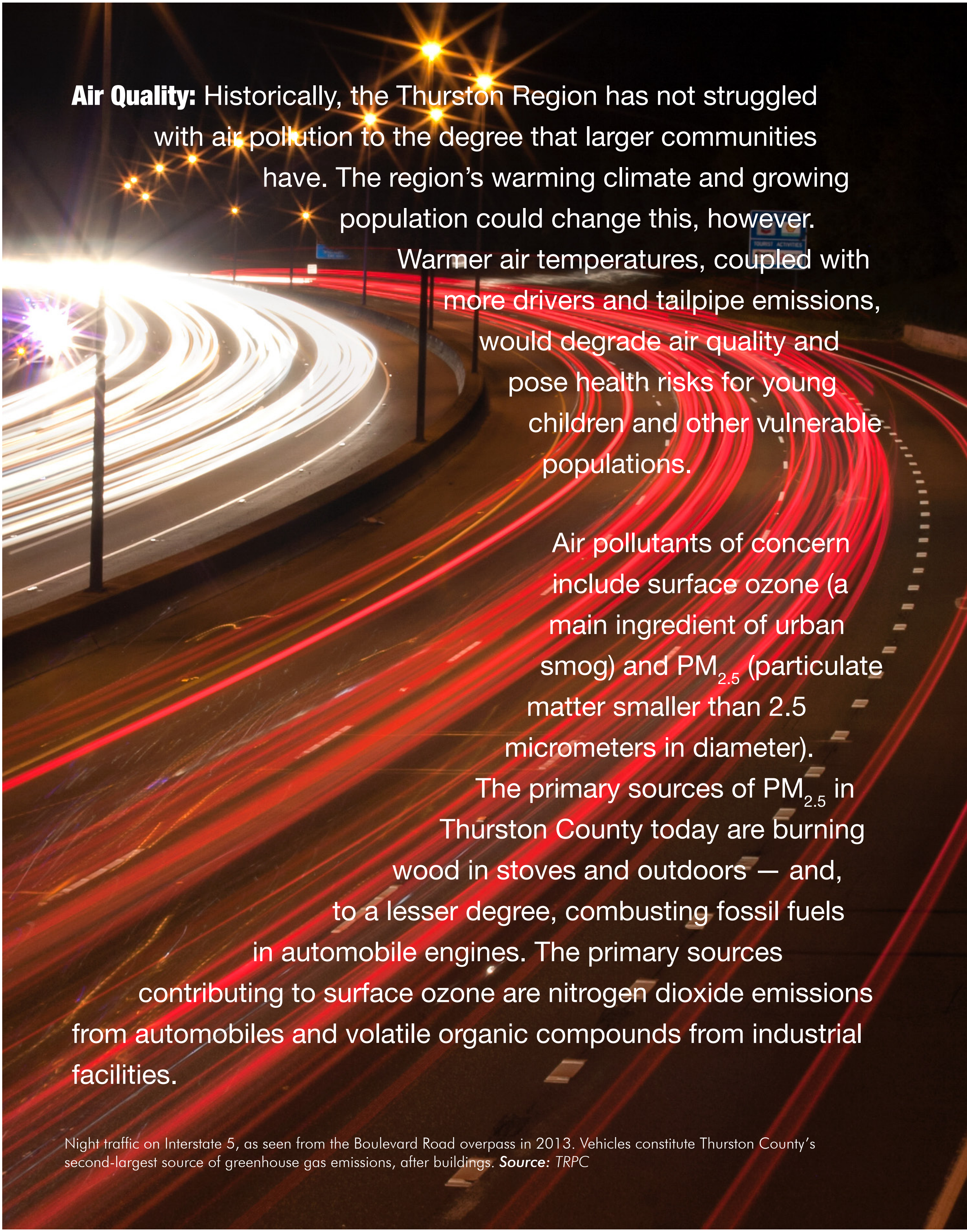


Figure 04: This series of maps, which utilizes UW Climate Impacts Group data, shows observed and projected extreme high daytime temperatures for the Nisqually, Deschutes, and Kennedy-Goldsborough watersheds. The full vulnerability assessment [*See Appendix B*] includes dozens more South Puget Sound watershed maps of climate change indicators, including precipitation, snowpack, and runoff.

Source: *Adapted from Figure 4b in Appendix B of Mauger et al., 2015.*



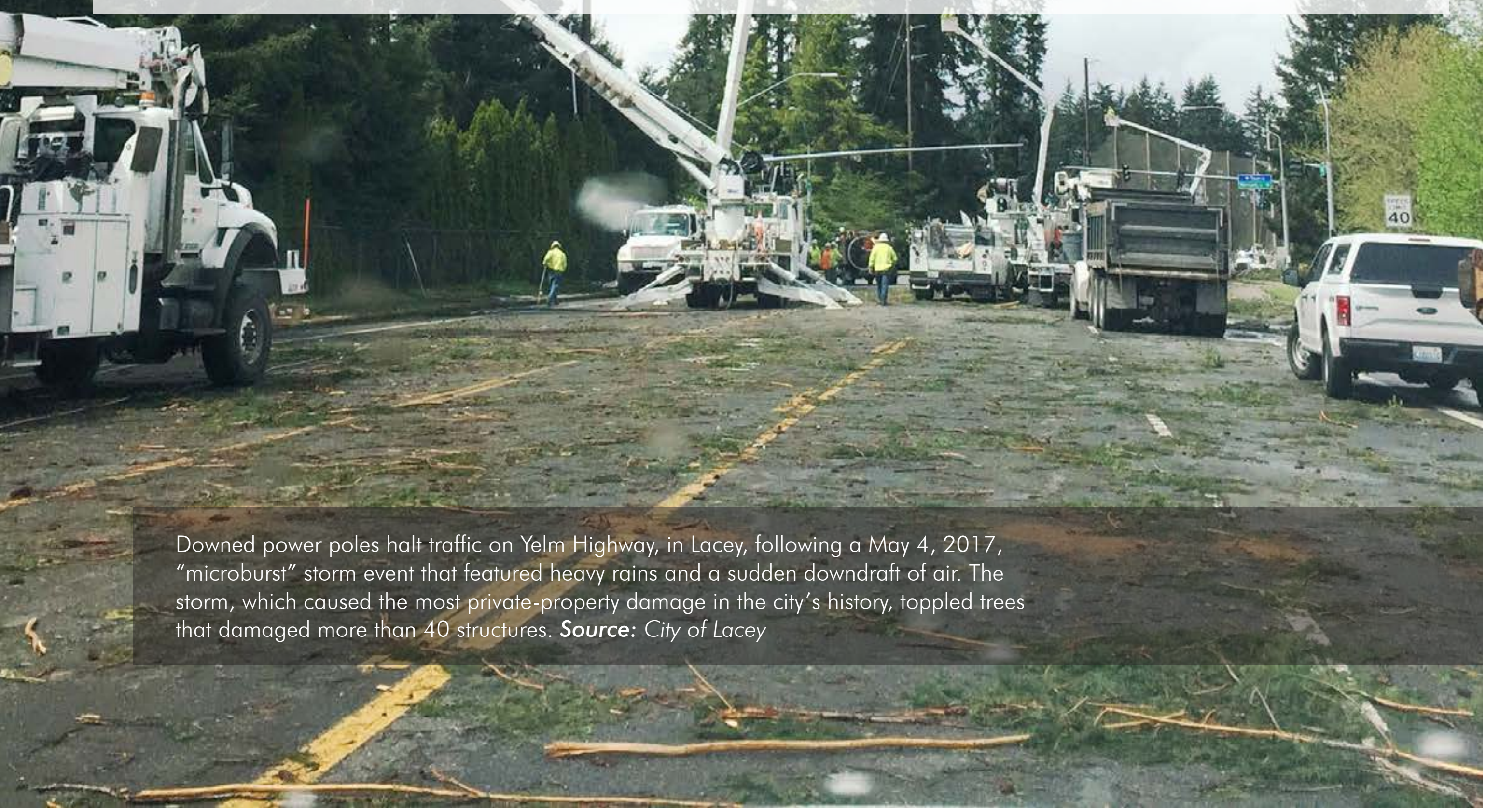
Air Quality: Historically, the Thurston Region has not struggled with air pollution to the degree that larger communities have. The region's warming climate and growing population could change this, however. Warmer air temperatures, coupled with more drivers and tailpipe emissions, would degrade air quality and pose health risks for young children and other vulnerable populations.

Air pollutants of concern include surface ozone (a main ingredient of urban smog) and $PM_{2.5}$ (particulate matter smaller than 2.5 micrometers in diameter). The primary sources of $PM_{2.5}$ in Thurston County today are burning wood in stoves and outdoors — and, to a lesser degree, combusting fossil fuels in automobile engines. The primary sources contributing to surface ozone are nitrogen dioxide emissions from automobiles and volatile organic compounds from industrial facilities.

Night traffic on Interstate 5, as seen from the Boulevard Road overpass in 2013. Vehicles constitute Thurston County's second-largest source of greenhouse gas emissions, after buildings. ***Source:*** *TRPC*

Precipitation: There is no discernable historical trend in precipitation across the Puget Sound region, which averaged about 78 inches annually during the latter half of the 20th century. The region's annual precipitation volume is not projected to change significantly this century. Seasonal precipitation volumes are projected to change considerably, however: Models indicate generally hotter and drier summers and warmer and wetter winters. Highland forest areas of the Deschutes and Nisqually watersheds would see the biggest shifts in precipitation timing, type, and volume.

The frequency of the region's heaviest 24-hour rain events (top 1 percent) is projected to increase — occurring about seven days a year by late century, compared to two days a year historically. The intensity of such events is projected to increase as well, making communities more vulnerable to downed trees and power poles, floods, landslides, and water-borne pollution [*See Figure 05, opposite*].



Downed power poles halt traffic on Yelm Highway, in Lacey, following a May 4, 2017, "microburst" storm event that featured heavy rains and a sudden downdraft of air. The storm, which caused the most private-property damage in the city's history, toppled trees that damaged more than 40 structures. ***Source:*** *City of Lacey*

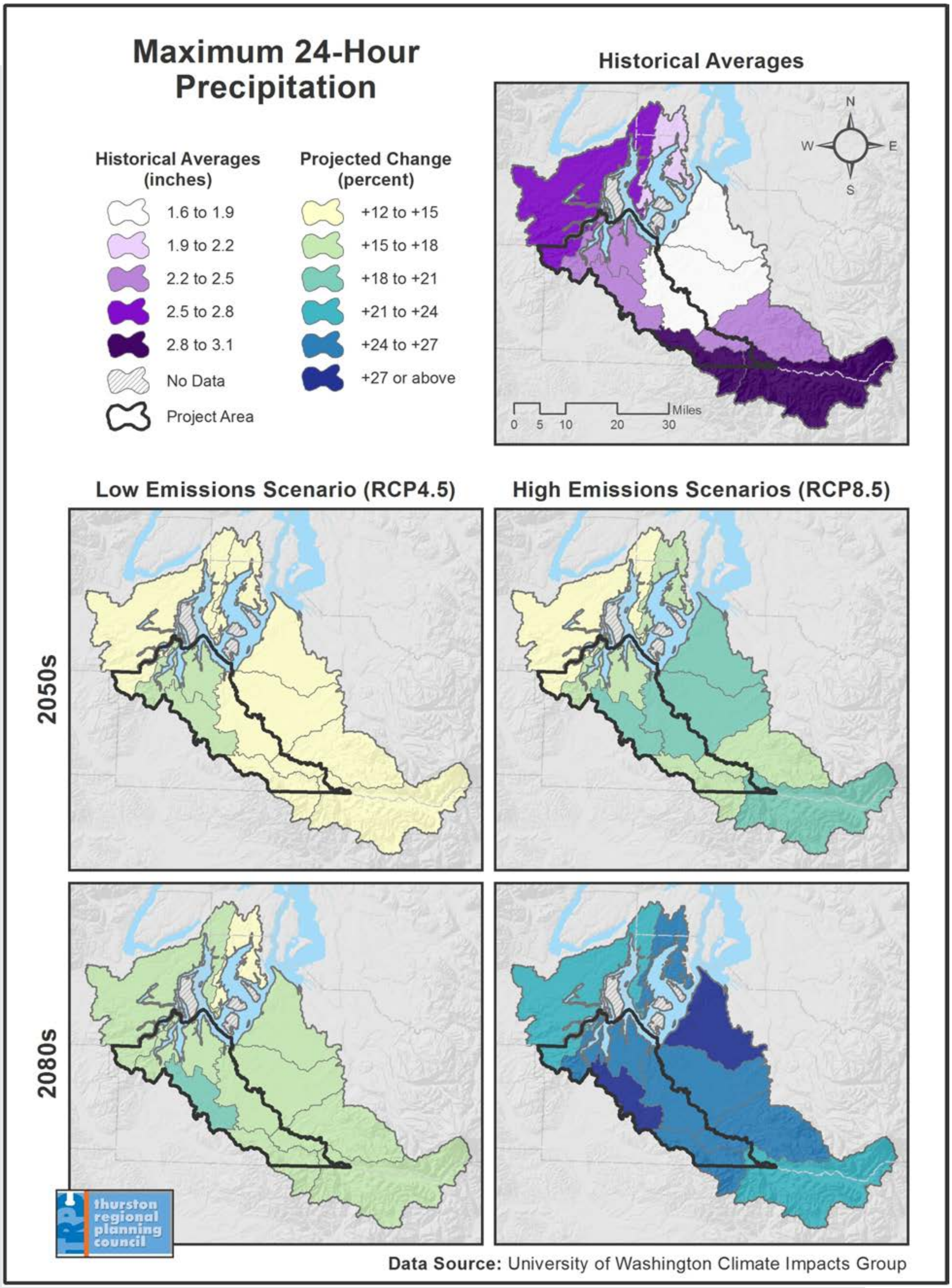
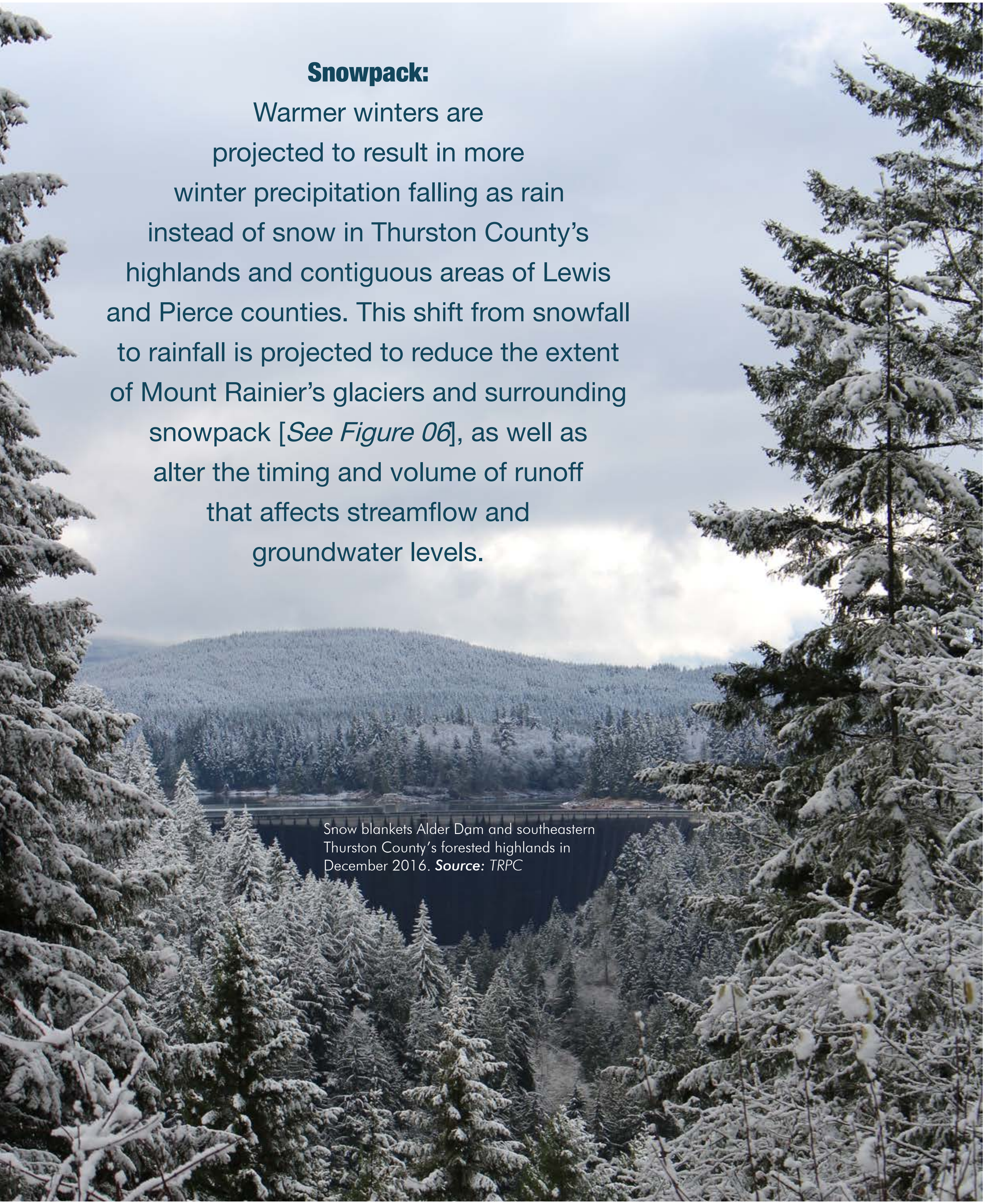


Figure 05: The intensity of the heaviest 24-hour rain events (top 1 percent) — as measured in inches of precipitation — is projected to increase amid the project area. ***Source:*** *Adapted from Figure 8b in Appendix B of Mauger et al., 2015.*

Snowpack:

Warmer winters are projected to result in more winter precipitation falling as rain instead of snow in Thurston County's highlands and contiguous areas of Lewis and Pierce counties. This shift from snowfall to rainfall is projected to reduce the extent of Mount Rainier's glaciers and surrounding snowpack [*See Figure 06*], as well as alter the timing and volume of runoff that affects streamflow and groundwater levels.



Snow blankets Alder Dam and southeastern Thurston County's forested highlands in December 2016. ***Source:*** *TRPC*

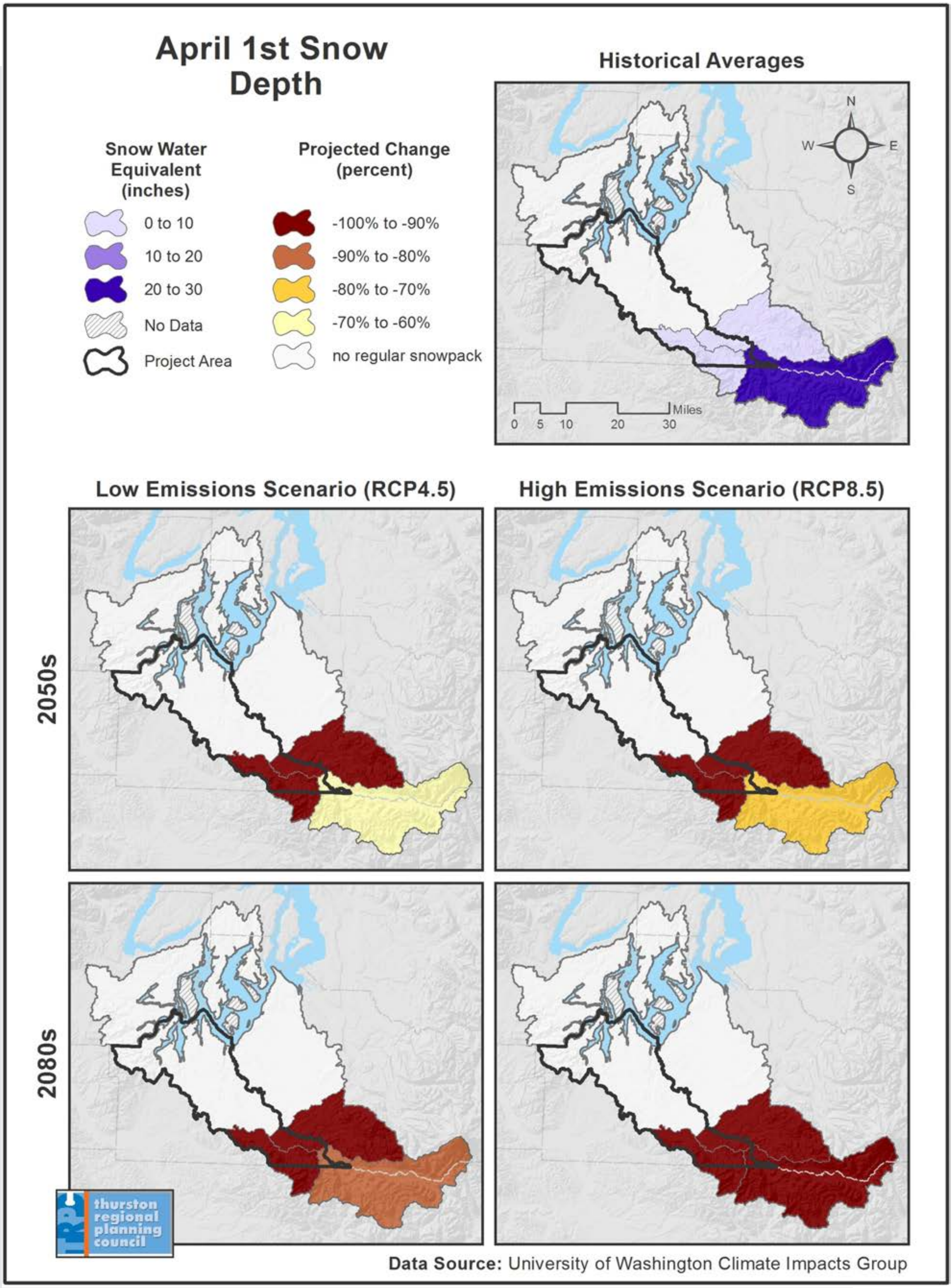
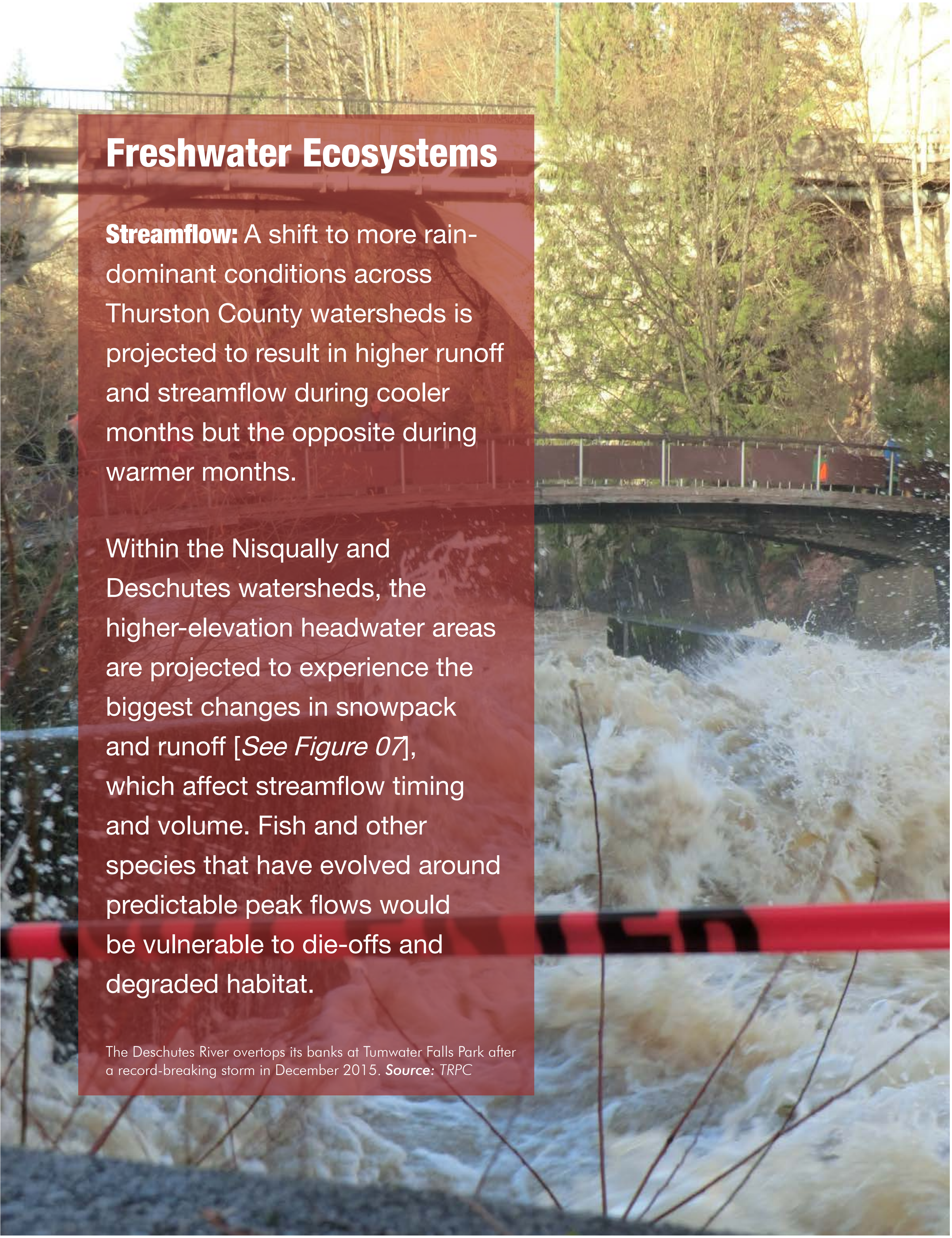


Figure 06. Projected changes in April 1st peak snowpack, expressed as snow water equivalent (measure of the total amount of water contained in snowpack) amid South Puget Sound watersheds. ***Source:*** *Adapted from Figure 11b in Appendix B of Mauger et al., 2015.*

Freshwater Ecosystems

Streamflow: A shift to more rain-dominant conditions across Thurston County watersheds is projected to result in higher runoff and streamflow during cooler months but the opposite during warmer months.

Within the Nisqually and Deschutes watersheds, the higher-elevation headwater areas are projected to experience the biggest changes in snowpack and runoff [*See Figure 07*], which affect streamflow timing and volume. Fish and other species that have evolved around predictable peak flows would be vulnerable to die-offs and degraded habitat.



The Deschutes River overtops its banks at Tumwater Falls Park after a record-breaking storm in December 2015. ***Source:*** *TRPC*

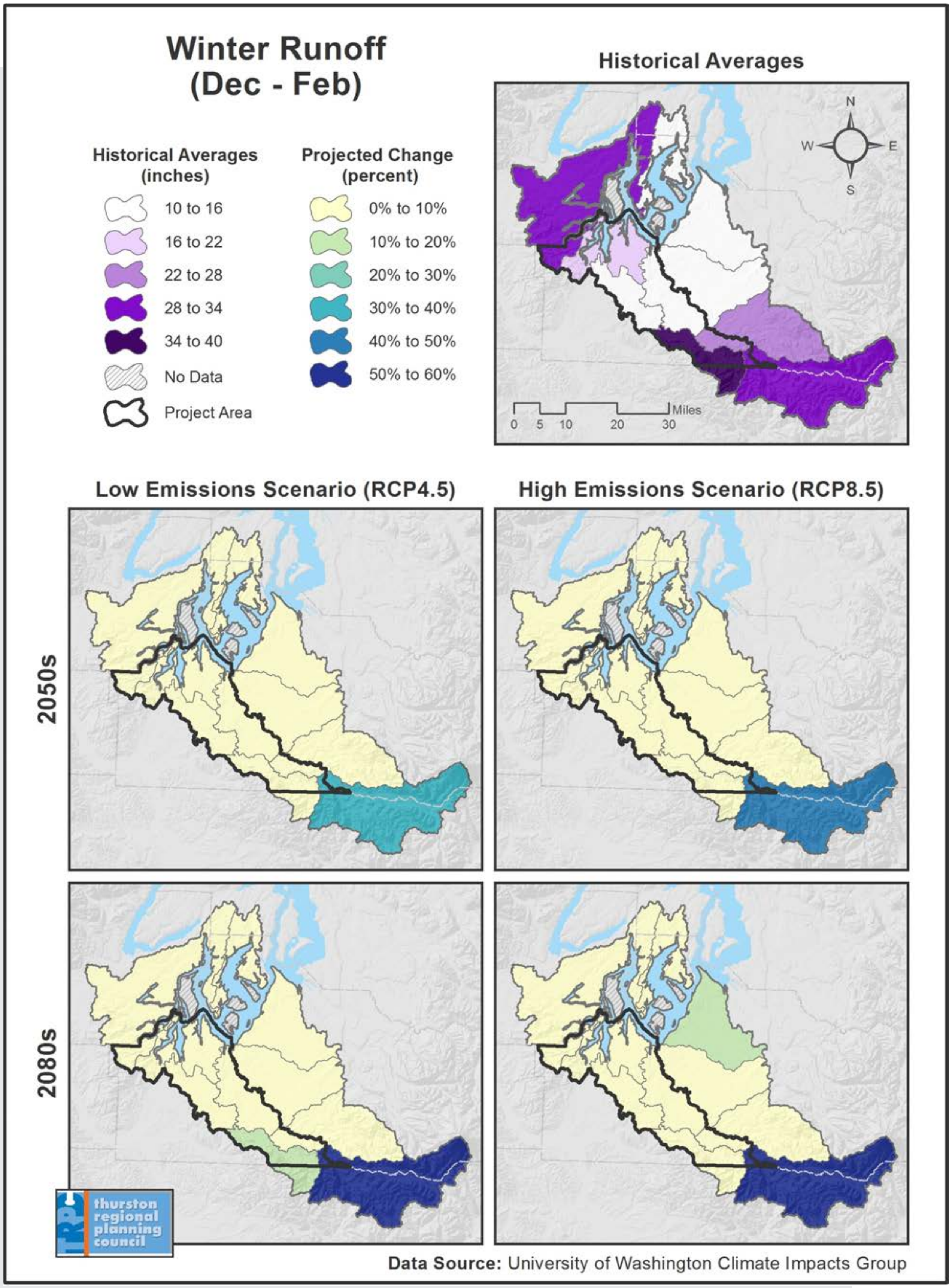
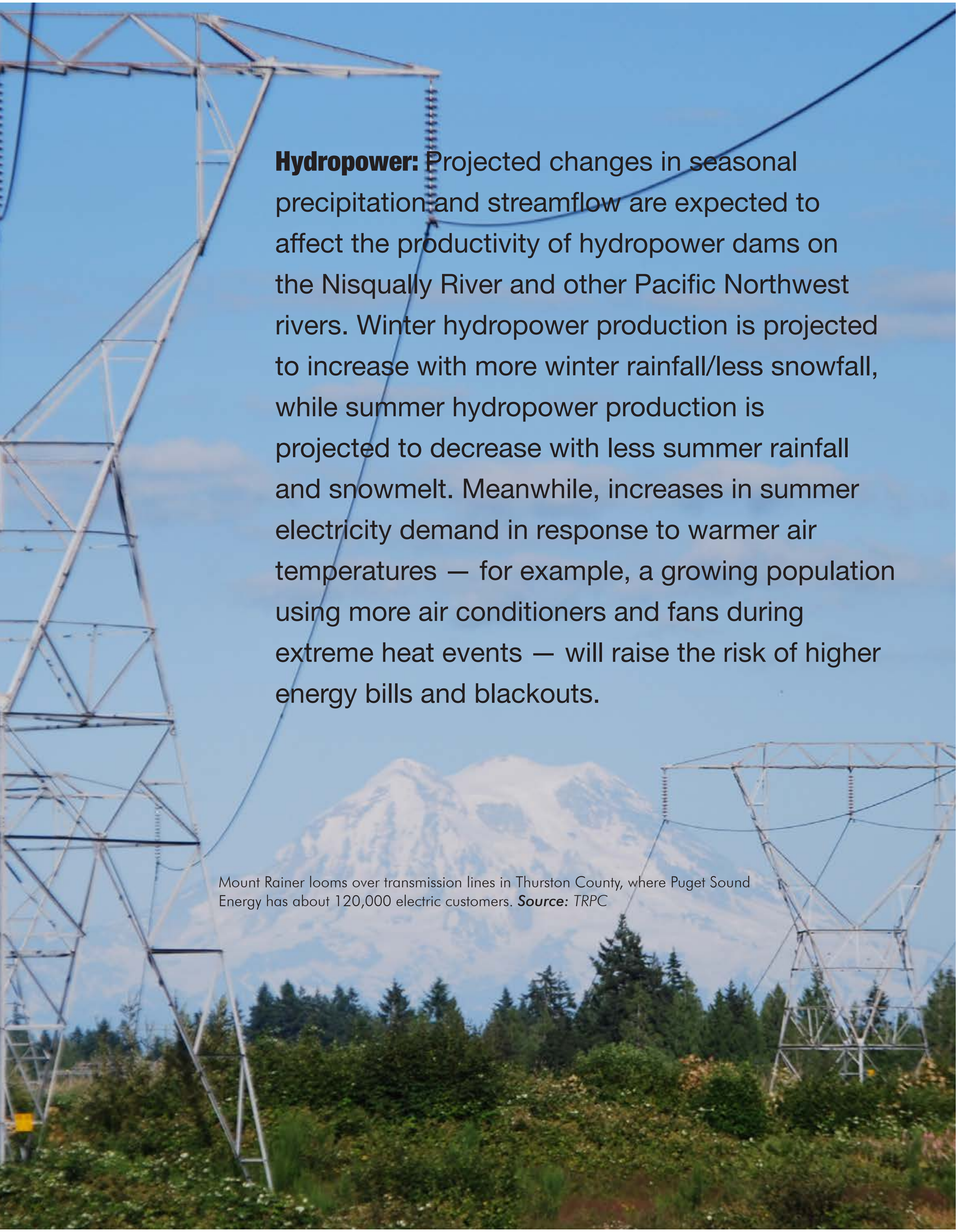
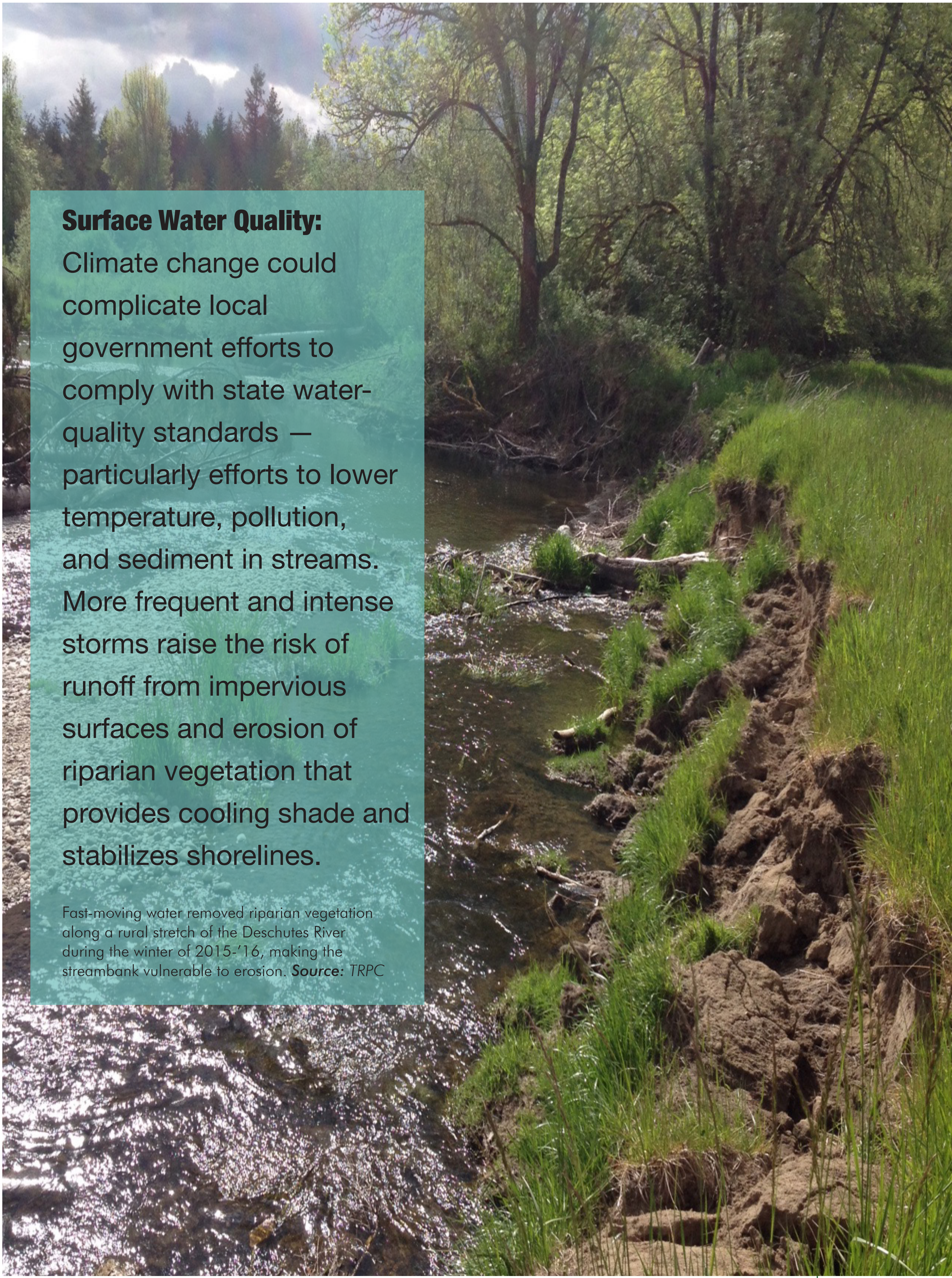


Figure 07. Projected changes winter runoff amid South Puget Sound watersheds per emissions scenarios. Source: Adapted from Figure 14b in Appendix B of Mauger et al., 2015.

Hydropower: Projected changes in seasonal precipitation and streamflow are expected to affect the productivity of hydropower dams on the Nisqually River and other Pacific Northwest rivers. Winter hydropower production is projected to increase with more winter rainfall/less snowfall, while summer hydropower production is projected to decrease with less summer rainfall and snowmelt. Meanwhile, increases in summer electricity demand in response to warmer air temperatures — for example, a growing population using more air conditioners and fans during extreme heat events — will raise the risk of higher energy bills and blackouts.

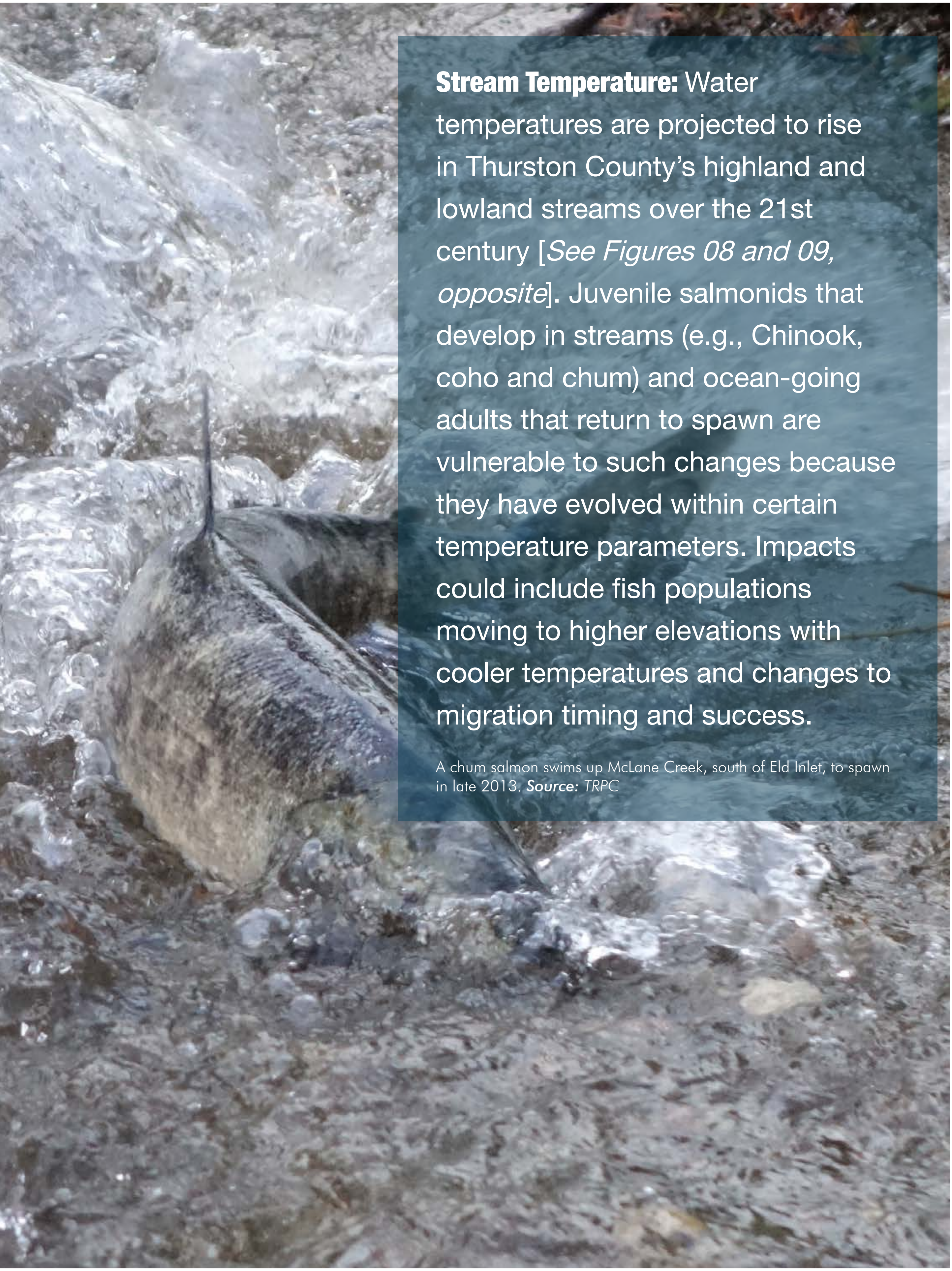


Mount Rainer looms over transmission lines in Thurston County, where Puget Sound Energy has about 120,000 electric customers. ***Source:*** *TRPC*



Surface Water Quality: Climate change could complicate local government efforts to comply with state water-quality standards — particularly efforts to lower temperature, pollution, and sediment in streams. More frequent and intense storms raise the risk of runoff from impervious surfaces and erosion of riparian vegetation that provides cooling shade and stabilizes shorelines.

Fast-moving water removed riparian vegetation along a rural stretch of the Deschutes River during the winter of 2015-'16, making the streambank vulnerable to erosion. ***Source:*** *TRPC*



Stream Temperature: Water temperatures are projected to rise in Thurston County's highland and lowland streams over the 21st century [*See Figures 08 and 09, opposite*]. Juvenile salmonids that develop in streams (e.g., Chinook, coho and chum) and ocean-going adults that return to spawn are vulnerable to such changes because they have evolved within certain temperature parameters. Impacts could include fish populations moving to higher elevations with cooler temperatures and changes to migration timing and success.

A chum salmon swims up McLane Creek, south of Eld Inlet, to spawn in late 2013. ***Source:*** *TRPC*

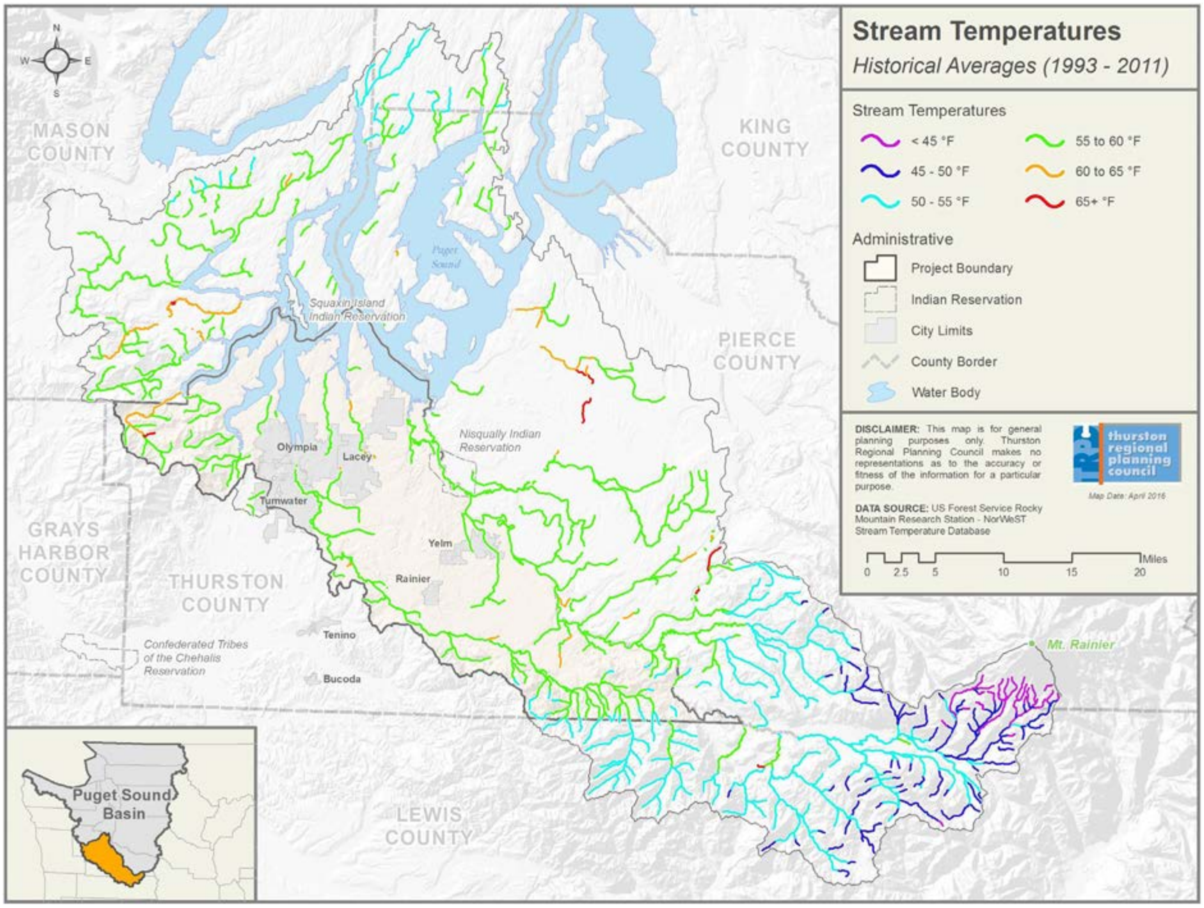
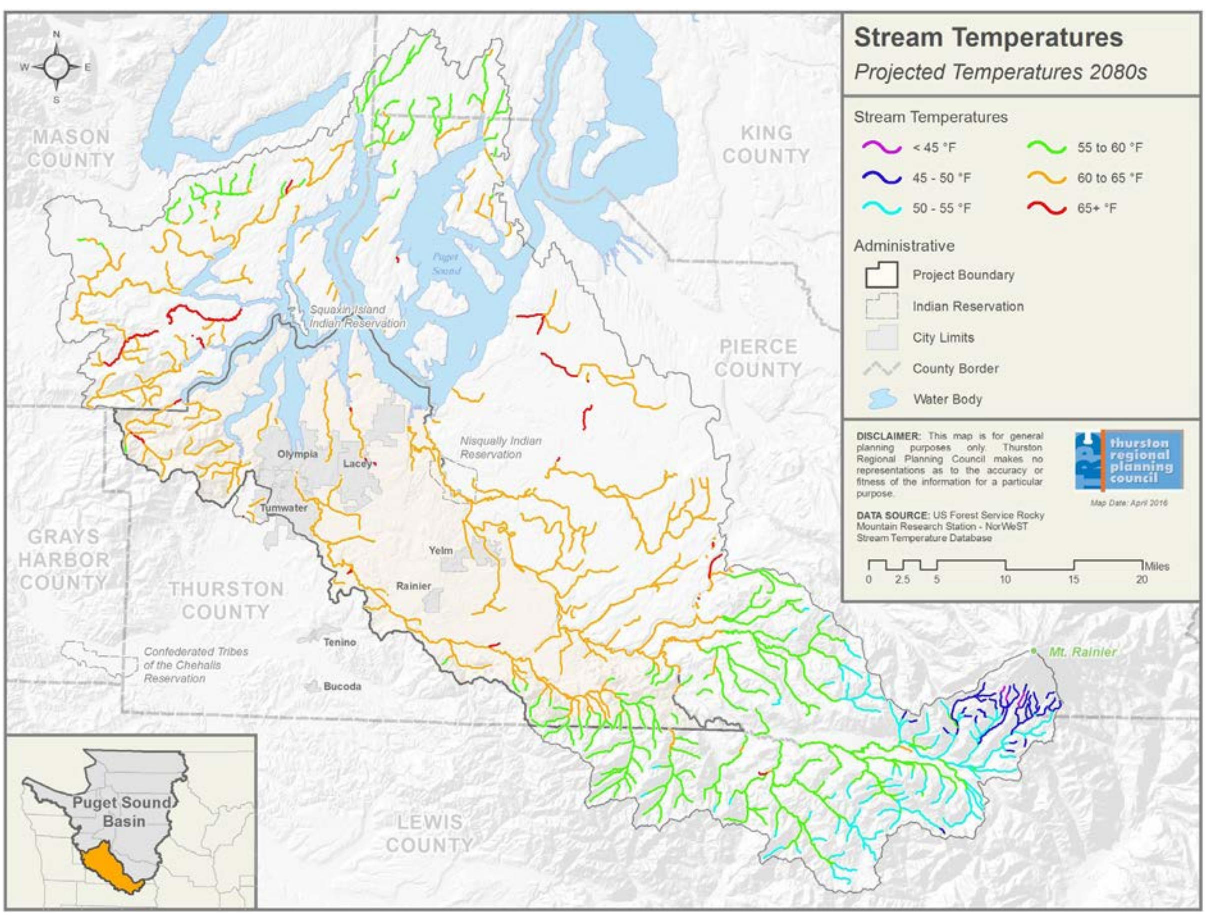
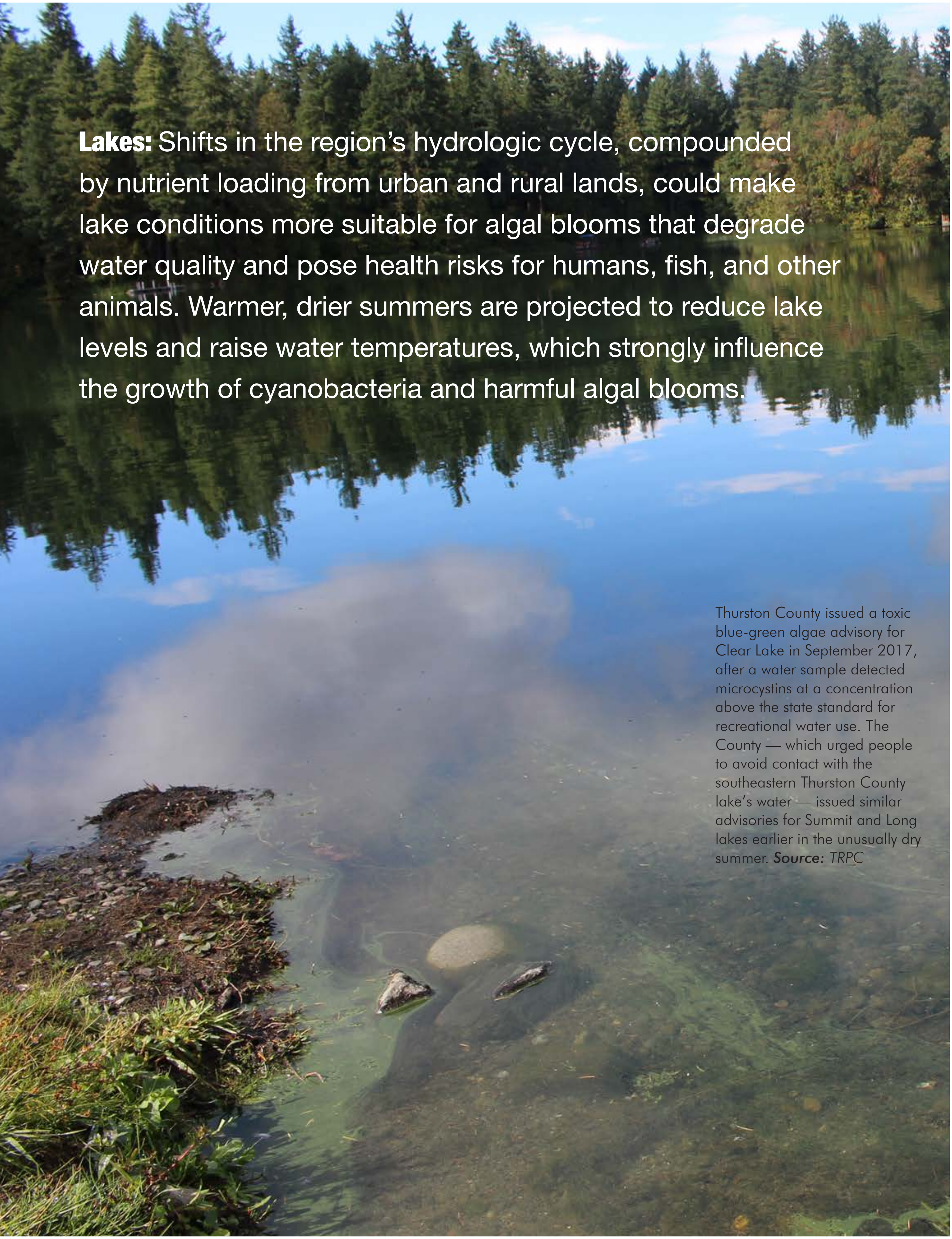


Figure 08 (above) shows historical stream temperature averages, from 1993 - 2011, while **Figure 09** (below) shows projected temperatures for the 2080s.



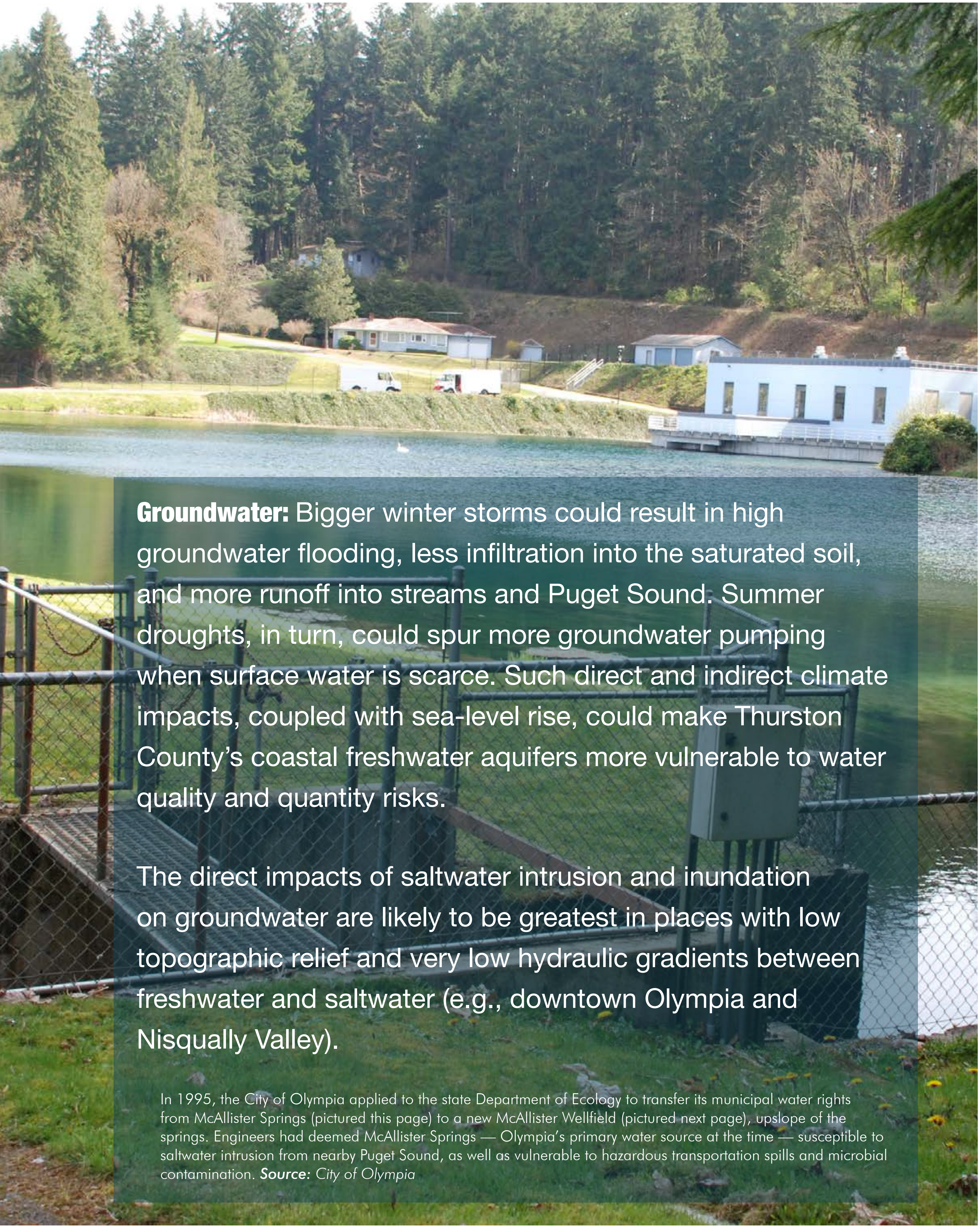


Lakes: Shifts in the region's hydrologic cycle, compounded by nutrient loading from urban and rural lands, could make lake conditions more suitable for algal blooms that degrade water quality and pose health risks for humans, fish, and other animals. Warmer, drier summers are projected to reduce lake levels and raise water temperatures, which strongly influence the growth of cyanobacteria and harmful algal blooms.

Thurston County issued a toxic blue-green algae advisory for Clear Lake in September 2017, after a water sample detected microcystins at a concentration above the state standard for recreational water use. The County — which urged people to avoid contact with the southeastern Thurston County lake's water — issued similar advisories for Summit and Long lakes earlier in the unusually dry summer. ***Source:*** *TRPC*

Wetlands: Warmer, drier summers are projected to reduce the flow of water that replenishes and cools non-tidal marshes — which are mostly freshwater wetlands near lakes or on poorly drained soils. These wetland areas provide important habitat for frogs, birds, and other wildlife.

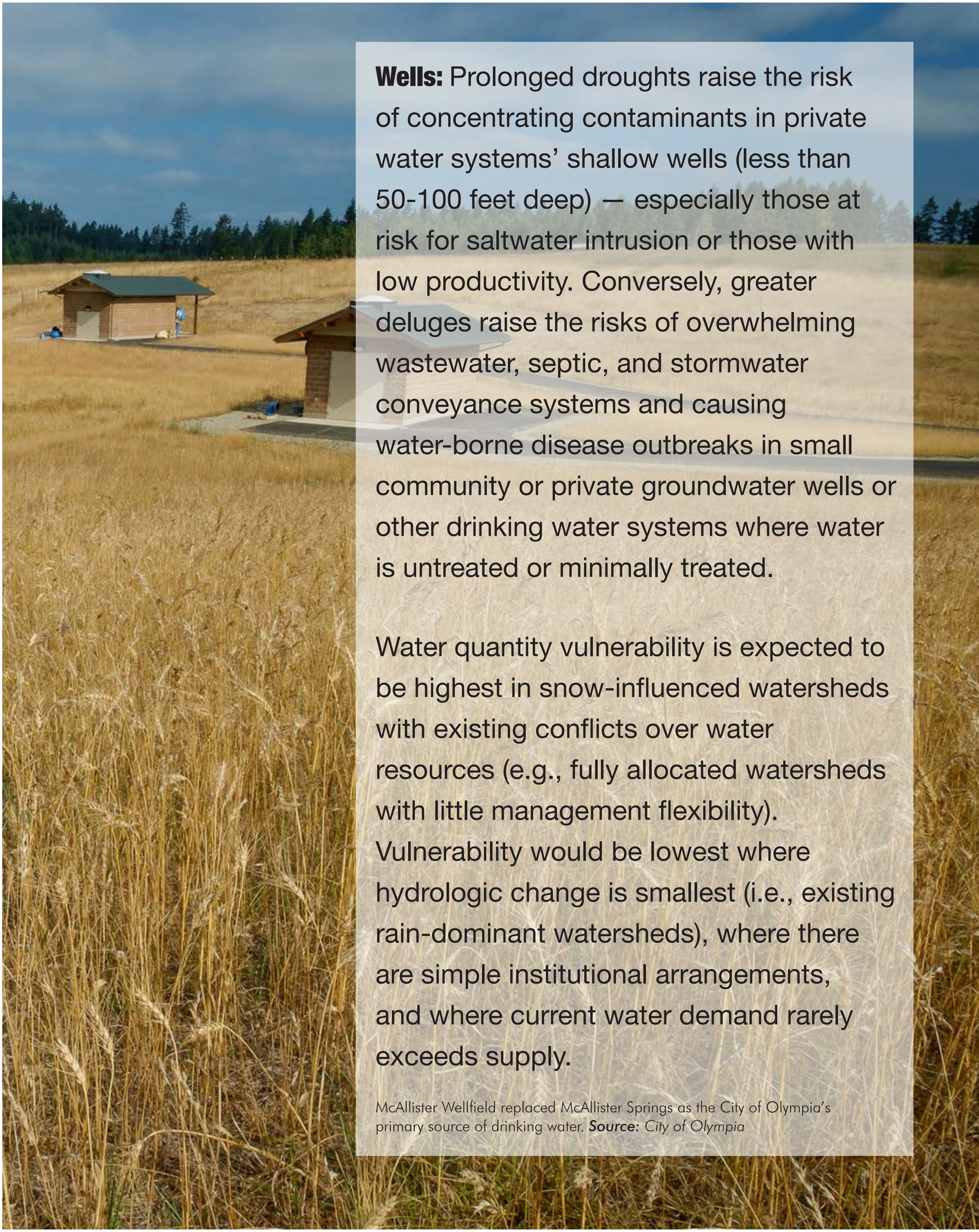
A wetland in east Olympia provides water for Woodard Creek and supports frogs, ducks, and other wildlife. ***Source:*** *TRPC*



Groundwater: Bigger winter storms could result in high groundwater flooding, less infiltration into the saturated soil, and more runoff into streams and Puget Sound. Summer droughts, in turn, could spur more groundwater pumping when surface water is scarce. Such direct and indirect climate impacts, coupled with sea-level rise, could make Thurston County's coastal freshwater aquifers more vulnerable to water quality and quantity risks.

The direct impacts of saltwater intrusion and inundation on groundwater are likely to be greatest in places with low topographic relief and very low hydraulic gradients between freshwater and saltwater (e.g., downtown Olympia and Nisqually Valley).

In 1995, the City of Olympia applied to the state Department of Ecology to transfer its municipal water rights from McAllister Springs (pictured this page) to a new McAllister Wellfield (pictured next page), upslope of the springs. Engineers had deemed McAllister Springs — Olympia's primary water source at the time — susceptible to saltwater intrusion from nearby Puget Sound, as well as vulnerable to hazardous transportation spills and microbial contamination. ***Source:*** *City of Olympia*



Wells: Prolonged droughts raise the risk of concentrating contaminants in private water systems' shallow wells (less than 50-100 feet deep) — especially those at risk for saltwater intrusion or those with low productivity. Conversely, greater deluges raise the risks of overwhelming wastewater, septic, and stormwater conveyance systems and causing water-borne disease outbreaks in small community or private groundwater wells or other drinking water systems where water is untreated or minimally treated.

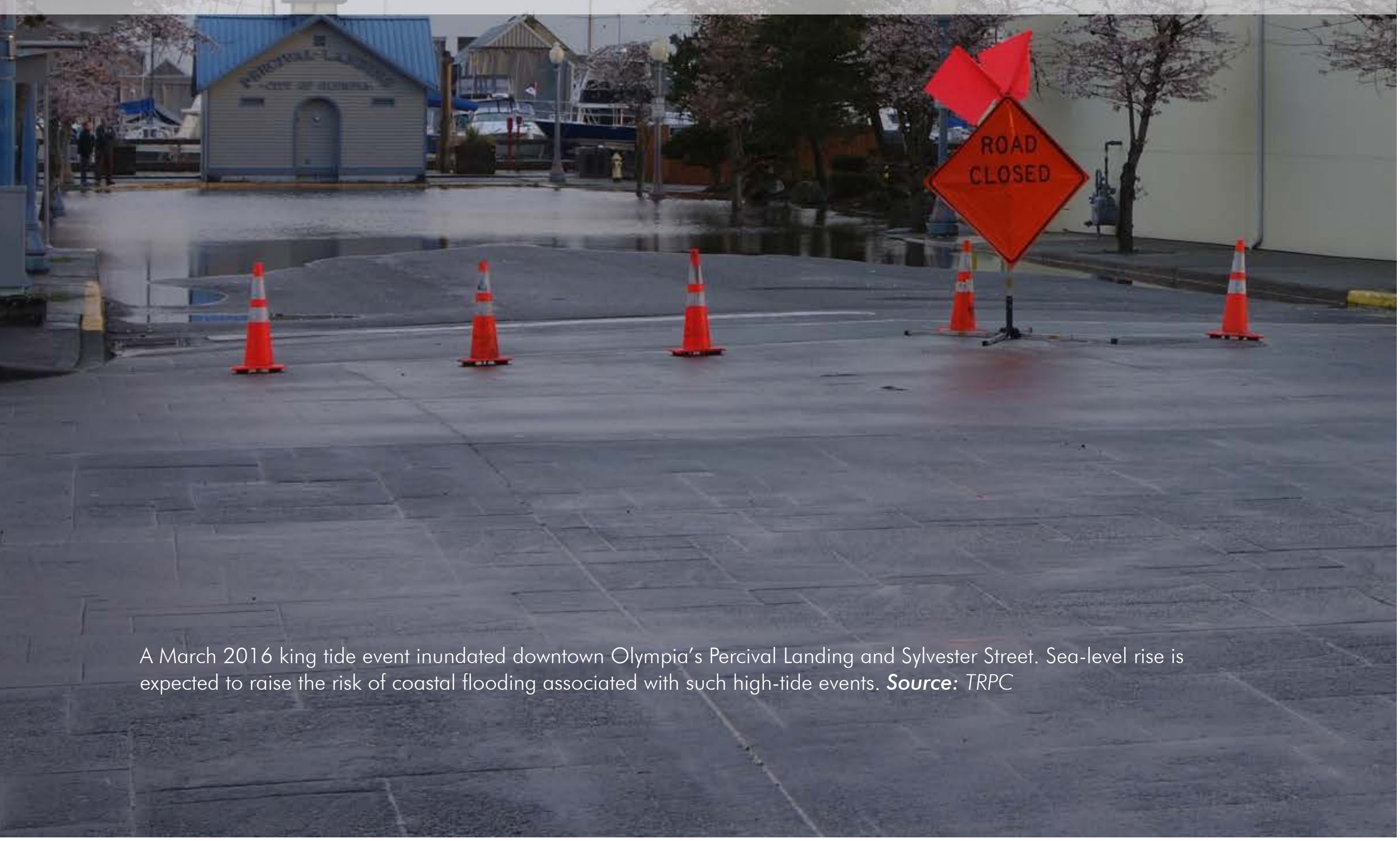
Water quantity vulnerability is expected to be highest in snow-influenced watersheds with existing conflicts over water resources (e.g., fully allocated watersheds with little management flexibility). Vulnerability would be lowest where hydrologic change is smallest (i.e., existing rain-dominant watersheds), where there are simple institutional arrangements, and where current water demand rarely exceeds supply.

McAllister Wellfield replaced McAllister Springs as the City of Olympia's primary source of drinking water. ***Source:*** *City of Olympia*

Marine Ecosystems

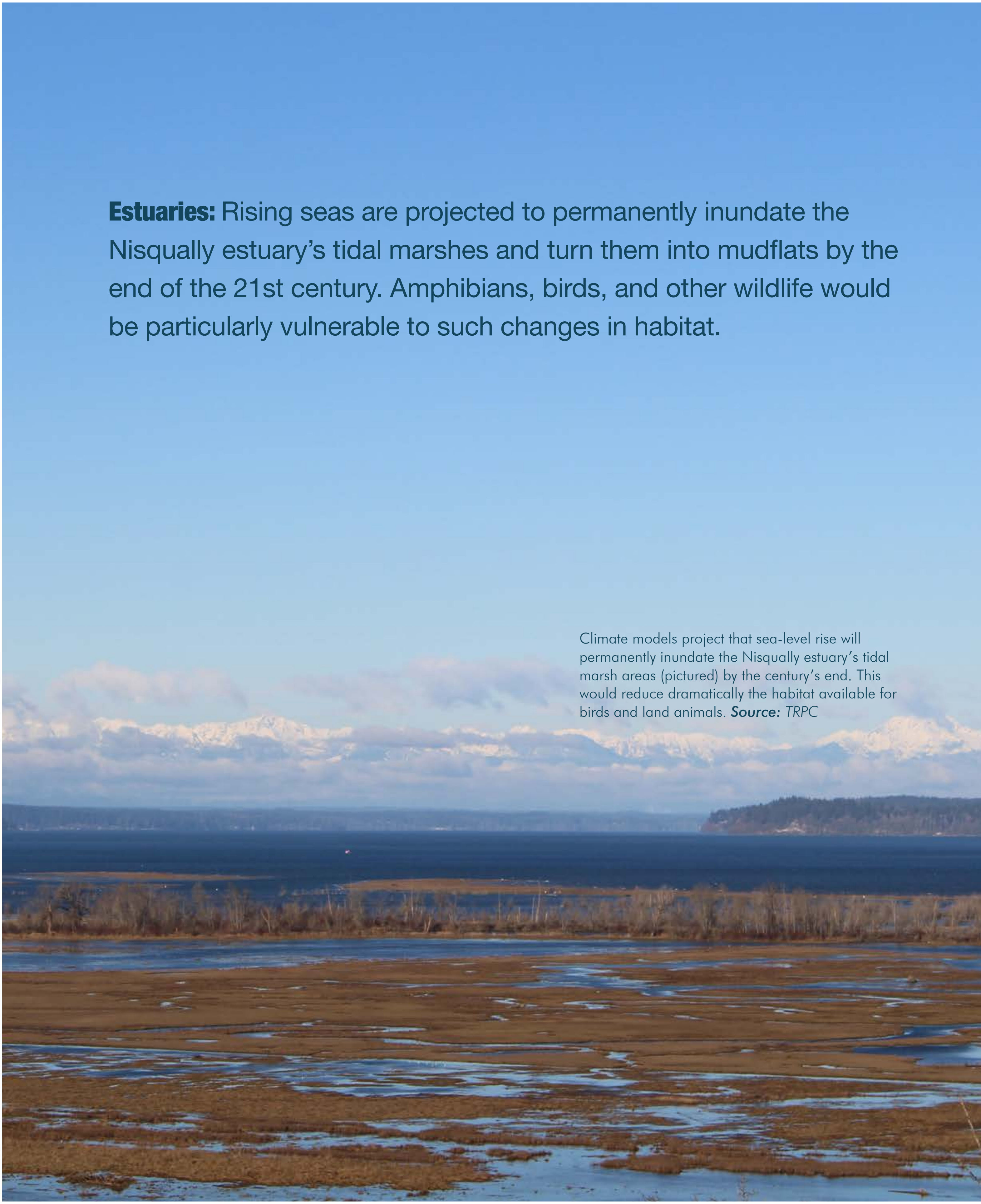
Sea-level Rise: The Puget Sound region is projected to experience continued, and possibly accelerated, sea-level rise in coming decades as a result of melting ice sheets and warmer oceans. This may result in permanent inundation of some low-lying areas, and increased frequency, depth, and duration of coastal flooding due to greater reach of tides and storm surges.

Downtown Olympia, part of which is built atop fill, floods today during high tides. Rising sea levels are projected to exacerbate this problem and increase the vulnerability of key roads, LOTT's Budd Inlet Treatment Plant, and other important assets. Vulnerable infrastructure along other parts of Thurston County's Puget Sound shoreline include low-lying homes, seawalls, and sections of Interstate 5 and U.S. Highway 101.

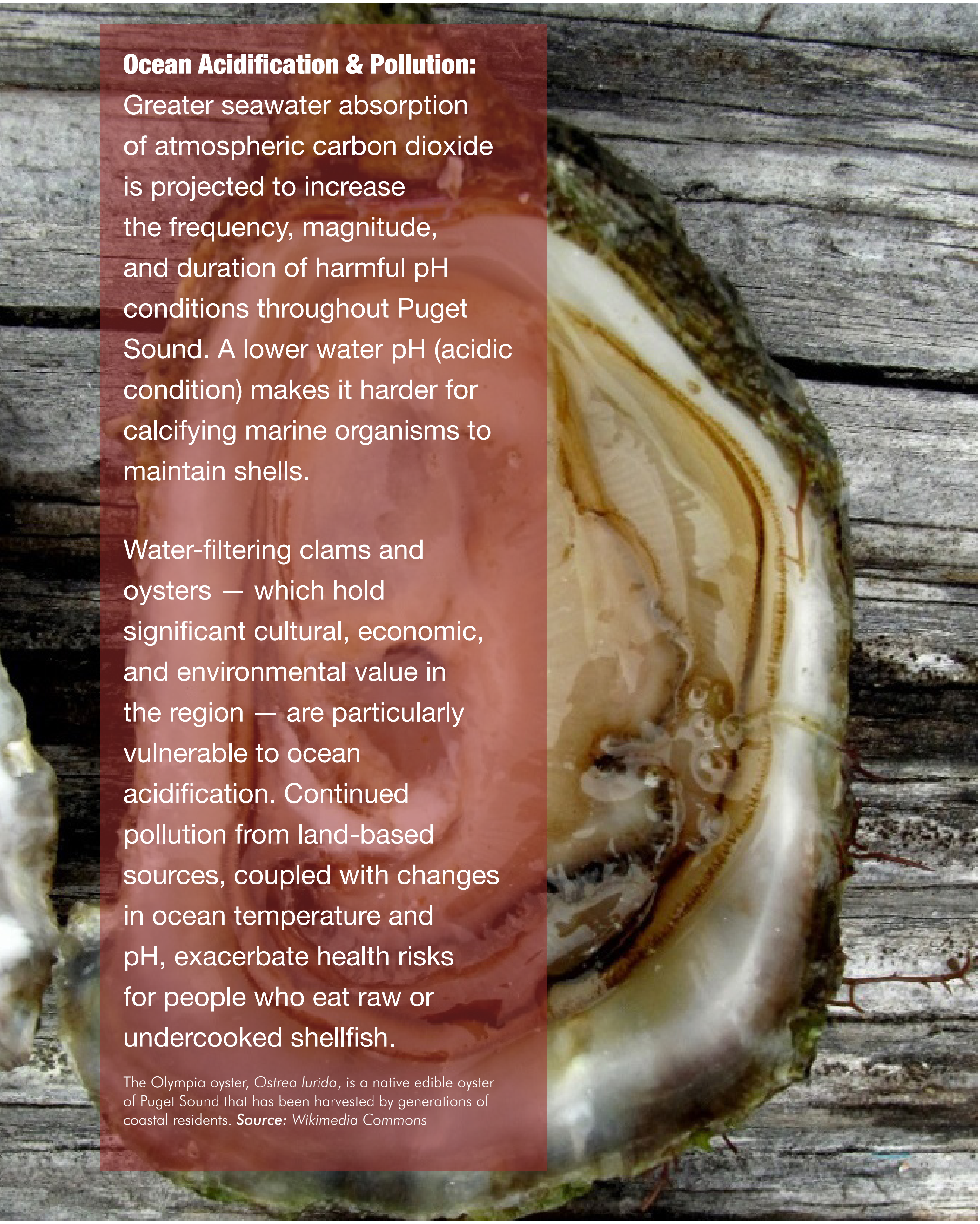


A March 2016 king tide event inundated downtown Olympia's Percival Landing and Sylvester Street. Sea-level rise is expected to raise the risk of coastal flooding associated with such high-tide events. ***Source:*** *TRPC*

Estuaries: Rising seas are projected to permanently inundate the Nisqually estuary’s tidal marshes and turn them into mudflats by the end of the 21st century. Amphibians, birds, and other wildlife would be particularly vulnerable to such changes in habitat.



Climate models project that sea-level rise will permanently inundate the Nisqually estuary’s tidal marsh areas (pictured) by the century’s end. This would reduce dramatically the habitat available for birds and land animals. ***Source:*** *TRPC*



Ocean Acidification & Pollution:
Greater seawater absorption of atmospheric carbon dioxide is projected to increase the frequency, magnitude, and duration of harmful pH conditions throughout Puget Sound. A lower water pH (acidic condition) makes it harder for calcifying marine organisms to maintain shells.

Water-filtering clams and oysters — which hold significant cultural, economic, and environmental value in the region — are particularly vulnerable to ocean acidification. Continued pollution from land-based sources, coupled with changes in ocean temperature and pH, exacerbate health risks for people who eat raw or undercooked shellfish.

The Olympia oyster, *Ostrea lurida*, is a native edible oyster of Puget Sound that has been harvested by generations of coastal residents. ***Source:*** *Wikimedia Commons*

Terrestrial Ecosystems

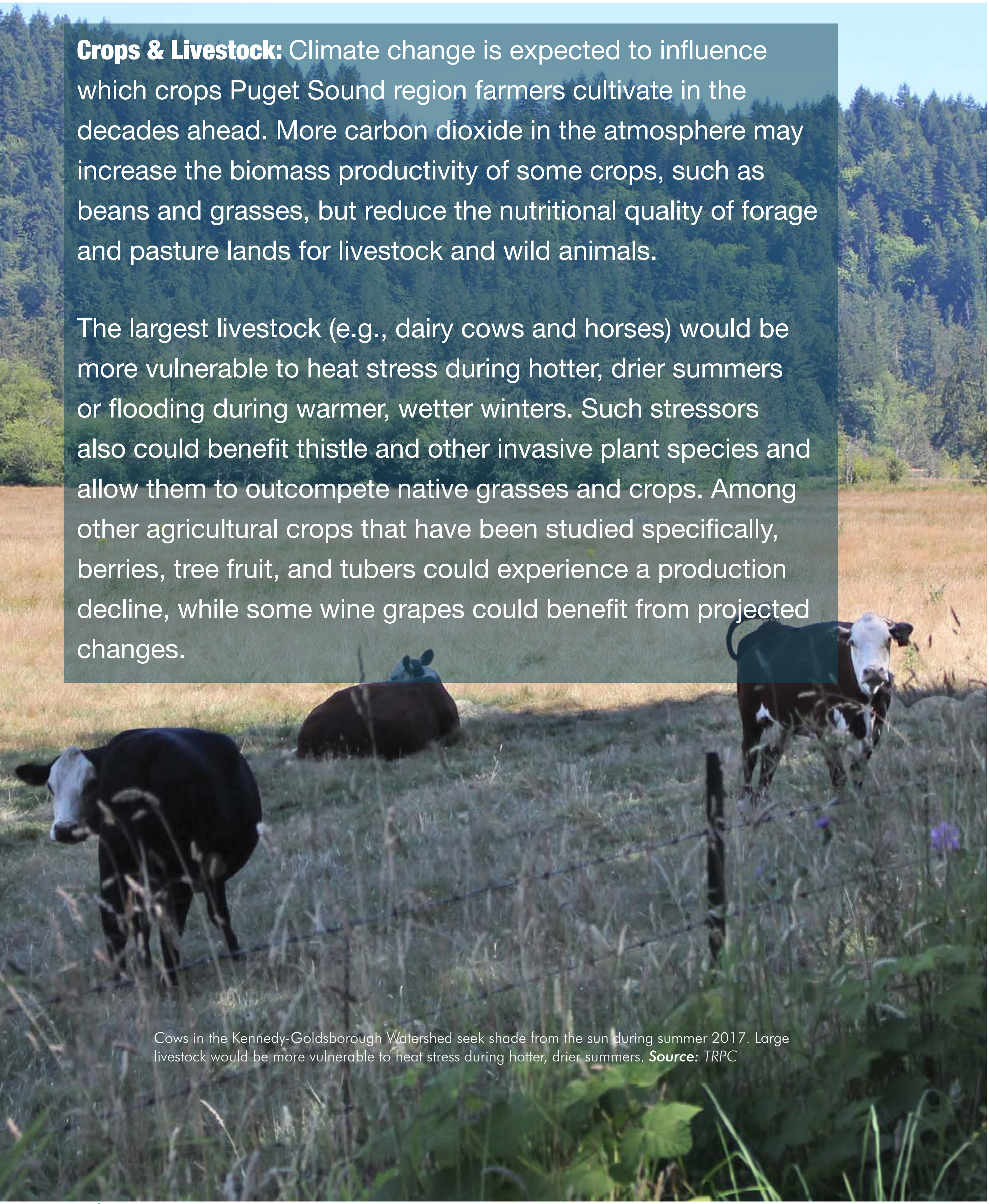
Farms & Ranches: Puget Sound's agricultural sector is expected to be relatively resilient to climate change — and some crops may even benefit from a longer growing season and more atmospheric carbon dioxide. However, periodic drought and flood events, as well as invasive pests and plants, still pose risks for local farms and ranches.

Sustained periods of low or no precipitation could make surface water supplies scarce, forcing farmers and ranchers to rely more heavily on groundwater for irrigating agricultural crops and watering livestock. Conversely, sustained periods of heavy rain, coupled with sea-level rise, could reduce the ability of drainage ditches and other infrastructure to handle flood events in near-coastal agricultural lands.

Young tomatos grow in a Lacey garden during summer 2013. ***Source:*** *TRPC*

Crops & Livestock: Climate change is expected to influence which crops Puget Sound region farmers cultivate in the decades ahead. More carbon dioxide in the atmosphere may increase the biomass productivity of some crops, such as beans and grasses, but reduce the nutritional quality of forage and pasture lands for livestock and wild animals.

The largest livestock (e.g., dairy cows and horses) would be more vulnerable to heat stress during hotter, drier summers or flooding during warmer, wetter winters. Such stressors also could benefit thistle and other invasive plant species and allow them to outcompete native grasses and crops. Among other agricultural crops that have been studied specifically, berries, tree fruit, and tubers could experience a production decline, while some wine grapes could benefit from projected changes.



Cows in the Kennedy-Goldsborough Watershed seek shade from the sun during summer 2017. Large livestock would be more vulnerable to heat stress during hotter, drier summers. ***Source:*** *TRPC*

Forests & Prairies: Climate change is projected to affect the region's forest and prairie vegetation growth, productivity, and range, as well as the prevalence and location of diseases, insects, and invasive species.

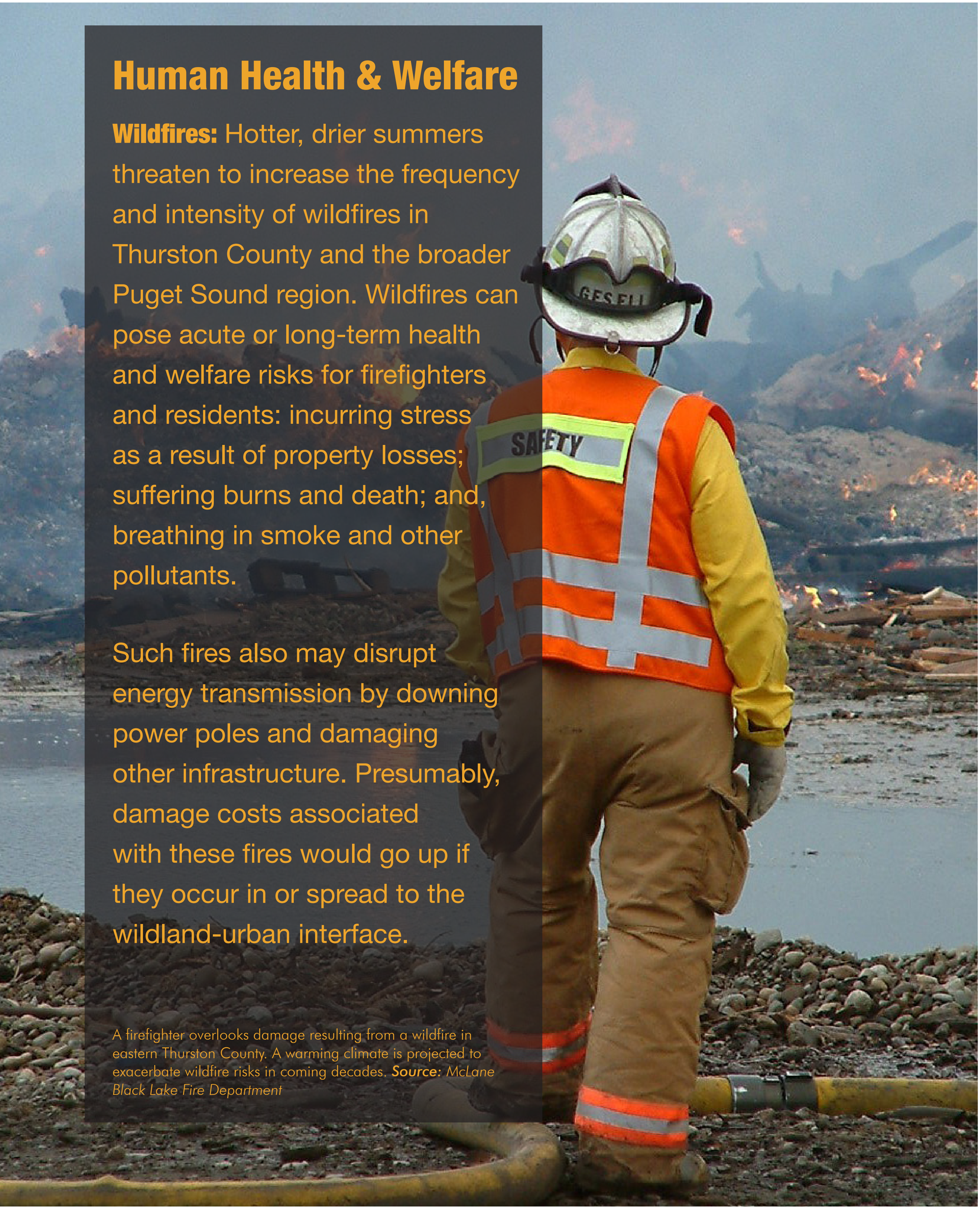
Shifts in seasonal temperature and precipitation threaten to alter the timing of flowering and the abundance of insect pollinators amid prairies, which could reduce some plant species. Such shifts also threaten to alter the range of Garry oak, Douglas-fir and other important tree species, as well as threaten their survival due to pest and disease outbreaks.

South Thurston County, as seen from Tumwater during summer 2013, appears as a sea of rolling blue ridges and towering green trees. Douglas-fir, which have thrived in the region's temperate climate, provide abundant natural capital. ***Source:*** *TRPC*

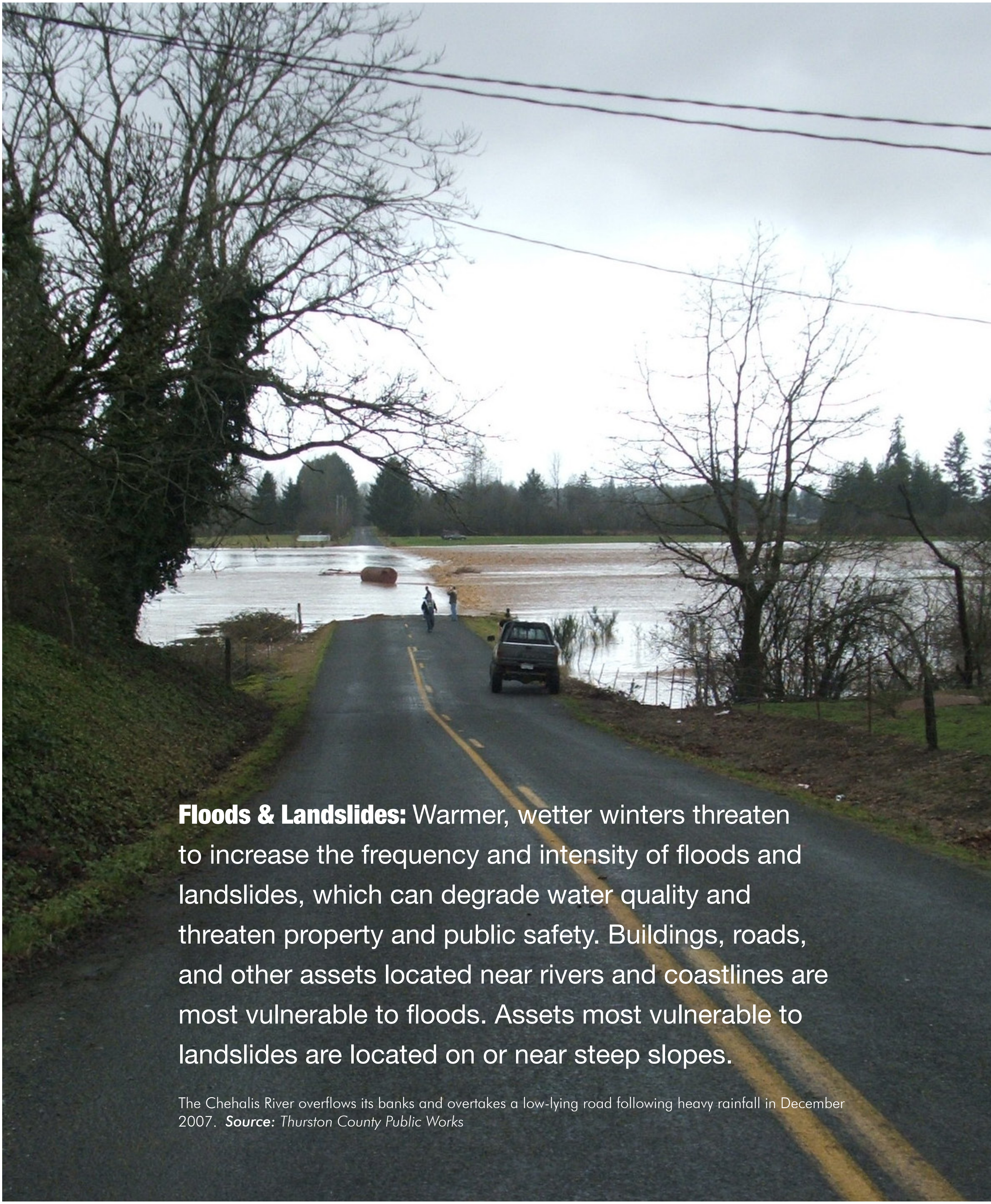
Human Health & Welfare

Wildfires: Hotter, drier summers threaten to increase the frequency and intensity of wildfires in Thurston County and the broader Puget Sound region. Wildfires can pose acute or long-term health and welfare risks for firefighters and residents: incurring stress as a result of property losses; suffering burns and death; and, breathing in smoke and other pollutants.

Such fires also may disrupt energy transmission by downing power poles and damaging other infrastructure. Presumably, damage costs associated with these fires would go up if they occur in or spread to the wildland-urban interface.



A firefighter overlooks damage resulting from a wildfire in eastern Thurston County. A warming climate is projected to exacerbate wildfire risks in coming decades. ***Source:*** *McLane Black Lake Fire Department*

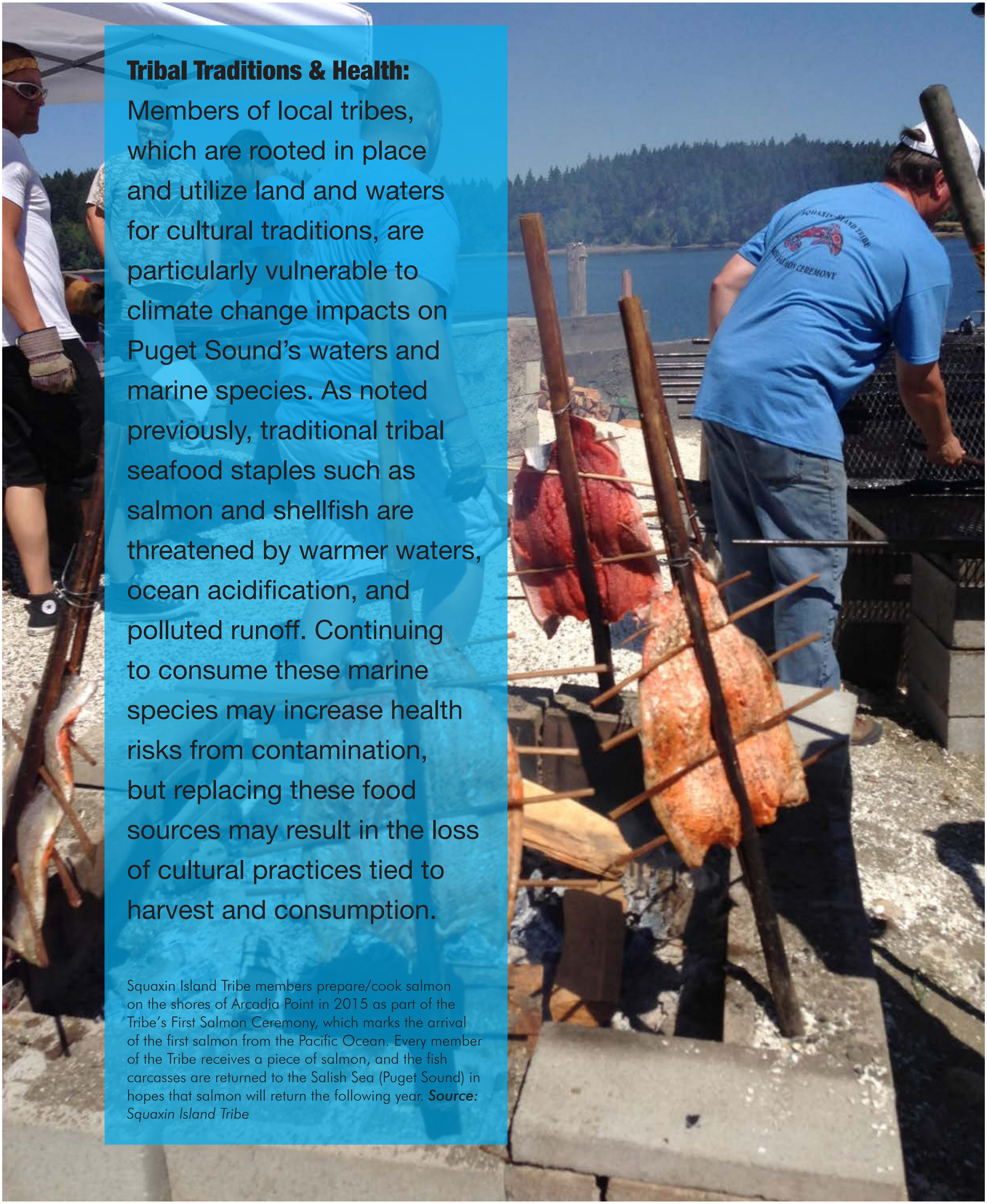


Floods & Landslides: Warmer, wetter winters threaten to increase the frequency and intensity of floods and landslides, which can degrade water quality and threaten property and public safety. Buildings, roads, and other assets located near rivers and coastlines are most vulnerable to floods. Assets most vulnerable to landslides are located on or near steep slopes.

The Chehalis River overflows its banks and overtakes a low-lying road following heavy rainfall in December 2007. ***Source:*** *Thurston County Public Works*

Disease Vectors: The shifts in temperature and precipitation noted previously are projected to exacerbate or introduce a wide range of threats, including infectious diseases from exposure to viruses and bacteria, which would affect human health outcomes. Exposure pathways include food, water, air, soil, trees, insects, and other animals.

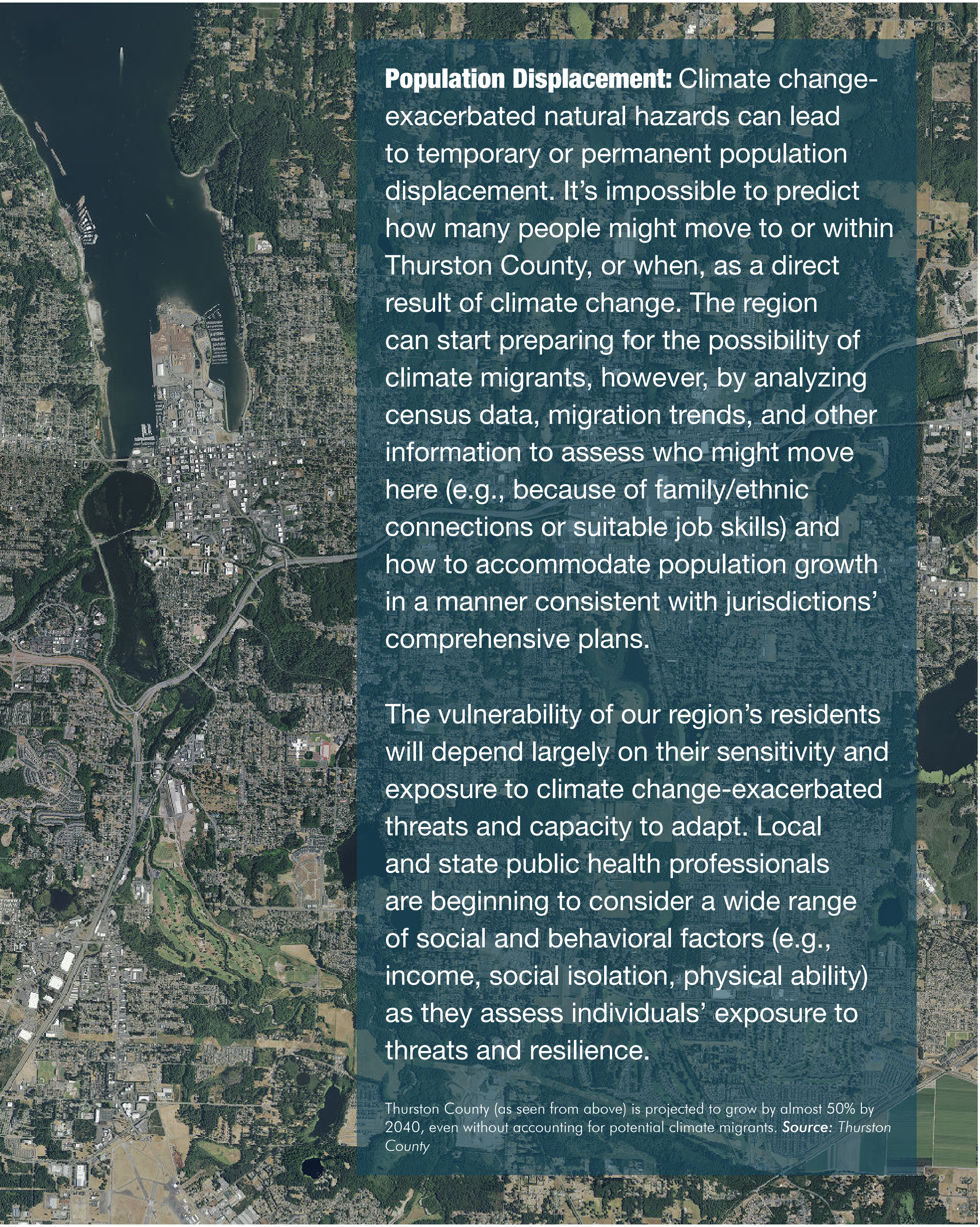
A warming climate is expected to make western Washington more hospitable for mosquitos that carry West Nile Virus, which can cause a fatal neurological disease in humans. ***Source:*** *Thurston County Public Health & Social Services*



Tribal Traditions & Health:

Members of local tribes, which are rooted in place and utilize land and waters for cultural traditions, are particularly vulnerable to climate change impacts on Puget Sound's waters and marine species. As noted previously, traditional tribal seafood staples such as salmon and shellfish are threatened by warmer waters, ocean acidification, and polluted runoff. Continuing to consume these marine species may increase health risks from contamination, but replacing these food sources may result in the loss of cultural practices tied to harvest and consumption.

Squaxin Island Tribe members prepare/cook salmon on the shores of Arcadia Point in 2015 as part of the Tribe's First Salmon Ceremony, which marks the arrival of the first salmon from the Pacific Ocean. Every member of the Tribe receives a piece of salmon, and the fish carcasses are returned to the Salish Sea (Puget Sound) in hopes that salmon will return the following year. ***Source:*** *Squaxin Island Tribe*



Population Displacement: Climate change-exacerbated natural hazards can lead to temporary or permanent population displacement. It's impossible to predict how many people might move to or within Thurston County, or when, as a direct result of climate change. The region can start preparing for the possibility of climate migrants, however, by analyzing census data, migration trends, and other information to assess who might move here (e.g., because of family/ethnic connections or suitable job skills) and how to accommodate population growth in a manner consistent with jurisdictions' comprehensive plans.

The vulnerability of our region's residents will depend largely on their sensitivity and exposure to climate change-exacerbated threats and capacity to adapt. Local and state public health professionals are beginning to consider a wide range of social and behavioral factors (e.g., income, social isolation, physical ability) as they assess individuals' exposure to threats and resilience.

Thurston County (as seen from above) is projected to grow by almost 50% by 2040, even without accounting for potential climate migrants. ***Source:*** *Thurston County*

4.3 Risk Assessment

TRPC's project team and Stakeholder Advisory Committee used U.S. EPA's *Being Prepared for Climate Change* workbook (EPA, 2014) to evaluate how risks identified by the vulnerability assessment [*See Section 4.2*] would affect the region's ability to achieve the 12 project goals [*See Section 3*]. The assessment, which resulted in a strategy for each risk, took about four months to complete.

Members of the Stakeholder Advisory Committee identify connections between climate risks and project goals during a fall 2016 meeting. ***Source:*** *TRPC*

Risk Identification

In October 2016, the project team and Stakeholder Advisory Committee identified how 85 risks intersect with the 12 project goals and eight climate stressors: Warmer Summer; Warmer Winter; Warmer Water; Increasing Drought; Intensifying Precipitation; Sea-Level Rise; Ocean Acidification; and, Population Change [*See Figure 10*].

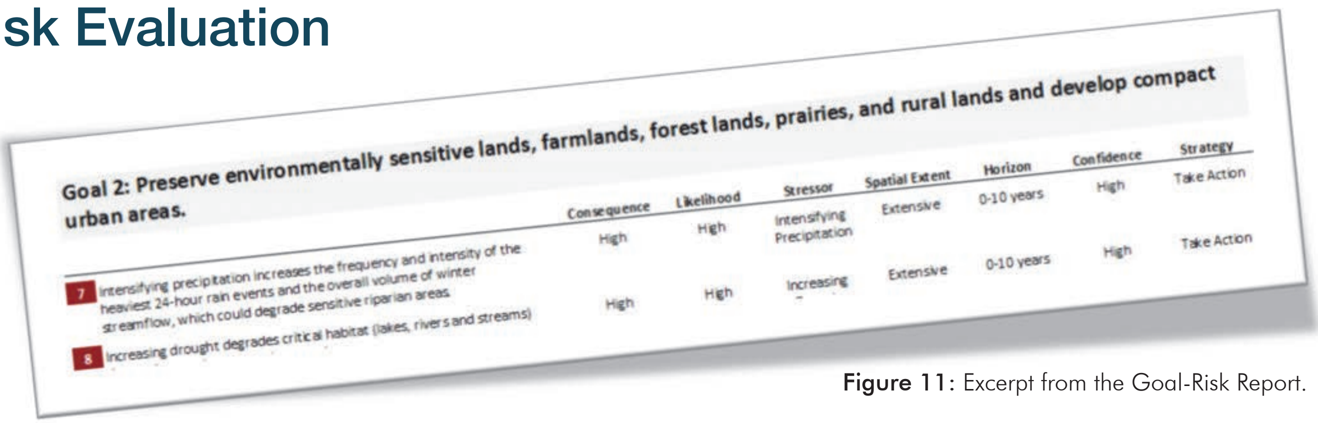
STRESSOR	DESCRIPTION
Warmer Summer	Encompasses the risks of the region's warm months (April-September) being warmer than they have been historically
Warmer Winter	Encompasses the risks of the region's cool months (October-March) being warmer than they have been historically
Warmer Water	Encompasses the risks of warming affecting the chemical, biological and/or physical characteristics of the region's freshwater and marine waterbodies during any season
Increasing Drought	Encompasses the risks of drought — a deficiency in precipitation over an extended period — increasing in frequency and intensity
Intensifying Precipitation	Encompasses the risks of rain events increasing in frequency and intensity
Sea-Level Rise	Encompasses the risks of Puget Sound's water levels rising
Ocean Acidification	Encompasses the risks of Puget Sound absorbing more atmospheric carbon dioxide
Population Change	Encompasses the risks that climate change will cause temporary or permanent population displacement

Figure 10: This table describes the eight climate stressors the project's Stakeholder Advisory Committee considered in its risk assessment.

Risk Analysis

In November 2016, the project team and its Stakeholder Advisory Committee used the vulnerability assessment's scientific research and modeling to analyze each risk's likelihood, consequence, spatial extent, and time horizon [*See Goal-Risk Report, Appendix C*].

Risk Evaluation



Goal 2: Preserve environmentally sensitive lands, farmlands, forest lands, prairies, and rural lands and develop compact urban areas.

	Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
7 Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas	High	High	Intensifying Precipitation	Extensive	0-10 years	High	Take Action
8 Increasing drought degrades critical habitat (lakes, rivers and streams)	High	High	Increasing	Extensive	0-10 years	High	Take Action

Figure 11: Excerpt from the Goal-Risk Report.

In January 2017, the project team placed each of the 85 risks in a matrix [*See Figure 12*] to show their consequence and likelihood.

Likelihood expressed the probability of impacts, given the climate modeling and research. Consequence expressed the severity of impacts, given local assets' risk exposure.

Thirty-nine risks of greatest impact fell in the matrix's upper-right third (red); 23 risks of lesser impact fell in the middle third (yellow); and, 23 risks of least impact fell in the lower-left third (green).

In February 2017, the Stakeholder Advisory Committee used the matrix to select a broad strategy — either *Take Action* or *Accept* — for each climate change risk.

- **Take Action** — means choosing to reduce the risk's impacts by recommending actions (new or continuing) and determining leads, partners, and timeframe. The Stakeholder Advisory Committee selected this strategy for all "red" risks and many "yellow" risks of high consequence or likelihood.
- **Accept** — means choosing to continue business as usual, monitor, and reassess the risk if impacts occur. The Stakeholder Advisory Committee selected this strategy for "green" and "yellow" risks of lesser consequence and/or likelihood.

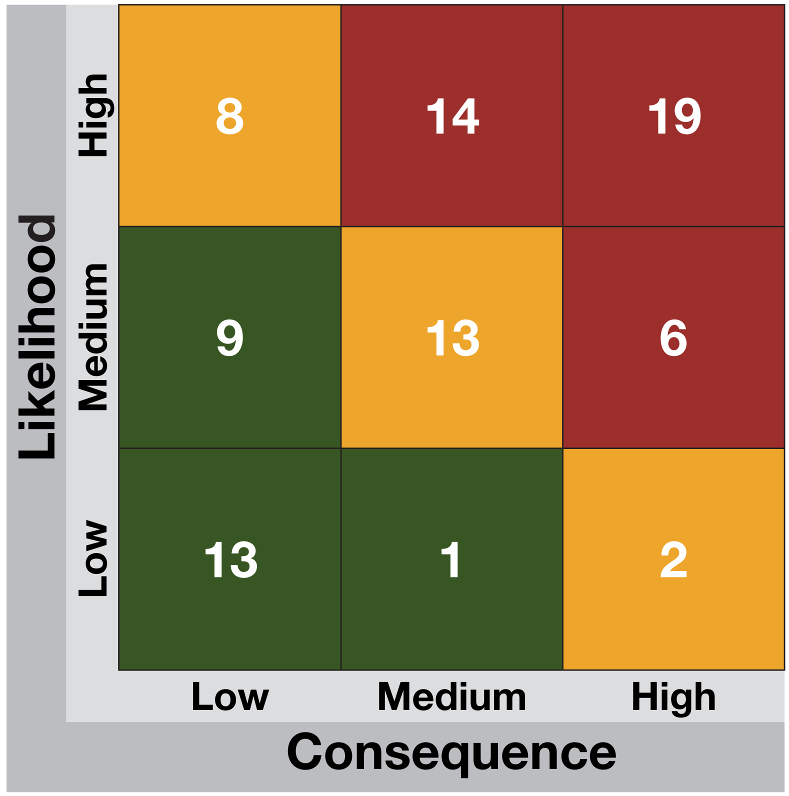
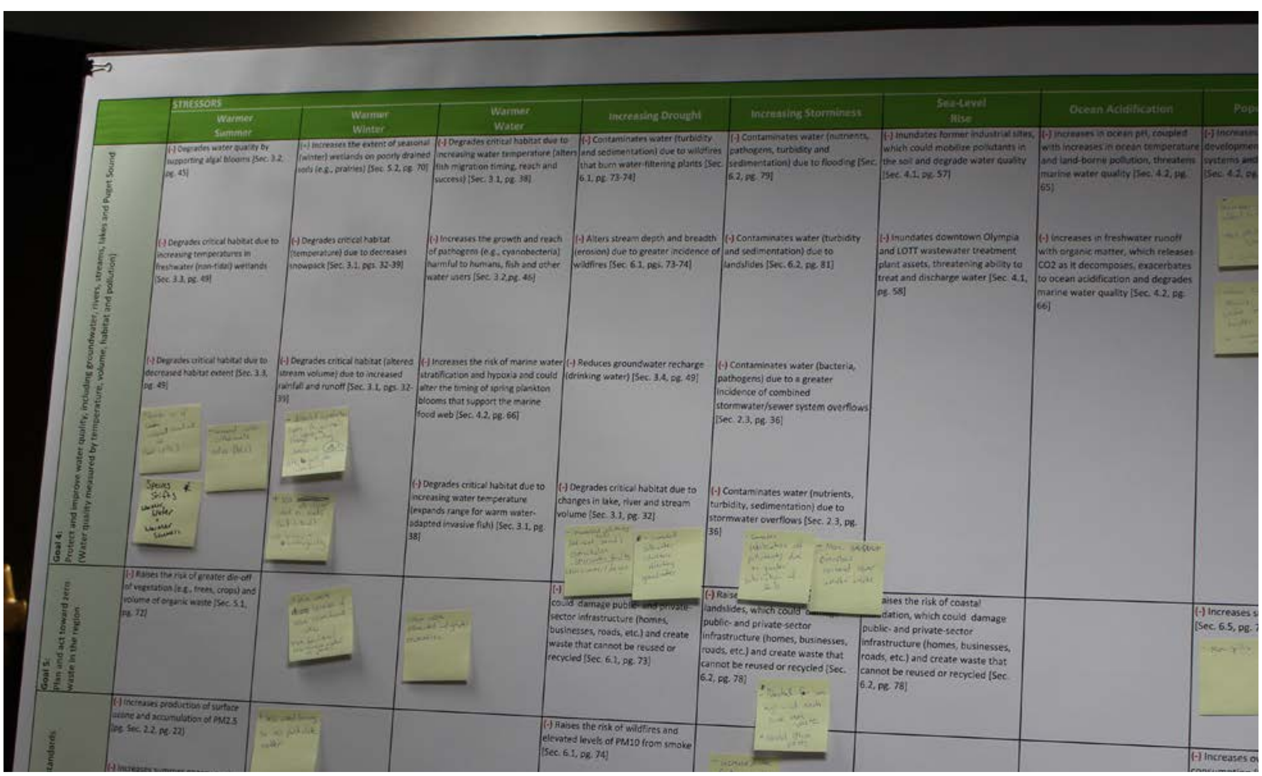


Figure 12: The Consequence/Likelihood Matrix enabled stakeholders to show the relative impact — low, medium, or high — of 85 climate risks. *Source:* TRPC



The project team created a grid (pictured) that enabled the Stakholder Advisory Committee to identify risks that intersect with project goals and climate stressors. ***Source:*** *TRPC*

4.4 Public Engagement

In early spring 2017, the project team began executing a public-engagement strategy [See *Appendix D*] to communicate the region's climate risks widely and elicit adaptation action ideas.

The project team met with more than 20 diverse organizations — ranging from the Black Hills Audubon Society and the South Thurston Economic Development Initiative, to the Nisqually River Council and the Thurston County Fire Chiefs Association. The project team also hosted a community forum and administered online surveys. TRPC promoted these events via an online video, newspaper editorial, social media, word-of-mouth, and other methods that reached more than 50,000 people.

The community forum and online survey enabled participants to learn about the region's climate risks and recommend adaptation and mitigation actions.

Figure 13: The project team used posters, including those pictured, at the April 2017 community forum to help communicate what climate risks the Thurston Region faces and what actions it could take to prepare for and adjust to climate impacts. ***Source:*** *TRPC*

PLANTS & ANIMALS

Changes in temperature and precipitation threaten the health and resilience of our region's plants and animals.

WHAT IS AT RISK:

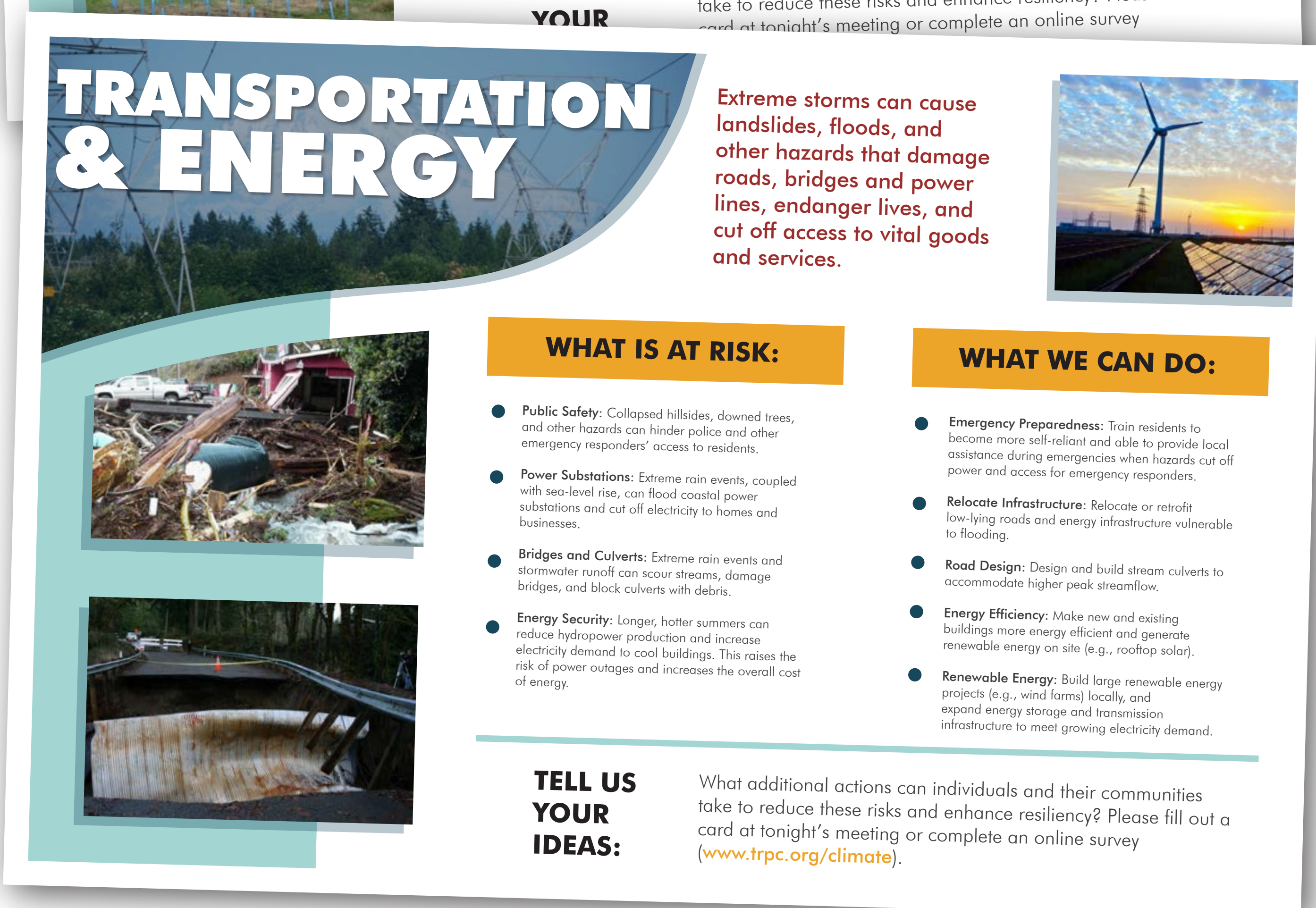
- **Shellfish:** As the ocean becomes more acidic, shellfish have a difficult time developing shells.
- **Agriculture:** Crop yields and harvests can decrease or fail because summers are drier and hotter for longer periods of time.
- **Habitat:** Warmer summers stress sensitive plants and habitat. This can leave them more vulnerable to damage and disease caused by pests and pathogens.

WHAT WE CAN DO:

- **Marine Habitat:** Enhance marine vegetation (e.g., eelgrass) and reduce polluted runoff to help sustain local fisheries.
- **Freshwater Habitat:** Enhance streambank vegetation to slow erosion, provide shade and cool water for salmon.
- **Agriculture:** Increase options for urban farming, permaculture, and aquaponics. Provide incentives, education, and other resources for farmers to use more water-wise irrigation methods. Grow crops that are better adapted to warmer, drier summers.
- **Control Invasive Species:** Actively monitor, remove, and control the spread of invasive plants and insects. This means expanding existing programs.

TELL US YOUR

What additional actions can individuals and their communities take to reduce these risks and enhance resiliency? Please fill out a card at tonight's meeting or complete an online survey



TRANSPORTATION & ENERGY

Extreme storms can cause landslides, floods, and other hazards that damage roads, bridges and power lines, endanger lives, and cut off access to vital goods and services.

WHAT IS AT RISK:

- **Public Safety:** Collapsed hillsides, downed trees, and other hazards can hinder police and other emergency responders' access to residents.
- **Power Substations:** Extreme rain events, coupled with sea-level rise, can flood coastal power substations and cut off electricity to homes and businesses.
- **Bridges and Culverts:** Extreme rain events and stormwater runoff can scour streams, damage bridges, and block culverts with debris.
- **Energy Security:** Longer, hotter summers can reduce hydropower production and increase electricity demand to cool buildings. This raises the risk of power outages and increases the overall cost of energy.

WHAT WE CAN DO:

- **Emergency Preparedness:** Train residents to become more self-reliant and able to provide local assistance during emergencies when hazards cut off power and access for emergency responders.
- **Relocate Infrastructure:** Relocate or retrofit low-lying roads and energy infrastructure vulnerable to flooding.
- **Road Design:** Design and build stream culverts to accommodate higher peak streamflow.
- **Energy Efficiency:** Make new and existing buildings more energy efficient and generate renewable energy on site (e.g., rooftop solar).
- **Renewable Energy:** Build large renewable energy projects (e.g., wind farms) locally, and expand energy storage and transmission infrastructure to meet growing electricity demand.

TELL US YOUR IDEAS:

What additional actions can individuals and their communities take to reduce these risks and enhance resiliency? Please fill out a card at tonight's meeting or complete an online survey (www.trpc.org/climate).

WILDFIRES & EXTREME HEAT

Longer, hotter and drier summers can increase the number and severity of wildfire and extreme heat events. These risks have social, economic, and environmental costs.

WHAT IS AT RISK:

- **Infrastructure:** Wildfires can damage or destroy homes, power poles, forests, and other important buildings and infrastructure.
- **Human Health:** Extreme heat events make cities hotter, especially in densely developed areas. Hospitalizations and emergency service calls for heat-related illnesses place greater demands on the region's emergency medical services. The elderly and homeless are especially vulnerable.
- **Agriculture:** Extreme heat events can damage or kill crops and livestock.

WHAT WE CAN DO:

- **Extend Burn Ban:** Most wildfires are caused by people. Extend and enforce the rural burn ban during periods of drought and/or extreme heat.
- **Expand Wildfire Response:** Enhance training and financial support for wildfire response efforts.
- **Outreach and Education:** Increase public outreach and education efforts about how extreme heat and other climate impacts affect human health and welfare. Awareness can influence behavior.
- **Public Safety:** Increase the availability and community awareness of cooling shelters (e.g., schools and community centers) than can serve vulnerable and special-needs populations during the hottest days of the year.
- **Increase Tree Canopy:** Plant drought-tolerant trees and other landscaping that provide cooling shade. This also helps reduce the urban heat island effect, absorb stormwater, improve air quality, and reduce maintenance costs.
- **Agriculture:** Grow crops that are better suited to drier, warmer conditions.

FLOODING & EROSION

Rising sea levels and heavier rain events raise the risk of flooding, erosion, and landslides that threaten people, plants, and animals.

WHAT IS AT RISK:

- **Stormwater:** Heavier rainfall and runoff can overwhelm stormwater systems (e.g., roadside swales, drains, and pipes), especially in urban communities.
- **Wildlife Habitat:** Heavier rainfall and runoff can erode streambeds and streambanks and degrade sensitive habitat for fish and wildlife.
- **Roads and Homes:** Heavier rainfall and saturated soil can trigger landslides that endanger homes, roads, and lives near steep slopes. Sea-level rise and wave exposure raises such risks for coastal bluffs.
- **Marshes and Estuaries:** Sea-level rise can cause low-lying coastal areas to be under water more frequently and for longer periods of time. This can turn our region's coastal marshes and forests into mudflats and alter habitat for birds and other animals.

WHAT WE CAN DO:

- **Stormwater:** Design, install, and maintain stormwater infrastructure that can manage larger rain events, as well as capture and filter runoff on site (e.g., porous pavement, bioswales, rain gardens). Retrofit existing stormwater infrastructure.
- **Habitat Restoration:** Restore native trees, bushes, and other vegetation along freshwater and marine shorelines to help control flooding, stabilize banks, and filter out pollutants.
- **Stabilize Slopes:** Locate new homes and roads farther from steep slopes near lakes, rivers, streams, and Puget Sound. Maintaining trees and other vegetation helps slow the erosion of these areas.
- **Coastal Transition:** Remove or retrofit roads and other barriers to support the inland migration of coastal estuaries as sea levels rise.

TELL US YOUR IDEAS:

What additional actions can individuals and their communities take to reduce these risks and enhance resiliency? Please fill out a card at tonight's meeting or complete an online survey (www.trpc.org/climate).

People who attended the April 17 community forum at Lacey's South Sound Community College campus wrote what a resilient community means to them. ***Source:*** *TRPC*

Figure 14: The comments above were collected during TRPC's April 2017 public forum in Lacey. The project team considered these and other comments for plan actions.

Provide young trees and bushes to homeowners by watershed creek/ river/etc.

Re-evaluate our landscaping designs and specs for low water use plants and retain trees.

Be prepared to relocate move intra-regionally or inter regionally.

Continue planting shade trees for riparian zones to help control summer water temps in streams and rivers to help protect fisheries.

Wildfire - fire safety regulations/ teaching. Extreme heat- Make this a "fun" and engaging concept.

Be wise - reduce driving! And stay home - flexible workplaces and schools.

Build with greater resilience in mind in how you site buildings and structures.

Business perspective. Intergrading community solar and workforce development. Non profit - group purchase of vehicles. Work force transitioning - new jobs.

Restore estuaries. Preserve mature woodlands and wildlife corridors.

More P.R. so more people really get this. Support local food supply and local reliant economics to inter regional transportation is not the only things we're relying on.

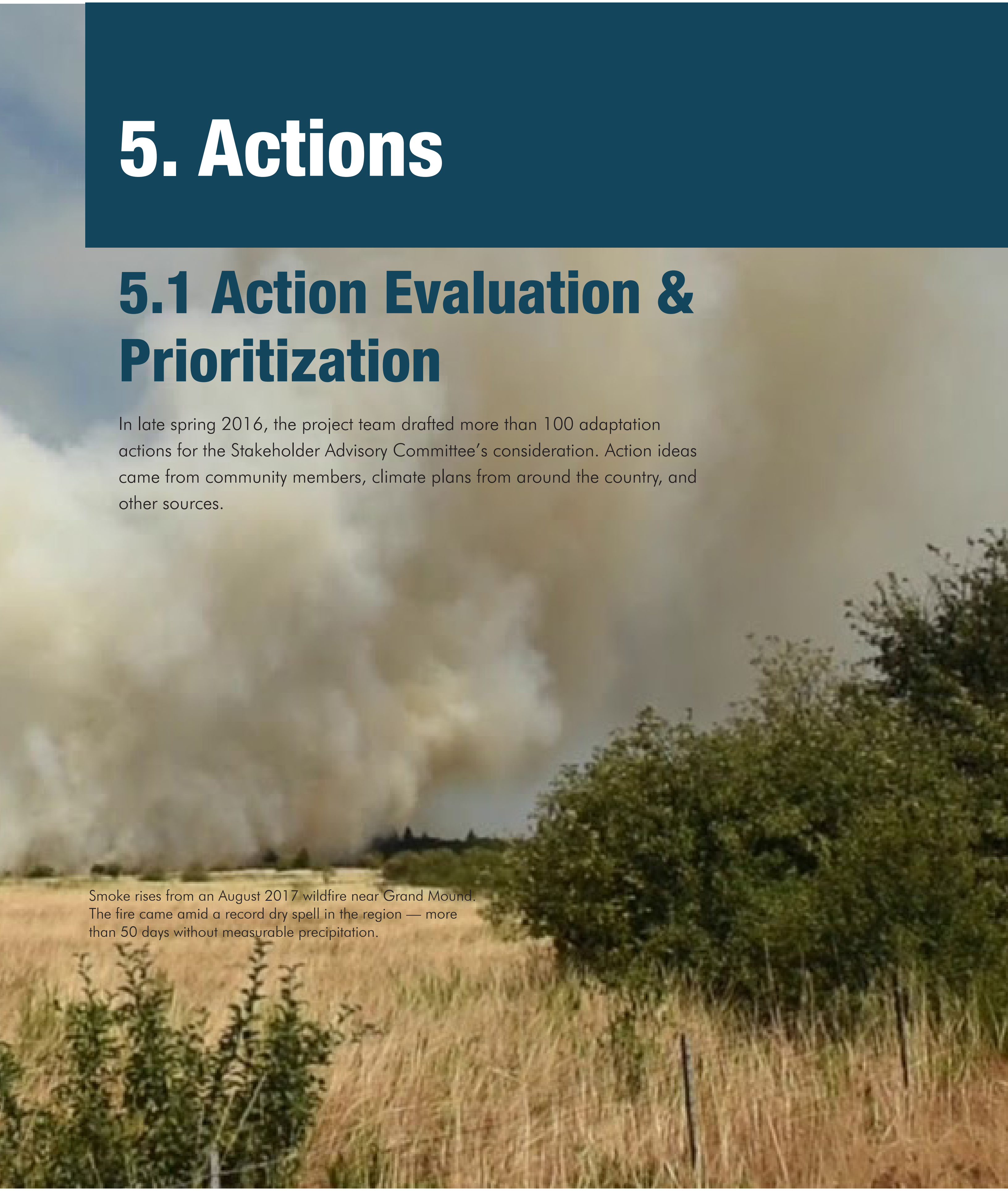
Teach youth/ people to withstand temps! Reserve energy systems for elderly and disabled. Encourage innovation by creating personalized community cooling and fire suppression systems.

Help neighborhoods maintain woods while also being safe.

5. Actions

5.1 Action Evaluation & Prioritization

In late spring 2016, the project team drafted more than 100 adaptation actions for the Stakeholder Advisory Committee's consideration. Action ideas came from community members, climate plans from around the country, and other sources.



Smoke rises from an August 2017 wildfire near Grand Mound. The fire came amid a record dry spell in the region — more than 50 days without measurable precipitation.

The Stakeholder Advisory Committee added, removed and revised actions. Next, the committee used common criteria [*See Figure 15*] to evaluate the actions and an online survey to prioritize them. This collaborative exercise yielded a final list of 91 adaptation actions, including 25 priority actions.

Criteria		Answer Range
Magnitude:	How many risks does this action address?	One, Few, or Many
Effectiveness:	Is this action a long-term solution (i.e., durable)?	Yes or No
	To what degree would this action reduce the risk(s)?	Low, Medium, High
	Is this action already being taken?	Yes or No
Side-effects:	Would this action have negative effects on other goals?	Yes or No
	Would this action have positive effects on other goals?	Yes or No
Equity:	Would the costs and benefits of this action be shared equally?	Yes or No

Figure 15: The project team assigned a positive or negative numeric value to each criterion, which resulted in a net score for each action. This exercise helped the stakeholder committee prioritize the actions. ***Source:*** *TRPC*

5.2 Action Tables

The action tables that follow include steps individuals, neighborhoods, cities, and the broader community can take to prepare for and adjust to adverse climate impacts — the very definition of "adaptation." The project's 22-member Stakeholder Advisory Committee drafted and prioritized the actions, incorporating the science-based vulnerability and risk assessments and community members' ideas.

The tables' "Lead" and "Partner" rows recommend community stakeholders who should take the action. The "Timeframe" row recommends when the community stakeholders should take the action. The "Stressor" row lists stressors (e.g., increasing drought) to which the action responds. See the actions legend at the end of this section [*page 89*] for a description of the lead, partner, timeframe, and stressor terms. See the Action-Risk Report (*Appendix E*) for the full list of the actions and the specific stressors and risks to which they respond.

The *Thurston Climate Adaptation Plan's* first and foremost action (*A-01, below*) calls for updating the plan periodically to ensure it remains a relevant reference tool for our region. In short, the adaptation plan must be adaptive.

A-01

Update the regional climate adaptation plan periodically with new information, evaluate implementation efforts and effectiveness, amend strategies and actions as necessary, and enhance community climate literacy (e.g., by working with schools, libraries, and other partners to enhance the public's understanding of climate change causes, impacts, and responses).

TRPC should update the plan every five years with new climate data (observed and projected) and community input to ensure that the plan remains a relevant reference tool for local policy makers and residents. As part of its adaptive management process, TRPC should track which actions the community takes and consider steps to overcome barriers to implementation and coordination.

LEAD: TRPC

PARTNER: All

TIMEFRAME: Short

STRESSOR: All

The remaining 90 actions are grouped into six thematic categories:

- General
- Drought & Water Quality
- Flood & Erosion
- Plants & Animals
- Transportation & Energy
- Wildfire & Extreme Heat

Actions marked with a star are "Priority Actions," as identified by the Stakeholder Advisory Committee. These are the most important actions the region should take to remain resilient.

While all actions are advisory recommendations, municipalities and other policymaking organizations may choose to adopt and integrate the actions into their respective codes and other regulations.

General Actions

The general actions that follow address a range of climate risks across several thematic categories. Such actions improve adaptation broadly by incorporating climate science into local planning and decision-making processes.

G-01

Direct government staff members to develop their technical expertise and skills to prepare for and respond to climate change impacts.

With clear policy direction from local and tribal government policymakers, staff members could invest in professional development that enhances their understanding of projected changes in the region's climate (e.g., air temperature and precipitation) and their impacts on municipal services and infrastructure. Staff members could use the skills and knowledge to protect human health and welfare, as well as adequately plan, design, build and maintain roads, culverts, and other assets.

LEAD: Cities/Towns, County, Tribes

PARTNER: State, Federal, TRPC

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Increasing Drought, Population Change, Warmer Winter

G-02

Create hazard recovery plans and prioritize the restoration of vital public safety facilities and other essential community assets (e.g., hospitals and major bridges).

As part of this action, ensure that all appropriate personnel — including municipal public works, planning, and public health workers — have adequate training and gear (e.g., reflective vests, hard hats, and agency vehicles) to respond to emergencies.

LEAD: Cities/Towns, County, Tribes

PARTNER: State, Residents, Fire Districts, LOTT, PSE, Port, Water Providers, Transit, Business Community, K-12, TRPC

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Warmer Summer, Increasing Drought

G-03

Pursue funding to implement highest-priority actions identified in the adopted Hazards Mitigation Plan for the Thurston Region.

This action would improve the region's resilience, its ability to recover more quickly and fully from hazards. Visit www.trpc.org/hazards to view a list of countywide and local partner actions.

LEAD: Cities/Towns, County, Federal, Fire Districts, Port

PARTNER: State, TRPC

TIMEFRAME: Underway (extensive)

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Increasing Drought, Warmer Summer

G-04

Factor climate impacts into the planning of operations and the coordination of disaster response and recovery activities among first-responders, including public health, law enforcement, fire, and emergency medical services personnel.

Examples of activities include: updating emergency services communications equipment; enhancing training of emergency personnel and other responders; taking regular inventory of emergency facility needs (e.g., cooling centers and temporary shelters); assessing and improving the adaptive capacity of people who are most vulnerable to climate change-exacerbated hazards (e.g., people who are homeless, elderly, socially isolated, and/or live in high-risk areas).

LEAD: Cities/Towns, County, State, Federal, Fire Districts, Port, Water Providers, Transit, Tribes, K-12

PARTNER: TRPC

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Warmer Summer, Increasing Drought

G-05

Assess potential climate change-induced population migration within and to the Thurston Region, and evaluate response strategies.

This action could entail assessing who in the region is most vulnerable to temporary or permanent displacement (e.g., low-income or socially isolated residents who may be forced to move because of climate-exacerbated hazards) and what resources they might need. This action also could entail assessing who is most likely to move to the region and how to accommodate them in ways consistent with community values. For example, this could be done by studying "chain migration" (the tendency of migrants to follow those of similar ethnicity, language or job skillset), as well as by evaluating such migrants' needs and where/how much growth should occur so that it's consistent with local comprehensive plans. TRPC could integrate such analysis into its periodic population and employment forecasts. For more information, visit: http://www.trpc.org/236/Population-Employment-Forecasting.

LEAD: TRPC

PARTNER: Cities/Towns, County, Development Community

TIMEFRAME: Long

STRESSOR: Increasing Drought, Population Change

G-06

Create a household preparedness plan and store of food, water, and other supplies (lanterns, bicycles, etc.) to use in case a flood or other hazard cuts off access to goods, services, and emergency responders.

Municipalities, neighborhood associations, and their partners (e.g., the American Red Cross) can encourage these household preparedness practices by enhancing outreach and incentives. See TRPC's online Resilience Toolkit (www.trpc.org/climate/resiliencetoolkit) for links to preparedness resources.

LEAD: Residents

PARTNER: Cities/Towns, County, State, Nonprofits, Neighborhoods

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Increasing Drought

G-07

Identify a neighborhood site (e.g., a school, house of worship, or other location that's safe, accessible, and well-known) to serve as a temporary coordination center for local hazard response and recovery efforts, and publicize the hub's location widely.

This action could help increase household and neighborhood resilience, in the event that police and fire personnel cannot provide immediate assistance. Households and their broader neighborhoods could work with municipal agencies (e.g., through neighborhood and sub-area plans) and nonprofits (e.g., the American Red Cross) to plan, select, and publicize emergency coordination sites.

LEAD: Neighborhoods, Residents

PARTNER: Cities/Towns, County, Nonprofits, Tribes, Fire Districts

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Warmer Summer, Increasing Drought

G-08

Encourage neighborhoods to become familiar with residents who have skills and tools to assist others with special needs (e.g., elderly or disabled), should residents need to provide emergency response in the event that police and fire personnel cannot provide immediate assistance.

Programs such as "Map Your Neighborhood" are effective ways to develop maps and inventories/directories of neighborhood assets. [Thurston County Emergency Management Map Your Neighborhood: http://www.co.thurston.wa.us/em/MYN/MYN.htm]

LEAD: Cities/Towns, County, Fire Districts, Tribes

PARTNER: Neighborhoods, Residents

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Warmer Summer, Increasing Drought

G-09

Encourage residents to organize or participate in regular emergency preparedness, response, and recovery planning and training events.

Such events can include neighborhood potlucks with disaster drills, skills sharing, and discussions about hazards (extreme heat, wildfires, etc.) with local emergency responders.

LEAD: Cities/Towns, County, Fire Districts, Tribes

PARTNER: Residents

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Population Change, Warmer Summer

G-10

Increase the number of residents who receive Community Emergency Response Team (CERT) training to improve local hazard preparedness, response, and recovery efforts. Ensure such efforts are ongoing.

This action would help increase household and neighborhood resilience, in the event that police and fire personnel cannot provide immediate assistance.

LEAD: Cities/Towns, County, Tribes

PARTNER: State, Residents, Fire Districts

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Warmer Summers, Increasing Drought

G-11

Factor climate impacts into the full life-cycle costs of roads, buildings, parks, and other assets — from their initial siting and design to their ongoing operations and maintenance.

The Thurston Climate Adaptation Plan, which should be updated periodically by TRPC [See Action A-01], will serve as a regional reference guide for understanding local climate impacts and asset risks. By considering such impacts (e.g., projected sea levels), public- and private-sector property owners will be better able to protect their assets and reduce operations and maintenance costs.

LEAD: All

PARTNER: --

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Population Change, Increasing Drought

G-12

Increase incentives to make urban infill and redevelopment projects more viable financially.

Incentives could include, but are not limited to, tax credits and fee waivers for infill and redevelopment projects, as well as stormwater control transfer programs (e.g., Redmond, Washington's stormwater mitigation banking program).

Infill and redevelopment projects within urban centers and corridors inside of the urban growth areas enhance residents' resilience by providing better access to transportation options and services (e.g., food stores, hospitals, and emergency responders). Such projects also have potential climate mitigation benefits, enabling residents to drive fewer miles and reduce their greenhouse gas emissions.

LEAD: Cities/Towns, State, Federal, Tribes

PARTNER: County, Nonprofits, Residents, Higher Education, Port, Transit, Business Community, K-12, TRPC, Development Community

TIMEFRAME: Long

STRESSOR: Increasing Drought, Intensifying Precipitation, Population Change

G-13

Align land use, hazard mitigation, transportation, capital improvement, and other plans so that they take into account climate change and work toward the same goals.

This action, in which TRPC could take the lead as a coordinating body, would help ensure consistent interjurisdictional and interagency planning and policymaking with regard to climate change mitigation and adaptation.

LEAD: Cities/Towns, State, TRPC, Federal, Tribes, County

PARTNER: Nonprofits, Residents, Higher Education, Port, Transit, Business Community, K-12, Development Community

TIMEFRAME: Short

STRESSOR: Increasing Drought, Intensifying Precipitation, Population Change

G-14

Expand ability to predict drought and flood events by tracking soil moisture, streamflow, precipitation, groundwater levels, tide levels, well levels, reservoir levels, and weather forecasts.

The City of Olympia proposes working with the Port of Olympia and the U.S. Geological Survey (USGS) to establish a tide gauge in Olympia.

Additionally, the National Oceanic & Atmospheric Administration (NOAA) hosts the online Water Resources Dashboard — which includes maps and data that can help local resource managers monitor for the potential for extreme precipitation and drought events: https://toolkit.climate.gov/topics/water-resources/water-resources-dashboard.

LEAD: County, Cities/Towns

PARTNER: State, Federal, Higher Education, Tribes, TRPC, Water Providers

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Increasing Drought, Intensifying Precipitation, Warmer Summer, Warmer Winter

G-15

Create a website that details health risks exacerbated by climate change and provides information that helps residents prepare for and respond to drought, poor air quality, extreme heat, disease vectors, and other threats.

This action would improve the region's climate literacy and resilience.

LEAD: County

PARTNER: Cities/Towns, State, Federal, Higher Education, Tribes, TRPC

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Increasing Drought, Intensifying Precipitation, Warmer Summer, Warmer Winter

G-16

Develop a countywide disaster debris management plan with actions to dispose of or recycle materials (organic and artificial) efficiently after a disaster.

This action would improve the region's resilience, its ability to recovery quickly and fully from hazards.

LEAD: County

PARTNER: Cities/Towns, PSE, State, Federal, Tribes, Residents, Business Community, Agricultural Community

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Increasing Drought, Population Change

G-17

Advocate for expanding the eligibility of federal disaster-assistance funding to allow for the replacement or relocation of aging or vulnerable infrastructure before it fails.

This includes facilities such as water infrastructure, fire stations, transportation infrastructure, emergency coordination shelters, and buildings that are used as emergency shelters.

LEAD: County, Cities/Towns

PARTNER: PSE, State, Federal, Tribes, Residents, Business Community, Agricultural Community

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Increasing Drought, Population Change

G-18

Limit access to parks, lakes, and other outdoor recreation areas when natural hazards (e.g., algal blooms, wildfires, floods) pose risks to public safety.

This action would help protect public health and welfare.

LEAD: Cities/Towns, County

PARTNER: Residents

TIMEFRAME: Underway (extensive)

STRESSOR: Sea-Level Rise, Increasing Drought, Intensifying Precipitation, Warmer Water, Warmer Winter

Drought & Water Quality Actions

Projected shifts in seasonal precipitation and temperature (e.g., warmer, wetter winters and hotter, drier summers) threaten the region's water quality and quantity. Impacts include:

- **Groundwater:** Bigger winter storms can result in more runoff and less infiltration into aquifers. Summer droughts, in turn, could spur more groundwater pumping. Such direct and indirect climate impacts, coupled with sea-level rise, make Thurston County's water resources more vulnerable to water quality and quantity risks.
- **Surface water:** Changes in water volume and temperature threaten to scour streams and spur algal blooms that can degrade critical habitat for fish and wildlife, including salmon.

The following actions can help the region reduce and respond to these and other climate impacts identified through the project's vulnerability and risk assessments.

D-01

Develop and implement a comprehensive drought-response strategy that sets action levels for different drought stages.

Thurston County experienced moderate or more extreme drought conditions in the summer months nine out of the last sixteen years, including the last three consecutive years. Climate change and population growth will exacerbate these water shortages. A possible funding source for this action is the Washington Department of Ecology's Watershed Planning Implementation and Flow Achievement grant; the next funding cycle is 2019-2021.

LEAD: Cities/Towns, County

PARTNER: State, Federal, Neighborhoods, Fire Districts, LOTT, Water Providers, Business Community, Tribes, TRPC

TIMEFRAME: Short

STRESSOR: Increasing Drought

D-02

Evaluate and secure sustained funding to support long-term monitoring of ground and surface water quality and quantity.

This action includes enhancing monitoring of water volume, temperature, and pollution in streams, lakes, and Puget Sound. Existing resources include:

The state Department of Ecology measures changes in the Puget Sound lowland streams and urban shoreline areas as a result of stormwater management: www.ecy.wa.gov/programs/wq/stormwater/municipal/rsmp/status.html.

Thurston County conducts data analysis and regular monitoring of specific lakes, rivers, and streams: www.co.thurston.wa.us/health/ehswat/swater.html.

LEAD: Cities/Towns, County, Water Providers, Tribes

PARTNER: Federal, State, TRPC

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Warmer Summer, Increasing Drought

D-03

Increase reuse of reclaimed water for irrigating plants, supplementing low streamflow, and other purposes.

In the north Thurston County area, the LOTT Clean Water Alliance produces reclaimed water. LOTT's partner cities — Lacey, Olympia, and Tumwater — operate reclaimed water utilities and purvey the water to customers for reuse.

LOTT develops reclaimed water production capacity based primarily on the need for additional treatment capacity in the wastewater system. Other community needs, such as climate resilience, can influence planning for additional reclaimed water.

Because reclaimed water must be conveyed in a separate purple pipe network, distribution and reuse is generally limited to areas within close proximity to existing reclaimed water pipelines. Decisions about the expansion of the distribution line network are generally made by the partner cities' utilities. Significant cost is involved in adding reclaimed water production capacity and expanding the distribution system. Local and outside funding committments may be necessary.

LEAD: Cities/Towns, LOTT

PARTNER: County, Neighborhoods, Residents, Higher Education, Business Community

TIMEFRAME: Long

STRESSOR: Increasing Drought, Population Change

D-04

Conduct benefit-cost analyses of adaptation actions that conserve water resources.

Benefit-cost analyses (BCAs), also commonly called cost-benefit analyses, would provide Thurston Region policymakers an important economic tool for evaluating water-conservation actions, including those in this plan [See Drought & Water Quality actions].

LEAD: TRPC

PARTNER: All

TIMEFRAME: Short

STRESSOR: Increasing Drought, Population Change

D-05

Increase the number of water rights that are transferred to a trust, temporarily or permanently.

This action would be measurable and could involve a variety of leads and partners. Washington's Trust Water Rights Program provides a way for the State to legally hold water rights for future uses without the water right relinquishing. Water rights holders may sell, lease, or donate their unused capacity to the program. The Department of Ecology, guided by RCW 90.42.40, holds the water rights in a trust to support instream flows and other beneficial uses. Water rights that are donated or leased temporarily to Ecology retain their original priority date while held in the trust. Water rights that are sold permanently to Ecology are retired. For more information, visit ecy.wa.gov/programs/wr/market/waterbank.html.

LEAD: County, State, Tribes

PARTNER: Nonprofits, Residents, Agricultural Community, Property Owners

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Population Change

D-06

Set up a water bank in Thurston County's watersheds to enable water rights trading that supports conservation.

Thurston County does not currently have an active water bank for its watersheds. Under RCW 90.42.40, however, communities in the Yakima River, Columbia River, Dungeness River, and Walla Walla River watersheds have set up water banks for buying and selling water rights. In Walla Walla's water bank, for example, the Walla Walla Watershed Management Partnership buys water rights and then divides them into exempt well mitigation credits for sale to prospective water users. Thurston County could explore creating a similar partnership.

LEAD: County

PARTNER: Cities/Towns, State, Nonprofits, Residents, Development Community, Agricultural Community

TIMEFRAME: Medium

STRESSOR: Increasing Drought, Population Change

D-07

Implement tiered water pricing.

This action, in which municipal water customers pay more per gallon as they use more, would provide a clear price signal and support conservation.

LEAD: Cities/Towns

PARTNER: Business Community

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Population Change

D-08

Increase incentives for water conservation during dry months.

This action would investigate and implement additional incentives that could be offered, including for outdoor use and for properties on private water systems or wells.

LEAD: Cities/Towns, County, Water Providers

PARTNER: Residents, Business Community, Agricultural Community

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Population Change

D-09

Incentivize new commercial construction to include on-site rainwater harvesting facilities.

This action would reduce runoff and provide a source of water for irrigating plants and flushing toilets.

LEAD: Cities/Towns, County

PARTNER: Water Providers, Business Community, K-12

TIMEFRAME: Long

STRESSOR: Increasing Drought, Intensifying Precipitation, Population Change

D-10

Install efficient plumbing fixtures and equipment in buildings so as to conserve water.

The Uniform Plumbing Code, part of the Washington State Building Code, sets maximum water consumption levels for new faucets, toilets, showerheads, and other plumbing fixtures in buildings.

The LOTT Clean Water Alliance provides free water-saving kits (showerheads, leak-detection kits, etc.) to rate-payers within its Lacey, Olympia and Tumwater service area. LOTT also provides rebates to residential, commercial, industrial, and institutional rate-payers who install water-saving toilets, appliances, and other equipment. For more information, visit http://lottcleanwater.org/programs.

LEAD: Residents, Higher Education, Business Community, Development Community, Property Owners

PARTNER: LOTT, Cities/Towns, County

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Population Change

D-11

Evaluate and offer new incentives for residents to install rain gardens on well-draining soils and plant drought-tolerant landscaping (e.g. xeriscaping) to adapt to changes in seasonal precipitation.

Incentives can include utility rebates or credits. [U.S. EPA has published a handbook with “Water-Smart” landscaping tips for rain gardens and other parts of the yard: https://www3.epa.gov/watersense/docs/water-efficient_landscaping_508.pdf]

LEAD: Cities/Towns, County, Nonprofits

PARTNER: State, Higher Education

TIMEFRAME: Long

STRESSOR: Warmer Summer, Intensifying Precipitation, Increasing Drought

D-12

Construct new water-storage systems (e.g., large cisterns, water towers, and reservoirs) to provide back-up water supplies during droughts.

Per state law (RCW Title 90), a municipality or other party would need state approval to store and withdraw water that exceeds its allocated water rights.

LEAD: Cities/Towns, County, Water Providers, Tribes

PARTNER: State, Federal, Nonprofits, Residents, Agricultural Community

TIMEFRAME: Short

STRESSOR: Increasing Drought, Population Change

D-13

Expand Thurston County's septic system operation and maintenance education and outreach programs.

Climate models project more frequent and intense rain storms, which could oversaturate drain fields around septic tanks and cause them to flood, overflow, and release pollutants into surface waters. A 2016 report by Thurston County and TRPC — Deschutes Watershed Land Use Analysis: Scenario Development Report — estimated that it would cost about $43,000 annually to administer a voluntary septic system operation and maintenance program in the Deschutes Watershed alone.

LEAD: County

PARTNER: Cities/Towns, Nonprofits, Neighborhoods, Residents

TIMEFRAME: Short

STRESSOR: Warmer Water, Population Change, Intensifying Precipitation

D-14

Reduce zoning density (i.e., "downzone") and lower limits for impervious surfaces on parcels near streams and lakes with nutrient-loading problems.

When considering whether to take this action, which would mitigate the combined impacts of water pollution and warming, government agencies should consider whether it would result in more impervious surfaces elsewhere.

LEAD: Cities/Towns, County, Tribes

PARTNER: Neighborhoods, Residents, Development Community, Agricultural Community, Property Owners

TIMEFRAME: Underway (extensive)

STRESSOR: Increasing Drought, Warmer Water, Population Change, Intensifying Precipitation, Warmer Winter

D-15

Facilitate new residential water connections to municipal sources, where feasible.

This action would help protect water quality and quantity.

LEAD: Cities/Towns, County

PARTNER: Residents, Development Community, LOTT

TIMEFRAME: Short

STRESSOR: Increasing Drought, Population Change

D-16

Incentivize water metering for all wells.

Metering all wells, either through voluntary or regulatory means, would help fill water usage data gaps and provide water managers with information they can use to ensure there is sufficient supply to meet demand (water for people, fish, and other users).

Every municipal water supplier in Washington — i.e., Group A water systems with at least 15 service connections — must install a source meter that shows total system production, as well as install service meters that show authorized consumption for each connection (e.g., a single-family home). All new Group B water systems — those with multiple, but fewer than 15 connections, often in less-urbanized areas — must install a source meter as well.

Most of Thurston County's Group B systems have source meters, in compliance with state law, but such systems are not required to report their production data to state and local governments. Few of Thurston County's Group B systems have individual service meters, which are not required by state law.

About a quarter of Thurston County's wells are considered "permit-exempt" and are not in a Group A or B water system. Washington's groundwater permit exemption (RCW 90.44.050) allows for single or group domestic well water use up to 5,000 gallons per day without first obtaining water right permits.

LEAD: County, Water Providers

PARTNER: State, Residents, Agricultural Community

TIMEFRAME: Short

STRESSOR: Increasing Drought, Population Change

D-17

Establish a local non-regulatory entity to provide technical assistance to private well owners regarding conserving water and detecting leaks and pollution.

This action would help protect water quality and quantity.

LEAD: Cities/Towns, County, Water Providers, TRPC

PARTNER: State, Nonprofits, Neighborhoods, Residents, Agricultural Community

TIMEFRAME: Short

STRESSOR: Increasing Drought, Sea-Level Rise, Population Change

Flood & Erosion Actions

Projected rising sea levels and heavier rain events increase the risk of flooding, erosion, and landslides that threaten people, plants, and animals. Impacts include:

- **Stormwater:** Heavier rainfall and runoff can overwhelm stormwater systems (e.g., roadside swales, drains, and pipes), especially in urban communities.
- **Wildlife Habitat:** Heavier rainfall and runoff can erode streambeds and streambanks and degrade sensitive habitat for fish and wildlife.
- **Roads and Homes:** Heavier rainfall and saturated soil can trigger landslides that endanger homes, roads, and lives near steep slopes. Sea-level rise and wave exposure magnify risks for coastal bluffs.
- **Marshes and Estuaries:** Sea-level rise can cause low-lying coastal areas to be under water more frequently and for longer periods of time. This can turn our region's coastal marshes and forests into mudflats and alter habitat for birds and land animals.

The following actions can help the region reduce and respond to these and other climate impacts identified through the project's vulnerability and risk assessments.

F-01

Evaluate and secure sustained funding to restore and protect riparian vegetation along freshwater and marine shorelines.

Plant buffers stabilize banks, provide shade and flood storage, slow and filter polluted runoff, store carbon emissions, and enhance air quality. A local government, for example, could add a vegetation surcharge to its stormwater utility rate to fund restoration of these riparian areas.

LEAD: Cities/Towns, County, Nonprofits, Tribes, TCD

PARTNER: State, Federal, Residents, Development Community, Agricultural Community

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Increasing Drought, Warmer Winter, Warmer Water

F-02

Incorporate projected sea-level rise and flooding information into the designation of regulatory hazard areas.

Development and activities typically are required to be set back and/or buffered from regulated hazard areas, such as floodplains, marine shorelines, and high groundwater areas, which are determined by historic water level information. This action could involve updating regulations to better reflect projections about how water levels may change (e.g., the Ordinary High Water Mark [OHWM], the 100-year floodplain or channel migration area) in order to ensure new homes and other development are located and/or designed appropriately for future conditions.

LEAD: Cities/Towns, County, Tribes

PARTNER: Residents, Development Community, Property Owners

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise

F-03

Design new and replacement stream culverts and other drainage infrastructure to accommodate projected higher peak flows associated with more frequent and intense heavy precipitation events.

This action would improve fish passage and reduce flooding that occurs when debris blocks culverts. Additional funding could help Thurston County address problematic culverts more quickly.

LEAD: Cities/Towns, County, State

PARTNER: Nonprofits, K-12 Neighborhoods, TCD, Tribes, Development Community

TIMEFRAME: Short

STRESSOR: Intensifying Precipitation

F-04

Install flood gates and pumps on stormwater outfalls connected to Puget Sound to mitigate back-ups during high tides and heavy rains exacerbated by rising seas.

This action, to be considered as part of the City of Olympia's sea-level rise response strategy for downtown (2018), would help reduce flooding and its impacts on public budgets and mobility.

LEAD: Cities/Towns, County, State

PARTNER: --

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Intensifying Precipitation

F-05

Build floodwalls or other protective structures around critical facilities located in areas vulnerable to flooding as a result of sea-level rise and heavy precipitation.

This action will be considered as part of the City of Olympia's sea-level rise response strategy for downtown (2018). Local policymakers could utilize best available science to evaluate site-specific responses, which could include walls, berms, or other "hard" or "soft" structures. As a follow-up to this action, policymakers could identify and set aside areas to receive critical facilities that could be moved at the end of their useful lifespan.

LEAD: Cities/Towns, County, LOTT, Port, Tribes

PARTNER: Development Community

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation

F-06

Require that new or renovated buildings utilize flood-protection measures (such as raised finished-floor levels and temporary flood barriers) to accommodate projected sea-level rise over the structures' lifespan.

Chapter 16.80 of the Olympia Municipal Code, which focuses on reducing damage from sea-level rise, requires that all new buildings have the lowest floor (including basement) protected from flooding or elevated to 16 feet or greater. Other parts of the county could replicate this requirement.

LEAD: Cities/Towns, County, Tribes

PARTNER: Development Community, State

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Intensifying Precipitation

F-07

Increase education and enforcement efforts to ensure that commercial and residential building owners properly maintain low-impact development (LID) facilities that treat stormwater runoff on site.

Washington's municipal stormwater permit directs recipients to make LID the "preferred and commonly used approach to site development," where feasible. Such facilities, even those on private property, must be maintained properly to reduce stormwater runoff, flooding, and water pollution.

LEAD: Cities/Towns, County, Tribes

PARTNER: Nonprofits, Neighborhoods, Residents, Higher Education, K-12

TIMEFRAME: Short

STRESSOR: Intensifying Precipitation, Increasing Drought, Population Change

F-08

Assess drinking water wells' vulnerability to saltwater intrusion and inundation from rising sea levels, and develop adaptation measures (e.g., relocating wells).

This action would help ensure drinking water supplies are sustainable.

LEAD: Cities/Towns, County, Water Providers, Tribes

PARTNER: State

TIMEFRAME: Long

STRESSOR: Sea-Level Rise

F-09

For sites where elevating or relocating a building is not a viable option in response to flood risks, acquire the property, use the land for appropriate uses (e.g., flood storage or agriculture), and help the occupants resettle in the community.

This action would help protect public welfare and physical assets while mitigating flood risks.

LEAD: Cities/Towns, County

PARTNER: State, Federal, Residents, Business Community, Agricultural Community

TIMEFRAME: Medium

STRESSOR: Sea-Level Rise, Intensifying Precipitation

F-10

Implement brownfield clean-up strategies/planned actions for low-lying sites that are most vulnerable to sea-level rise.

This action would reduce the risk of water contamination from polluted coastal sites that become inundated with seawater.

LEAD: Cities/Towns, State

PARTNER: County, Business Community

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise

F-11

Protect important historical or cultural sites that are at risk of coastal or inland flooding, erosion, and wildfires.

Options can include allowing inundation of the site, relocating the structure, or stabilizing the site's shoreline with vegetation, rip-rap or other materials.

LEAD: Cities/Towns, County, State, Tribes

PARTNER: Residents

TIMEFRAME: Long

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Increasing Drought

F-12

Limit construction of buildings and roads in areas where flood and landslide risks are highest.

This action would reduce the risk of infrastructure damage from floods and landslides exacerbated by changes in precipitation timing, type and volume.

LEAD: Cities/Towns, County, Tribes

PARTNER: State, Federal

TIMEFRAME: Underway (extensive)

STRESSOR: Sea-Level Rise, Intensifying Precipitation

F-13

Identify where and how the region could support the natural inland transition of coastal lowlands to estuaries as sea levels rise.

Supportive actions can include modifying artificial barriers such as roads, as well as purchasing vulnerable properties (e.g., low-lying agricultural lands) that could transition to estuaries over time.

LEAD: State, Federal, Tribes

PARTNER: Nonprofits, Residents, Agricultural Community, Property Owners, County, Cities/Towns

TIMEFRAME: Long

STRESSOR: Sea-Level Rise

F-14

Construct flood-storage facilities (e.g., wetlands or artificial ponds) upstream of concentrated development areas that are at risk of flooding.

This action would reduce the risk of flooding and protect downstream built and natural assets.

LEAD: Cities/Towns, County, Tribes

PARTNER: Nonprofits, Agricultural Community

TIMEFRAME: Long

STRESSOR: Intensifying Precipitation

F-15

Minimize development, disturbance, and vegetation removal on or near steep slopes (>25% gradient) adjacent to waterbodies.

This action would reduce the risks of landslides and sediment runoff.

LEAD: Cities/Towns, County, State, Tribes

PARTNER: Federal, Residents, TRPC, Development Community

TIMEFRAME: Short

STRESSOR: Sea-Level Rise Intensifying Precipitation

F-16

Retrofit or reroute pedestrian/bicycle trails and bridges in areas that are subject to repetitive flooding and/or landslides.

This action would help protect public welfare.

LEAD: Cities/Towns, County

PARTNER: State

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation

F-17

Decouple remaining combined storm and sewer systems, where cost-effective, so as to add capacity and mitigate back-ups and water-borne disease outbreaks.

This action would help protect the LOTT Clean Water Alliance's downtown Olympia treatment plant from marine water inundation during coastal flood events exacerbated by rising seas and heavy rains. Marine water would kill the plant's biological water-treatment process.

LEAD: Cities/Towns, LOTT

PARTNER: --

TIMEFRAME: Long

STRESSOR: Sea-Level Rise, Intensifying Precipitation

Plants & Animals Actions

Projected changes in temperature and precipitation threaten the health and resilience of our region's plants and animals. Impacts include:

- **Shellfish:** As the ocean becomes warmer and more acidic, shellfish have a harder time developing shells. Land-borne pollution can exacerbate such threats and make shellfish toxic and dangerous to consume.
- **Agriculture:** Crop yields and harvests can decrease or fail when summers are drier and hotter for longer periods of time. Extreme heat and flooding also threatens cattle, horses, and other large livestock.
- **Vegetation:** Warmer, drier summers can stress sensitive plants and habitat, including riparian vegetation and urban landscaping. This can leave them more vulnerable to extreme heat, pests, and pathogens.
- **Salmon:** Changes in stream temperature and volume can threaten critical habitat for juvenile salmonids that develop in streams and ocean-going adults that return to spawn.

The following actions can help the region reduce and respond to these and other climate impacts identified through the project's vulnerability and risk assessments.

P-01

Increase funding, education, and incentives for private landowners to manage lands in ways that enhance ecological and economic resilience (e.g., protecting and restoring forests, prairies, and shoreline/riparian areas).

Incentives can include expanding Thurston County's Transfer of Development Rights (TDR) program, conservation easement funding, as well as expanding market-based approaches for ecosystem service payments or credits (e.g., for water quality, carbon sequestration and flood management).

LEAD: Cities/Towns, County, State, Higher Education, Tribes, TCD

PARTNER: Nonprofits, Neighborhoods, Residents, Agricultural Community

TIMEFRAME: Long

STRESSOR: Warmer Water, Warmer Winter, Increasing Drought, Intensifying Precipitation, Warmer Summer, Population Change, Ocean Acidification

P-02

Use best-management practices, such as installing large woody debris in rivers, to improve water temperature, streamflow, and channel conditions.

Placing large woody debris in rivers alters the flow of water, digs out cooler pools for fish to rest, and creates sediment-free riffles for fish to spawn. It will be necessary to choose proper sites and structures that do not cause flooding.

LEAD: State, Nonprofits

PARTNER: County, Residents, Tribes, Agricultural Community, TCD

TIMEFRAME: Underway (limited)

STRESSOR: Intensifying Precipitation, Increasing Drought, Warmer Winter

P-03

Create/Update basin plans that integrate climate impacts, and include goals and targets for protecting natural resources and habitat.

This action would ensure that region continues to assess how climate change affects watersheds and takes measurable steps to protect the water, plants (e.g., riparian areas), and animals within.

LEAD: Cities/Towns, County, Tribes, TRPC

PARTNER: State, Residents, Development Community, Agricultural Community

TIMEFRAME: Short

STRESSOR: Increasing Drought, Warmer Winter, Warmer Summer, Sea-Level Rise, Ocean Acidification, Population Change, Warmer Water, Intensifying Precipitation

P-04

Implement monitoring practices that provide early detection of invasive species on land and in water, and expand biological control and manual removal of such plants and insects.

This action would help halt the spread of invasive plant and insect species that thrive in a warmer climate.

LEAD: Cities/Towns, County, State, Federal, Higher Education

PARTNER: Nonprofits, Neighborhoods, Agricultural Community

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Warmer Winter, Warmer Water

P-05

Evaluate additional assisted migration of vulnerable plant and animal species to suitable habitat.

This action would help ensure species survival as changes in temperature and precipitation shift the location of suitable habitat.

LEAD: County, State, Federal, Higher Education, Tribes

PARTNER: Nonprofits, Residents, Development Community

TIMEFRAME: Underway (limited)

STRESSOR: Intensifying Precipitation, Increasing Drought, Warmer Summer, Warmer Winter

P-06

Expand efforts to monitor the cause and extent of changes in native and invasive plant distribution.

This action would help land managers select and implement effective actions to ensure the survival of native plants.

LEAD: County, State, Higher Education

PARTNER: Residents

TIMEFRAME: Short

STRESSOR: Increasing Drought, Warmer Summer, Warmer Winter, Warmer Water

P-07

Increase organic matter content and water retention in soils within urban and agricultural settings.

Integrating perennials into cropping systems such as grass forages, cover cropping, compost application and conservation tillage help improve water infiltration and storage, as well as increase soil organic matter content and carbon sequestration.

LEAD: Residents, Agricultural Community

PARTNER: Higher Education, TCD

TIMEFRAME: Short

STRESSOR: Increasing Drought, Warmer Summer, Intensifying Precipitation

P-08

Increase urban agriculture and biointensive farming methods to maximize crop yields and ecosystem services.

Municipalities and their partners can encourage such practices by providing technical support and incentives.

LEAD: Agricultural Community

PARTNER: Cities/Towns, County, Nonprofits, Neighborhoods, K-12, Higher Education

TIMEFRAME: Short

STRESSOR: Increasing Drought, Warmer Summer, Intensifying Precipitation, Warmer Winter, Population Change

P-09

Protect and enhance marine vegetation, such as eelgrass, so as to help clean water, sequester carbon dioxide, and improve fish habitat and survival.

The Nisqually estuary has Thurston County's only significant eelgrass beds.

LEAD: County, State, Federal, Port, Tribes

PARTNER: Nonprofits, Neighborhoods, Residents, Agricultural Community, Property Owners

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Ocean Acidification

P-10

Educate waterfront property owners about the benefits of voluntary oyster seeding and other shellfish production, and encourage such practices.

This action would help improve water quality and sustain the region's shellfishery, which are threatened by ocean acidification and land-borne pollution.

LEAD: State, Tribes, Business Community

PARTNER: Federal, Nonprofits, Higher Education, County

TIMEFRAME: Long

STRESSOR: Warmer Water, Increasing Drought, Sea-Level Rise, Ocean Acidification

P-11

Support Voluntary Stewardship Program (VSP) implementation to encourage conservation of agricultural lands and critical areas (e.g., riparian stream buffers) that provide ecosystem services.

Under the VSP program, which was created via state law, Thurston County works with landowners to develop voluntary, site-specific plans to protect critical areas on agricultural lands.

LEAD: County, TCD

PARTNER: Residents, Higher Education, Agricultural Community

TIMEFRAME: Underway (limited)

STRESSOR: Intensifying Precipitation, Increasing Drought, Warmer Winter

P-12

Grow woody perennial crops that help conserve water, store carbon, and provide other ecosystem services.

This action — which includes planting fruit trees and other crops whose woody stems and branches don't die off each winter — has both climate adaptation and mitigation co-benefits.

LEAD: Residents, Agricultural Community

PARTNER: --

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Warmer Summer, Warmer Winter

Transportation & Energy Actions

Projected extreme precipitation events threaten to increase the frequency and intensity of floods, landslides, and other hazards that damage roadways and power lines, endanger lives, and cut off access to vital goods and services. Impacts include:

- **Public Safety:** Collapsed hillsides, downed trees, and other hazards can hinder police and other emergency responders' access to residents.
- **Power Substations:** Extreme rain events, coupled with sea-level rise, can flood coastal power substations and cut off electricity to homes and businesses.
- **Bridges and Culverts:** Extreme rain events and stormwater runoff can scour streams, damage bridges, and block culverts with debris.
- **Energy Security:** Longer, hotter summers can reduce hydropower production and increase electricity demand to cool buildings. This raises the risk of power outages and increases the overall cost of energy.

The following actions can help the region reduce and respond to these and other climate impacts identified through the project's vulnerability and risk assessments.

T-01

Expand and retrofit the region's energy distribution, monitoring, and storage infrastructure to support more on-site renewable energy generation.

Bolstering the region's electricity distribution, monitoring, and storage infrastructure to handle more on-site renewable energy generation (e.g., solar panels on residential rooftops) would provide a hedge against the risk of service disruptions as a result of storms and blackouts.

LEAD: PSE, State

PARTNER: Federal

TIMEFRAME: Short

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Increasing Drought, Warmer Summer

T-02

Provide additional utility incentives to support energy efficiency and renewable energy investments in buildings.

Thurston County's electric utility, Puget Sound Energy, could offer new incentives to help building owners cover the cost of investing in energy efficiency (e.g., installing new windows and insulation) and installing solar panels, small-scale wind turbines, and other equipment that generates electricity on site from clean, renewable resources.

Washington state law allows "on-bill" financing, for example, in which an electric utility provides a loan to the owner of a commercial or residential building to invest in on-site renewable energy generation and efficiency upgrades. The borrower, which pays back the loan on its electric bill, saves money over time as it reduces its need for utility-provided electricity. This, in turn, reduces pressure on the utility to invest in generation from new sources (e.g., coal and natural gas power plants).

LEAD: PSE, State. Federal

PARTNER: Business Community, Property Owners

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Warmer Summer

T-03

Offer additional utility rebates or bill credits to induce residents to buy and install energy-efficient appliances and other equipment.

Thurston County's electric utility, Puget Sound Energy, could provide residential rate-payers additional financial incentives to buy and install energy-efficient light bulbs, clothes dryers, air conditioners, and other equipment that saves energy and lowers bills. To enhance equity, PSE could increase incentives for low-income renters and homeowners.

LEAD: PSE, State, Federal

PARTNER: Property Owners, Business Community

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Warmer Summer

T-04

Evaluate strategies to protect important electrical equipment that is within critical areas at risk of flooding and/or landslides.

Examples of such critical electrical equipment include underground power lines and low-elevation substations near the Puget Sound shoreline. Strategies could include elevating, reinforcing, or relocating such equipment.

LEAD: PSE

PARTNER: --

TIMEFRAME: Long

STRESSOR: Sea-Level Rise, Intensifying Precipitation

T-05

Map transportation infrastructure that is vulnerable to repeated floods and/or landslides, and designate alternative travel routes for critical transportation corridors when roads must be closed because of natural hazards.

Integrate this lifeline transportation route map's data into the Thurston County Emergency Operations Plan and other local planning efforts.

LEAD: TRPC

PARTNER: Cities/Towns, County, State, Fire Districts, Tribes

TIMEFRAME: Underway (extensive)

STRESSOR: Sea-Level Rise, Intensifying Precipitation

T-06

Relocate or retrofit low-lying roads vulnerable to coastal or inland flooding.

This action, for example, could include relocating or raising Interstate 5 at the Nisqually estuary and U.S. Highway 101 at Mud Bay (e.g., building taller, longer bridges). Such near-shore areas are vulnerable to coastal flooding exacerbated by sea-level rise and heavy precipitation.

LEAD: Cities/Towns, County, State

PARTNER: Federal

TIMEFRAME: Long

STRESSOR: Sea-Level Rise, Intensifying Precipitation

T-07

Increase the energy efficiency of the region's water infrastructure.

This action includes replacing pumps and other drinking water, wastewater, and stormwater systems that consume large amounts of energy.

LEAD: Cities/Towns, County, LOTT, Water Providers

PARTNER: PSE

TIMEFRAME: Underway (limited)

STRESSOR: Sea-Level Rise, Intensifying Precipitation, Increasing Drought

T-08

Build additional large-scale renewable energy projects (e.g., utility-scale solar arrays and wind farms) in Thurston County.

Such clean-energy projects offset demand for electricity from polluting fossil fuels (coal and natural gas) and hydropower — which is vulnerable to less summer precipitation/lower streamflow.

LEAD: PSE, Business Community

PARTNER: State

TIMEFRAME: Long

STRESSOR: Increasing Drought, Warmer Summer

T-09

Establish energy goals/benchmarks (e.g., LEED) for new buildings, and adopt permitting practices and building code and/or design guidelines that support clean and efficient energy practices and technologies (e.g., passive design, rooftop solar panels, electric vehicle charging stations).

This action, which could be taken by tribal, state or local governments, would reduce building electricity consumption and demand/costs for utility-provided power.

LEAD: Cities/Towns, County, State, Tribes

PARTNER: PSE, Business Community, Development Community

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Warmer Summer, Intensifying Precipitation

T-10

Expand utility outreach to and education of commercial and residential power customers about the benefits of clean and efficient energy technologies and practices.

Generating electricity from clean, renewable resources (e.g., the wind and sun) — and using electricity more efficiently — helps reduce the region's greenhouse gas emissions that contribute to global climate change. Such actions also offset demand for electricity Puget Sound Energy gets from polluting fossil fuels (coal and natural gas) and hydropower — which is vulnerable to less summer precipitation/lower streamflow.

LEAD: PSE

PARTNER: Cities/Towns, County, State

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Warmer Summer

T-11

Develop and adopt policies that require residential and commercial properties to undertake an energy audit at the time of sale or during a substantial remodel.

Tribes or local governments could require such energy audits. If the energy audits identify deficiencies, regulators could recommend energy retrofits to upgrade properties to a specified level.

LEAD: Cities/Towns, County, Tribes

PARTNER: Residents, PSE, Business Community, Development Community

TIMEFRAME: Long

STRESSOR: Increasing Drought, Warmer Summer

T-12

Generate additional energy from waste products (e.g., woody biomass and sewage) in Thurston County.

LOTT's wastewater-treatment plant, located in downtown Olympia, already captures methane to generate heat and electricity on site. Such projects offset demand for electricity from polluting fossil fuels (coal and natural gas) and hydropower — which is vulnerable to less summer precipitation/lower streamflow.

LEAD: Cities/Towns, LOTT, PSE

PARTNER: State, Business Community, Development Community, Agricultural Community, Property Owners

TIMEFRAME: Long

STRESSOR: Increasing Drought, Warmer Summer

T-13	**Increase resources to monitor air quality, and enforce regulations to reduce the health risks of air pollution (e.g., surface ozone and particulate matter) exacerbated by warmer temperatures and automobile emissions.** This action would help reduce air pollution that threatens the region's residents.	**LEAD:** Federal, ORCAA **PARTNER:** Cities/Towns, County, State **TIMEFRAME:** Long **STRESSOR:** Warmer Summer, Population Change, Increasing Drought
T-14	**Retrofit neighborhood power lines that are subject to repeated damge from storm impacts, including fallen trees and branches.** Strategies could include burying or rerouting overhead power lines, replacing them with stronger materials, or building in transmission redundancies. The electric utility and its partners could investigate new funding mechanisms to pay for such work, which could reduce the risks of outages and injuries from downed power lines.	**LEAD:** Cities/Towns, County, PSE **PARTNER:** -- **TIMEFRAME:** Underway (limited) **STRESSOR:** Intensifying Precipitation

Wildfire & Extreme Heat

Projected hotter and drier summers threaten to increase the number and severity of wildfire and extreme heat events that carry significant social, economic, and environmental costs. Impacts include:

- **Infrastructure:** Wildfires can damage or destroy homes, power poles, forests, and other important buildings and infrastructure.
- **Urban Heat Islands:** Extreme heat events make cities hotter, especially in densely developed areas. Hospitalizations and emergency service calls for heat-related illnesses can place increasing demands on the region's emergency medical services. The elderly and homeless are especially vulnerable.
- **Air Quality:** Increasing drought raises the risk of wildfires and elevated levels of PM_{10} (coarse particulate matter) from smoke, which degrades air quality and threatens human health.

The following actions can help the region reduce and respond to these and other climate impacts identified through the project's vulnerability and risk assessments.

W-01	**Create and maintain a map of the region's high-risk Wildland Urban Interface (WUI) communities and locations of wildfires.** Such a map can be used to regulate Firewise development practices (e.g., requiring building fire-suppression sprinklers and setbacks), as well as to educate property owners about wildfire risks.	**LEAD:** County, TRPC **PARTNER:** Cities/Towns, State, Federal, Residents, Fire Districts, Tribes, Development Community **TIMEFRAME:** Underway (extensive) **STRESSOR:** Increasing Drought
W-02	**Require new developments in high-risk wildfire areas to submit a fire-protection plan during site plan review.** This action would help reduce the risk of wildfire spreading to and damaging buildings.	**LEAD:** Cities/Towns, County **PARTNER:** Development Community, Property Owners **TIMEFRAME:** Short **STRESSOR:** Increasing Drought

W-03

Provide private forestland owners and residents living in Wildland-Urban Interface (WUI) areas information about fire prevention/Firewise practices, and encourage application of such practices.

Firewise is a program of the National Fire Protection Association (NFPA) and co-sponsored by the USDA Forest Service, the US Department of the Interior and the National Association of State Foresters. Firewise practices include limiting vegetation near homes and building such structures with flame-resistant materials.

LEAD: Cities/Towns, County, Fire Districts

PARTNER: Neighborhoods, Residents

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought

W-04

Plant drought- and pest-resistant trees, shrubs, and grasses in parks, landscaping strips, and other urban areas.

Such vegetation reduces the need for watering, provides cooling shade, improves air and water quality, and supports flood storage/infiltration.

LEAD: Cities/Towns, County, Neighborhoods, Residents, Business Community

PARTNER: Nonprofits, K-12

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought, Warmer Summer, Population Change, Intensifying Precipitation

W-05

Adopt wildfire hazard overlay districts with development regulations (for new structures) based on factors such as slope, structure, and fuel hazards.

This action would help reduce the risk of wildfire spreading to and damaging buildings.

LEAD: Cities/Towns, County

PARTNER: Development Community

TIMEFRAME: Short

STRESSOR: Increasing Drought

W-06

Lower the density of development allowed in areas with the highest risk of wildfire.

Downzoning rural, unincorporated areas within the region's Wildland-Urban Interface (WUI), the zone where natural areas and development meet, would decrease the number of homes and businesses at risk of fire damage. Downzoning areas within city and town urban growth areas, however, may be in conflict with state Growth Management Act and local density goals.

LEAD: Cities/Towns, County, Tribes

PARTNER: Residents, Development Community, Property Owners

TIMEFRAME: Short

STRESSOR: Increasing Drought

W-07

Extend and enforce the rural burn ban when wildfire risks are high.

This action would lower the risk of wildfires during periods of extreme heat and drought.

LEAD: County, Tribes

PARTNER: Neighborhoods, Residents, Agricultural Community, Property Owners

TIMEFRAME: Underway (limited)

STRESSOR: Increasing Drought

W-08

Modify building codes, where necessary, to require fire sprinkler systems and enable emergency access/egress in all new residential and commercial construction.

This action would help mitigate the risks of wildfires spreading.

LEAD: Cities/Towns, County

PARTNER: State, Development Community

TIMEFRAME: Underway (limited)

STRESSOR: Intensifying Precipitation, Population Change, Increasing Drought

W-09

Account for the inclusion of defensible spaces into future developments (e.g., designing roads, pathways, sidewalks, and landscaping to create firebreaks) in areas where there is high wildfire risk.

This action would reduce the risk of wildfires spreading to and damaging homes.

LEAD: Cities/Towns, County, Residents

PARTNER: Fire Districts, Development Community

TIMEFRAME: Short

STRESSOR: Increasing Drought

W-10

Enhance training and financial support for wildfire response.

This action would lower the risk of wildfires spreading during periods of extreme heat and drought.

LEAD: Cities/Towns, County, Fire Districts

PARTNER: State, Federal, Tribes

TIMEFRAME: Short

STRESSOR: Increasing Drought

W-11

Expand the region's urban tree canopy and manage forests responsibly.

Planting more native and drought-tolerant tree species in rights-of-way, parks, plazas, and other urbanized areas reduces the urban heat island effect and hyperthermia risks by providing cooling shade (Also see Action W-04). Such trees also conserve water (less irrigation needed), improve air quality (e.g., capturing and storing carbon dioxide) and support infiltration (stormwater).

LEAD: Cities/Towns, County, Port

PARTNER: Nonprofits, Neighborhoods, Residents, Property Owners, K-12

TIMEFRAME: Underway (limited)

STRESSOR: Warmer Summer, Increasing Drought

W-12

Install reflective and/or vegetated roofs to reduce building energy consumption and the urban heat island effect.

"Cool" roofs covered with light colors or reflective pigments help direct away the sun's heat, cooling buildings and surrounding areas. Similarly, "green" roofs covered with sedum and other low-maintenance vegetation help insulate buildings from solar heat. Such rooftops help reduce building cooling costs and heat-related illnesses and deaths.

LEAD: Development Community

PARTNER: All

TIMEFRAME: Underway (limited)

STRESSOR: Warmer Summer

ACTIONS LEGEND

TIMEFRAME	
Name	**Description**
Underway--Limited	A few community stakeholders are taking this action now
Underway--Extensive	Many community stakeholders are taking this action now
Short	Take action within the decade (0-10 years)
Long	Take action within the following decade (10-20 years)

LEADS & PARTNERS	
Name	**Description**
Agricultural Community	Farms, ranches, suppliers, processors, shippers, sellers
All	All community stakeholders
Business Community	Thurston Economic Development Council, chambers of commerce, private-sector companies
Cities/Towns	Olympia, Lacey, Tumwater, Yelm, Tenino, Rainier, Bucoda
County	Thurston County government
Development Community	Builders, surveyors, architects, lenders, real estate agents for all building types
Federal	U.S. government agencies and installations (e.g., Joint Base Lewis McChord)
Fire Districts	Fire districts that serve rural and urban Thurston County
Higher Education	Colleges and universities
K-12	Kindergarten-Grade 12 schools (public and private)
LOTT	LOTT Clean Water Alliance
Neighborhoods	Home owners' associations (HOAs), neighborhood associations and informal neighborhood groups
Nonprofits	Organizations that focus on land conservation/restoration (Sierra Club), emergency response (e.g., the American Red Cross), and other issue areas
ORCAA	Olympic Region Clean Air Agency
Port	Port of Olympia
Property Owners	People who own commercial, industrial, residential or resource lands but don't necessarily occupy them
PSE	Puget Sound Energy
Residents	People who live in Thurston County
State	Legislature, Governor, and state agencies
TCD	Thurston Conservation District
Transit	Intercity Transit, Rural & Tribal Transportation (R/T)
Tribes	Nisqually Indian Tribe, Squaxin Island Tribe, Confederated Tribes of the Chehalis Reservation
TRL	Timberland Regional Library
TRPC	Thurston Regional Planning Council
Water Providers	Thurston Public Utility District, municipal water systems, private systems

STRESSORS	
Name	**Description**
Warmer Summer	This stressor encompasses the risks of the region's warm months (April-September) being warmer than they have been historically.
Warmer Winter	This stressor encompasses the risks of the region's cool months (October-March) being warmer than they have been historically.
Warmer Water	This stressor encompasses the risks of warming affecting the chemical, biological and/or physical characteristics of the region's freshwater or marine waterbodies during any season.
Increasing Drought	This stressor encompasses the risks of drought — a deficiency in precipitation over an extended period — increasing in frequency and intensity.
Intensifying Precipitation	This stressor encompasses the risks of "heavy" 24-hour precipitation events (top 1 percent) — increasing in frequency and intensity.
Sea-Level Rise	This stressor encompasses the risks of Puget Sound being higher than it was historically and the effects on the region's shorelines and areas farther inland.
Ocean Acidification	This stressor encompasses the risks of Puget Sound absorbing more atmospheric carbon dioxide.
Population Change	This stressor encompasses the risks of climate change-induced displacement and migration (temporary or permanent) within, to and from our region.

5.3 Action Benefit-Cost Analyses

TRPC hired the Tacoma-based consulting firm Earth Economics to perform benefit-cost analyses (BCAs) of a pair of representative actions with climate adaptation and mitigation co-benefits:

- **Action F-01:** Evaluate and secure sustained funding to restore and protect riparian vegetation along freshwater and marine shorelines.
- **Action G-12:** Increase incentives to make urban infill and redevelopment projects more viable financially.

Earth Economics' analyses [*See Appendix F*] factored in the value of forests, grasslands, riparian shorelines, and other land cover types. Such areas have social, economic, and environmental benefits — "ecosystem services" such as providing wildlife habitat and filtering water — which the economists measured in real dollars.

After running the actions through planning scenarios that focused on specific areas of the region [*See Figure 16*], Earth Economics produced for each action a benefit-cost ratio that showed the dollar value of ecosystem service benefits produced by each dollar of related costs (i.e., the return on investment for every $1 in expenditures or forfeited revenue). The analyses show that both actions have positive benefit-cost ratios, or BCRs:

- The BCR for Action F-01 ranges from 1.73 (based on low estimates of the value of ecosystem services) to 9.34 (based on high estimates).
- The BCR for Action G-12 ranges from 14.78 (low estimates) to 18.15 (high estimates).
- Ecosystem services in restored riparian areas would produce between $2,644 and $8,311 per acre, every year.

Earth Economics did not include additional community benefits, such as expanded employment opportunities and associated income, in its analyses. Even without accounting for such benefits, however, the report concluded that investing in climate adaptation in Thurston County offers exceptionally good returns. Thus, it is TRPC's hope that municipalities, tribes and other stakeholders will consider the ecosystem service values calculated in the BCAs when evaluating whether to take these and other actions.

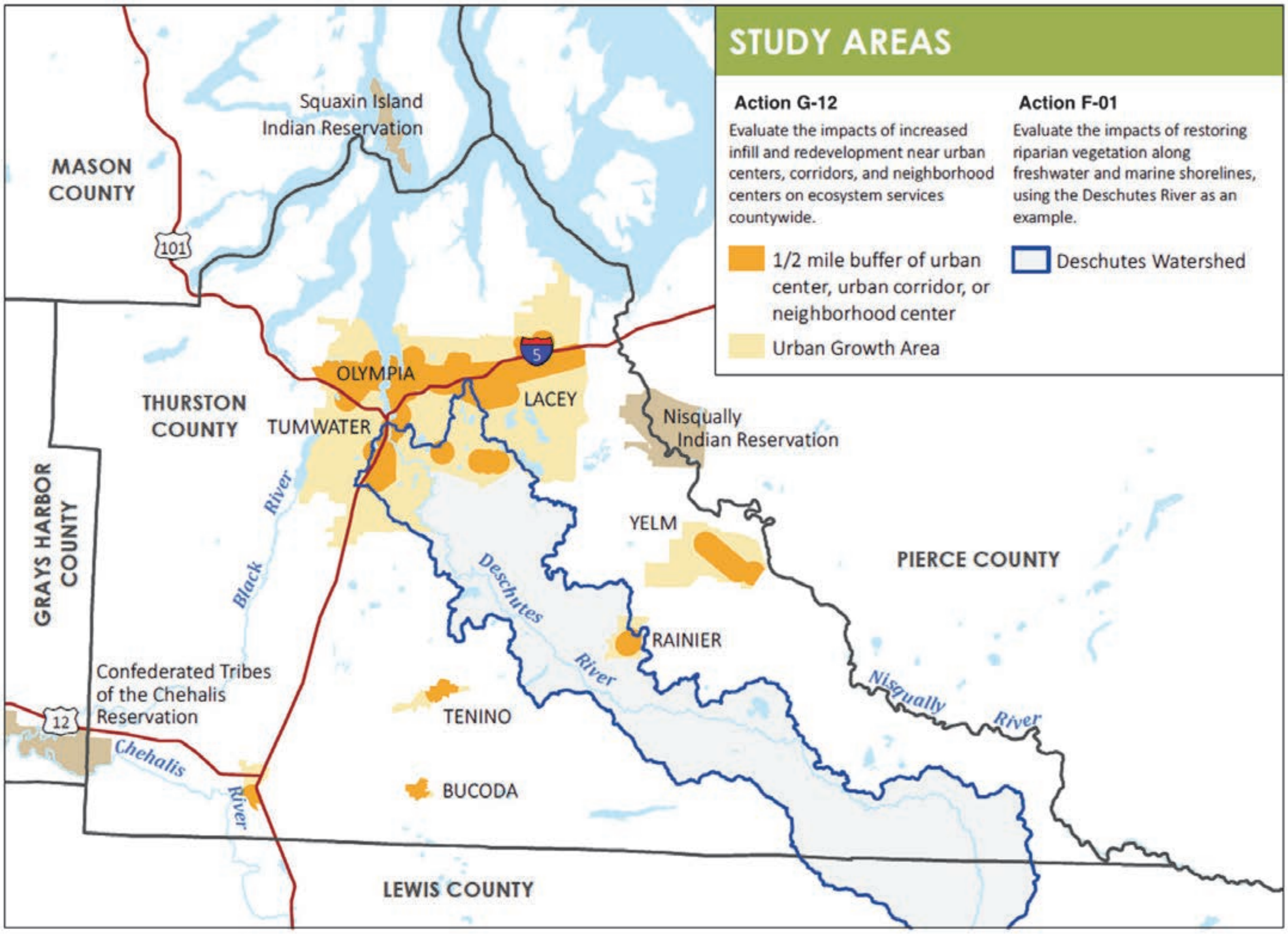
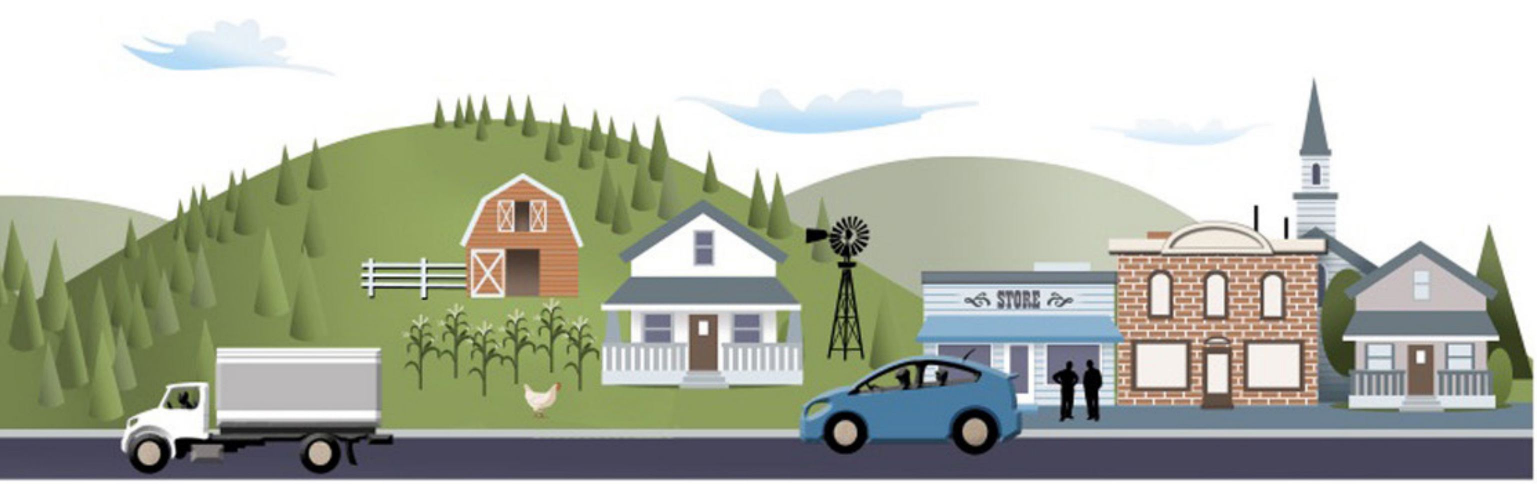
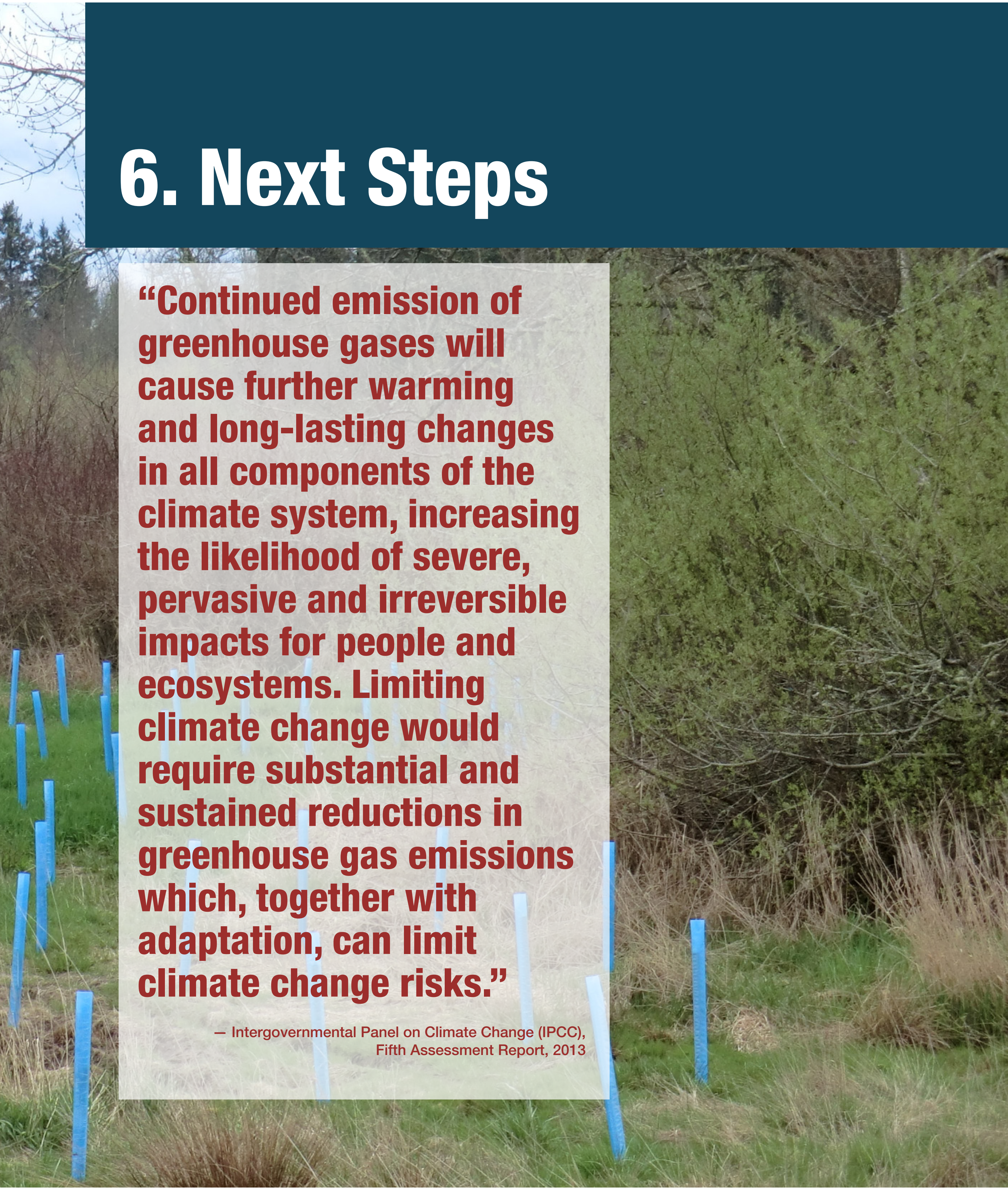


Figure 16: Earth Economics' planning scenarios for Action G-12 focused on Thurston County's urban corridors and centers; scenarios for Action F-01 focused on the Deschutes Watershed. Such scenarios provide quantitative inputs for holistic BCAs that can be adjusted or replicated as other implementation scenarios or actions are considered. ***Source:*** *TRPC*





6. Next Steps

"Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks."

— Intergovernmental Panel on Climate Change (IPCC), Fifth Assessment Report, 2013

6.1 Ongoing Implementation & Engagement

As noted previously, some actions in this plan are new to the region, while other actions are underway.

TRPC encourages all community stakeholders — from households and neighborhood associations to businesses and nonprofits — to consider how, when, and where to take actions. Tribal and local governments, for example, could consider ways to integrate adaptation actions into their major policy documents, including municipal and tribal codes and plans.

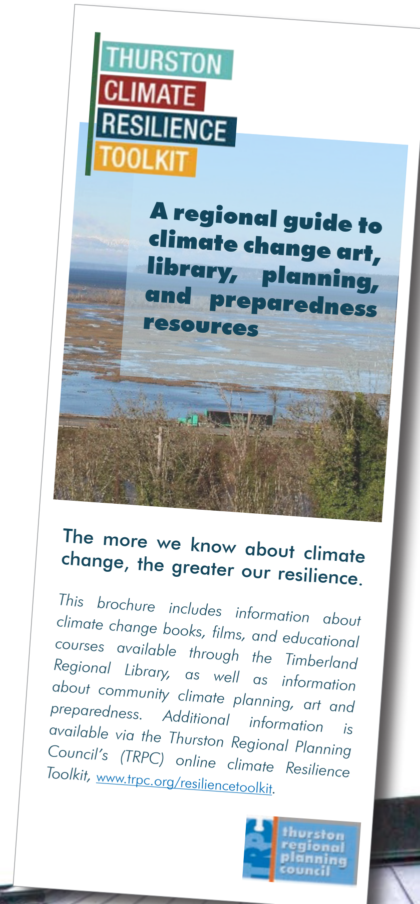
Some such efforts are already underway. In 2017, Thurston County staff members identified adaptation actions that could be integrated into the Thurston County Comprehensive Plan. The City of Olympia, LOTT, and Port of Olympia — which also had representatives on this project's Stakeholder Advisory Committee — began analyzing site-specific actions for protecting downtown Olympia assets from sea-level rise. This collaborative effort — which incorporates several of this plan's priority actions — will wrap up at the end of 2018 and identify decision-making thresholds, implementation schedules, and funding needs.

Local artist Carrie Zeigler painted a mural of plankton — a critical link in the marine food chain — on the exterior of downtown Olympia's Puget Sound Estuarium. Her hope is to raise awareness about marine organisms affected by climate change and inspire action. ***Source:*** *Carrie Ziegler*

For its part, TRPC will continue working with local artists, educators, and other diverse partners to increase the community's understanding of climate change causes, impacts, and responses.

In October 2017, the Timberland Regional Library, TRPC, City of Olympia, and other partners hosted "Art of Change," a community event that merged climate literacy, art, science, and policy. Against the backdrop of an ocean acidification mural painted freshly on downtown's Puget Sound Estuarium building, Timberland staged a "pop-up library" during fall 2017 Arts Walk. Patrons signed up for a card and checked out books, films, and other resources focused on climate change.

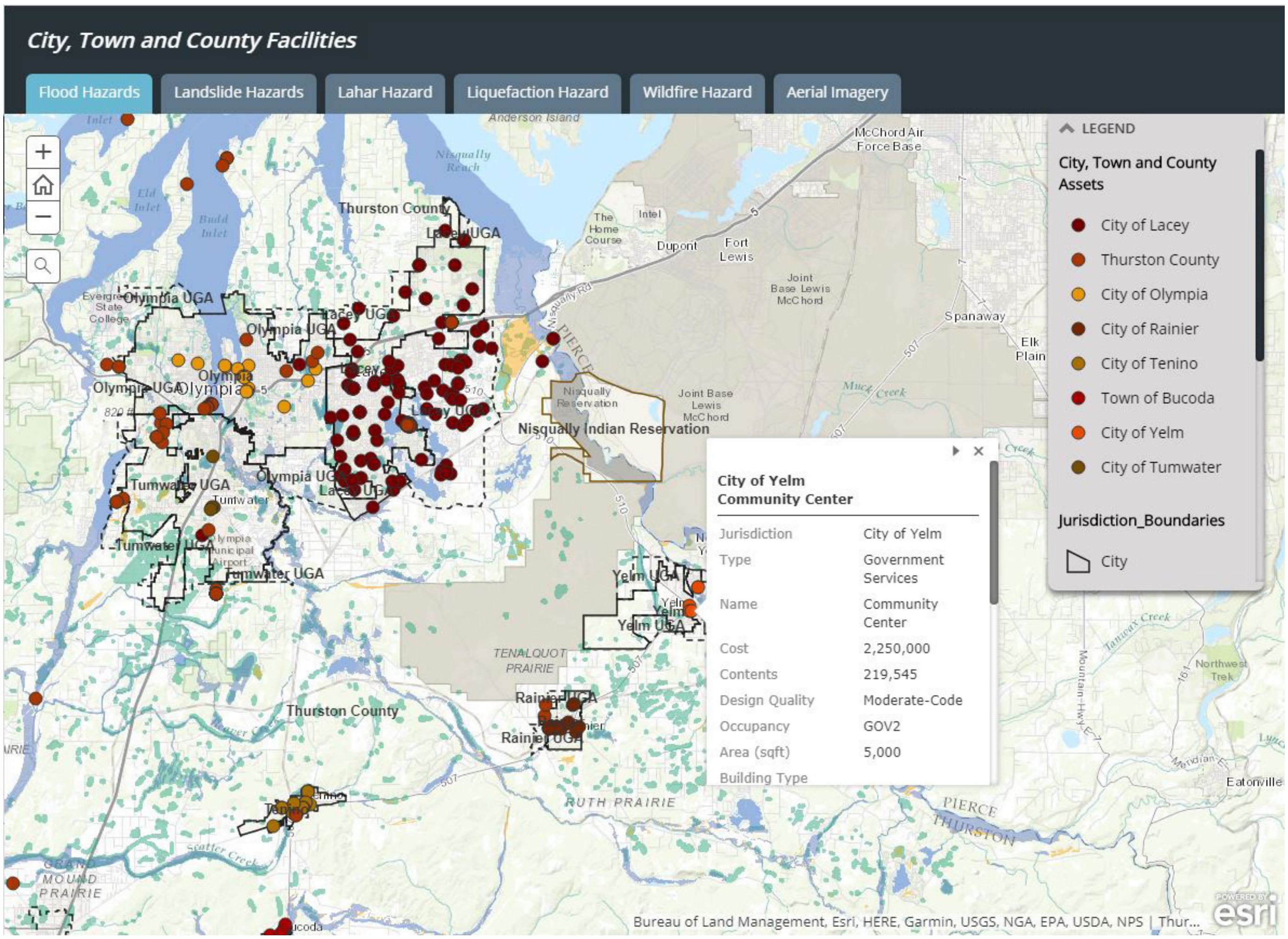
City of Olympia and TRPC staff hosted an adjacent information station that featured print and online materials related to their climate planning work. Among the materials were a draft of this plan, a climate "Resilience Toolkit" brochure, and an adaptation board game that TRPC created as part of this project.



The "Art of Change" event during fall Arts Walk in downtown Olympia featured TRPC, City of Olympia, Timberland Regional Library, and other organizations working on climate issues. ***Source:*** *TRPC*

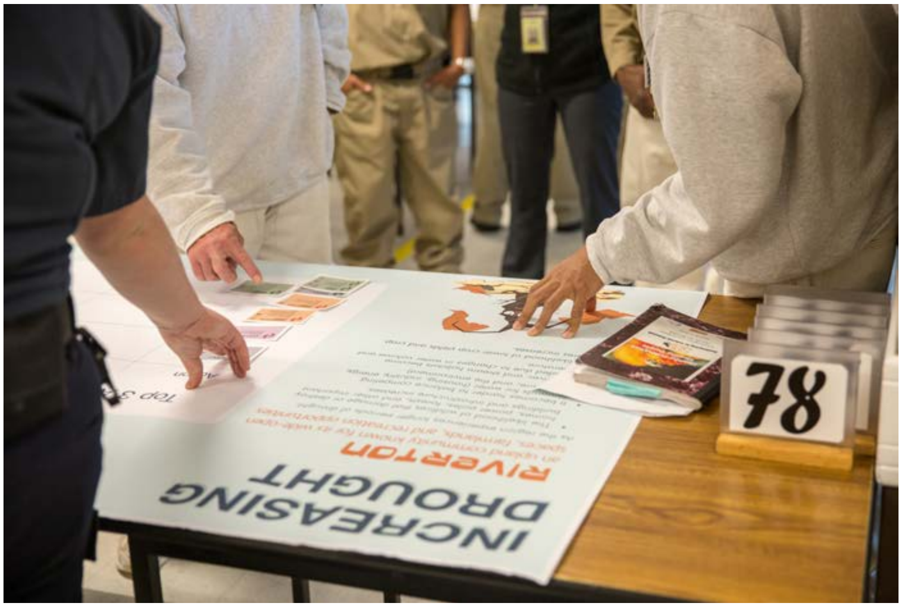
The Resilience Toolkit — also featured on TRPC's website (trpc.org/resiliencetoolkit) — includes links to information to enhance the community's climate resilience: tips for enhancing household and neighborhood emergency preparedness; data and maps showing climate change impacts at national, regional and local scales; economic analyses of potential adaptation policies; and, library books, films, and online courses about climate change. The toolkit also links to TRPC's Thurston Region Hazards Assessment Map — an interactive story map that enables users to view the locations of medical buildings, wells, fire stations, and other important assets and their exposure to floods, landslides, wildfires and other hazards.

TRPC encourages municipalities and other partners to link to the online toolkit from their website, as well as to place the brochure in their buildings (e.g., city halls, libraries, transit centers).



TRPC's interactive Thurston Region Hazards Assessment Map (*pictured*) enables users to explore the hazard vulnerability of medical buildings, wells, fire stations, and other important assets. ***Source:*** *TRPC*

The board game, *Resilience Road: A Game of Climate Change & Chance,* enables players to explore the climate stressors, risks, and actions featured in this plan. Players attempt to reach "Resilience Ridge" by traveling through Thurston County along "Resilience Road," drawing adaptation action cards and cooperating to respond to intensifying precipitation, drought, and other stressors along the way.



TRPC presented its climate adaptation plan to inmates at a local correctional facility in October 2017. Inmates then had an opportunity to discuss the implementers and effectiveness of actions in the plan. The presentation and group exercise were part of a Sustainability in Prisons Project symposium on climate change. ***Source:*** *Ricky Osborne*

TRPC staff members presented the board game to other diverse audiences around the Puget Sound region — including to climate scientists and policy practitioners at the 2017 Northwest Climate Conference, in Tacoma, and to inmates at the Stafford Creek Corrections Center, in Aberdeen. The latter event was part of a Sustainability in Prisons Project symposium on climate change.

TRPC staff members will look for future opportunities to share and play the board game — for example, at neighborhood association, school, and municipal government meetings. The game is designed to be adaptable, so communities anywhere may play it using their own climate stressors and actions.

In summary, TRPC's multifaceted public-engagement strategy responds directly to this plan's guiding principle to "seek broad community input, as well as educate residents about climate change and inspire them to take action." What better way to do this than with a simple board game?

Northwest Climate Conference attendees play TRPC's climate board game, "Resilience Road," in October 2017. The interactive game spurs players to take adaptation actions to respond to climate stressors. ***Source:*** *TRPC*

6.2 Mitigation Planning

Many of this plan's adaptation actions have mitigation co-benefits. For example, the same trees that stabilize slopes and cool urban areas also soak up carbon dioxide — the main greenhouse gas.

To be sure, the Thurston Region must do much more than planting trees to hit its emissions-reduction targets [*See Section 3*]. In mid-2017, TRPC hired a team of consultants to show just how far we have to go.

Seattle-based Clean Energy Transition and the Stockholm Environment Institute developed for TRPC an "energy map" that shows the carbon emissions associated with Thurston County's 2015 electricity generation sources (coal, natural gas, etc.) and end uses (buildings, vehicles, etc.) [*See Figure 16*].

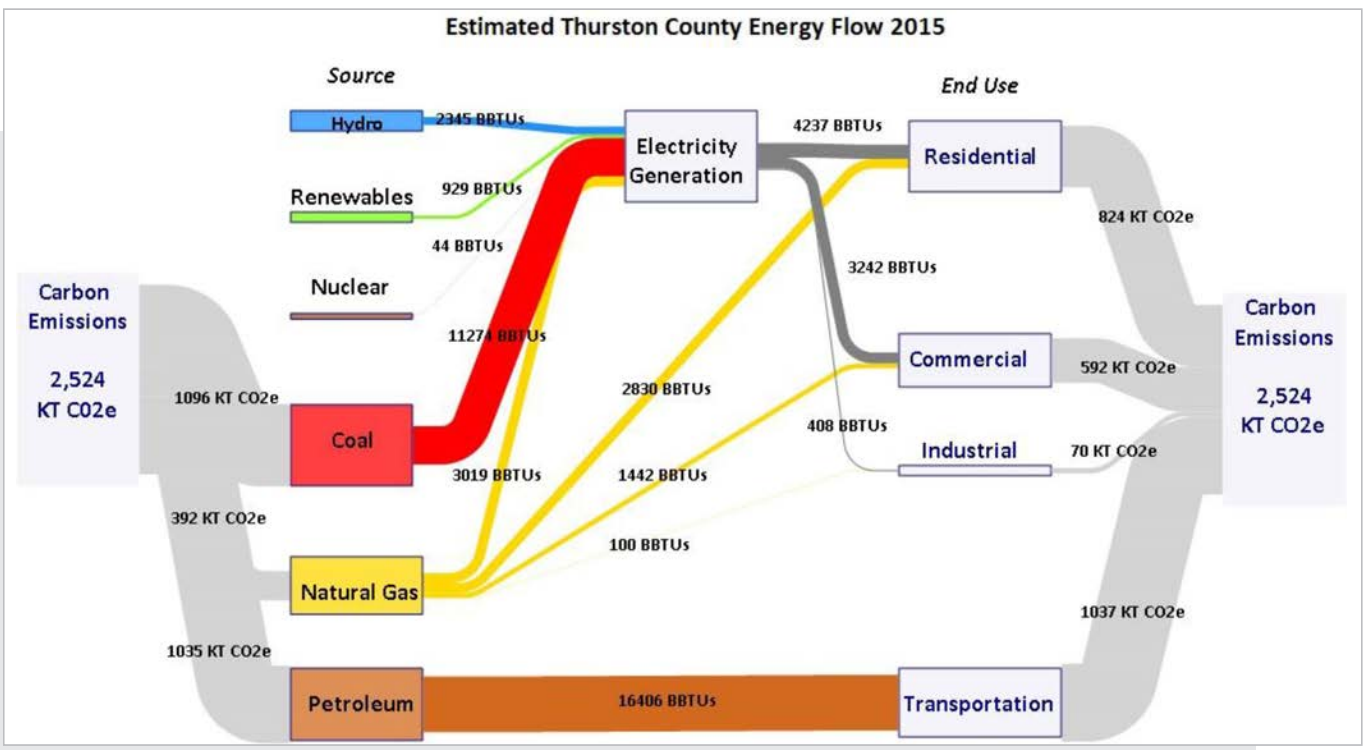


Figure 16: This graph shows the 2015 carbon emissions associated with electricity generation sources and end uses.
Source: *Clean Energy Transition and Stockholm Environment Institute*

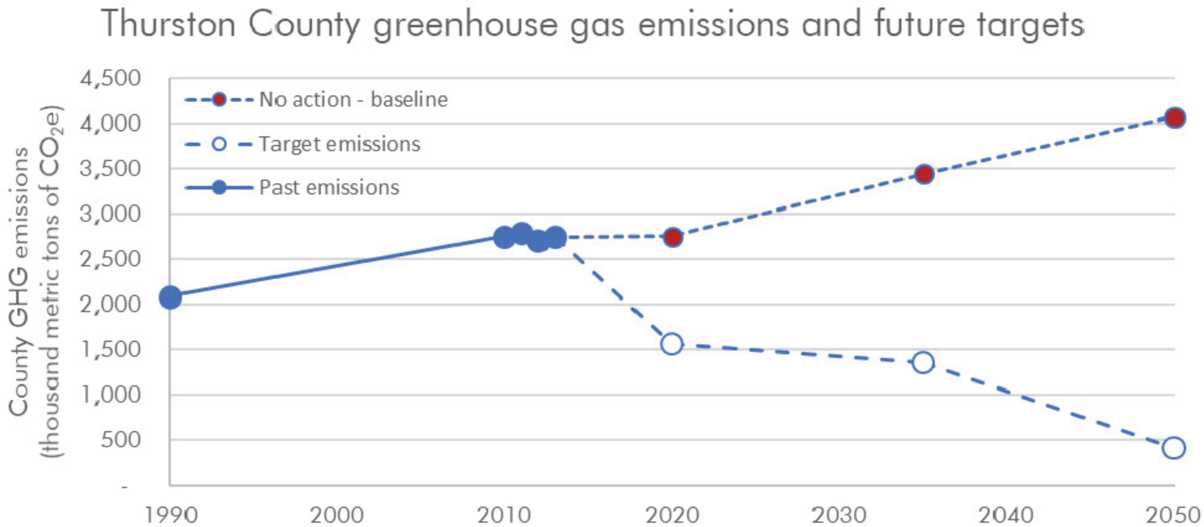


Figure 17: This graph shows Thurston County's past emissions through 2015 (solid blue line) and projected "business-as-usual" emissions through 2050 (dotted blue line with red circles). The region's 2020, 2035, and 2050 emissions targets are shown as hollow blue circles. ***Source:*** *Clean Energy Transition and Stockholm Environment Institute*

The consultants also graphed the Thurston Region's actual 1990 and 2015 emissions and its 2020, 2035, and 2050 emissions targets, which were adopted as part of the Sustainable Thurston plan [*See Figure 17*].

Using this information, the consultants produced several "carbon wedge" scenarios, which show the cumulative emissions reductions in Thurston County that are expected from existing and potential laws and policies. For each scenario, the effects of laws or policies are stacked as wedges to show their respective contribution toward hitting the 2020, 2035 and 2050 emissions-reduction targets [*See Figure 18*].

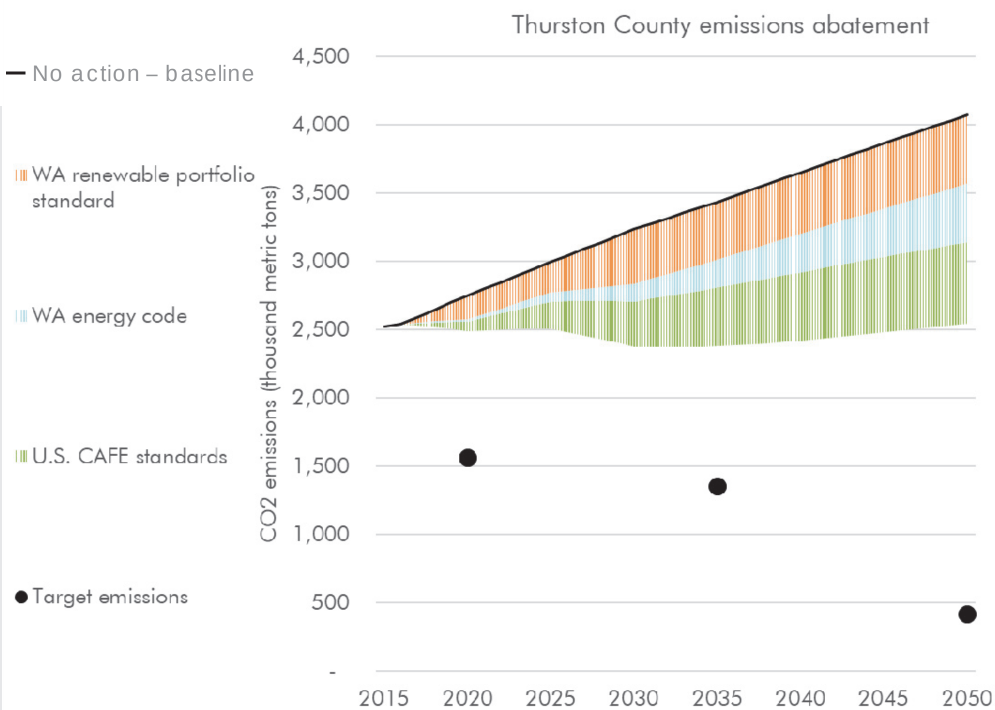


Figure 18: This graph shows emissions reductions from a baseline (2015) due to existing state and federal policies: Washington's renewable portfolio standard for electric utilities; the Washington Energy Code for buildings; and, the federal Corporate Average Fuel Economy (CAFE) standards for automobiles. ***Source:*** *Clean Energy Transition and Stockholm Environment Institute*

The consultants produced a summary memo that includes broad recommendations about where the Thurston Region should focus its mitigation efforts (vehicles, buildings, power plants, etc.) to hit the 2050 target. The memo and associated materials may be downloaded via TRPC's climate Resilience Toolkit (trpc.org/resiliencetoolkit).

Per the direction of local policymakers, TRPC staff will pursue funding and partners to develop a companion climate mitigation plan with actions sufficient to meet the regional emissions-reduction targets. TRPC's climate adaptation plan, as well as the energy map and carbon wedges, provide a solid foundation for such work. This multifaceted approach recognizes that many climate adaptation and mitigation actions — large and small — are needed to help our region and planet remain resilient. Success requires each of us to do our part.

Source: *NASA*

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8. Appendices

Appendix A: Science Summary

Appendix B: Vulnerability Assessment

Appendix C: Goal-Risk Report

Appendix D: Public-Engagement Strategy

Appendix E: Action-Risk Report

Appendix F: Action Benefit-Cost Analyses

Appendix A

Science Summary

THURSTON
CLIMATE
ADAPTATION
PLAN

Science Summary

Thurston Regional Planning Council

August 2016

FINAL

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Table of Contents

1: Planning Framework

The Thurston Regional Planning Council (TRPC) is using a U.S. EPA National Estuary Program (NEP) grant administered by the Washington Department of Commerce to draft a watershed-based climate adaptation plan (Thurston Climate Adaptation Plan). The Plan will recommend strategies for the Thurston County region (Thurston Region) to prepare for and cope with storms, floods, droughts, wildfires, and other hazards exacerbated by climate change in the decades ahead.

This *Science Summary* — the adaptation plan's first deliverable — provides an overview of observed and projected climate change impacts at the global, national and regional scales. The *Science Summary* also provides an overview of the emissions scenarios and models used by the United Nations Intergovernmental Panel on Climate Change (IPCC) and the University of Washington Climate Impacts Group (UW CIG). The UW CIG's 2015 *State of Knowledge* report (Mauger et al., 2015), which projects climate change impacts within Puget Sound's watersheds, is the main data source for the analysis, maps and tables in the Thurston Climate Adaptation Plan's second deliverable — a *Vulnerability Assessment*, which serves as the foundational document for assessing the region's climate change risks and developing adaptation strategies.

Regional Goals & Targets

The Sustainable Thurston plan that Thurston Regional Planning Council (TRPC) policymakers adopted in late 2013 and subsequently integrated into local comprehensive planning efforts envisions the Thurston Region as a model for sustainable development in the decades ahead. The plan — formally known as *Creating Places—Preserving Spaces: A Sustainable Development Plan for the Thurston Region* — has 12 priority goals,[1] including:

- Protect and improve water quality, including groundwater, streams, lakes, and Puget Sound;
- Ensure that the water supply sustains people in perpetuity while protecting the environment;
- Move toward a "carbon-neutral" community (i.e., zero-out the region's net greenhouse gas emissions that contribute to global climate change);
- Maintain compliance with state and federal air-quality standards; and,
- Preserve environmentally sensitive lands, including farms, wetlands, forests and prairies.

One of Sustainable Thurston's first action steps is to develop a comprehensive climate plan with mitigation and adaption strategies for the region's public and private sectors (TRPC, 2013). Sustainable Thurston's targets to reduce regional greenhouse gas emissions provide the mitigation framework:

- Achieve 25 percent reduction of 1990 levels by 2020;
- Achieve 45 percent reduction of 1990 levels by 2035; and,
- Achieve 80 percent reduction of 1990 levels by 2050.

The Thurston Region — which includes the municipalities, urban growth areas, unincorporated rural lands, tribal reservations, and usual and accustomed tribal harvest areas within Thurston County — has been growing about twice as fast as its carbon footprint. Even so, the region has much work ahead to hit its emissions-reduction targets.

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[1] At its second meeting (July 2016), the project's Stakeholder Advisory Committee selected the 12 Sustainable Thurston goals as the goals for the *Thurston Climate Adaptation Plan*.

In 2012, the Thurston Region's direct greenhouse gas emissions totaled roughly 2.71 million metric tons of carbon dioxide equivalent — up about 30 percent from the 1990 total [2.09 million metric tons of CO_2 equivalent] (Thurston Climate Action Team, 2014); the region's population grew by about 59 percent over the same period (TRPC, 2016).

Figure 1. Night traffic on Interstate 5, as seen from the Boulevard Road overpass. Vehicles constitute Thurston County's second-largest source of greenhouse gas emissions, after buildings. ***Source:*** *TRPC*

Global Targets

A growing body of scientific research concludes that the United States and other industrialized nations must hit something close to the 2050 emissions target — which also has been adopted by California, King County, Portland, Ore., and many other state and local governments — in order to stabilize atmospheric concentrations of carbon dioxide and other heat-trapping gases at 450 parts per million. This stabilization target, expressed as 450 ppm CO_2eq, provides a medium chance of preventing the global average temperature from rising more than 2 °Celsius (3.6 °Fahrenheit) above pre-industrial levels (i.e., before the 1860s) (Luers, Mastrandrea, Hayhoe, & Frumhoff, 2007).

The United Nations Framework Convention on Climate Change's "Paris Agreement," which the United States and other nations brokered in late 2015, includes the 2°C target but also stresses the importance of pursuing a more aggressive 1.5°C (2.7°F) target so as to mitigate the most dangerous climate change risks (Figueres, 2015). Such risks include warming oceans, melting polar ice, and rising seas sufficient to displace millions of coastal residents around the world in the centuries ahead (Clark et al., 2016).

Climate change adaptation — that is, preparing for and adjusting to the effects of a warming world — is just as critical as mitigation. Indeed, adaptation is "necessary to address impacts resulting from the warming that is already unavoidable" due to past emissions, the IPCC — the United Nations' climate research arm — concluded in its Nobel Prize-winning 2007 climate assessment (Klein et al., 2007).

Climate change adaptation entails "efforts by society or ecosystems to prepare for or adjust to future climate change."

— U.S. Environmental Protection Agency

Even the most stringent efforts to reduce emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tropospheric ozone (O_3) and other greenhouse gases "cannot avoid further impacts of climate change in the next few decades," the report explained. Fortunately, there's a lot we can do as a region today to remain resilient tomorrow.

Adaptation Plan Overview

The Thurston Climate Adaptation Plan's study area [*Figure 2*] includes the parts of three watersheds that overlay Thurston County and drain into Puget Sound; these watersheds — defined by the Washington Department of Ecology as Watershed Resource Inventory Areas (WRIAs) — include Nisqually (WRIA 11), Deschutes (WRIA 13), and Kennedy/Goldsborough (WRIA 14).

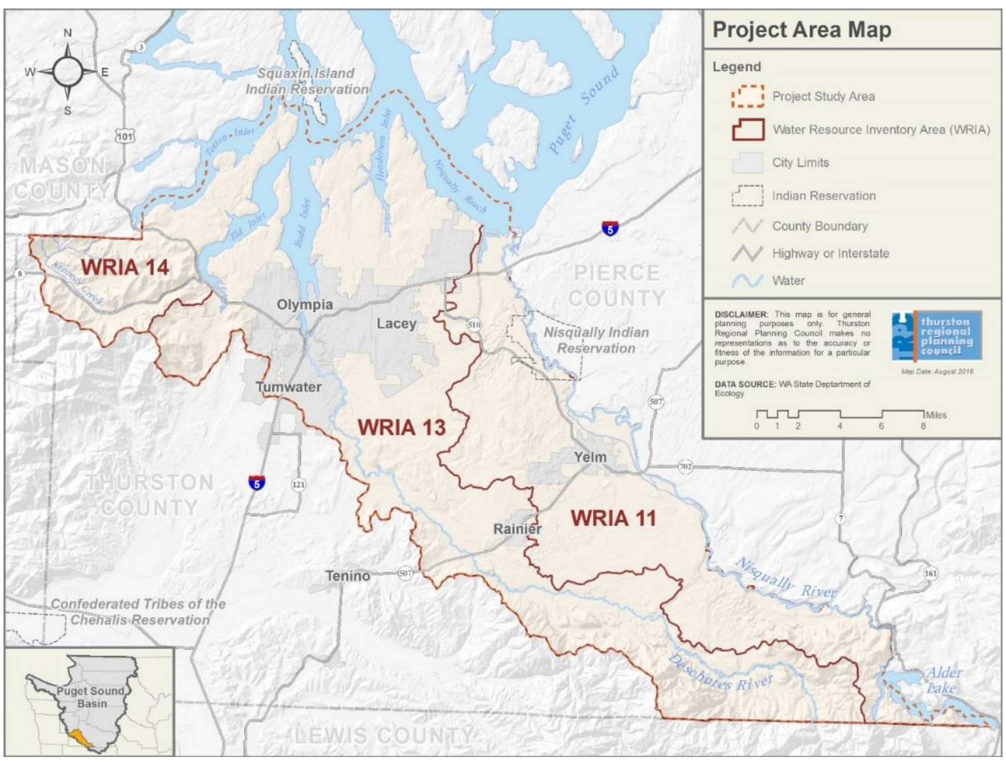

Figure 2: TRPC Climate Adaptation Plan study area. **Note:** The Nisqually and Squaxin tribes also have usual and accustomed harvest areas beyond the reservations noted within the study area. ***Source:*** *TRPC*

The planning scope of work includes: researching and analyzing global climate change projections; assessing regional climate change vulnerabilities and risks; developing adaptation strategies and conducting benefit-cost analyses; and, presenting TRPC policymakers a draft plan with adaptation recommendations for the region's public- and private-sector stakeholders.

2: Climate Change Impacts

> **"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased."**
>
> *— IPCC Synthesis Report, Summary for Policymakers, 2013*

Our individual actions affect our collective carbon footprint — whether we drive a car, charge a cellphone, or catch a plane. Emissions from burning all of those gallons of fuel and generating all of those kilowatts of electricity are adding up and changing the climate in significant ways.

Consider the science: The IPCC concluded in its 2013 global climate change synthesis report, it is "extremely likely" that human influence was the "dominant cause" of observed planetary warming between 1951 and 2010 (IPCC, 2013). Indeed, global climate models used in the report detect a human hand in warming of the atmosphere and the ocean, in changes in the global water cycle[2], in reductions in snow and ice, in global mean (average) sea-level rise, and in changes in some climate extremes.

There's no crystal ball that shows what the future holds, so scientists develop projections by running plausible scenarios of future greenhouse gas emissions through models that simulate global climate. These global scenarios can then be downscaled by researchers to produce climate change projections for temperature, precipitation, and other climate indicators at scales ranging from the Pacific Northwest to individual watersheds.

Science isn't static, of course. Climate scenarios reflect the scientific community's current understanding of complex and dynamic natural systems, coupled with informed assumptions about future human behaviors, economies, and technologies. Our understanding of these various components will continue to evolve over time, as will the climate projections developed on the basis of these components. Additionally, natural variability has and will continue to play a role in shaping Pacific Northwest climate.

The scientific research is clear, however: Our climate is changing in ways that could have significant implications for human and natural systems. Such research, summarized below,[3] provides the scientific foundation for the Thurston Climate Adaptation Plan.

2.1: The Planet

Shortly after calendars flipped to 2016, scientists reported that 2015 was the warmest year globally since modern record-keeping began in 1880. Last year's global average temperature was 58.62°F — about 1.62°F above the 20th century average (Borenstein, 2016). For the first time, the planet is now 1°C (1.8°F) warmer than it was in pre-industrial times (National Aeronautics and Space Administration, 2016). Just as noteworthy, 2015 marked the fourth time this century that a new record high for average

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[2] The global water cycle includes precipitation over land, humidity, and ocean surface salinity as it relates to precipitation and evaporation.

[3] In several cases, this summary modifies text from the source documents (e.g., IPCC, 2013) only slightly so as to ensure technical accuracy. In-text citations are used to credit sources; footnotes are used to clarify terms, including those within quotation marks.

global temperature was set (National Oceanic and Atmospheric Administration, 2016). Taking a longer view, scientists conclude that each of the last three decades has been successively warmer at the planet's surface than any preceding decade since 1950. The rise in global temperatures is one of many lines of evidence, gathered through observations and instrumental data, that our climate is changing [*Figure 3*] (IPCC, 2013). For example, the 2013 IPCC report noted:

- **Atmosphere:** It is "virtually certain"[4] that the troposphere, the lowest layer of Earth's atmosphere where weather occurs, has warmed globally since the middle of the 20th century.
- **Ocean:** It is "virtually certain" that the upper ocean (roughly 0-1000 feet) warmed from 1971 to 2010, and it "likely" warmed between 1870s and 1971.
- **Cryosphere:** There is "high confidence" that, during the last two decades, the Greenland and Antarctic ice sheets lost mass, glaciers continued to shrink almost worldwide, and the extent of Arctic sea ice and Northern Hemisphere spring snow cover continued to decrease.
- **Sea Level:** There is "high confidence" that the rate of sea-level rise since the mid-19th century has been larger than the average rate during the previous two millennia.
- **Greenhouse Gases**: Atmospheric concentrations of carbon dioxide, methane, and nitrous oxide "substantially exceed" the highest concentrations recorded in ice cores spanning the past 800,000 years. The average rates of increase in concentrations over the past century are, with "very high confidence," unprecedented during the past 22,000 years.

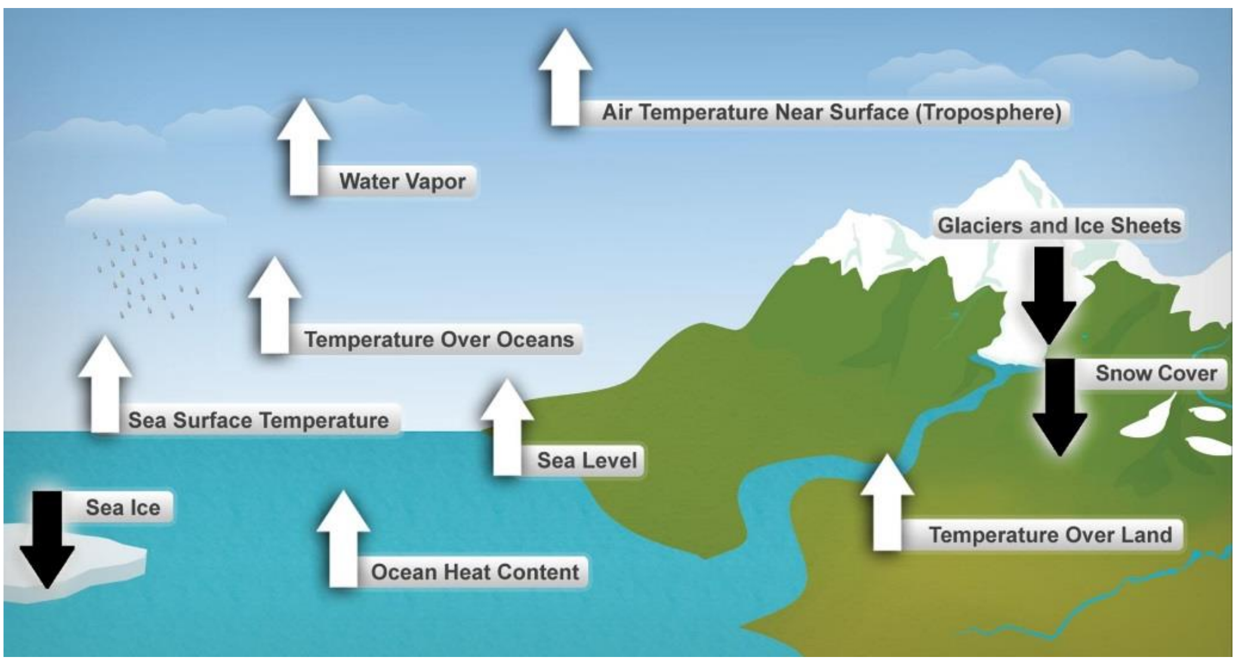

Figure 3: Key indicators of a changing climate (white arrows indicate increasing trends based on global observations; black arrows indicate decreasing trends)
Source: *U.S. Global Change Research Program, 2014: National Climate Assessment*

[4] The IPCC's 2013 *Summary for Policymakers* uses the following terms, which are based on the type, amount, quality, and consistency of evidence, to indicate the assessed likelihood of an outcome: "virtually certain," 99-100% probability; "very likely," 90-100% probability; "likely," 66-100% probability; "about as likely as not," 33-66% probability; "unlikely," 0-33% probability; "very unlikely," 0-10% probability. The report uses the following qualifiers to denote a level of confidence that is based on the degree of scientific agreement and available evidence: "very low," "low," "medium," "high," and "very high."

As noted previously, greenhouse gas scenarios — also known as Representative Concentration Pathways (RCPs) — are used in model simulations of the earth's future climate. These RCPs range from an "extremely low" scenario, involving aggressive emissions reductions, to a "high" (i.e., business-as-usual) scenario, involving continued substantial greenhouse gas emissions through 2100[5] [*Figure 4*]. Variations in the global climate model simulations reflect differences in how the models simulate major modes of natural variability (e.g., El Niño) and how the models respond to rising greenhouse gas emissions. The RCPs used by the University of Washington Climate Impacts Group in its latest synthesis of Puget Sound climate change impacts are noted with asterisk (*) in Figure 4.

Greenhouse gas scenarios (IPCC, 2013) [6]	**Scenario characteristics**	**Amount of carbon dioxide in the atmosphere, 2100**[7]	**Qualitative description, as used by UW CIG**
RCP 2.6	A very low emissions scenario that assumes ambitious greenhouse gas emissions reductions (*50% reduction in global emissions by 2050 relative to 1990 levels, and near or below zero net emissions in the final decades of the 21st century*)	400 parts per million (ppm)	"Very Low"
RCP 4.5*	A low scenario in which greenhouse gas emissions stabilize by mid-century and fall sharply thereafter	538 ppm	"Low"
RCP 6.0	A medium scenario in which greenhouse gas emissions increase gradually until stabilizing in the final decades of the 21st century	670 ppm	"Medium"
RCP 8.5*	A high scenario that assumes continued increases in greenhouse gas emissions until the end of the 21st century	936 ppm	"High"

Figure 4: Greenhouse gas emissions scenarios used in global and regional climate studies. The scenarios most commonly used in Pacific Northwest climate change studies are noted with an asterisk. Emission scenarios are typically updated every 5-10 years for use in Intergovernmental Panel on Climate Change (IPCC) global assessment reports, which are released every 5-7 years.
Source: *UW Climate Impacts Group*

[5] The IPCC and UW reports cited in this climate science summary make projections through 2100. However, a considerable fraction of the human-caused greenhouse gases that has been emitted or could be emitted during this century is expected to remain in the atmosphere for much longer and continue to impact sea levels and other climate indicators (Clark, et al., 2016).
[6] (IPCC) Intergovernmental Panel on Climate Change. 2013. *The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.
[7] Atmospheric concentration values from Meinshausen, M., S.J Smith, K. Calvin, J.S. Daniel, M.L.T. Kainuma, J-F., Lamarque, K. Matsumoto, S.A. Montzka, S.C.B. Raper, K. Riahi, A. Thomson, G.J.M. Velders, and D.P. van Vuuren. 2011. The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. *Climatic Change*, 109(1-2):213-241.

2.1A: Temperature

Global average temperature is projected to increase by 1.8°F to 6.7°F, on average, by the end of the century depending on the greenhouse gas scenario [*Figure 5*]. Further, it is "virtually certain" there will be more frequent hot and fewer cold temperature extremes across most land areas on daily and seasonal time scales as the global average temperature rises (IPCC, 2013). And while cold winter extremes will continue to occur, it is also "very likely" that summer heat waves will occur with a higher frequency and duration.

		2046-2065		**2081-2100**	
	Scenario	**Mean**	***Likely Range****	**Mean**	***Likely Range***
Global Mean Surface Temperature Change (°F)	RCP 2.6	1.8	0.7 to 2.9	1.8	0.5 to 3.1
	RCP 4.5	2.5	1.6 to 3.6	3.2	2.0 to 4.7
	RCP 6.0	2.3	1.4 to 3.2	4.0	2.5 to 5.6
	RCP 8.5	3.6	2.5 to 4.7	6.7	4.7 to 8.6
	Scenario	**Mean**	***Likely Range***	**Mean**	***Likely Range***
Global Mean Sea-Level Rise (inches)	RCP 2.6	9.5	6.7 to 12.6	15.7	10.2 to 21.7
	RCP 4.5	10.2	7.5 to 13.0	18.5	12.6 to 24.8
	RCP 6.0	9.8	7.1 to 12.6	18.9	13.0 to 24.8
	RCP 8.5	11.8	8.7 to 15.0	24.8	17.7 to 32.3

Figure 5: Projected change in global mean surface air temperature and global mean sea-level rise for the mid- and late-21st century relative to 1986-2005 [*Figures converted from Celsius to Fahrenheit and from meters to inches*].

Notes: * These figures are calculated from projections as 5-95% model ranges and then assessed to be "likely" ranges after accounting for additional uncertainties or different levels of confidence in models, the 2013 IPCC report explained. Confidence is "medium" for projections of global mean surface temperature change in 2046-2065; this is because the relative importance of natural internal variability, and uncertainty in non-greenhouse gas forcing and response, are larger than for 2081-2100. For projections of global mean sea-level rise, confidence is "medium" for both time periods. However, based on current understanding, only the collapse of marine-based portions of the Antarctic ice sheet could cause global average sea level to rise "substantially" above the likely range during the 21st century, the 2013 IPCC report underscored.

***Source:** Adapted from Table SPM 2, IPCC 2013, Summary for Policy Makers*

2.1B: Precipitation

Changes in the global water cycle in response to warming will not be uniform. The contrast in precipitation between wet and dry regions and seasons will increase, although there may be regional exceptions (IPCC, 2013).

Indeed, it is "likely" that the equatorial Pacific Ocean and high latitudes will experience an increase in annual mean precipitation under RPC 8.5 (IPCC, 2013). In subtropical dry regions, precipitation will "likely" decrease by the end of the century; mean precipitation will "likely" increase in many mid-latitude regions (e.g., the Pacific Northwest) over the same period.

Extreme precipitation events over mid-latitude land masses and wet tropical regions will "very likely" become more intense and frequent as the global mean surface temperature rises (IPCC, 2013). As explained in greater detail in the following pages, projected changes in the timing, type, and intensity of precipitation will pose significant risks for the nation's and region's human and natural systems — everything from our stormwater and energy infrastructure to our streams and forests. This document's companion *Vulnerability Assessment* explores such risks throughout South Puget Sound and the project area.

2.1C: Oceans

Global ocean temperatures will continue to rise throughout the 21st century. The strongest ocean warming is projected, with "high confidence," for the surface in tropical and Northern Hemisphere subtropical regions; at greater depth, the strongest ocean warming will be throughout the southern extent of the world's oceans (IPCC, 2013). By the end of the century, warming in the oceans' top 100 meters (roughly 0-328 feet) will be about 1.1°F for RCP2.6 to 3.6°F for RCP8.5; at a depth of 1,000 meters (roughly 3,000 feet) warming will be about 0.6°F for RCP2.6 to 1.1°F for RCP8.5. The warmer temperatures will drive changes in ocean chemistry, depth, and ice coverage.

Global average sea-level rise for 2081-2100 relative to 1986-2005 will "likely" be in the ranges of 10.2 to 21.7 inches for RCP 2.6 and 17.7 to 32.3 inches for RCP 8.5 due to increased ocean warming and loss of mass from glaciers and ice sheets (IPCC, 2013).[8] Sea-level rise will not be uniform across the earth, however.

By the end of the 21st century, it is "very likely" that sea level will rise amid more than 95 percent of the global ocean area (IPCC, 2013), but coastal flood depths will vary depending on how land moves vertically.

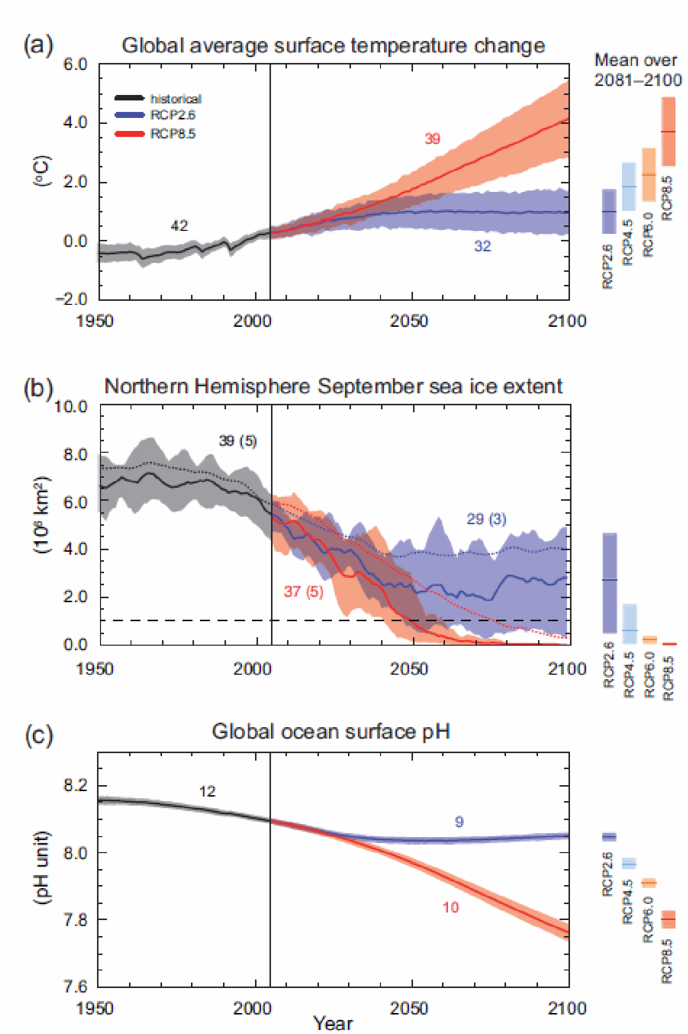

Figure 6: Ocean surface temperature, pH and sea ice extent, 1950-2100
Source: *IPCC, 2013: Summary for Policymakers*

The IPCC report stated with "high confidence" that the pH level of ocean surface water has decreased by 0.1 units since the beginning of the industrial era, increasing the acidity of the ocean [*Figure 6*]. Ocean acidification will, with "very high confidence," continue to increase throughout the 21st century in all scenarios due to the continued uptake of carbon emissions in the oceans (IPCC, 2013). This will likely

[8] Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet could cause global average sea level to rise "substantially" above the "likely" range during the 21st century, the 2013 IPCC report underscored.

have wide-ranging effects on marine ecosystems and inhibit the ability of some organisms to form shells (Nagelkerken & Connell, 2015).

2.1D: Air Quality

Changes in air quality are driven primarily by emissions as opposed to physical climate change. Modelling indicates that, with locally higher surface temperatures in polluted regions, regionally triggered feedbacks in chemistry and local emissions will, with "medium confidence," (IPCC, 2013) increase peak levels of ozone and PM2.5 (particulate matter smaller than 2.5 micrometers).[9]

PM2.5 poses a human health risk because such fine particles (about 1/30th the average width of a human hair) can be inhaled and lodge deeply in lungs (EPA, 2016). Combustion sources of PM2.5 include automobile engines and power plants. Surface ozone (tropospheric), a main ingredient of urban smog, is also harmful to breathe and damages vegetation (EPA, 2014).

2.2: The Nation

Climate change impacts will vary across the United States during the 21st century. Already, extreme weather events (e.g., prolonged periods of heat and drought, as well as severe storms and flooding) are becoming more prevalent, according to the U.S. Global Change Research Program's 2014 *National Climate Assessment* report, which utilized emissions scenarios published by the IPCC in 2000 (Melillo, Richmond, & Yohe, 2014).

Other climate change-exacerbated impacts are already being felt across large parts of the United States — notably, sea-level rise — in part, because of where and how we build: Almost 5 million residents, hundreds of billions of dollars of property, and many industrial hubs are located within 4 feet of the local high tide line (Melillo, Richmond, & Yohe, 2014). Below is a summary of projected impacts amid the nation's regions:

The Northeast — the nation's most densely populated region — is expected to experience more extreme summer heat waves, more extreme precipitation events, and coastal flooding due to sea-level rise and storm surges (Melillo, Richmond, & Yohe, 2014). Heading down the Atlantic Coast, population growth and land-use change will also exacerbate fresh water security.

The Southeast and Caribbean regions are expected to be hit by increasingly intense — and potentially more frequent — hurricanes (Melillo, Richmond, & Yohe, 2014). The Gulf Coast, which features a comparatively flat topography and stretches of degraded wetlands, is particularly susceptible to the impacts of sea-level rise and more intense storm surges. The area is economically and strategically important because it includes significant oil and gas infrastructure.

Increases in heavy precipitation are projected to occur in the Midwest and Great Plains — where recent heavy downpours have overwhelmed stormwater systems and levees — and cause large flooding events

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[9] The Clean Air Act requires the U.S. EPA to set National Ambient Air Quality Standards for six criteria pollutants, including PM2.5. The federal law identifies two types of national ambient air quality standards: "Primary" standards protect the health of children, elderly and other sensitive populations; "secondary" standards protect against decreased visibility and damage to animals, vegetation and buildings (TRPC, 2013). The federal primary/secondary standards for PM2.5 are as follows: 12 micrograms per cubic meter of air (µg/m3), annual average; 35 µg/m3, 24-hour average.

and accelerate erosion (Melillo, Richmond, & Yohe, 2014). A projected increase in drought is expected to increase competition for water resources.

Such is already true for the Southwest, which is projected to experience potentially severe drought associated with stretches of warmer, drier weather in the decades ahead. Further, earlier snowmelt and reduced snowpack in the mountains are expected to have widespread impacts across ecosystems and economies that rely on snowmelt during dry months.

Alaska, the nation's only Arctic state, will continue to experience receding glaciers, thawing permafrost, and warming waters that will melt sea ice and change ocean chemistry (Melillo, Richmond, & Yohe, 2014). Such changes are expected to decrease the productivity of fisheries and increase the vulnerability of coastal communities to erosion. Further, melting summer sea ice in the Arctic and Alaska — a loss of ice cover roughly equal to half of the area of the continental U.S. — will reduce the reflectivity of the Earth's surface and create a positive feedback loop of heat absorption (Melillo, Richmond, & Yohe, 2014).

In Hawaii and the U.S. Pacific territories, lower frequency of large precipitation events and increased temperatures will likely lead to decreased water and food security (Melillo, Richmond, & Yohe, 2014). Sea-level rise will also be a major challenge for communities on low-lying islands.

2.3: The Pacific Northwest

As is true for the nation, climate change impacts this century will be varied and potentially significant across Washington and the broader Pacific Northwest.

The Pacific Northwest's average annual temperature is expected to rise 4.3°F (range: +2.0 to +6.7°F) for a "low" emissions scenario (RCP 4.5) or 5.8°F (range: +3.1 to +8.5°F) for a high emissions scenario (RCP 8.5) for the 2050s, relative to 1950-1999 (Snover et al., 2013).[10] The changing temperature will come with a changing hydrological cycle.

Summer precipitation is expected to decrease, while autumn, winter, and spring precipitation is likely to increase (Adelsman & Ekrem, 2012). More of that winter precipitation, however, will fall as rain rather than snow.

Warmer, wetter winters are expected to lead to less snow cover on Cascade and Olympic mountain peaks, as well as increased floods, scouring flows, and overwhelmed urban stormwater systems. Conversely, a future with warmer, drier summers increases the risk of wildfires, drought, and reservoirs and rivers with less water for fish, irrigation, recreation, hydropower production, and other competing needs.

Forest fire intensity is expected to increase throughout the region, due in part to higher temperatures, more frequent summer heat waves, decreased snowpack, earlier snowmelt, and decreased summer precipitation. For example, one set of fire models for the Pacific Northwest projected that total area

[10] Many characteristics of Washington's climate and vulnerabilities are similar to those of the broader Pacific Northwest, so projections for the state are generally expected to align with those for the region — with potential for some variation at any specific location (Snover et al., 2013).

burned by wildfire could increase from 0.5 million acres historically (1916-2006) to 1.1 million acres by the 2040s for a moderate greenhouse gas scenario (Littell et al., 2010). With this increase, the cost and risk of fighting fires will also rise.

Changes to the ocean have the potential to put additional stresses on coastal communities. Low-lying roads, bridges, buildings, industrial facilities, ferry docks, port facilities, and fisheries are among the coastal infrastructure threatened by rising sea levels.

Ocean acidification, compounded in developed areas by terrestrial pollution and other stressors, is already posing major challenges for salmon, shellfish, and other sea creatures with significant cultural, economic and environmental value (Suatoni, 2015). Studies indicate that as the acidity of seawater increases, shell calcification rates decline, harmful algae grow faster and more toxic, and salmon fry growth rates decrease (Klinger, 2016).

2.4: The Puget Sound region

The University of Washington Climate Impacts Group (CIG) has downscaled global climate models to project impacts in the Pacific Northwest and the Puget Sound region [*Figure 7*]. The following analysis draws heavily from the UW CIG's 2015 Puget Sound *State of Knowledge* report (Mauger et al., 2015).

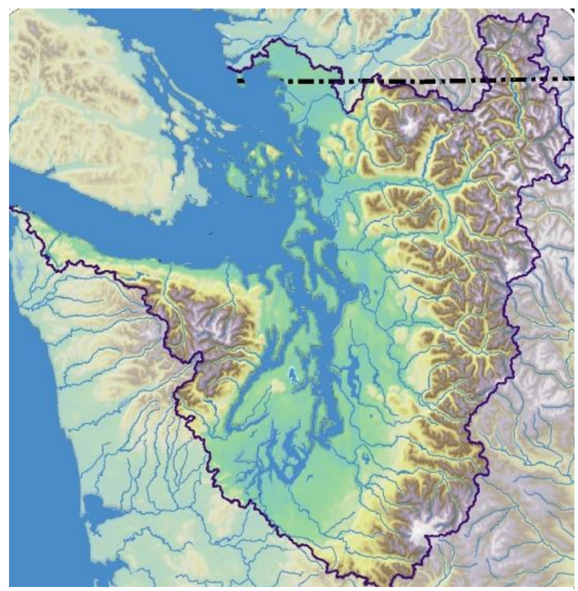

Figure 7: Puget Sound region as defined in the *State of Knowledge* report. The region includes all watersheds that drain into Puget Sound.
Source: *UW Climate Impacts Group, Robert Norheim*

2.4A: Temperature

Our region experienced a warming trend during the 20th century, and all but six of the years from 1980 to 2014 were above the century average (Mauger et al., 2015). Other observed changes include a longer frost-free season and warmer nighttime temperatures.

Additional warming is projected this century, with the change in average annual temperature projected to be at least double that experienced last century and possibly nearly 10 times as large (Mauger et al, 2015). The Puget Sound region's average annual temperature is expected to rise 4.2°F (range: +2.9 to +5.4°F) for the low emissions scenario or 5.9°F (range: +4.3 to +7.1°F) for the high emissions scenario for the 2050s, relative to 1970-1999 [*Figure 8*].

There is no scientific consensus regarding local projected changes in wind speeds and patterns. Observed trends in wind speed and pattern are ambiguous, with some studies finding increases, others finding decreases, and others concluding that there is no significant trend in winds for the Pacific Northwest region (Mauger et. al, 2015).

		2050s *(2040-2069, relative to 1970-1999)*		**2080s** *(2070-2099, relative to 1970-1999)*	
Indicator	**Scenario***	**Mean**	**Range**	**Mean**	**Range**
Average annual air temperature	Low (*RCP 4.5*)	+4.2°F	2.9°F to 5.4°F	+5.5°F	2.3°F to 11°F
	High (*RCP 8.5*)	+5.9°F	4.3°F to 7.1°F	+9.1°F	4.3°F to 17°F
Temperature of hottest days[11]	Average of RCP 4.5 and 8.5	+6.5°F	4.0°F to 10.2°F	+9.8°F	5.3°F to 15.3°F
Temperature of coolest nights[12]	Average of RCP 4.5 and 8.5	+5.4°F	1.3°F to 10.4°F	+8.3°F	3.7°F to 14.6°F

Figure 8. Projected changes in average annual temperature and extreme heat, cold events for the Puget Sound region for the 2050s and 2080s.
Notes: * Under the "low" greenhouse gas scenario (RCP 4.5), global emissions stabilize by mid-century and fall sharply thereafter. Under the "high" greenhouse gas scenario (RCP 8.5), emissions continue to increase through 2100 and beyond. RCP 8.5 is considered a "business-as-usual" scenario; global emissions are currently following this trajectory (footnote adapted from Raymond 2016)[13]
Source: *Mauger, et al., 2015*

2.4B: Precipitation

There is no discernable long-term trend in regional precipitation over the past few decades. Looking ahead, our seasonal precipitation totals — and to a lesser extent, our annual precipitation totals — are projected to change. Generally, future Puget Sound summers are expected to be warmer and drier, with more extreme heat events; winters are likely to be warmer and wetter, with more intense heavy rain events. Such changes during cold-weather months will continue to reduce snowpack, as well as the number and volume of glaciers on high peaks such as Mount Rainier (Mauger et al., 2015).

Summer precipitation is projected to decline 22 percent, on average, by the 2050s[14] under both the "low" and "high" emissions scenarios (Mauger et al., 2015). Less summer rainfall will mean streams with lower flows and higher temperatures — particularly in rain-dominant watersheds such as the Deschutes and Kennedy-Goldsborough, as well as in mixed rain-and-snow watersheds such as the Nisqually. Indeed, by the 2080s,[15] the number of Puget Sound region river miles with August stream temperatures in excess of thermal tolerances for adult salmon (64°F) and char (54°F) is projected to increase by 1,016 and 2,826 miles, respectively (Mauger et al., 2015).

A majority of climate scenarios project increases in fall, winter, and spring precipitation by the 2050s — ranging from +3 percent to +11 percent — on average, depending on the season and greenhouse gas scenario (Mauger et al. 2015). The largest changes are projected for winter (about 10 percent wetter on average by the 2050s for the low and high greenhouse gas scenarios, with a range of -1.6 to +21

[11] Projected change in the top 1% of daily maximum temperature. Projections are based on 10 global models and two greenhouse gas scenarios (RCP 4.5 and 8.5).
[12] Projected change in bottom 1% of daily minimum temperature for climate scenarios described in Footnote 8.
[13] Raymond, C. 2016. Seattle City Light Climate Change Vulnerability and Adaptation Assessment. Seattle City Light, Environmental Affairs and Real Estate Division.
[14] References to the 2050s refer to the 2040-2069 period, relative to 1970-1999.
[15] References to the 2080s refer to the 2070-2099 period, relative to 1970-1999.

percent). This precipitation could come in the form of more heavy rainfall events, increasing the risk of river and stormwater flooding.

The heaviest[16] 24-hour rain events in the region could intensify by +22 percent, on average, by the 2080s for a "high" greenhouse gas scenario (Mauger et al., 2015). Such high-intensity events [*Figure 9*] are also projected to occur more frequently — about seven days per year by the 2080s compared to two days per year historically.

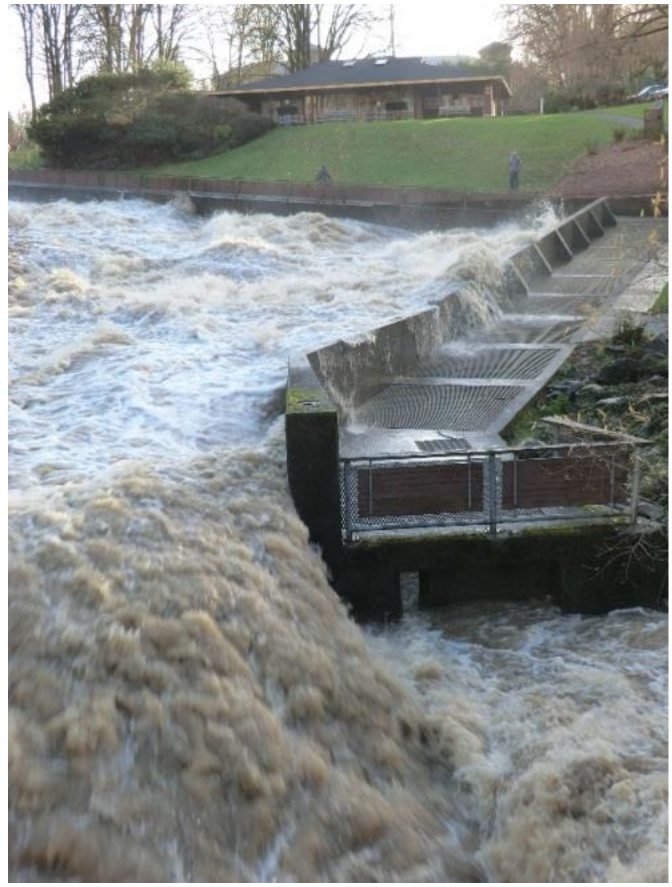

Figure 9: The Deschutes River surges over its banks at Tumwater Falls Park following a record-breaking rainstorm in December 2015. ***Source:*** *TRPC*

Heavy rain events can reduce the stability of slopes by quickly raising the water table and boosting drainage through the soil to lower layers (Mauger et al., 2015). This can cause flooding amid areas with high groundwater, as well as trigger landslides or significant sediment runoff amid steep slopes where vegetation has been removed. Such hazards can damage homes, roads and fish habitat in streams.

Hydrologic models project a dramatic shift to more rain-dominant conditions across the Pacific Northwest as a result of warming temperatures, resulting in higher streamflow during the autumn and winter months but lower streamflow during the late spring and summer months. Locally, the Nisqually Watershed is projected to shift from a mixed rain-and-snow watershed (i.e., watersheds that receive between 10 and 40 percent of precipitation as snow) to a rain-dominant watershed (i.e., watersheds where less than 10 percent precipitation is snow) by the 2080s (Mauger et al., 2015). The lower-elevation Deschutes and Kennedy-Goldsborough watersheds would remain rain-dominant.

[16] The term "heaviest" means the top 1 percent (99th percentile) in daily water vapor transport, the principal driver of large rain events in region. The UW researchers evaluated projected changes in storm intensity for latitudes ranging from 40N to 49N.

2.4C: Streamflow

Modeling for the Nisqually River and 11 other major Puget Sound watersheds shows important shifts in streamflow temperature, volume and timing [*Figure 10*]. In general, the highest "peak" river flows are projected to increase by 18-50 percent, on average, by the 2080s, for a "moderate" greenhouse gas scenario (Mauger et al., 2015).

Streamflow is a key indicator of a watershed's health. Major storm events can flood streams with sediment and fast-moving water that destroys critical habitat for fish and other organisms. Conversely, warmer and drier weather can leave streams with low flows and high temperatures that are also harmful to such organisms.

Nisqually River	
Indicator	**Change**
River miles with August stream temperatures in excess of thermal tolerances for fish	+24 miles (*adult salmon*) +179 miles (*char*)
Streamflow volume associated with 100-year (*1 percent annual probability*) flood event	+18% (*range: -7% to +58%*)
Summer minimum streamflow volume	-27% (*range: -35% to -17%*)
Peak streamflow timing (*days earlier*)	-34 days (*range: -45 to -25 days*)

Figure 10. Projected changes in the Nisqually River's streamflow temperature, volume and timing for the 2080s (moderate emissions scenario).
Source: *Adapted from Mauger et al., 2015*

2.4D: Sea-Level Rise

Throughout the 21st century, the Puget Sound region is expected to experience continued, and possibly accelerated, sea-level rise. This may result in permanent inundation of some low-lying areas, and increased frequency, depth, and duration of coastal flood events due to increased tidal and storm surge reach. Sea-level rise may also exacerbate river flooding by slowing the ability of floods to drain into the Puget Sound (Mauger et al., 2015).

Globally, average sea level rose about 8 inches — about the same level recorded at the Seattle tidal gauge — during the 20th century (Mauger et al., 2015). The Puget Sound region's sea level is projected to rise another 14 to 54 inches this century, relative to 2000. Local levels could be higher or lower than this range, however, depending upon the rate of vertical land motion.

Most Thurston County shorelines are stable. However, Olympia City Hall in downtown is subsiding by about 2.5 millimeters (0.9 inch) per decade (Pacific Northwest Geodetic Array, 2016). Thus, City of Olympia engineers estimate that sea-level rise could be 11 inches greater amid low-lying downtown — much of which is built atop fill — than the surrounding shoreline areas (Christensen, 2016).

2.4E: Farms & Forests

Higher air temperature, lower summer precipitation, increasingly varied winter precipitation, and more CO_2 fertilization are expected to lead to significant changes in many aspects of vegetation growth and distribution amid the Puget Sound region (Mauger et al., 2015). Below is a summary of projected impacts on farms, forests, prairies, and freshwater and marine ecosystems.

Agriculture

Puget Sound agriculture as a whole is expected to be relatively resilient to the impacts of climate change. Even so, changes in water availability, sea-level rise, saltwater intrusion into groundwater, and warmer temperatures are likely to lead to changes in the types of crops grown in Puget Sound. Among the agricultural crops that have been studied specifically, berries, tree fruit, and tubers could experience a decline in production due to climate change stresses (Mauger et al., 2015). Conversely, certain invasive species may benefit, potentially gaining a competitive advantage over native species and crops. Wine grapes could thrive under the projected climate changes amid the region.

Forests

As a whole, there will likely be a continued shift in the geographic distribution of Puget Sound species, changes in forest growth and productivity, an increased risk of forest fire, and changes in the prevalence and location of disease, insects and invasive species (Mauger et al., 2015).

The Nisqually River Council's *Nisqually Watershed Forest and Water Climate Adaptation Plan* notes that, by the 2080s, peak snowmelt is expected to occur 4 to 9 weeks earlier in the year in the South Puget Sound region (Greene & Thaler, 2014). This will allow tree growth to expand into subalpine and alpine meadows where snowpack has historically limited growing seasons.

At lower elevations, warmer summer temperatures will likely decrease the extent of suitable habitat for Douglas-fir trees. Indeed, the range of Douglas-fir trees may decline by as much as 32 percent by 2060, with most of the loss occurring in low-elevation forests, particularly in the South Puget Sound region (Greene & Thaler, 2014). Conversely, western hemlock, white bark pine, and western red cedar may expand their range across the entire Pacific Northwest.

Increased water stress and lower productivity may in turn lead to higher forest mortality, decreased fuel moisture, and more intense fires (Greene & Thaler, 2014). These disturbances may be compounded by a higher incidence of pest and disease outbreaks.

Prairies & Woodlands

Prairies that existed historically amid South Puget Sound lowlands are characterized as open, well-drained sites with native grasses and oak trees. Such prairies can range from open savanna-type landscapes to areas with scattered woodlands dominated by Garry oak, Douglas-fir, Oregon ash, bigleaf maple, and/or Pacific madrone trees (Washington Department of Fish and Wildlife, 2011). These ecosystems, which historically covered 10 percent of the landscape in the South Puget Sound lowlands, have been reduced by 90 percent during the past 150 years, due largely to settlement. Such ecosystems also have become increasingly fragmented by development and natural factors that limit their distribution to specific physical environments.

Climate change will exacerbate shifts in the composition of these ecosystems in the decades ahead. A recent study concluded that climate suitability for Garry oak is likely to improve throughout Washington, Oregon and British Columbia by the century's end; however, climate suitability in specific areas that now support the oak will decline in the near future and will not likely return to current conditions (Bodtker, 2009).

2.4F: Freshwater Ecosystems

Rising temperature is a major stressor for freshwater species. In the decades ahead, plants and animals will either adapt and shift to new habitats or potentially be eliminated from the ecosystem. Spring pool and freshwater lake species are likely to be more susceptible to stresses because their habitats could potentially dry up (Washington Department of Fish and Wildlife, 2011). Furthermore, fish and amphibian species will experience increased habitat temperatures that will ultimately affect their food supply and fitness. Warmer air and water conditions could lead to fewer nutrients in the water, higher competition for nutrients between native and invasive species, and higher instances of pathogens and associated diseases (Washington Department of Fish and Wildlife, 2011).

Warmer water, changes in snowmelt and peak stream flows, and changes in timing and type of precipitation all create a number of consequences for species that depend on very specific aquatic conditions. For example, lifecycles of many aquatic organisms depend on temperature, and warmer water could increase organism growth rates and ecosystem production. Warmer water also contains less dissolved oxygen, however, which could affect the ability of non-photosynthetic organisms to thrive. In lakes and ponds, higher water and air temperatures will likely support the growth of nuisance algae, and potentially eliminate cold, deep-water refuges for local species (Washington Department of Fish and Wildlife, 2011).

Temperatures also control the timing of biological events such as reproduction and development in many species, and even slight temperature changes may be detrimental to those biological processes (Washington Department of Fish and Wildlife, 2011). Additionally, as precipitation shifts to more high-volume rain events during winter, and snowmelt shifts to earlier in the year, species that have evolved around predictable springtime peak flows may experience negative impacts and potentially die-offs.

Higher air temperatures and less summer precipitation also could lead to less riparian recharge, ultimately stressing trees and other plant species living near streams, lakes and ponds (Washington Department of Fish and Wildlife, 2011). Lake levels may change directly as a result of climate change, and those areas that become drier will experience higher water stress, higher competition for nutrients and water resources, and lower water quality.

2.4G: Marine Ecosystems

The Nisqually Estuary and other coastal areas amid the region support diverse ecosystem services, including fisheries, flood protection, and wildlife habitat, which will be affected by climate change.

A 2010 National Wildlife Federation report identified six climate-driven effects that will alter Washington marine and coastal ecosystems: rising sea surface temperature, sea-level rise, altered hydrology, coastal erosion, coastal hypoxia, and ocean acidification. All of these effects may lead to significant changes in the structure and health of such ecosystems (Morgan & Siemann, 2010).

For example, increased sea surface temperature affects species' metabolism, growth patterns, and reproductive health. Thus, it is likely that warmer water will result in regional declines in abundance of some fish and seabird species, altered distribution of some fish species, higher susceptibility to disease, and physiological changes (Morgan & Siemann, 2010). Some cold-blooded marine organisms may actually experience an increase in growth rate due to warmer water; however, this could be offset by higher competition for food and/or lower concentration of dissolved oxygen in the water (hypoxia).

As noted previously, ocean acidification is also expected to impact coastal ecosystems. Higher acidity (lower pH) inhibits calcification and can interfere with normal development of shellfish, coral, plankton, and other organisms. Thus, in the decades ahead, our region could see a decline of these and other species that support biodiversity, fisheries, and the broader food web (Morgan & Siemann, 2010).

Sea-level rise will likely inundate coastal habitats such as marshes, beaches, and tidal flats if ecosystems cannot shift inland quickly enough, or if habitats are prevented from doing so because of development or coastal armoring (Morgan & Siemann, 2010). Erosion due to sea-level rise could increase the rate of loss amid these habitats. Coastal armoring (e.g., sea walls and levees) may hold off erosion in some places, yet such armoring may also accelerate erosion rates in other places and prevent redistribution of sand and other sediments important to adaptation (Morgan & Siemann, 2010).

A 2007 National Wildlife Federation analysis of sea-level rise and coastal habitats in the Pacific Northwest predicted major changes in marine and coastal ecosystems due to the compounding effect of sea-level rise and erosion over the next century (Glick et al., 2007):

- 65% loss of estuarine beaches do to erosion and inundation;
- 6% loss of ocean beaches;
- 61% loss of tidal swamps;
- 44% loss of tidal flats;
- 52% conversion of brackish marshes to tidal flats, transitional marsh, and saltmarsh; and,
- Expansion of traditional marshes.

3: Next Steps

This summary of climate change projections — which was reviewed by TRPC's ad hoc Science Advisory Committee — marks the first significant step toward developing a regional climate adaptation plan. In coming months, TRPC will work with its scientific advisors, as well as a group of community members (Stakeholder Advisory Committee), to assess climate change vulnerabilities and risks [*Figure 11*].

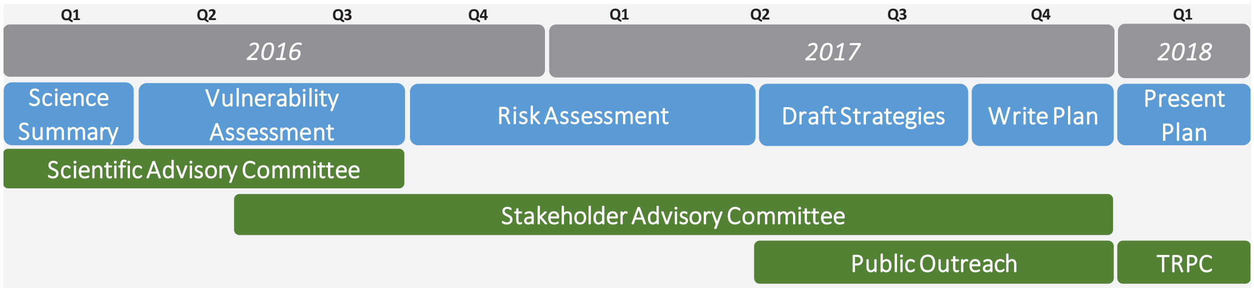

Figure 11: The process diagram above shows key Thurston Climate Adaptation Plan dates and components, including the vulnerability and risk assessments. ***Source:*** *TRPC*

TRPC will then work with community members to develop adaptation strategies for the region's human and natural systems (i.e., human health, as well as built and natural assets). The Tacoma-based firm Earth Economics will conduct a quantitative benefit-cost analysis for select strategies.

In early 2018, the project team will present TRPC policymakers a draft climate action plan with a menu of strategies that local governments could integrate into their comprehensive plans, development codes and other policies. Other strategies will be applicable to tribes and private-sector stakeholders.

In the meantime, TRPC and its partners will continue to take steps to mitigate the region's greenhouse gas emissions — the other half of the comprehensive climate strategy envisioned by Sustainable Thurston.

Sustainable Thurston's foundational principles and policies are now a part of the Countywide Planning Policies, the framework for coordinating local comprehensive plan updates. This is important in a regional context because Sustainable Thurston includes dozens of climate-related goals and actions — ranging from reigning in urban sprawl, to reducing vehicle miles traveled, to slashing waste production, to prioritizing weatherization funds for affordable housing. Going forward, TRPC will continue seeking out grant sources for mitigation planning, as well as continue working with regional public- and private-sector stakeholders to evaluate funding strategies for local clean-energy and energy-efficiency initiatives.

This multifaceted approach, comprised of climate change adaptation and mitigation strategies, is built on the premise that many actions — large and small — are needed to help the Thurston Region shrink its carbon footprint today and remain resilient tomorrow.

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Appendix B

Vulnerability Assessment

THURSTON CLIMATE ADAPTATION PLAN

Vulnerability Assessment

Thurston Regional Planning Council

December 2016

FINAL

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thurston regional planning council

Department of Commerce

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Table of Contents

1: Executive Summary

1.1: Approach

The Thurston Climate Adaptation Plan's vulnerability assessment uses text, tables, maps, and other tools to explain how the region's climate has changed historically, how it is projected to change during the 21st century, and how such changes affect the vulnerability of our human and natural systems.

The vulnerability assessment — the foundation of a risk assessment to be completed in 2017 — builds upon the project's *Science Summary* by describing how human health and welfare, as well as highways, municipal water systems, estuaries, and other built and natural "assets" within the project area [*Figure 1, below*] are vulnerable to the collective impacts of natural hazards (e.g., wildfires, landslides, floods) and human-caused stressors (e.g., water pollution) exacerbated by climate change.

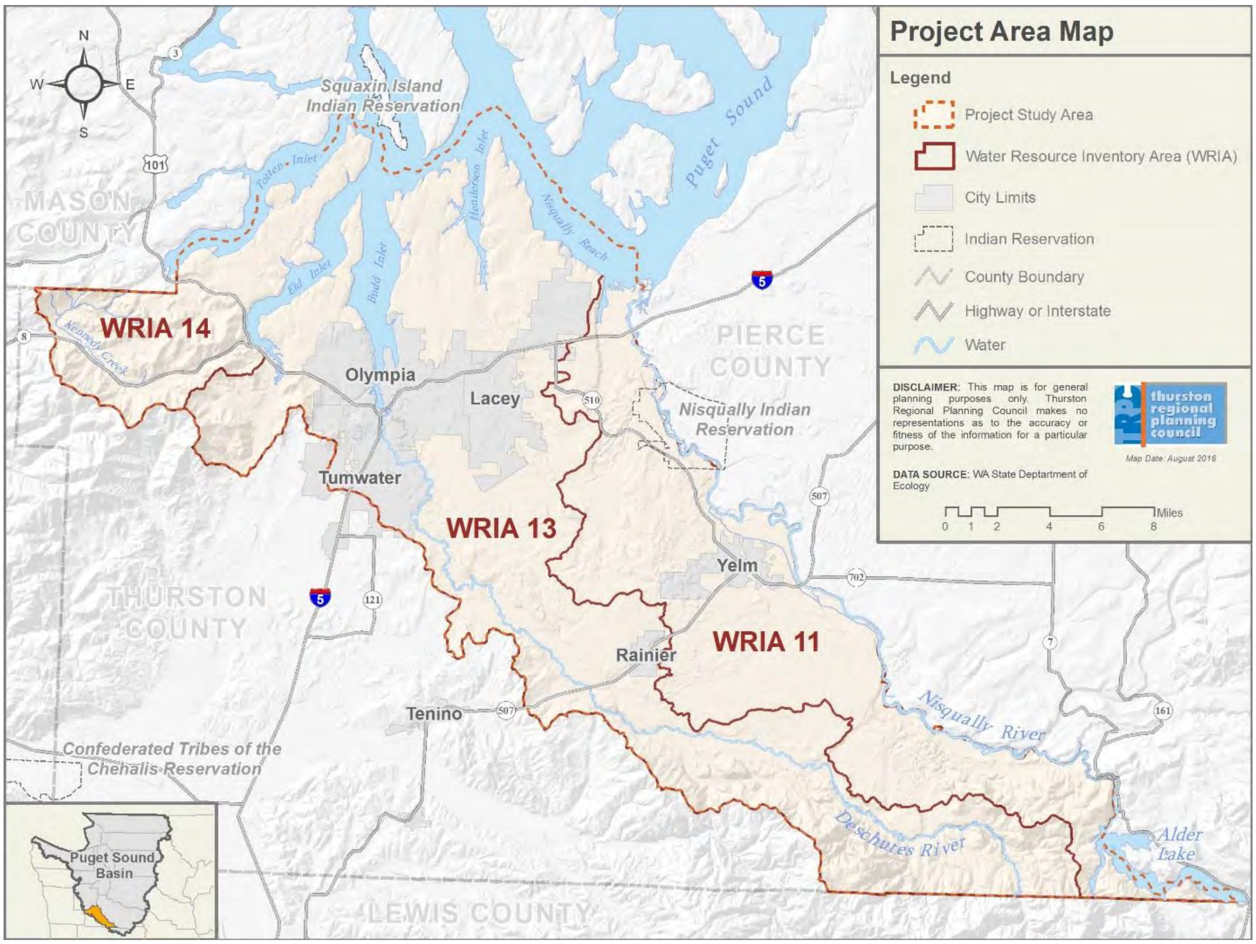

Figure 1. The Thurston Climate Adaptation Plan project area includes parts of the Puget Sound-draining Nisqually (WRIA 11), Deschutes (WRIA 13) and Kennedy-Goldsborough (WRIA 14) watersheds that are within Thurston County. The full Nisqually Watershed straddles Thurston, Pierce and Lewis counties and begins on the flanks of Mount Rainier; the Deschutes Watershed straddles Lewis and Thurston Counties and begins in the Mount Baker-Snoqualmie National Forest, southwest of Alder Lake; the Kennedy-Goldsborough Watershed (WRIA 14) straddles Mason and Thurston counties and includes Kennedy and Goldsborough creeks, as well as Totten, Hammersley and Little Skookum inlets.

1.2: Scenarios & Models

The vulnerability assessment incorporates plausible scenarios of future greenhouse gas emissions that researchers ran through global climate models to project changes in air temperature, precipitation, and other climate indicators [*Figure 2, below*]. Researchers then downscaled the global projections to Puget Sound-draining watersheds, including those that overlay most of Thurston County.

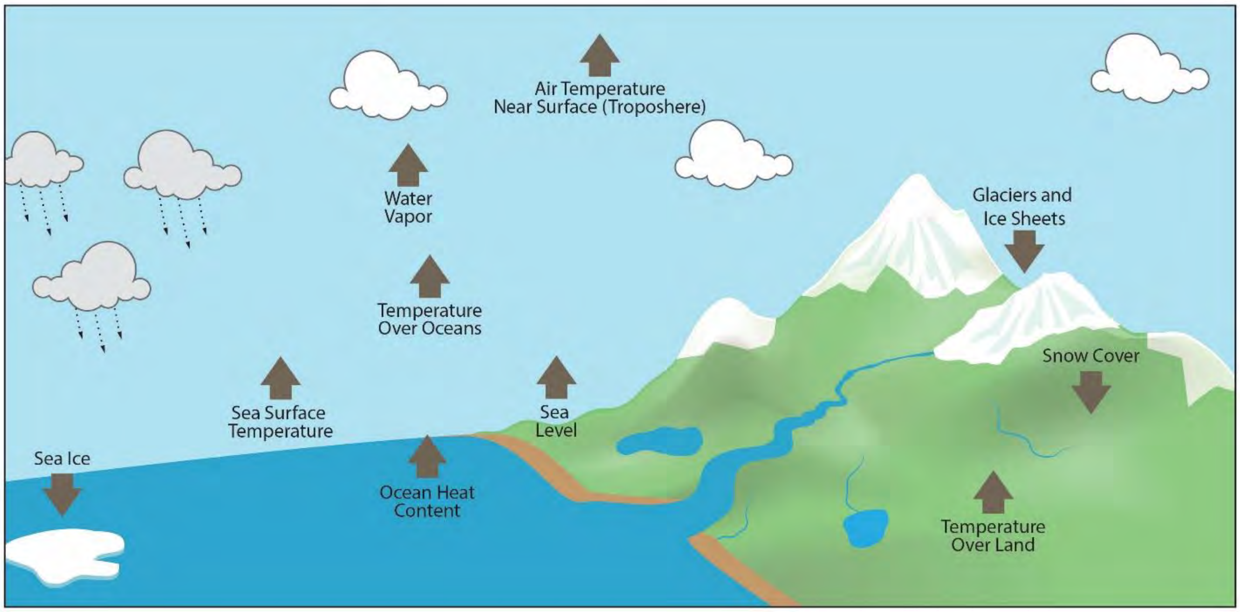

Figure 2: Pictured above are key indicators of the earth's changing climate. Arrows show increasing or decreasing trends based on global observations.
Source: *TRPC, adapted from image in U.S. Global Change Research Program's (USGCRP) 2014 National Climate Assessment*

The current set of greenhouse gas emissions scenarios used to drive global climate models were released in 2011. The scenarios, known as Representative Concentration Pathways (RCPs), were developed by an international collaboration of researchers for use by the global climate-modeling community. The scenarios reflect a range of informed assumptions about future human behaviors, energy sources, economies and technologies.

Global climate models are developed and maintained by numerous academic and governmental organizations around the world, notably the National Center for Atmospheric Research (NCAR), National Oceanic & Atmospheric Administration (NOAA), and National Aeronautics and Space Administration (NASA). The 2013 Intergovernmental Panel on Climate Change (IPCC) assessment of global climate change impacts used more than 40 global climate models; the University of Washington Climate Impacts Group (UW CIG) used ten models for its 2015 assessment of Puget Sound region impacts.

The climate change projections that emerge from the global climate models reflect the scientific community's current understanding of how complex and dynamic natural systems respond to increasing emissions of carbon dioxide (CO2) and other heat-trapping "greenhouse" gases. Understanding of these various components will continue to evolve over time, as will the climate projections developed on the basis of these components. Additionally, natural variability (e.g., the El Niño and La Niña cycles) has and will continue to play a role in shaping our region's climate. For more information about the global climate models, scenarios and projections (global, national and regional), please read this project's companion *Science Summary*, at www.trpc.org/climate.

1.3: Spatial Analysis

The UW CIG report,[1] titled *State of Knowledge: Climate Change in Puget Sound* (Mauger et al., 2015), is the main source of data used in the Thurston Climate Adaptation Plan's vulnerability assessment. Thus, most of the assessment's maps feature the same emissions scenarios (low and high), spatial extent (South Puget Sound watersheds analyzed by the CIG), and time intervals (historical, 2050s and 2080s)[2].

The South Puget Sound watersheds, as delineated by the U.S. Geological Survey (USGS), are subdivided into smaller watershed units so as to show how climate indicators such as air temperature, precipitation, snowpack and runoff vary with elevation [*Figure 3, right*]. The project area, encircled in black, shows the Thurston County extent of the Nisqually, Deschutes and Kennedy-Goldsborough Water Resource Inventory Areas (WRIAs), as delineated by the Washington State Department of Ecology. The appendix includes additional details about the watershed delineations [*See pg. 99*] and a more detailed reference map [*See pg. 101*] that shows major roads, municipalities, waterbodies and other important features that are referenced in the assessment.

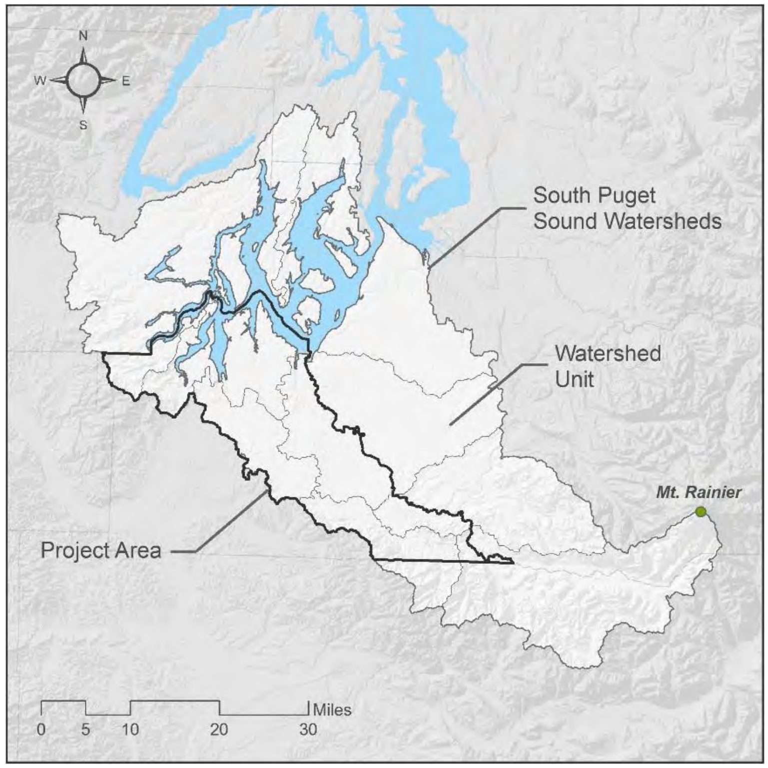

Figure 3. The image above shows the geographic delineations used in this assessment that incorporate UW CIG data. ***Source:*** *TRPC*

While diverse topographically, the project area does not exist within a bubble. Mount Rainier's glaciers and snowpack within Pierce County, for example, affect the timing and volume of the Nisqually River and the adaptive capacity of its estuary in Thurston County. So, when more local or regional detail is warranted or emissions scenarios or data differ, some assessment figures (maps, tables and graphs) focus on different time periods or geographies (e.g., the entire county or region or an individual lake or watershed).

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[1] Global climate models simulate changes at spatial scales of about 50-100 miles from one grid cell to the next. Downscaling translates such coarse-resolution projections to a level of detail and resolution (~5-10 miles from one grid cell to the next) that is more relevant to local decision-making. Almost all of the projections in the UW CIG report are based on statistical downscaling, which is a well-established approach that uses relationships between weather observations and coarse global climate model weather patterns. While statistical downscaling is an effective means of translating global-scale changes to smaller scales, the approach does not fully capture some of the local-scale processes that can affect how a particular location responds to warming (Mauger, et. al, 2015). Using regional climate models — an alternative approach to statistical downscaling — better captures such local-scale processes. There are a limited number of scenarios available at this time, however, given the high computational requirements for running regional climate models.

[2] With the exception of the air temperature maps, all of this assessment's maps created with data provided by UW CIG show projected changes (relative to historical averages) in percent. Such percent ranges are more reliable figures than absolute values. For additional details, see the assessment's appendix [*pg. 99*].

1.4: Organization

Water defines both the geography and organization of the Thurston Climate Adaptation Plan and its components. Section 2 of this report — the Troposphere — focuses on air (temperature, quality) and precipitation (timing, volume and type) because they are fundamental components of the hydrologic cycle that drives our watershed processes [*Figure 4, below*].

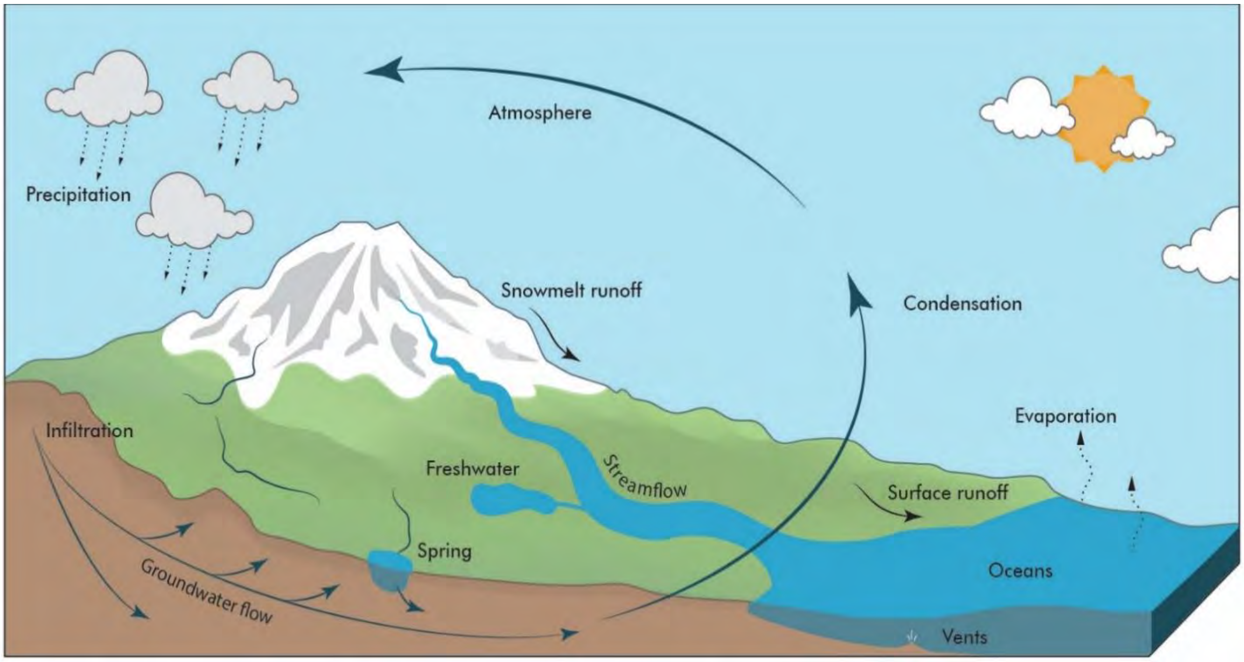

Figure 4. This illustration of the hydrologic cycle, also known as the water cycle, shows how water moves continuously in the form of liquid, vapor and ice on, above, and below the earth's surface. ***Source:*** *TRPC, adapted from USGS infographic*

Subsequent sections of the assessment — Freshwater Ecosystems [*Section 3*], Marine Ecosystems [*Section 4*], and Terrestrial Ecosystems [*Section 5*] — explore the vulnerability of our built assets (roads, seawalls and other infrastructure) and natural assets (fish, plants and animals). Climate change impacts on human health and welfare — perhaps our most precious asset — are explored throughout the report and summarized in Section 6.

This organizational approach recognizes that humans — more than any other species — affect and are affected by changes in multiple ecosystems. To help readers understand these connections, climate stressors and impacts that are referenced in multiple parts of the assessment are denoted with italicized and bracketed section titles and page numbers.

1.5: Summary Findings

The following list summarizes the observed and projected climate change impacts and vulnerabilities explored in this assessment's sections:

Section 2: Troposphere

- ***2.1: Air Temperature***: The Puget Sound region's annual average air temperature rose during the 20th century. The frost-free season lengthened, and nighttime air temperatures increased faster than daytime air temperatures in the lowlands (i.e., Lacey, Olympia and Tumwater) where most of the region's residents live *[See pg. 15]*.

    - **Extreme Temperatures:** The warming trends are projected to continue through the 21st century, intensifying heat waves and weakening cold snaps. Such changes in temperature extremes, coupled with shifts in seasonal precipitation, are expected to affect human and natural systems in many ways *[See pg. 17]*.

- ***2.2: Air Quality***: Historically, Thurston County has not struggled with air quality issues to the degree that many larger communities have. Local air quality could become a bigger threat to community health in coming decades, however, if Thurston County's population and air pollution increase with air temperature *[See pg. 22]*.

    - **Pollutants**: Air pollutants of particular concern include surface ozone (a main ingredient of urban smog) and $PM_{2.5}$ (particulate matter smaller than 2.5 micrometers in diameter). The primary sources of $PM_{2.5}$ in Thurston County today are wood burning in stoves and outdoors — and, to a lesser degree, combusting fossil fuels in automobile engines. The primary sources contributing to surface ozone are nitrogen dioxide emissions from automobiles and volatile organic compounds from industrial facilities *[See pg. 22]*.

- ***2.3: Precipitation***: There is no discernable historical trend in precipitation across the Puget Sound region, which averaged about 78 inches annually during the latter half of the 20th century. The region's annual precipitation volume is not projected to change significantly this century. Seasonal precipitation volumes are projected to change considerably, however: Models indicate generally hotter and drier summers and warmer and wetter winters. Highland forest areas of the Deschutes and Nisqually watersheds would see the biggest shifts in precipitation timing, type, and volume *[See pg. 23]*.

    - **Storm Frequency & Intensity:** The frequency of the region's heaviest 24-hour rain events (top 1 percent) is projected to increase — occurring about seven days a year by late century, compared to two days a year historically. The intensity of such events is projected to increase as well, making communities more vulnerable to floods, landslides, and water-borne pollution *[See pg. 26]*.

    - **Snowfall & Snowpack Volume:** Warmer winters are projected to result in more winter precipitation falling as rain instead of snow in Thurston County's highlands and contiguous areas of Lewis and Pierce counties. This shift is projected to reduce the extent of mountain snowpack and glaciers on Mount Rainier and alter the timing and volume of runoff that affects streamflow and groundwater levels *[See pg. 29]*.

Section 3: Freshwater Ecosystems

- ***3.1 Streams:*** A shift to more rain-dominant conditions across Thurston County watersheds is projected to result in higher runoff and streamflow during cooler months but the opposite during warmer months *[See pg. 32]*.

    - **Water Volume Vulnerability:** Within the Nisqually and Deschutes watersheds, the higher-elevation headwater areas are projected to experience the biggest changes in snowpack and runoff, which affect streamflow timing and volume. Fish and other species that have evolved around predictable peak flows would be vulnerable to die-offs and degraded habitat *[See pg. 32]*.

        - **Hydropower Vulnerability:** Projected changes in seasonal precipitation and streamflow — generally, more water during cool months and less water during warm months — are expected to affect the productivity of hydropower dams on the Nisqually River and other Pacific Northwest rivers. Winter hydropower production is projected to increase modestly in coming decades, while summer hydropower production and overall peak energy demand would decrease more sharply. This could lead to energy blackouts and price spikes during periods of extreme heat *[See pg. 36]*.

    - **Water Temperature & Salmonid Vulnerability:** Water temperatures are projected to rise in Thurston County's highland and lowland streams over the 21^{st} century. Juvenile salmonids that develop in streams (e.g., Chinook, Coho and chum) and ocean-going adults that swim back up streams to spawn are vulnerable to such changes because they have evolved within certain temperature parameters. Impacts could include upgradient shifts in suitable stream habitat and changes to migration timing and success *[See pg. 38]*.

    - **Water Quality Vulnerability:** Climate change could complicate local government efforts to comply with state water-quality standards — particularly with regard to lowering temperature, pollution, and sediment loading in streams. More frequent and intense storms raise the risk of runoff from impervious surfaces and erosion of riparian vegetation that provides cooling shade and stabilizes shorelines *[See pg. 43]*.

- ***3.2 Lakes:*** Shifts in the region's hydrologic cycle, compounded by nutrient loading from urban and rural lands, could make lake conditions more suitable for algal blooms that degrade water quality and pose health risks for humans, fish, and animals *[See pg. 45]*.

    - **Water Temperature & Quality Vulnerability:** Warmer, drier summers are projected to reduce lake levels and raise water temperatures, which strongly influence the growth of cyanobacteria and harmful algal blooms *[See pg. 45]*.

- ***3.3 Wetlands:*** Warmer, drier summers are projected to reduce the flow of water that replenishes and cools non-tidal marshes — which are mostly freshwater wetlands near lakes or on poorly drained soils. Such areas provide important habitat for frogs, birds, and other wildlife *[See pg. 47]*.

- ***3.4 Groundwater:*** Bigger winter storms and high groundwater flooding can result in less infiltration into the soil and aquifers, as well as more runoff into streams and Puget Sound. Summer droughts, in turn, could spur more groundwater pumping when surface water is scarce. Such direct and indirect climate impacts, coupled with sea-level rise, could make Thurston County's coastal freshwater aquifers more vulnerable to water quality and quantity risks *[See pg. 49]*.

  - **Saltwater Intrusion & Inundation Vulnerability:** The direct impacts of saltwater intrusion and inundation on groundwater are likely to be greatest in places with low topographic relief and very low hydraulic gradients between freshwater and saltwater (e.g., downtown Olympia and Nisqually Valley) *[See pg. 49]*.

  - **Pathogen & Pollution Vulnerability:** Prolonged droughts raise the risk of concentrating contaminants in private water systems' shallow wells (less than 50-100 feet deep) — especially those at risk for saltwater intrusion or those with low productivity. Conversely, greater deluges raise the risk of overwhelming wastewater, septic, and stormwater conveyance systems and causing water-borne disease outbreaks in small community or private groundwater wells or other drinking water systems where water is untreated or minimally treated. *[See pg. 51]*.

  - **Water Quantity Vulnerability:** Water quantity (supply-and-demand) vulnerability is expected to be highest in snow-influenced watersheds with existing conflicts over water resources (e.g., fully allocated watersheds with little management flexibility). Vulnerability would be lowest where hydrologic change is smallest (i.e., existing rain-dominant watersheds), where there are simple institutional arrangements, and where current water demand rarely exceeds supply *[See pg. 53]*.

Section 4: Marine Ecosystems

- ***4.1 Sea-level Rise:*** The Puget Sound region is projected to experience continued, and possibly accelerated, sea-level rise in coming decades as a result of melting ice sheets and warmer oceans. This may result in permanent inundation of some low-lying areas, and increased frequency, depth, and duration of coastal flooding due to greater reach of tides and storm surges *[See pg. 54]*.

  - **Coastal Infrastructure Vulnerability:** Downtown Olympia, part of which is built atop fill and subsiding, floods today when there is heavy precipitation and a high tide that inundates the gravity-fed stormwater drainage system. Rising sea levels are projected to exacerbate this problem and increase the vulnerability of key roads and bridges, the LOTT Budd Inlet Treatment Plant, and other important assets. Vulnerable infrastructure along other parts of Thurston County's Puget Sound shoreline include low-lying homes, seawalls, and sections of Interstate 5 and U.S. Highway 101 *[See pg. 54]*.

  - **Coastal Species Vulnerability:** Rising seas are projected to permanently inundate the Nisqually Estuary's tidal marshes and turn them into mudflats. Amphibians, birds, and other wildlife would be particularly vulnerable to such changes in habitat *[See pg. 63]*.

- ***4.2 Ocean Acidification & Pollution:*** Increased seawater absorption of atmospheric carbon dioxide is projected to increase the frequency, magnitude, and duration of harmful pH conditions throughout Puget Sound, which will make it harder for calcifying marine organisms to maintain shells. Water-filtering clams and oysters — which hold significant cultural, economic, and environmental value in the region — are particularly vulnerable to such ocean acidification. Continued pollution from land-based sources, coupled with changes in ocean temperature and pH, exacerbate health risks for people who eat raw or undercooked shellfish *[See pg. 65]*.

Section 5: Terrestrial Ecosystems

- ***5.1 Farms & Ranches:*** Puget Sound's agricultural sector is expected to be relatively resilient to climate change — and some crops may even benefit from a longer growing season and more atmospheric carbon dioxide. However, periodic drought and flood events, as well as invasive pests and plants, still pose risks for local farms and ranches *[See pg. 67]*.

    - **Drought & Flood Vulnerability:** Sustained periods of low or no precipitation could make surface water supplies scarce, forcing farmers and ranchers to rely more heavily on groundwater for irrigating agricultural crops and watering livestock. Conversely, sustained periods of heavy rain, coupled with sea-level rise, could reduce the ability of drainage ditches and other infrastructure to handle flood events in near-coastal agricultural lands *[See pg. 67]*.

    - **Crop & Livestock Vulnerability:** Climate change is expected to influence which crops Puget Sound region farmers cultivate in the decades ahead. Emitting more carbon dioxide into the atmosphere may increase the biomass productivity of some crops, such as beans and grasses, but reduce the nutritional quality of forage and pasture lands for livestock and wild animals. The largest livestock (e.g., dairy cows and horses) would be more vulnerable to heat stress during hotter, drier summers or flooding during warmer, wetter winters. Such stressors also could benefit thistle and other invasive plant species and allow them to outcompete native grasses and crops. Among other agricultural crops that have been studied specifically, berries, tree fruit, and tubers could experience a production decline, while some wine grapes could benefit from projected changes. *[See pg. 67]*.

- ***5.2 Forest & Prairies:*** Climate change is projected to affect the region's forest and prairie vegetation growth, productivity, and range, as well as the prevalence and location of diseases, insects, and invasive species *[See pg. 70]*.

    - **Vegetation Vulnerability:** Shifts in seasonal temperature and precipitation threaten to alter the timing of flowering and the abundance of insect pollinators amid prairies, which could reduce some plant species. Such shifts also threaten to alter the range of Garry oak, Douglas-fir and other important tree species, as well as threaten their survival due to pest and disease outbreaks. Increased water stress associated with such seasonal changes is expected to lead to higher forest mortality, decreased fuel moisture, and more intense fires. These disturbances may be compounded by more pest and disease outbreaks *[See pg. 71]*.

Section 6: Human Health & Welfare

- ***6.1 Wildfires:*** Hotter, drier summers threaten to increase the frequency and intensity of wildfires in Thurston County and the broader Puget Sound region. Wildfires can pose acute or long-term health and welfare risks for firefighters and residents: incurring stress as a result of property losses; suffering burns and death; and, breathing in smoke and other pollutants. Such fires may also disrupt energy transmission by downing power poles and damaging other infrastructure. Presumably, damages associated with these fires would go up if they occur in or spread to the wildland-urban interface *[See pg. 73]*.

- ***6.2 Floods & Landslides:*** Warmer, wetter winters threaten to increase the frequency and intensity of floods and landslides, which can degrade water quality and threaten property and public safety. Buildings, roads and other assets located near rivers and coastlines are most vulnerable to floods. Assets most vulnerable to landslides are located on or near steep slopes *[See pg. 78]*.

- ***6.3 Diseases & Other Health Threats:*** The shifts in temperature and precipitation noted previously are projected to exacerbate or introduce a wide range of health threats, including infectious diseases from exposure to viruses and bacteria, which would affect human health outcomes. Exposure pathways include food, water, air, soil, trees, insects, and animals *[See pg. 84]*.

    - **Tribal Vulnerability:** Members of local tribes, which are rooted in place and utilize land and waters for cultural traditions, are particularly vulnerable to climate change impacts on Puget Sound's waters and marine species. Continuing to consume traditional seafood staples such as shellfish may increase health risks from contamination, but replacing such traditional foods may involve the loss of cultural practices tied to their harvest *[See pg. 85]*.

    - **Assessing Adaptive Capacity:** The vulnerability of our region's residents will depend largely on their sensitivity and exposure to climate change-exacerbated threats and capacity to adapt. Local and state public health professionals are beginning to consider a wide range of social and behavioral factors (e.g., social isolation, physical ability, etc.) as they assess individuals' exposure to threats and resiliency *[See pg. 86]*.

- ***6.4 Population Displacement:*** Climate change-exacerbated natural hazards can lead to temporary or permanent population displacement. It's impossible to predict how many people might move to or within Thurston County, or when, as a direct result of climate change. The region can start preparing for the possibility of climate migrants, however, by analyzing census data, migration trends, and other information to assess who might move here (e.g., because of family/ethnic connections or suitable job skills) and how to accommodate population growth in a manner consistent with comprehensive plans *[See pg. 88]*.

2: Troposphere

The troposphere is the first atmospheric layer above the earth's surface and where weather occurs. Air temperature and precipitation are as fundamental to weather as they are to the broader climate, so these indicators are among the first explored in this vulnerability assessment. Subsequent sections assess in greater detail how changes in these indicators affect freshwater, marine and terrestrial (land) ecosystems.

…

Weather vs. Climate

Weather is atmospheric conditions over the short term (e.g., minutes to days). Climate is the average of weather over longer periods of time and space (e.g., years and decades). … A good way to remember the difference is that climate is what you *expect* — like a long and hot summer; weather is what you *get* — like a dry and sunny day.

— NASA, 2005

2.1: Air Temperature

Rising air temperatures during the 21st century will affect human and natural systems in myriad ways — from shifting precipitation and vegetation patterns to changing the temperature and chemistry of the oceans. The following section examines past and projected changes in annual, seasonal and daily temperatures throughout the adaptation plan's project area and the broader Puget Sound region.

Annual Changes

During the past century, the air temperature rose and the frost-free season lengthened amid the Puget Sound region (Mauger et al., 2015). Nighttime air temperatures rose faster than daytime air temperatures throughout Puget Sound's lowlands — which include Thurston County's urban core of Olympia, Lacey and Tumwater. The lowlands' average temperature was 50.3°F historically[3] and increased 1.3°F (range: 0.7 to 1.9°F) between 1895 and 2014.

The broader Puget Sound region's average annual air temperature was 44°F historically and is projected to rise 4.2°F per a low global greenhouse gas emissions scenario (RCP 4.5)[4] and 5.9°F per a high scenario (RCP 8.5) for the 2050s[5] [*Figure 5, below*]. For the 2080s, the temperature is expected to rise 5.5°F per the low scenario and 9.1°F per the high scenario.

Indicator	Scenario	2050s		2080s	
		Mean	Range	Mean	Range
Average annual air temperature	Low (*RCP 4.5*)	+4.2°F	2.9°F to 5.4°F	+5.5°F	2.3°F to 11°F
	High (*RCP 8.5*)	+5.9°F	4.3°F to 7.1°F	+9.1°F	4.3°F to 17°F
Temperature of hottest days[6]	Average of RCP 4.5 and 8.5	+6.5°F	4.0°F to 10.2°F	+9.8°F	5.3°F to 15.3°F
Temperature of coolest nights[7]	Average of RCP 4.5 and 8.5	+5.4°F	1.3°F to 10.4°F	+8.3°F	3.7°F to 14.6°F

Figure 5. Projected changes in average annual air temperature and extremes for the Puget Sound region per the low (RCP 4.5) and high (RCP 8.5) global emissions scenarios. ***Source:*** *TRPC, adapted from Mauger et al., 2015*

[3] Historical average temperature for 1950-1999.
[4] These scenarios — known as Representative Concentration Pathways (RCPs) — are used in model simulations of the earth's future climate. Most of the UW CIG and TRPC assessments focus on two scenarios to show a range of potential climate impacts: RCP 4.5 — a "low" scenario that assumes greenhouse gas emissions stabilize by mid-century and fall sharply thereafter; and RCP 8.5 — a "high" scenario that assumes substantial greenhouse gas emission increases until the end of the 21st century.
[5] References to the 2050s throughout this assessment refer to the 2040-2069 period, relative to 1970-1999; references to the 2080s refer to the 2070-2099 period, relative to 1970-1999.
[6] Projected change in the top 1 percent of daily maximum temperature.
[7] Projected change in the bottom 1 percent of daily minimum temperature.

The U.S. Geological Survey (USGS) National Climate Change Viewer projects annual maximum and minimum temperatures for the two emissions scenarios over the full 21st century. The online tool shows that Thurston County's average annual maximum temperature is projected to rise from 60.9°F in 2000 to 65.1°F in 2099 per the low emissions scenario and to 69.3°F per the high scenario (Alder & Hostetler, 2013).[8] Over the same period, Thurston County's average annual minimum temperature is projected to rise from 41.4°F in 2000 to 45.9°F in 2099 per the low scenario and to 51.1°F per the high scenario.

Climate change of even a few degrees is consequential, considering that the global average temperature during the last ice age was just 7°F to 9°F colder than now (The Royal Society, 2016). Warmer air holds more moisture, so the projected increase in Thurston County's air temperature is expected to influence the timing, type and volume of precipitation. Such changes in the hydrologic cycle are also expected to affect human health and welfare, as well as native plants and fish that have evolved within certain parameters [*See subsequent sections*].

Seasonal Changes

Figures 7 and 8[9] [*See pgs. 18-19*] show that Thurston County's average winter and summer temperatures generally decrease as elevations increase. The elevation rises from sea level at Puget Sound's southern shore to almost 3,000 feet above sea level near Alder Lake area, in the county's southeastern corner. Historically, these highlands were about 6°F cooler than the lowlands during the winter and were the only part of the county that received snowpack regularly.

Per the low emissions scenario, the project area's average winter temperature is projected to increase 3°F to 4°F from an historical average of 36°F for the 2050s and 4°F to 5°F for the 2080s [*Figure 7*]. Per the high emissions scenario, the project area's average winter temperature would increase 4°F to 5°F for the 2050s and 7°F to 9°F for the 2080s. This would likely mean fewer days with freezing temperatures and more rain instead of snow.

Per the low emissions scenario, the entire project area's average summer temperature would increase 4°F to 5.5°F for the 2050s and 5.5°F to 7°F for the 2080s [*Figure 8*]. Per the high emissions scenario, the project area's average summer temperature would increase 5.5°F to 7°F for the 2050s and 8.5°F to 11.5°F for the 2080s.

Daily Changes

Across the entire Puget Sound region, daily minimum air temperatures (generally, during the nighttime) rose by 1.8°F between 1895 and 2014 (historical average); daily maximum air temperatures (generally, during the afternoon) rose by 0.8°F (Mauger et al., 2015). During roughly the same time period (1901-2009), warm nights became more frequent.

Daytime and nighttime temperatures [*Figures 9 & 10, on pgs. 20-21*] are likely to rise throughout the project area during the 21st century per both emissions scenarios. Such changes are consistent with

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[8] The National Climate Change Viewer's spatial analysis scales include the nation, regions, states and counties rather than the Watershed Resource Inventory Area (WRIA) units that define the adaptation plan's project area. The Washington Department of Ecology has divided the state into 62 WRIAs to delineate areas that drain into a river, lake or other waterbody.

[9] The South Puget Sound region maps show historical (1970-1999) and projected (2050s and 2080s) changes in air temperature across seasons (summer and winter) per the low and high emissions scenarios. Southwestern Thurston County drains into the Chehalis River, so it is not included in the National Estuary Program grant and project area (encircled in black). Hash marks overlay areas where no data are available (Squaxin, Hartstene, Anderson, McNeil and Ketron islands). Historical periods shown in the vulnerability assessment's other figures may vary due to the length of record-keeping.

those projected across the broader Puget Sound region, where heat waves are expected to intensify and cold snaps are expected to become less severe over the century (Mauger et al., 2015).

Figure 6: A bald cypress tree — brown and stressed following a bone-dry summer — rises from muddy water that spills over the southern shore of Olympia's Capitol Lake following a record-breaking rainstorm in December 2015. ***Source:*** *TRPC*

Such changes in temperature extremes, coupled with shifts in seasonal precipitation volume, are likely to affect human and natural systems in many ways. For example, projected increases in the frequency and intensity of extreme heat events are may stress plants [*Figure 6, right*], exacerbate algal blooms, and delay outdoor construction projects and increase costs. Extreme heat can also increase the urban heat island effect in the region's most densely developed areas, as well as hospitalization and emergency service calls and costs to treat heat-related physical and mental stress (Mauger et al., 2015).

Children and older adults have a higher risk of dying or becoming ill as a result of heat stress, also known as hyperthermia (USGCRP, 2016), with symptoms including cramps, loss of consciousness, weakness and stoke. Other populations especially vulnerable to extreme heat and other exposure pathways include people who work outdoors, people who are homeless, people with chronic disease (e.g., diabetes, asthma, obesity), people with mental illness, and people who are socially isolated and economically disadvantaged (Thurston County, 2010). Section 6.3 of this assessment — Human Health & Welfare — includes a table [*Figure 66, on pg. 85*] that summarizes these and other health threats exacerbated by climate change.

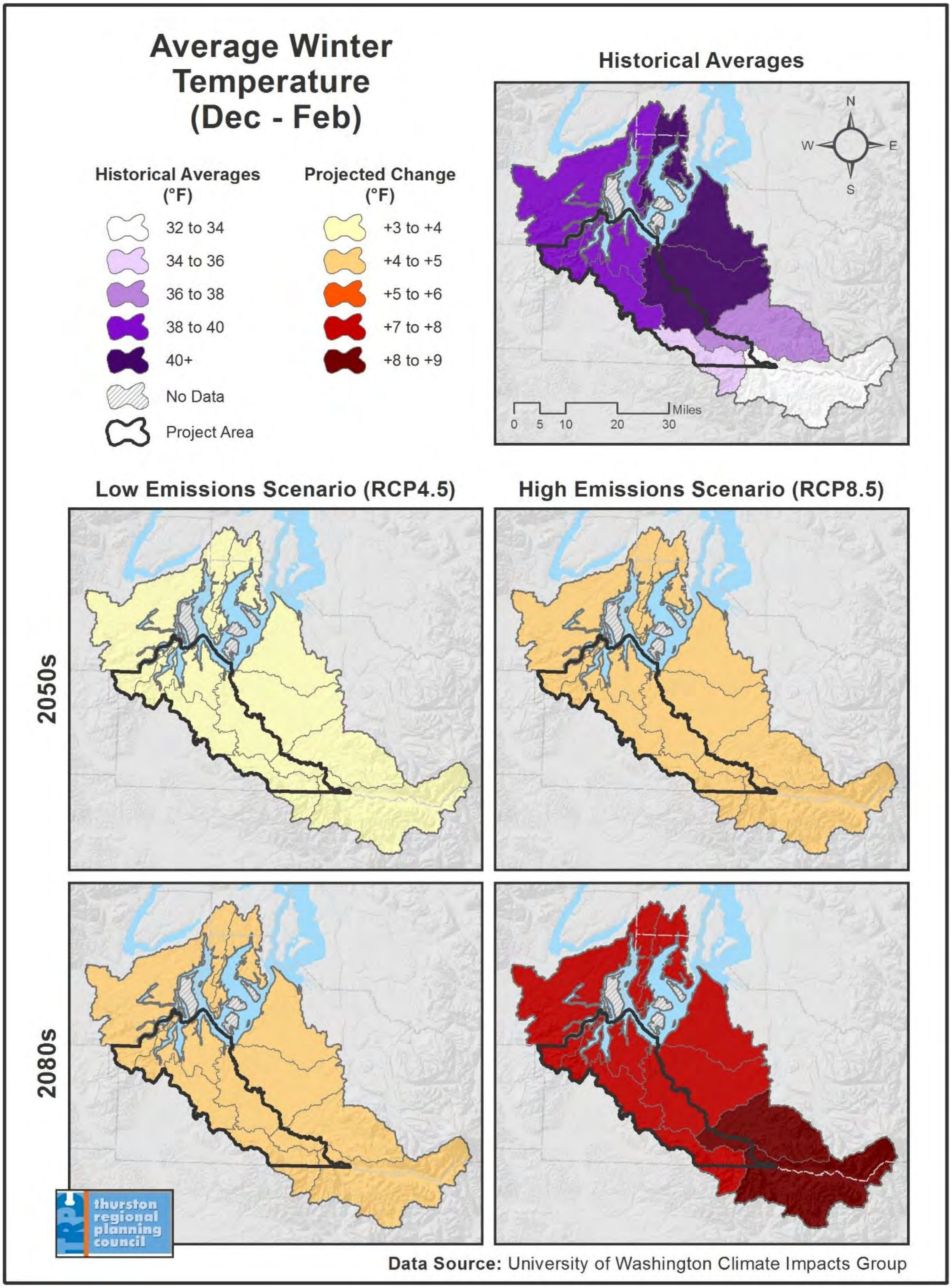

Figure 7. Projected changes in average winter temperature for South Puget Sound watersheds per emissions scenarios. ***Source:*** *Adapted from Figure 1b in Appendix B of Mauger et al., 2015.*

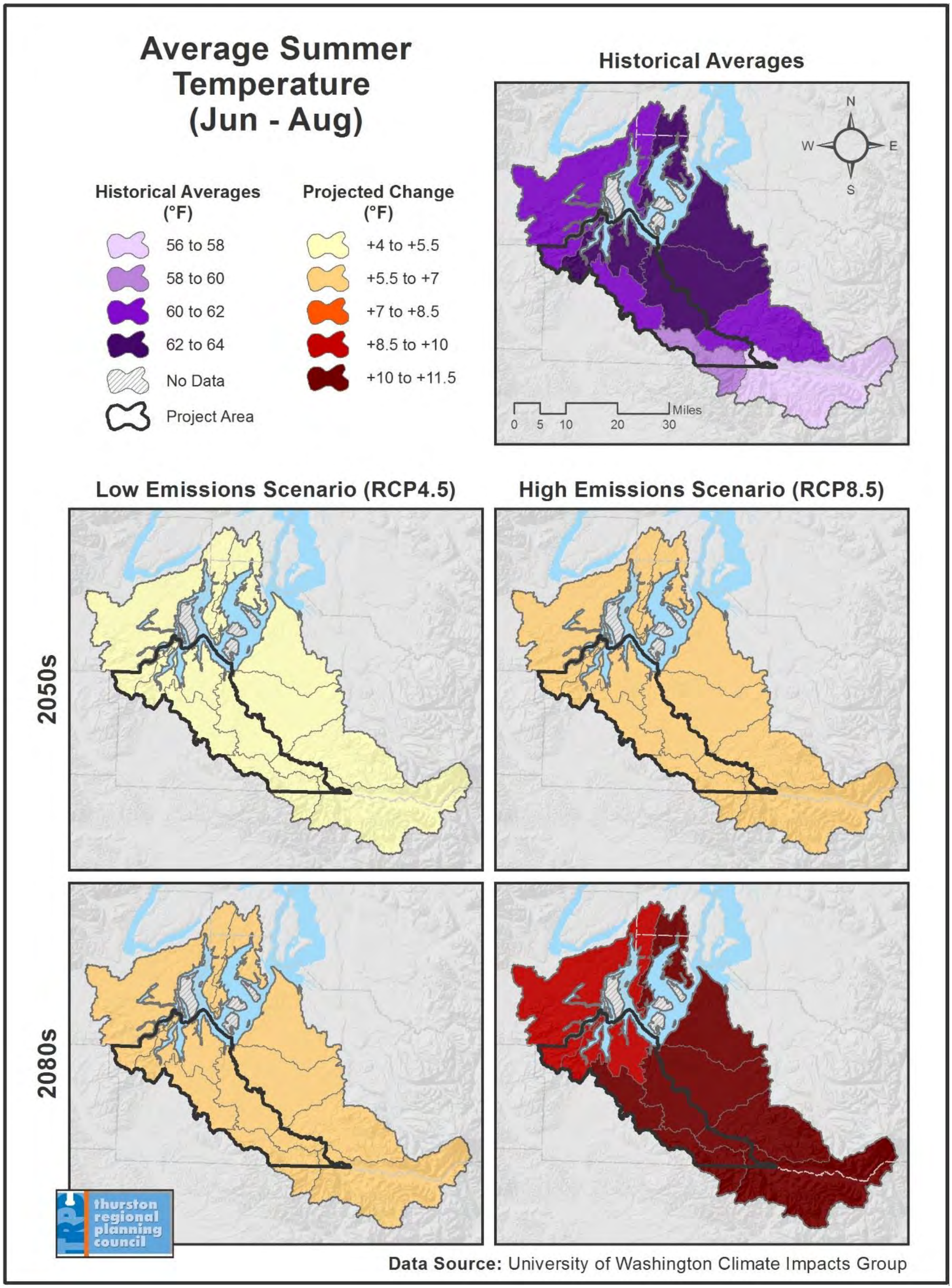

Figure 8. Projected changes in average summer temperature for South Puget Sound watersheds per emissions scenarios.
Source: *Adapted from Figure 2a in Appendix B of Mauger et al., 2015.*

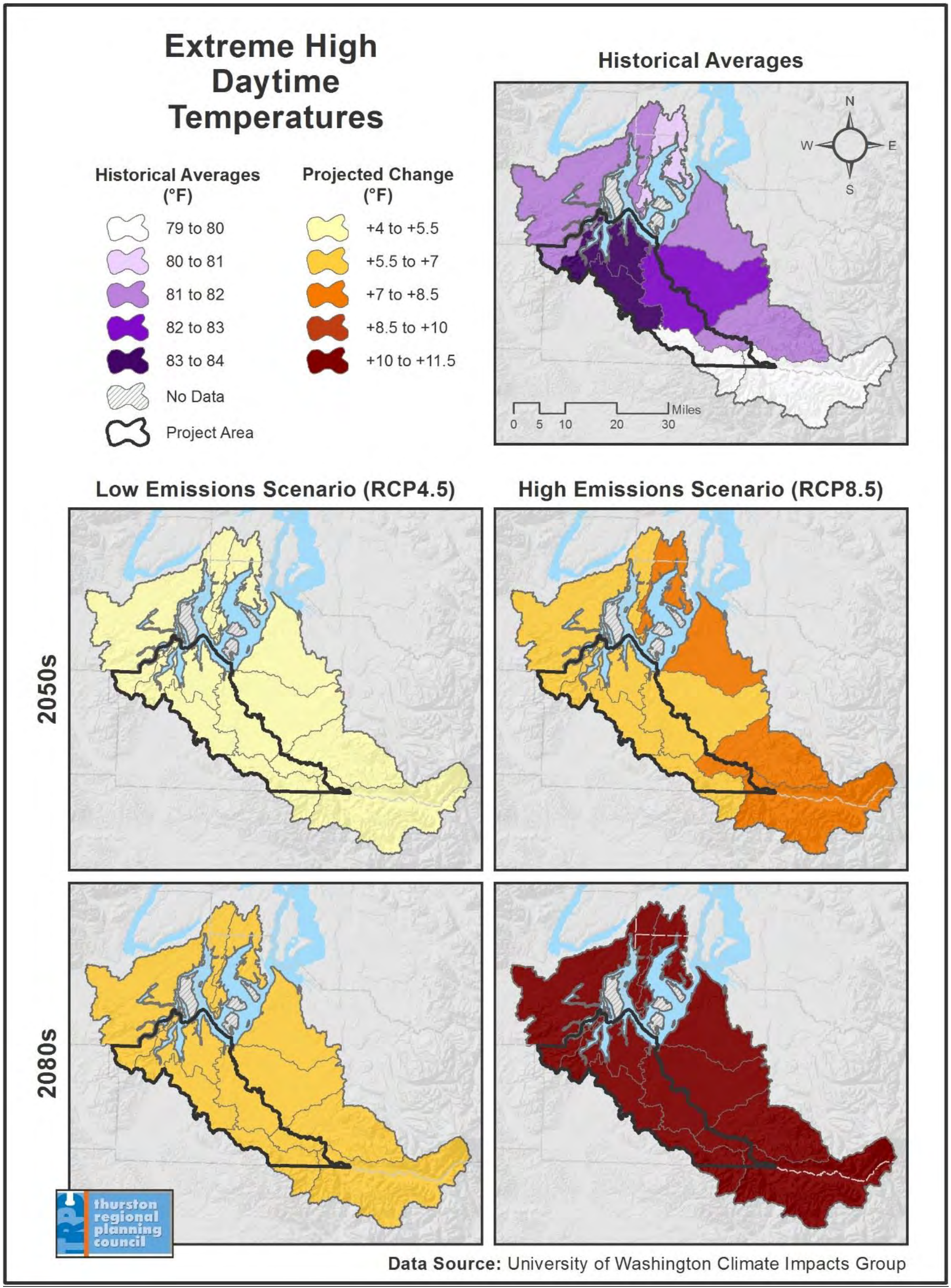

Figure 9. Projected changes in extreme high daytime temperatures for South Puget Sound watersheds per emissions scenarios. ***Note:*** *The "extreme high" temperature is the 95th percentile of daily maximum temperatures occurring annually.* ***Source:*** *Adapted from Figure 4b in Appendix B of Mauger et al., 2015.*

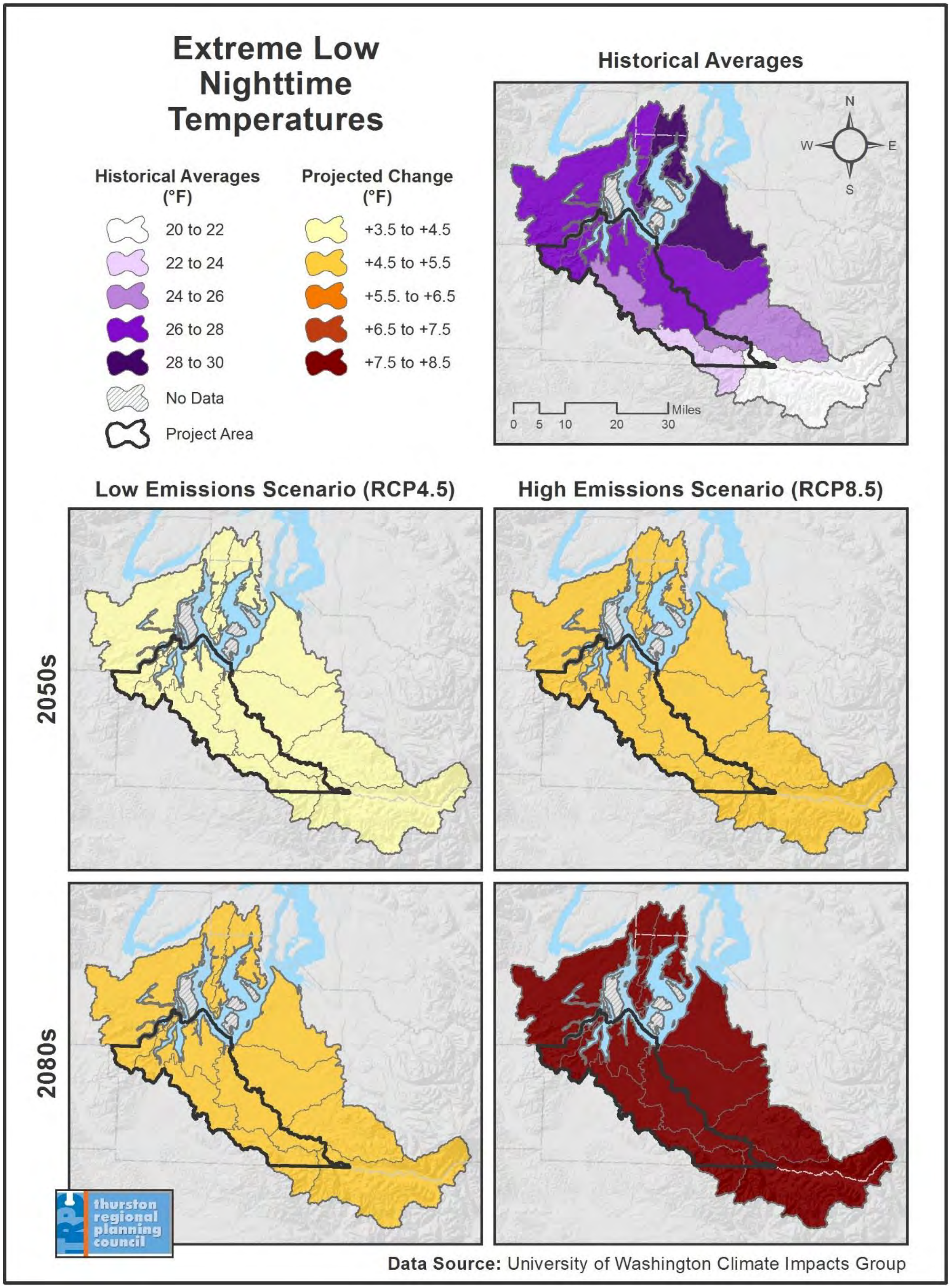

Figure 10. Projected changes in extreme low nighttime temperatures *(the 5th percentile of daily minimum temperatures occurring annually)* for South Puget Sound watersheds per emissions scenarios. ***Source:*** *Adapted from Figure 5b in Appendix B of Mauger et al., 2015.*

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2.2: Air Quality

Air quality changes are driven primarily by emissions and temperatures. Modeling indicates that, with locally higher surface temperatures in polluted regions, regionally triggered feedbacks in chemistry and local emissions will, with "medium confidence,"[10] (IPCC, 2013) increase peak levels of surface ozone and $PM_{2.5}$ (particulate matter smaller than 2.5 micrometers in diameter).

$PM_{2.5}$ poses a human health risk because such fine particles — about 1/30th the average width of a human hair — can be inhaled and lodge deeply in lungs (EPA, 2016). Surface ozone (tropospheric O_3), a main ingredient of urban smog, is harmful to breathe and damages vegetation (EPA, 2014). Children and older adults — as well as people of any age with preexisting heart and respiratory (cardiopulmonary) problems — are among groups that are most sensitive to these air pollutants. The primary sources of $PM_{2.5}$ in Thurston County are wood burning in stoves and outdoors (e.g., brush piles) — and, to a lesser degree, combusting fossil fuels in automobile engines (Hadley, 2016). The primary sources contributing to surface ozone are nitrogen dioxide emissions from automobiles and volatile organic compounds from industrial facilities [*Also see Section 6.3 and Figure 66, on pg. 85*].

The U.S. EPA sets national ambient air quality standards for particulate matter and ozone, as well as four other criteria pollutants: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). Thurston County is currently meeting standards for $PM_{2.5}$ and surface ozone, according to Olympic Region Clean Air Agency data analyzed by TRPC (TRPC, 2016).

While Thurston County doesn't struggle with air quality issues to the degree that many larger communities do, the county is one of the fastest-growing in the state. Local air pollution could become more severe in coming decades — especially if Thurston County's summers are hotter and drier and its roads add more petroleum-powered cars and trucks (Hadley, 2016). Thurston County's population is projected to increase by about 47 percent between 2015 and 2040, while the county's cumulative annual vehicle miles traveled is projected to increase 37 percent, according to TRPC modeling[11].

One study, which factored in projected growth in statewide population and $PM_{2.5}$ concentrations, estimated that $PM_{2.5}$ could cause 139 more deaths annually across Washington by 2050 compared to 2001 (Tagaris et al., 2009). A separate study, which factored in projected population growth and ground-level ozone concentration in the greater Seattle area, estimated that the attributed number of "excess deaths" (expected deaths above the baseline) during summer would nearly double — from about 69 annually (1997-2006 average) to about 132 annually by 2050 (Mauger et al, 2015).

The relationship between climate change, aeroallergens (e.g., pollen and fungal spores) and health outcomes has not been studied in the Puget Sound region (Mauger et al., 2015), but studies conducted elsewhere show that pollen production in some plant species (e.g., ragweed) increases with carbon dioxide (CO_2) levels. Other research concludes that warmer temperatures could lead to a longer pollen season with increased allergenicity to some allergens (WDOE, 2007).

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[10] IPCC 2013 uses the following terms, which are based on the type, amount, quality, and consistency of evidence, to indicate the assessed likelihood of an outcome: "virtually certain," 99-100% probability; "very likely," 90-100% probability; "likely," 66-100% probability; "about as likely as not," 33-66% probability; "unlikely," 0-33% probability; "very unlikely," 0-10% probability. The IPCC report uses the following qualifiers to denote a level of confidence that is based on the degree of scientific agreement and available evidence: "very low," "low," "medium," "high," and "very high." The UW CIG assessment reports climate trends only if they are statistically significant at or above a 90% or 95% confidence level. In several cases, this vulnerability assessment modifies text from such source documents only slightly so as to ensure technical accuracy of terms.

[11] The figures, previously unpublished, are derived from TRPC's transportation and population forecast models.

2.3: Precipitation

A continued rise in average annual temperature over the 21st century is expected to shift the region's seasonal cycle of precipitation, which could affect myriad assets within our human and natural systems: For example, too much rainfall at once could scour streambeds, flood valleys, and trigger landslides that destroy property and wildlife habitat; too little rainfall over a sustained period, however, could kill fish and vegetation, cause drought, diminish hydropower production, and increase the risk of wildfire.

Annual & Seasonal Changes

There is no discernable historical trend in precipitation across the Puget Sound region, which averaged about 78 inches annually from 1950-2005 (Mauger et al., 2015). In the decades ahead, however, the region's seasonal precipitation totals [*Figure 11, below*] — and to a much lesser extent, annual precipitation totals [*Figure 12, below*] — are projected to change.

Season	Scenario	2050s		2080s	
		Mean	Range	Mean	Range
Fall	Low *(RCP 4.5)*	+5.5%	-5.7% to +13%	+12%	+1.6% to -21%
	High *(RCP 8.5)*	+6.3%	-2.4% to +19%	+10%	+1.9% to +15%
Winter	Low *(RCP 4.5)*	+9.9%	-1.6% to +21%	+11%	+1.3% to +16%
	High *(RCP 8.5)*	+11%	+1.8% to +19%	+15%	+6.2% to +23%
Spring	Low *(RCP 4.5)*	+2.8%	-9.4% to +13%	+1.6%	-3.2% to +9.3%
	High *(RCP 8.5)*	+3.8%	-7.7% to +13%	+2.5%	-6.7% to +11%
Summer	Low *(RCP 4.5)*	-22%	-45% to -6.1%	-20%	-38% to -10%
	High *(RCP 8.5)*	-22%	-50% to -1.6%	-27%	-53% to -10%

Figure 11. Projected changes in Puget Sound region seasonal precipitation for the 2050s and 2080s per the low and high scenarios. ***Source:*** *TRPC, adapted from Mauger, et al., 2015*

Time Period	Scenario	Mean	Range
2050s	Low *(RCP 4.5)*	+4.2%	+0.6% to +12%
	High *(RCP 8.5)*	+5.0%	-1.9% to +13%
2080s	Low *(RCP 4.5)*	+6.4%	-0.2% to +10%
	High *(RCP 8.5)*	+6.9%	+1.0% to +9.4%

Figure 12. Projected changes in Puget Sound region annual precipitation. ***Source:*** *TRPC, adapted from Mauger, et al., 2015*

Future Puget Sound summers are likely to be hotter and drier, with more extreme heat events; winters are likely to be warmer and wetter, with more intense heavy rain events. Summer precipitation[12] is projected to decline 22 percent for the 2050s for both scenarios (Mauger et al., 2015). Conversely, winter precipitation is projected to increase by roughly 10 percent for the 2050s for both scenarios.

Within South Puget Sound and the project area, the biggest changes in seasonal precipitation would occur in southeastern Thurston County [*Figures 13 & 14, on pgs. 24-25*]. Summer precipitation[13] is projected to decrease by 8.5-11.5 percent for the 2080s for the low emissions scenario in this area — which includes the Nisqually Indian Reservation and the growing city of Yelm; precipitation would decrease by 11.5-13 percent per the high scenario. Conversely, this area would see the biggest relative increase in winter precipitation for the high scenario.

[12] Puget Sound summer (April-September) precipitation averaged 18.66 inches historically (1970-1999); winter (October-March) precipitation averaged 56.51 inches, according to TRPC calculations using UW CIG data.
[13] South Puget Sound summer precipitation averaged 15.06 inches historically; winter precipitation averaged 48.39 inches.

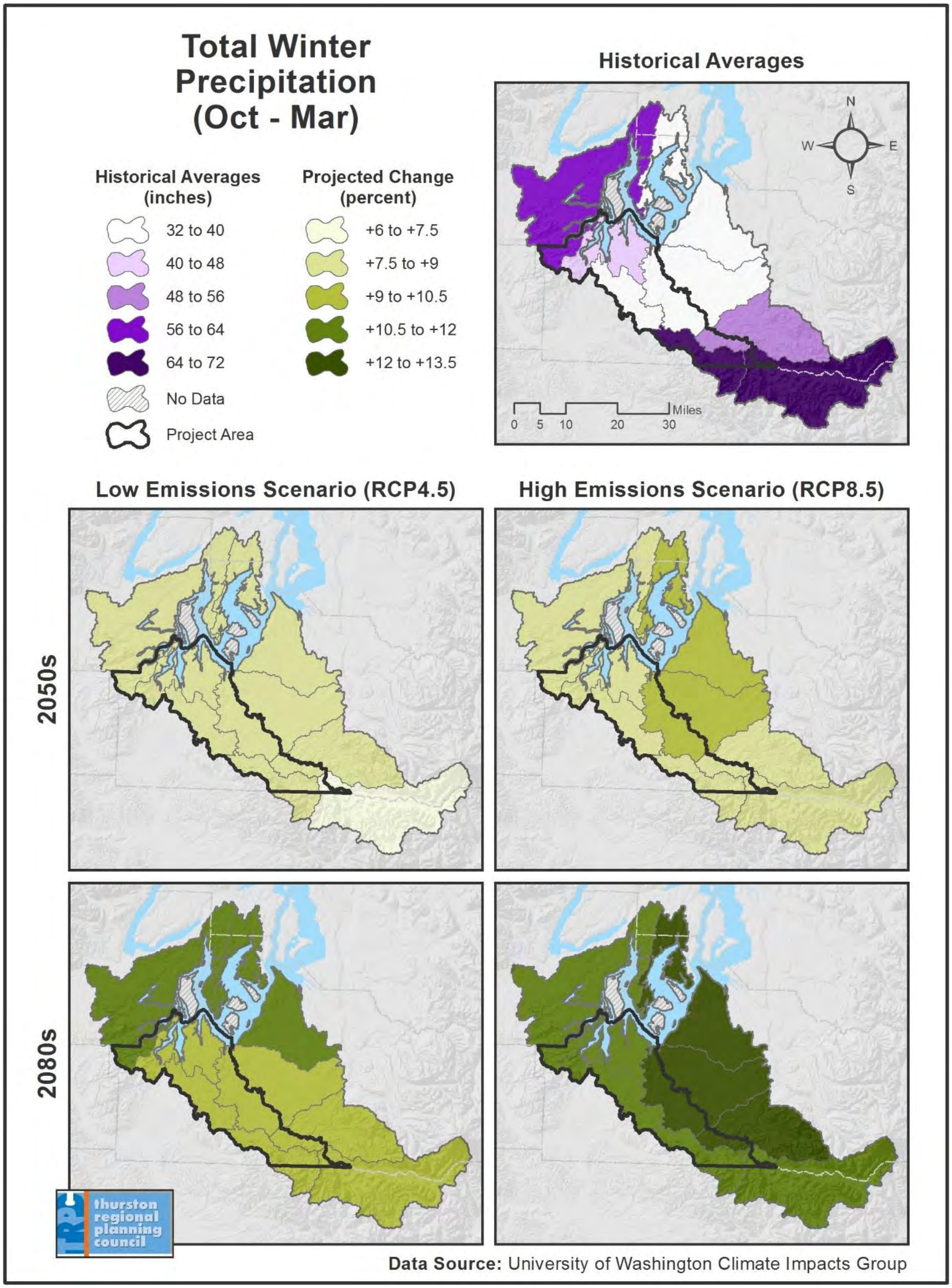

Figure 13. Projected changes in total winter precipitation for South Puget Sound watersheds per emissions scenarios. ***Source:*** *Adapted from Figure 6b in Appendix B of Mauger et al., 2015.*

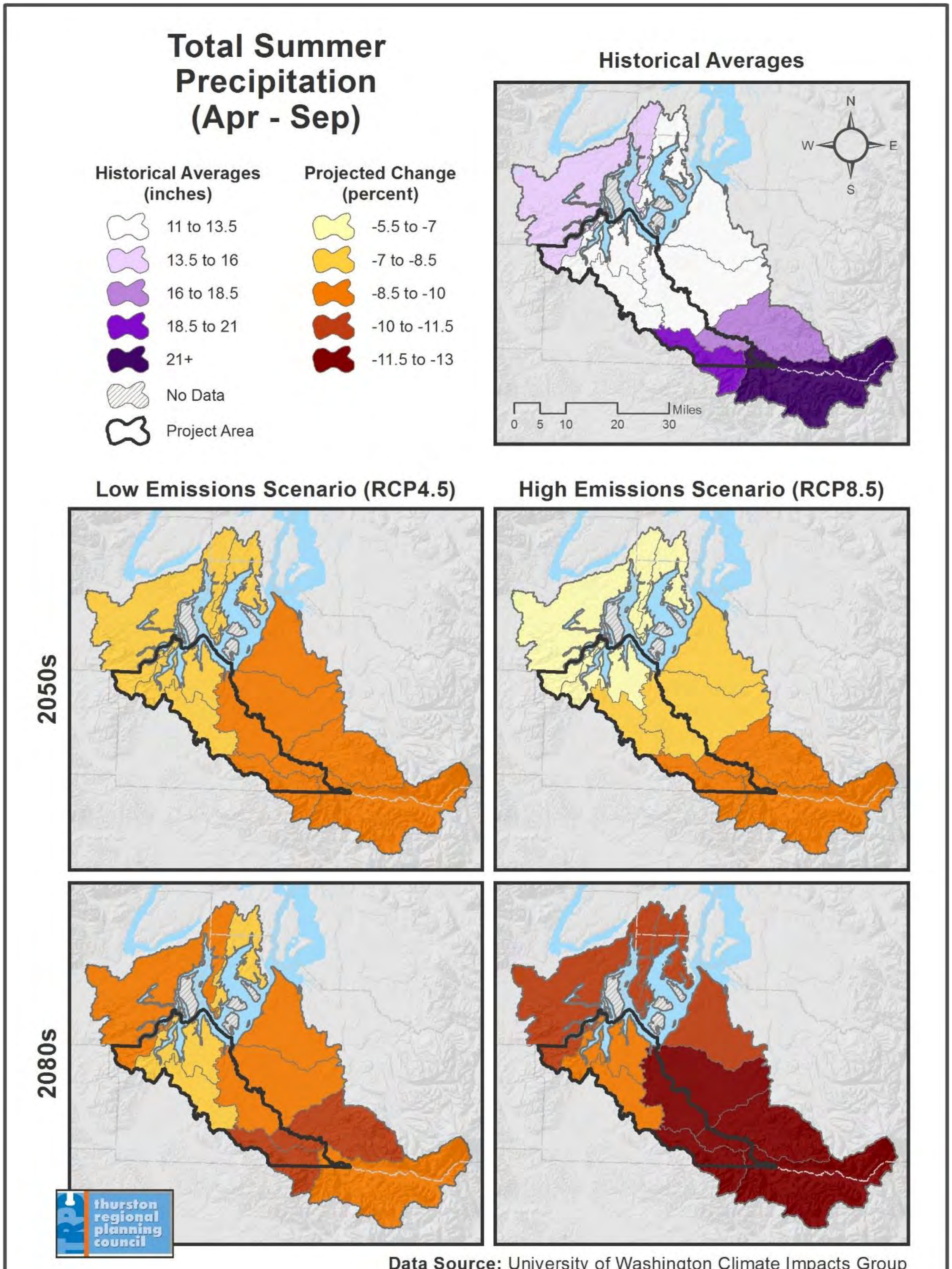

Figure 14. Projected changes in total summer precipitation for South Puget Sound watersheds per emissions scenarios. ***Source:*** *Adapted from Figure 7b in Appendix B of Mauger et al., 2015.*

25

Storm Frequency & Intensity

The *Natural Hazards Mitigation Plan for the Thurston Region* finds that damaging rain has a "high" (38 percent) annual chance of occurrence currently, based on analysis of past storm events (TRPC, 2009). A future with warmer and wetter winters increases the likelihood that such "heavy" rainstorms will be more frequent and intense (Mauger et al., 2015), potentially resulting in flooding and other hazards that endanger human health and welfare [*Figure 15, below*].

Within the broader Puget Sound region, the frequency of today's heaviest 24-hour rain events (top 1 percent) is projected to increase — occurring about seven days per year for the 2080s, per the high greenhouse gas scenario, compared to two days per year historically (Mauger et al., 2015). Within the project area, the intensity of such events is also projected to increase; the biggest increases would be along the Deschutes River as it heads into Capitol Lake [*Figure 16, on pg. 28]*.

Figure 15: The Deschutes River overtops its banks at Tumwater Falls Park after a record-breaking storm in 2015. **Source:** TRPC

While models project more frequent and intense storm events for the region, there is no scientific consensus regarding whether climate change will affect wind speeds and patterns. Observed trends in wind speed and pattern are ambiguous, with some studies finding increases and others finding decreases (Mauger et. al, 2015).

Heavy rainfall events could cause some septic systems to fail, which would degrade water quality and pose health risks.

Added to this, the region's oldest stormwater infrastructure — the network of ponds and pipes that capture and channel runoff from streets and other impervious surfaces — would be especially vulnerable to overflows associated with such events. Stormwater runoff from downtown Olympia and surrounding neighborhoods is piped directly into Puget Sound, and runoff from many newer subdivisions and commercial developments is captured on-site in stormwater ponds that have been designed to handle historic levels of rainfall.

To protect water quality — and, as a co-benefit, reduce the risk of stormwater-related flooding — the Washington Department of Ecology's revised municipal stormwater permit requires permittees to revise their drainage manuals to require more distributed, on-site infiltration and runoff mitigation. Local permittees — including Thurston County, Olympia, Lacey and Tumwater — are also revising their codes in 2016 to make such "low-impact development" the preferred and commonly used approach to site development, where feasible.

Going forward, key challenges for Thurston County communities include identifying where LID is infeasible (e.g., areas with tightly packed soils or steep slopes), as well as designing and investing sufficiently in stormwater infrastructure (new and retrofitted) that is able mitigate the flooding and runoff associated with more frequent more frequent and intense rain events. Subsequent sections of this assessment explore how such extreme rain events will exacerbate the risks of water pollution, flooding and landslides. [*See Section 3.4, on pg. 49, and Section 6.3, on pg. 85*].

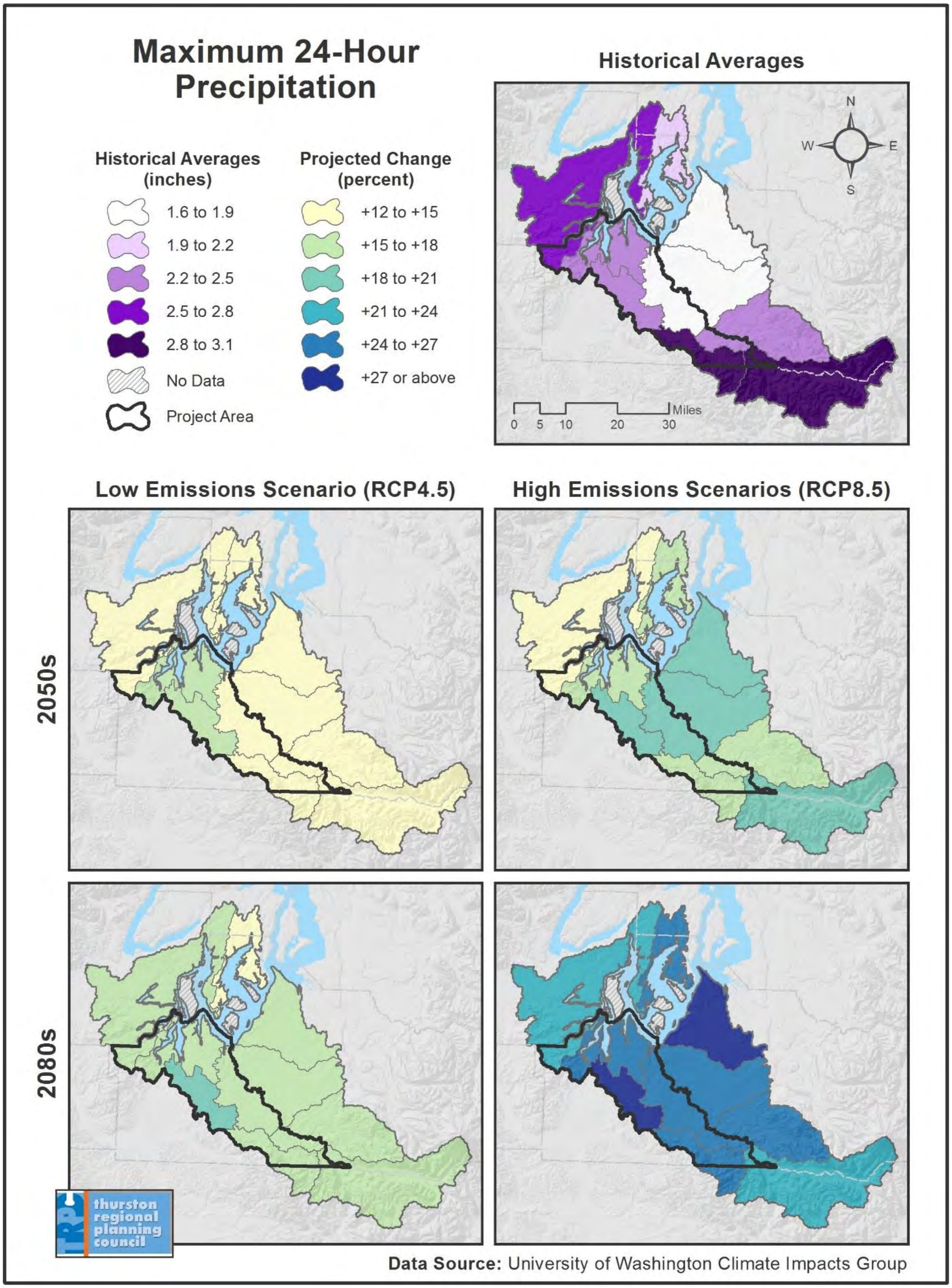

Figure 16: The intensity of the heaviest 24-hour rain events (top 1 percent) — as measured in inches of precipitation — is projected to increase amid the project area. ***Source:*** *Adapted from Figure 8b in Appendix B of Mauger et al., 2015.*

28

Snowfall & Snowpack Volume

A continued rise in the average annual temperature over the 21st century will result in more winter precipitation falling as rain instead of snow in the Puget Sound region. This shift would reduce the extent of mountain snowpack and glaciers and alter the timing of runoff and volume of streamflow. The potential loss of forestland — e.g., via timber harvesting, fire and disease — could degrade further the ability of highlands to retain snowpack and control streamflow (Greene and Thaler, 2014).

Thurston County's annual average snowfall is projected to decrease by just two-tenths of an inch per both the high and low emissions scenarios for the 2050s and 2080s and become virtually nonexistent by the end of the 21st century, according to the USGS National Climate Change Viewer (Alder & Hostetler, 2013). A key reason for this small figure is that all of Thurston County is less than 3,000 feet above sea level. In most years, there is little or no snowfall nor sustained snowpack outside of the county's higher-elevation forestlands (e.g., Capitol State Forest and Alder Lake area).

Snow blankets Alder Dam and southwestern Thurston County's forested highlands in December 2016. ***Source:*** *TRPC*

April 1 is considered the date of peak snowpack[14] in Pacific Northwest highlands. Historically, peak snowpack is about 20-30 inches within the watershed unit that includes Alder Lake and the southwestern flank of Mount Rainier within Lewis and Pierce counties — the headwaters of the Nisqually River [*Figure 17, on pg. 30*]. For the 2080s, peak snowpack would decline 80-90 percent in this watershed unit for the low emissions scenario and 90-100 percent for the high scenario. The length of the snow season in southeastern Thurston County and surrounding highlands also would decline significantly per both scenarios [*Figure 18, on pg. 31*].

Annual mean snowfall in Pierce County — which includes the Nisqually River's headwaters — is projected to decrease by about 43 percent over the 21st century per the low emissions scenario (from 5.8 inches historically[15] to 3.3 inches in 2099) and about 71 percent per the high scenario (from 5.8 inches to 1.7 inches) (Alder & Hostetler, 2013). Annual mean snowfall in Lewis County — which includes the Deschutes River's headwaters — is projected to decrease by about 63 percent over the century per the low scenario (from 3.8 inches historically to 1.4 inches) and about 87 percent per the high scenario.

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[14] Climate models express "peak snowpack" as April 1 snow water equivalent — the total amount of water contained in the snowpack. The UW Climate Impacts Group calculated changes only for Puget Sound areas that regularly accumulate snow (historical April 1 snowpack depth of about 0.4 inches, on average).

[15] Historical figures for both counties referenced in this paragraph denote the 1950-2005 average annual mean.

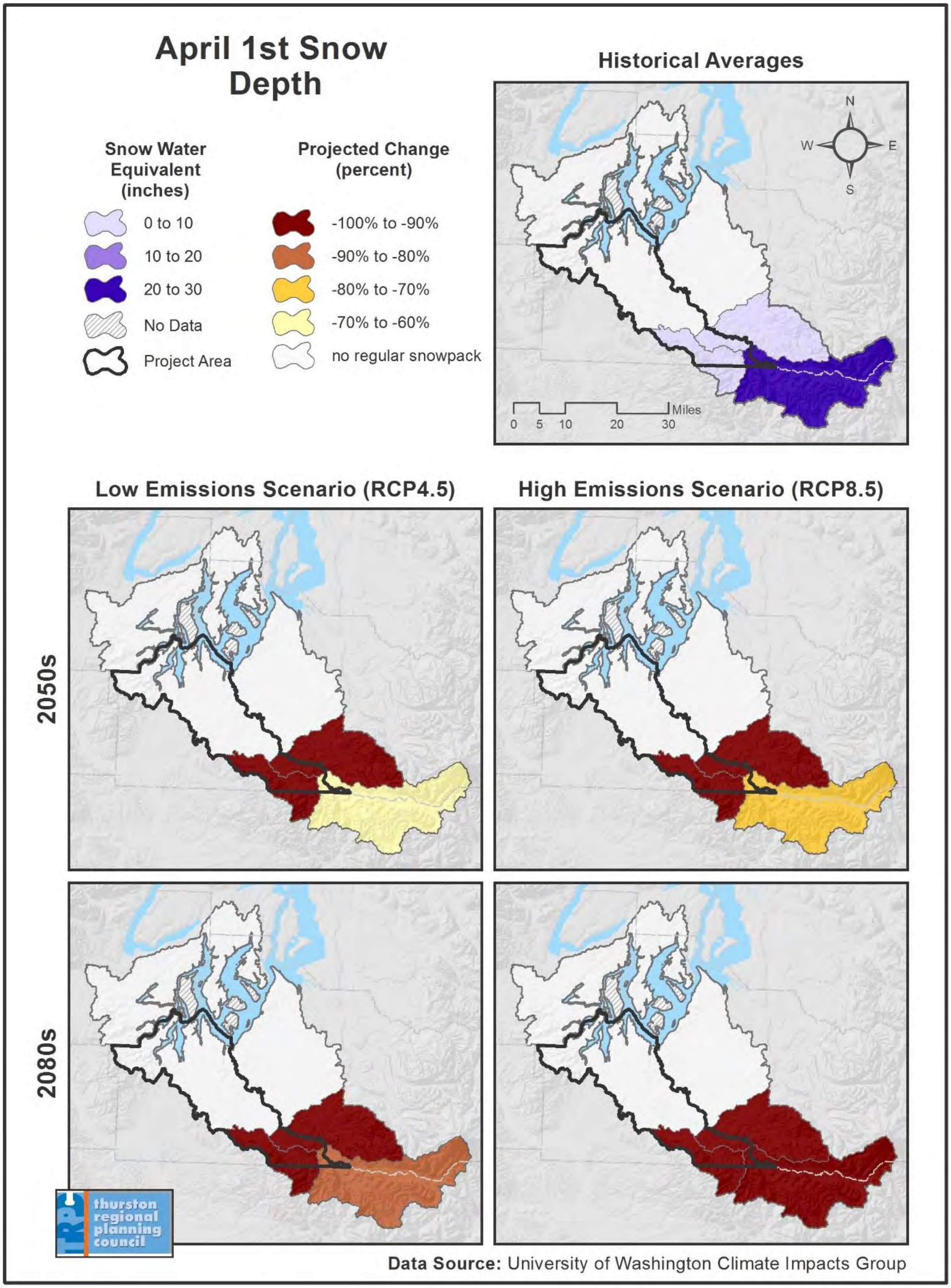

Figure 17. Projected changes in April 1st peak snowpack, expressed as snow water equivalent (measure of the total amount of water contained in snowpack) amid South Puget Sound watersheds. ***Source:*** *Adapted from Figure 11b in Appendix B of Mauger et al., 2015.*

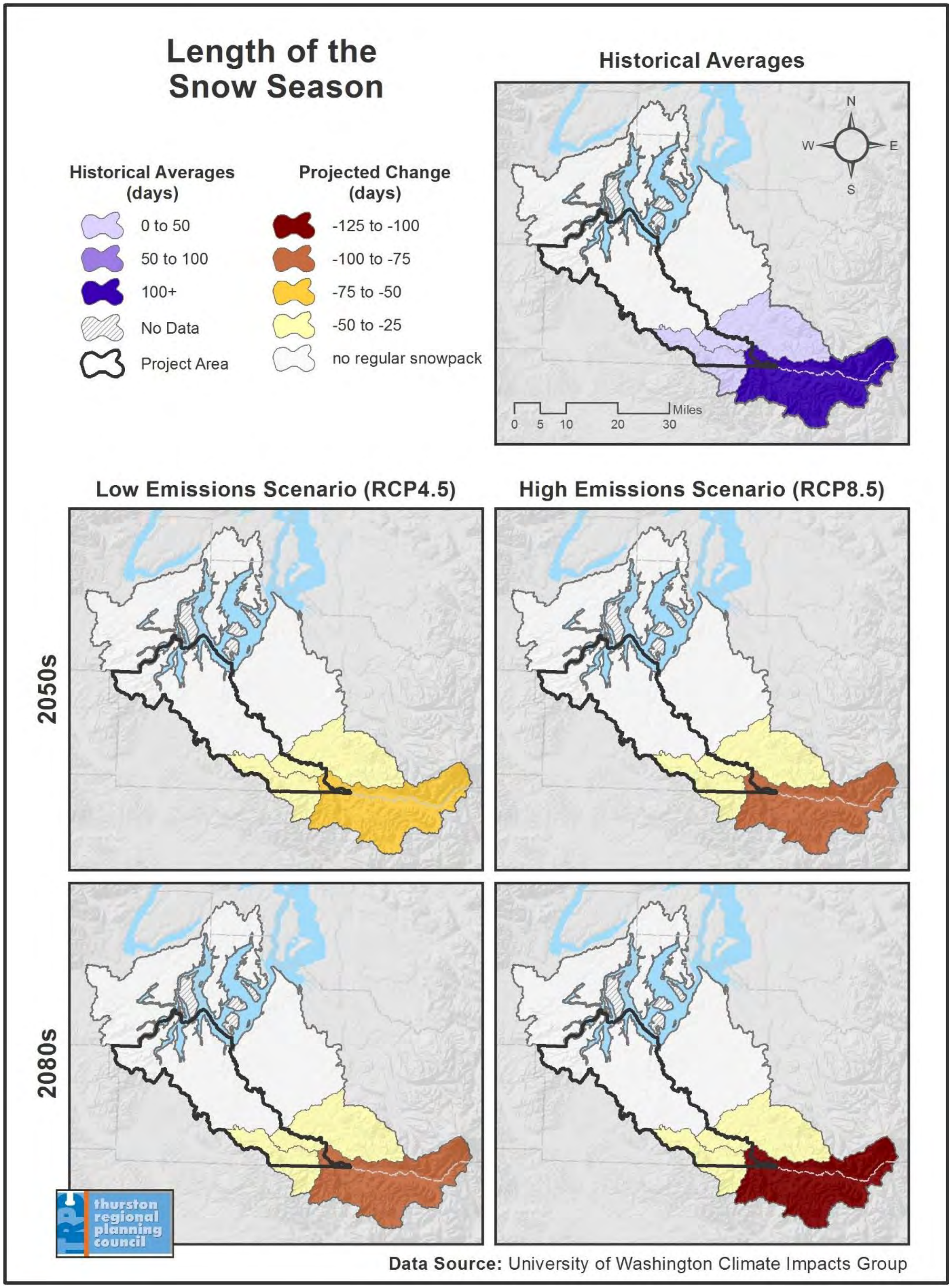

Figure 18. Projected changes in length of snow season amid South Puget Sound watersheds per emissions scenarios. ***Source:*** *Adapted from Figure 13b in Appendix B of Mauger et al., 2015.*

3: Freshwater Ecosystems

As noted previously, climate models project a shift to more rain-dominant conditions across the Puget Sound region as a result of progressively warmer air temperatures during the 21st century. This would result in higher runoff and streamflow during cooler months but the opposite during warmer months. The analysis below examines the effects of such changes on surface and subsurface waters.

…

3.1: Streams

Precipitation and stream temperature, timing and volume are linked inextricably and are key indicators of a watershed's health.

Major winter rainstorms can flood streams with sediment and fast-moving runoff that degrades water quality and critical habitat [*Figure 19, right*]. Fish eggs and benthic macroinvertebrates (small organisms that cycle nutrients and occupy an important place in the food web) are especially vulnerable to scouring, sediment-laden streamflow associated with major storm events.

Conversely, dry summers can leave streams with low, slow-moving flows and high temperatures that harm freshwater organisms and increase competition for water among farms, utilities and other users. Pollution from runoff and other sources can exacerbate the effects of such changes in stream temperature and volume.

Figure 19: Fast-moving water removed riparian vegetation along a rural stretch of the Deschutes River during the winter of 2015-'16, making the streambank vulnerable to erosion. ***Source:*** *TRPC*

Water Volume Vulnerability

Across the Puget Sound region, summer streamflow volume — which is influenced by runoff — is projected to decrease by 24-30 percent, on average, for the 2080s (Mauger et al., 2015). Within South Puget Sound watersheds, changes in summer runoff will be greatest amid the headwaters of the Deschutes and Nisqually rivers — higher-elevation areas with working forests [*Figure 20, on pg. 33*]. For example, in the watershed unit that stretches from Alder Lake to Mount Rainier, summer runoff is projected to decline 40-50 percent for the 2080s per the low emissions scenario; summer runoff is projected to decline 50-60 percent per the high emissions scenario.

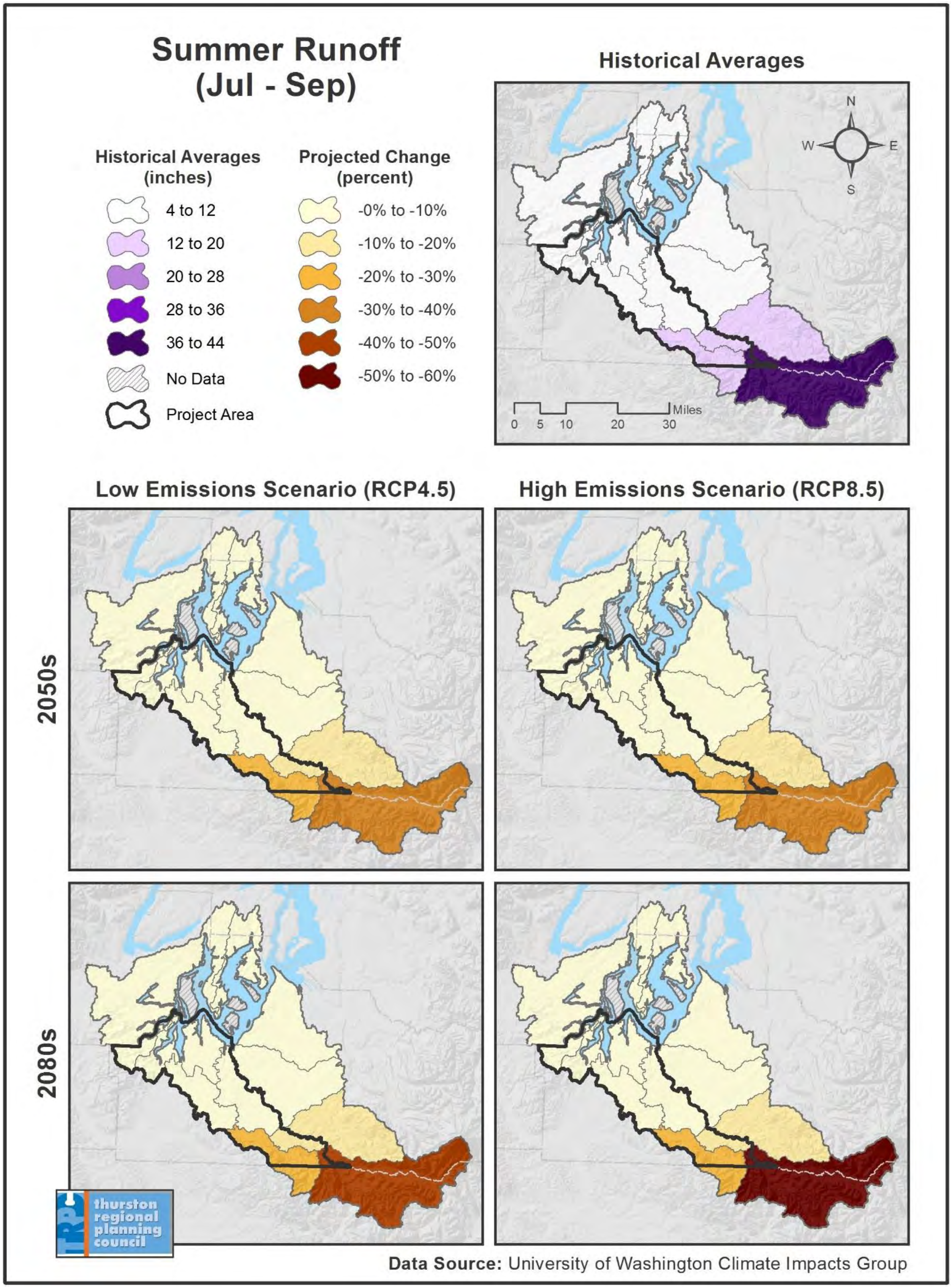

Figure 20. Projected changes summer runoff amid South Puget Sound watersheds per emissions scenarios. ***Source:*** *Adapted from Figure 15b in Appendix B of Mauger et al., 2015.*

The resultant slower, warmer water could stress fish, reduce suitable spawning habitat and alter migration (Mauger et al., 2015). A shift to more winter precipitation, however, will also pose challenges (e.g., degraded habitat and die-offs) for fish and other species that have evolved around predictable spring peak flows. The table below [*Figure 21*] estimates the impact of such changes in the Nisqually Watershed, which is projected to shift from a mixed rain-and-snow watershed (i.e., a watershed that receives 10-40 percent of its precipitation as snow) to a rain-dominant watershed (i.e., a watershed that gets less than 10 percent of its precipitation as snow) for the 2080s (Mauger et al., 2015).

Nisqually Watershed	
Indicator	**Change**
River miles with August stream temperatures in excess of thermal tolerances for fish	+24 miles (*adult salmon*) +179 miles (*char*)
Streamflow volume associated with 100-year (*1 percent annual probability*) flood event	+18% (*range: -7% to +58%*)
Summer minimum streamflow volume	-27% (*range: -35% to -17%*)
Peak streamflow timing (*days earlier*)	-34 days (*range: -45 to -25 days*)

Figure 21. Projected changes in Nisqually River streamflow timing, temperature and volume for the 2080s per a "moderate" emissions scenario. ***Source:*** *Adapted from Mauger, et al., 2015*

The UW GIC did not model future streamflow for the Deschutes and Kennedy-Goldsborough watersheds individually because each is projected to remain a rain-dominant system. Historical data collected by Thurston County, however, shows that the Deschutes River's summer streamflow volume has declined gradually since the 1950s [*Figure 22, below*], which is consistent with the projected trend for Puget Sound region streams.

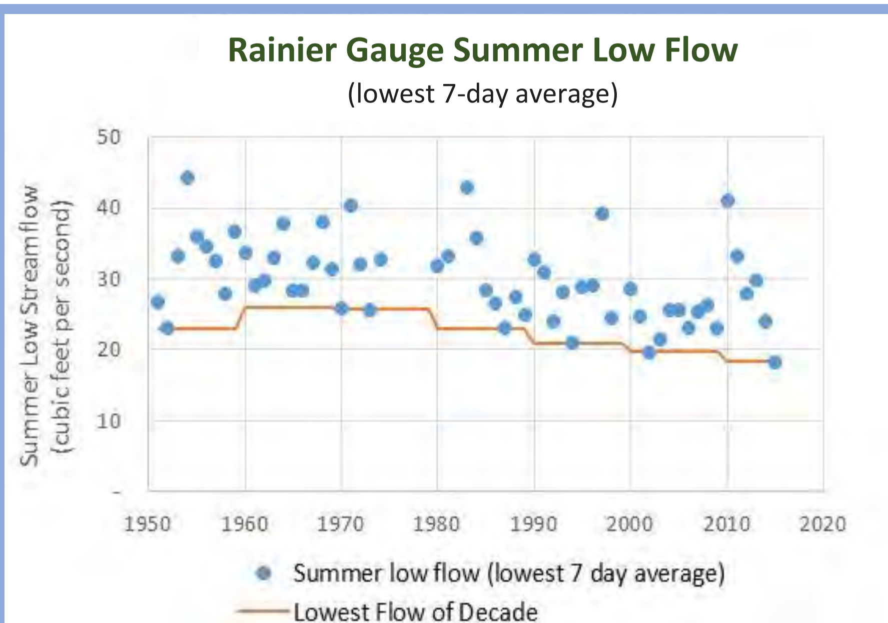

Figure 22. Where useful, this assessment uses local examples to show historical changes. The graphs below show how Deschutes River record low summer flows, as measured at Thurston County's Rainier gauge, have declined gradually since the mid-20th century. ***Source:*** *TRPC, using Thurston County data*

Looking ahead, winter runoff [*Figure 23, on pg. 35*] and streamflow in the Deschutes and Nisqually rivers would be higher as a result of more winter precipitation falling as rain amid southeastern Thurston County and surrounding highlands in Pierce and Lewis counties.

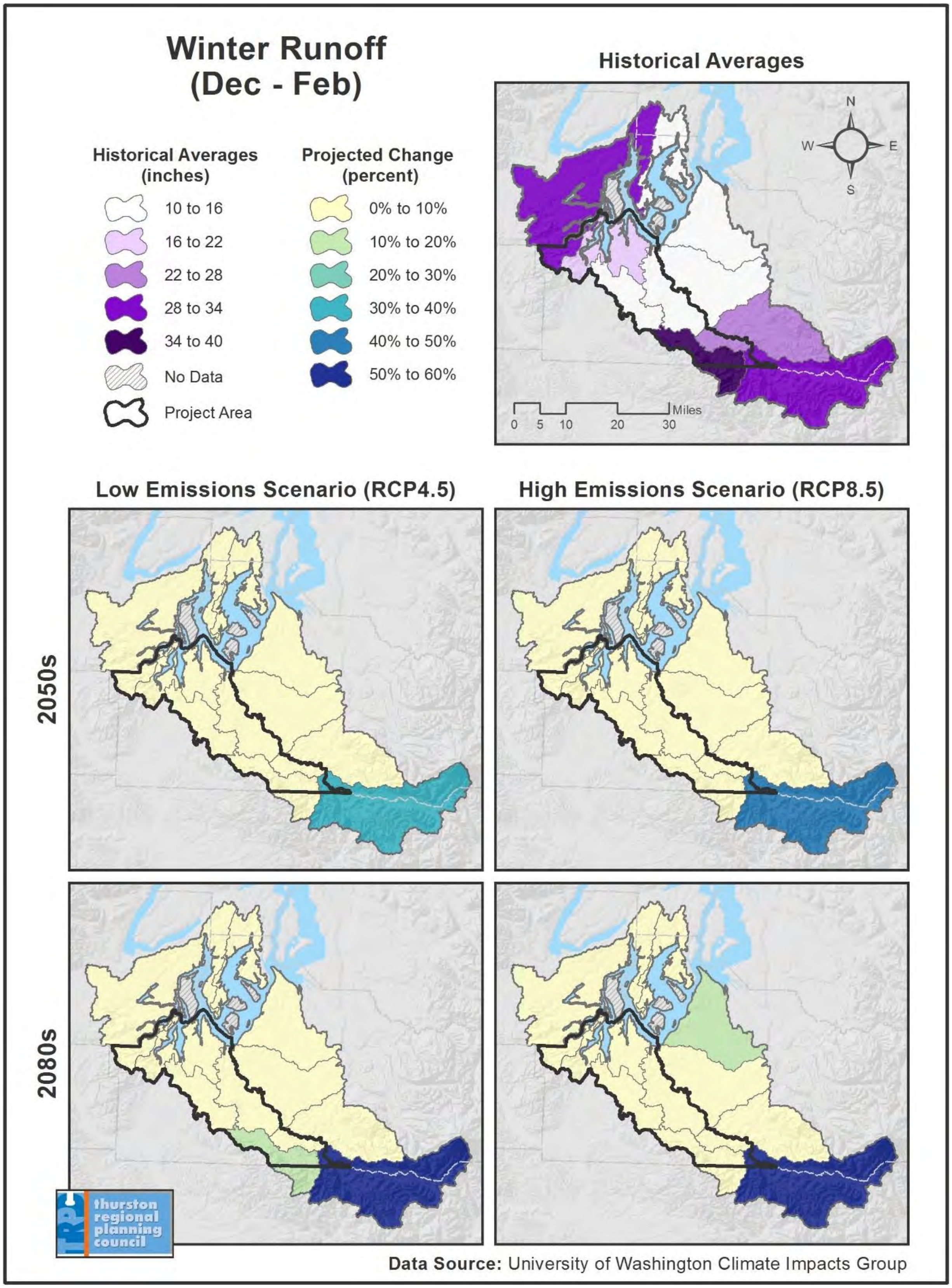

Figure 23. Projected changes winter runoff amid South Puget Sound watersheds per emissions scenarios. ***Source:*** *Adapted from Figure 14b in Appendix B of Mauger et al., 2015.*

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Hydropower Vulnerability

Projected changes in precipitation and streamflow are expected to affect the extent of glaciers on Mount Rainier and productivity of hydropower dams on the Nisqually River and other Pacific Northwest rivers. Mount Rainier's glaciers declined about 14 percent in volume between 1970 and 2008 (Mauger et al., 2015). The Nisqually Glacier's retreat [*Figure 24, below*] is adding to sediment loads aggregating in the Nisqually River and increasing flooding risks. Tacoma Power's Alder and LaGrande hydropower dams ameliorate the problem by holding back sediment at the 3,000-acre Alder Lake (USGS, 2012). This build-up could become a long-term problem, however, because it diminishes water storage capacity behind the dams, which provide power to roughly 43,000 households in Pierce County (Maurer, 2016). Added to this, organic materials that aggregate and decompose in such reservoirs emit greenhouse gases (Mooney, 2016).

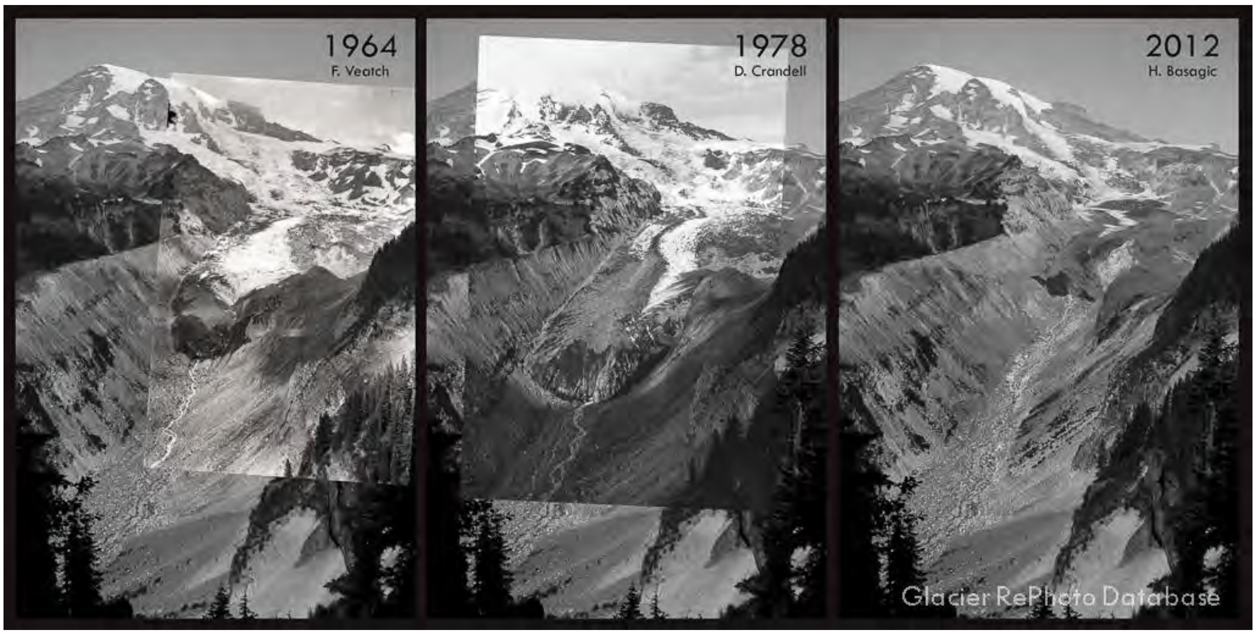

Figure 24. The Nisqually Glacier on Mount Rainier's southern flank [*pictured*] advanced slightly during the 1960s and 1970s but has retreated significantly in the decades since.
Source: *Glacier RePhoto Project Database (Basagic, 2013).*

In coming decades, the Nisqually River is expected to shift to increased early winter peak flows and decreased flows during the spring and summer, according to the UW CIG, which analyzed streamflow into Alder Lake at the request of Tacoma Power (Lee et al., 2015). The watershed is projected to shift from a rain-snow mix watershed with two periods of peak runoff (early winter and spring) to a rain-dominant watershed with peak flows in winter. In the near term, glacial melt may augment summer streamflow as temperatures warm. However, the supply of meltwater is projected to decline sharply by the end of the 21st century (Mauger et al., 2015).

Decreasing summer streamflow will make it harder to balance competing demands for water across the growing region (Hamlet et al., 2010). State law requires that Tacoma Power and other hydropower producers release enough water from behind their dams to support instream resources and uses, including fish, wildlife, recreation, aesthetics, water quality and navigation (Pacheco, 2016).

Pacific Northwest hydropower production is projected to decrease by 1-4 percent annually during the 2020s (increase by 0.5-4 percent in winter, and decrease by 9-11 percent in summer); winter increases and summer decreases for the 2040s and 2080s would be more pronounced (Hamlet et al., 2010). Meanwhile, residential cooling demand is projected to increase to 4.8-9.1 percent of Washington's total energy demand for the 2080s, relative to 1970-1999, due to the combined effects of higher air temperature, population growth, and greater use of air conditioners. Warmer winters, conversely, could lower residential heating demand and utility bills.

Climate change is also a consequential issue for Puget Sound Energy, which has 120,000 electric customers in Thurston County [*Figure 25, below*] and 1.1 million electric customers in Western Washington counties collectively. Hydropower accounts for 36 percent of the electricity PSE delivers to its customers; coal and natural gas account for 35 percent and 24 percent, respectively, while nuclear wind and other sources account for the rest of the utility's energy portfolio (Puget Sound Energy, 2016). The company owns and operates two dams — on the snowmelt-fed Baker and Snoqualmie rivers — and it purchases additional power from Central Washington public utility districts with Columbia River dams.

The investor-owned utility's 2015 Integrated Resource Plan — which uses scenarios to evaluate energy supply and demand decisions over the ensuing 20 years — projects that PSE's base peak demand[16] growth rate will average 1.6 percent annually (almost 1,000 additional megawatts, from 2015-2035) (Puget Sound Energy, 2015). The resource plan does not call for additional hydropower generation capacity. Rather, the plan targets significant investments in energy efficiency, wind power generation and other measures to meet projected demand and comply with renewable portfolio standards.[17]

Figure 25. Mount Rainer looms over transmission lines in Thurston County, where Puget Sound Energy has about 120,000 electric customers. ***Source:*** *TRPC*

[16] This term refers to the minimum amount of electricity needed when consumer demand is highest (e.g., during the hottest afternoons when air conditioner use is highest).

[17] Washington state's Renewable Portfolio Standard (RCW 19.285) requires large utilities to obtain 15 percent of their electricity from new renewable resources (e.g., solar and wind) by 2020 and to undertake cost-effective energy conservation measures.

Water Temperature & Salmonid Vulnerability

Stream temperature is a function of both flow and shading, as shallow rivers with sparse riparian vegetation are warmer than deep rivers with dense riparian vegetation. Historically, average annual stream temperatures have been warmest amid South Puget Sound's lowlands, where most of Thurston County's urban development is concentrated. Stream temperatures have been coolest in the less-developed, higher-elevation areas, where there is generally more riparian shade, steeper gradients and faster-moving water [*Figure 28, on pg. 40*].

The shifting hydrologic patterns noted above are projected to increase water temperatures in both Thurston County's highland and lowland streams during the 21st century. The average annual temperature of most streams within the project area is projected to rise roughly 5°F for the 2040s and 2080s [*Figures 29 & 30, on pgs. 41-42*] per a moderate emissions scenario[18], according to U.S. Forest Service modeling. That figure is similar to the UW CIG assessment's 4°F to 4.5°F estimate for the broader Puget Sound region, per the same scenario and time period.

Temperature is consequential for salmonids. Juveniles that develop in streams (e.g., Chinook, coho and chum salmonids) and ocean-going adults that swim back up streams to spawn [*Figure 26, right*] are vulnerable to temperature changes because they have evolved within certain parameters (Mauger et al., 2015).

Figure 26. A chum salmon swims up McLane Creek, south of Eld Inlet, to spawn in late 2013. ***Source:*** *TRPC*

Several salmon species listed under the endangered species act, including Chinook and coho, spawn in streams amid the project area. To protect these species, Washington State has defined water temperature standards of 16°C (60.8°F) for summer salmon survival and 17.5°C (63.5°F) for spawning, rearing and migrating.

Theoretically, suitable conditions for salmonids and other aquatic species would shift upstream to higher elevations as air and water temperatures warm. Some fish may even shift their migration timing earlier as stream temperature and volume conditions change.

Key challenges remain, however: Some salmonids may have lower migration success because they still must pass through warm areas to reach the cooler habitat. Added to this, projected changes in streamflow and volume may expand the range of pathogens, which could compromise the immunity of stressed fish, as well as an expand the range of warm water-adapted invasive fish that compete with or prey on salmonids (Mauger et al., 2015).

[18] The U.S. Forest Service's NorWeST database models stream temperatures for the 2040s and 2080s using the A1B scenario from a 2007 IPCC report. A1B is similar to the 2013 IPCC report's moderate RCP 6.0 scenario, in which emissions increase gradually until stabilizing during the final decades of the 21st century.

Diversity may provide an important hedge against fish species decline, as sub-populations that are more suited to warmer conditions would theoretically survive and reproduce in greater numbers (Mauger et al., 2015). Another factor critical to the survival of salmon and other organisms during warmer summer months would be the persistence of riparian vegetation and cold-water refugia — such as shade-covered side channels and deep pools — along streams that drain into Puget Sound.

Maintaining or increasing riparian shade cover [*Figure 27, below*] would help mitigate the impacts of climate change amid the Deschutes River and other waterbodies that already struggle with pollution and other development-related stressors.

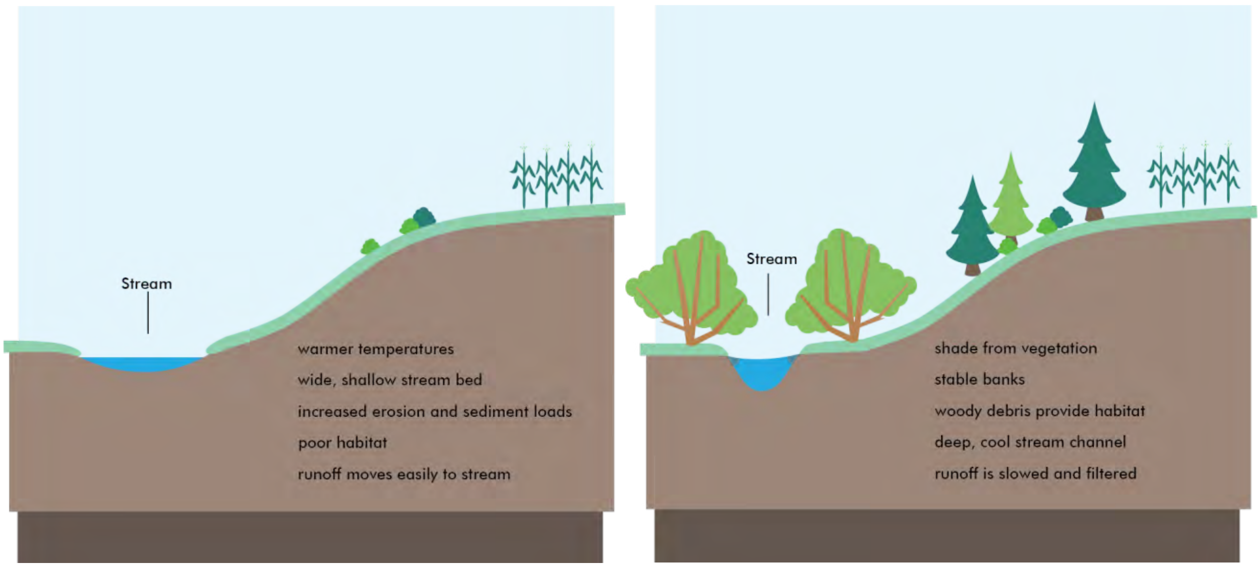

Figure 27. Maintaining or increasing riparian areas decreases stream temperature, runoff, erosion and improves overall habitat for salmon and aquatic species. ***Source:*** *TRPC*

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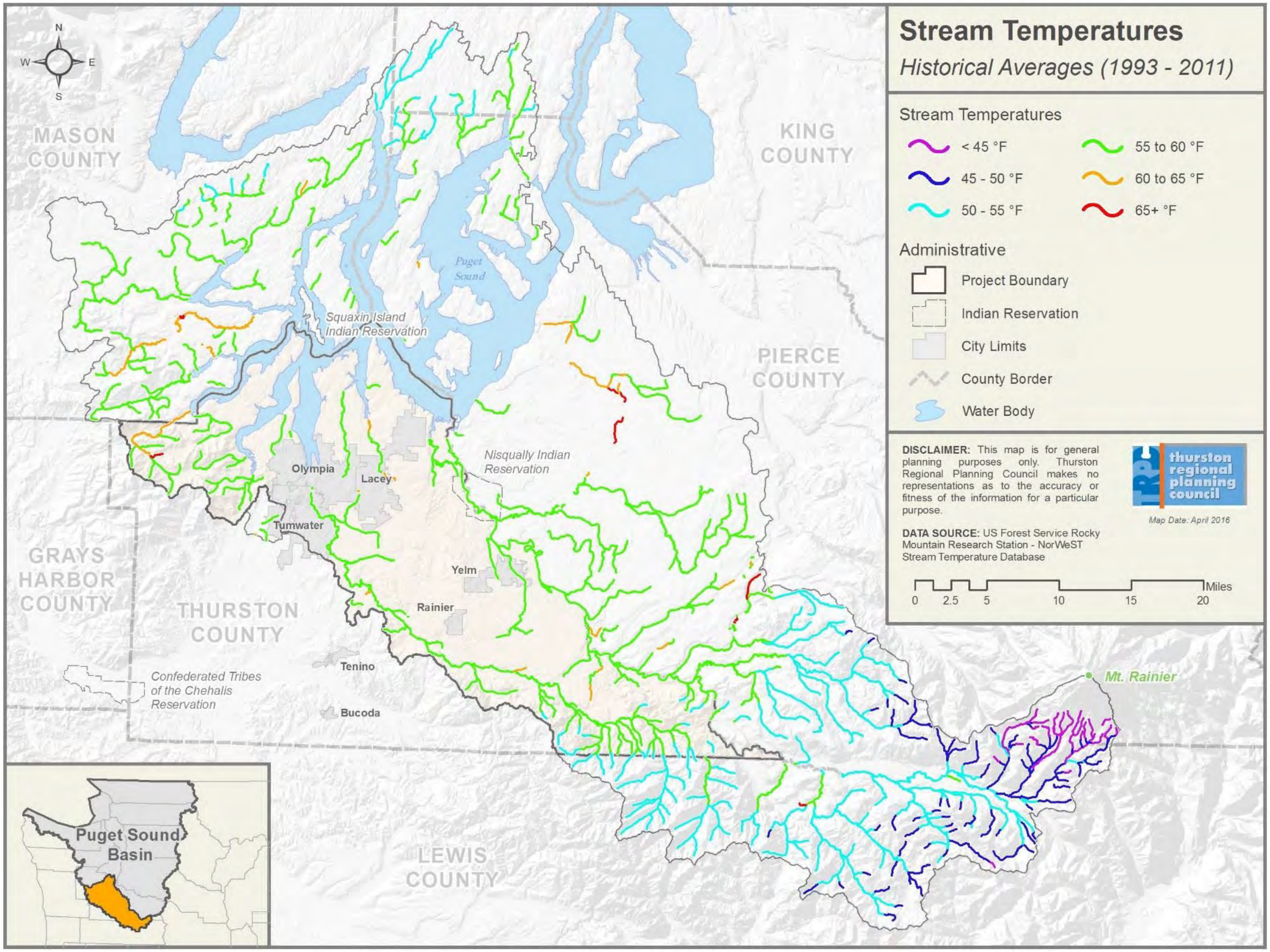

Figure 28: Historical annual average temperature amid South Puget Sound watersheds.

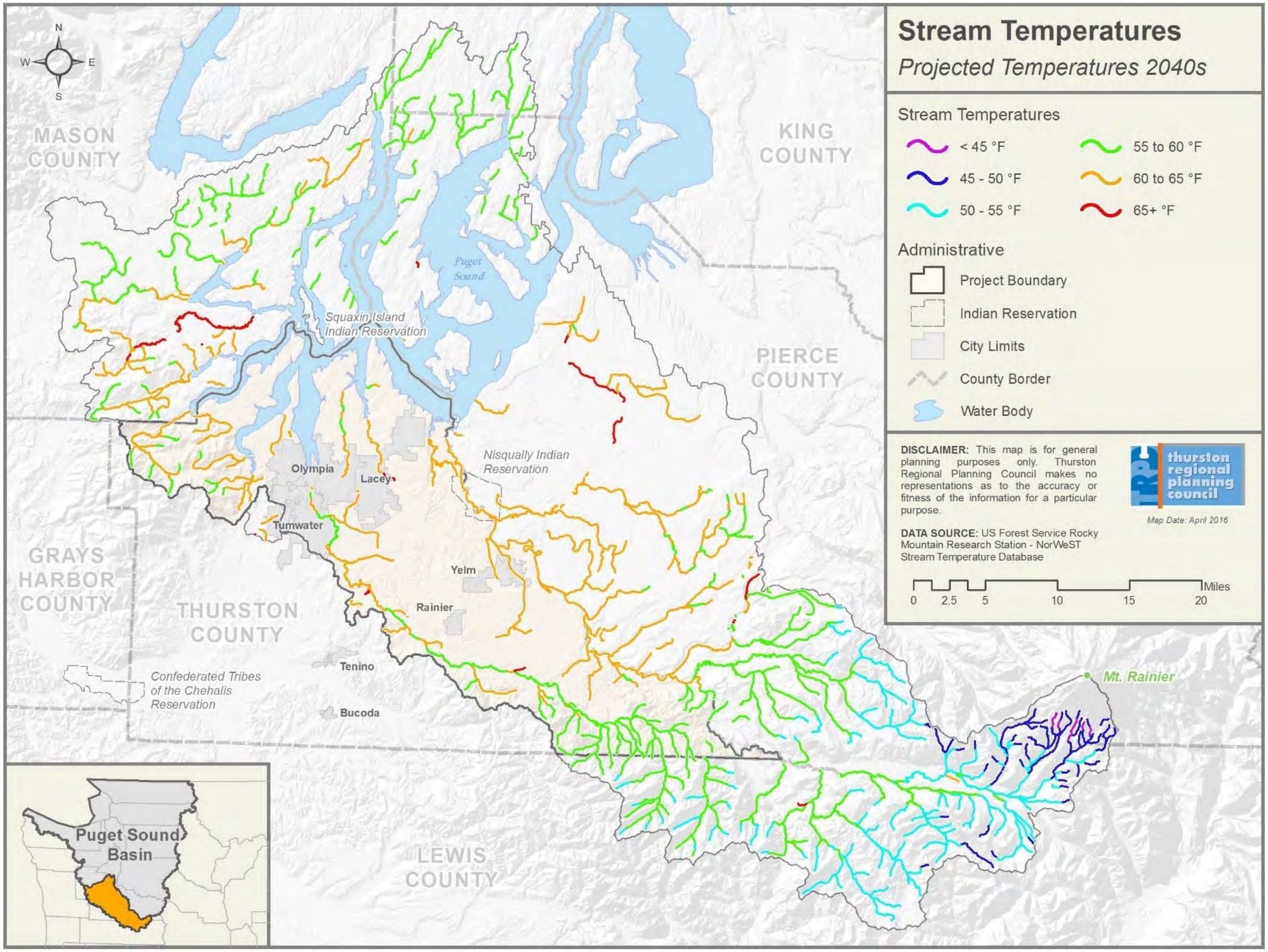

Figure 29: Projected (2040s) annual average temperature amid South Puget Sound watersheds per a moderate emissions scenario.

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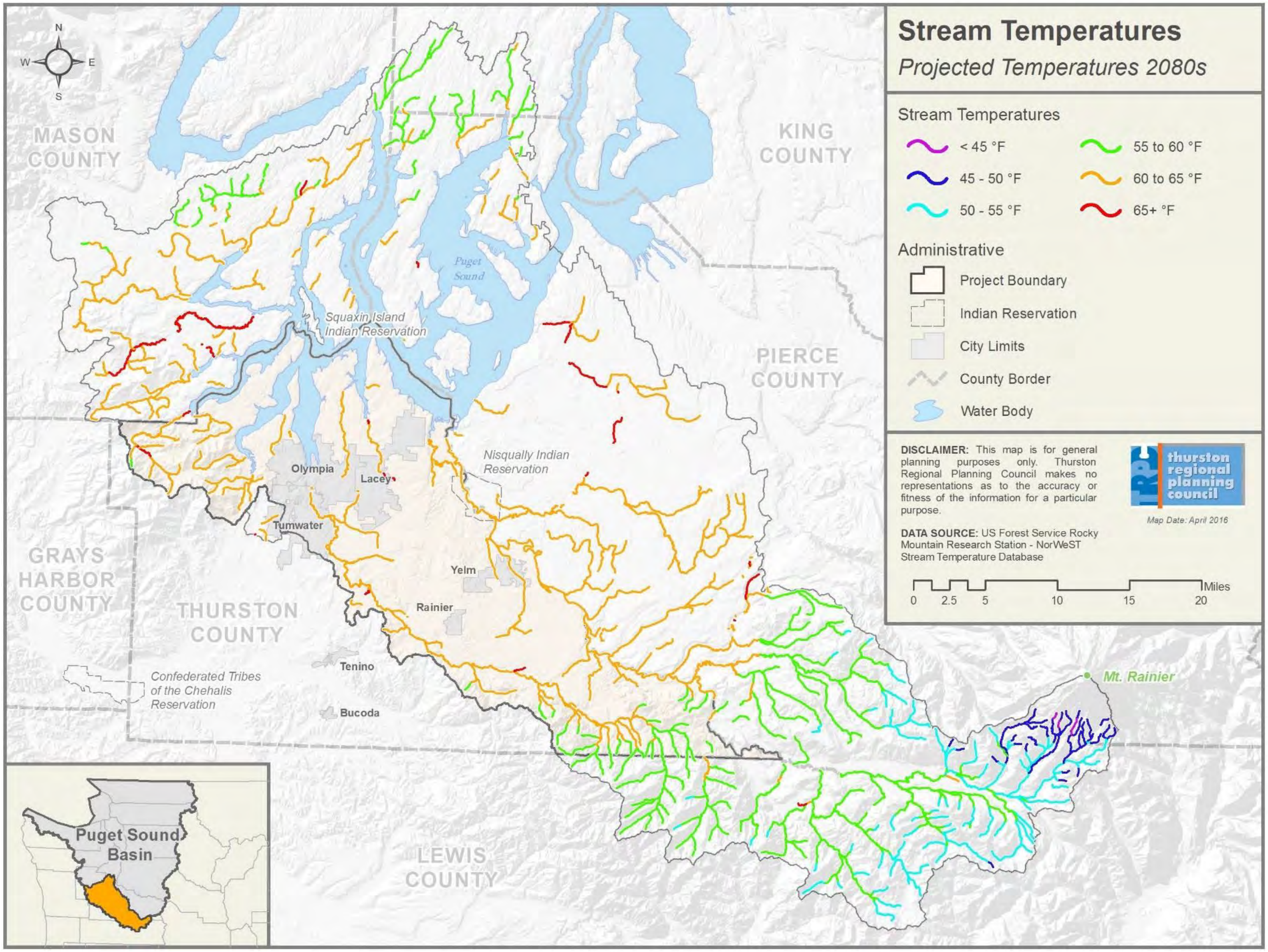


Figure 30: Projected (2080s) annual average temperature amid South Puget Sound watersheds per a moderate emissions scenario.

Water Quality Vulnerability

Shifts in the region's hydrologic cycle this century could complicate local government efforts to comply with state water-quality standards — particularly with regard to lowering water temperature, dissolved oxygen, and sediment loading in streams and other waterbodies.

The federal Clean Water Act requires that Washington develop a Total Maximum Daily Load (TMDL) — the maximum amount of pollutant (e.g., fecal coliform bacteria from human and animal waste) a surface waterbody can receive and still meet water-quality standards — for each waterbody on the state's 303(d) list.[19] The U.S. EPA has approved state implementation plans to address water-quality impairments in all three watersheds (WRIAs 11, 13 and 14) within the Thurston Climate Adaptation Plan's project area [*Figure 31, below*], and the Washington State Department of Ecology conducts monitoring to assess the effectiveness of local efforts to comply with the TMDLs.

TMDLs in Thurston County Watersheds

Watershed	Pollutants in Waterbodies	Status
Nisqually Watershed (WRIA 11)	Nisqually River: Dissolved Oxygen; Fecal Coliform	U.S. EPA approved implementation plan
Deschutes Watershed (WRIA 13)	Deschutes River and tributaries: Dissolved Oxygen; Fecal Coliform; pH; Sediment; Temperature	State Department of Ecology submitted implementation plan to U.S. EPA for approval
	Budd Inlet and Capitol Lake: Dissolved Oxygen; Phosphorous	State Department of Ecology developing implementation plan
	Henderson Inlet: Dissolved Oxygen; Fecal Coliform; pH; Temperature	U.S. EPA approved implementation plan
Kennedy-Goldsborough Watershed (WRIA 14)	Totten/Eld Inlets: Fecal Coliform; Temperature	U.S. EPA approved implementation plan
Upper Chehalis Watershed (WRIA 23)[20]	Upper Chehalis River: Fecal Coliform; Temperature; Dissolved Oxygen; Ammonia-N; BOD (5-day)	U.S. EPA approved implementation plan

Figure 31. The table above shows polluted waterbodies within Watershed Resource Inventory Areas (WRIAs) that over lay parts of Thurston County. ***Source:*** *TRPC, adapted from Washington State Department of Ecology table (WDOE, 2016).*

[19] Washington's 303(d) list, named for a section of the federal Clean Water Act, includes lakes, streams and inlets for which drinking, aquatic habitat and other beneficial uses are impaired by pollutants such as fecal coliform and high temperature. Such waterbodies fall short of the state's water-quality standards and are not expected to improve within two years (WDOE, 2016).

[20] The Upper Chehalis Watershed (WRIA 23) covers an area of southwestern Thurston County that drains into the Pacific Ocean and is therefore not include in the Thurston Climate Adaptation Plan project area.

In 2015, Ecology released a draft Water Quality Improvement Report / Implementation Plan for the Deschutes River TMDL area with numeric load allocations for temperature, bacteria, dissolved oxygen, pH, and fine sediment. Thurston County and other partners in the watershed are currently working on ways to address the TMDL.

In terms of improving water temperature, the most important implementation actions are to conserve forested riparian buffers and establish new ones along streams that have become degraded by development (e.g., clearing land for grazing animals or building homes) (Thurston County, 2015). Additional management actions include reducing fecal coliform bacteria during the summer months, stabilizing channels that contribute sediment (e.g., with downed trees), reducing nutrient sources, and quantifying water withdrawals in the watershed.

Figure 32. Trees planted adjacent to the Deschutes River near Rainier will provide multiple ecosystem services as they mature. ***Source:*** *TRPC*

Some of these implementation actions would have climate change adaptation and mitigation co-benefits. For example, trees planted in the riparian zone along streams [*Figure 32, right*] could help reduce erosion associated with more intense winter storms, shade and cool water for fish and amphibians, and sequester carbon dioxide — the main heat-trapping gas that contributes to climate change.

Such on-the-ground projects would not be immune to natural hazards exacerbated by climate change, however. More frequent and intense storm events and associated floods and landslides [*Also see Sections 2.3, 6.2 and 6.3*] could erode shade-providing riparian areas and increase sediment loading in streams.

3.2: Lakes

The shifting hydrologic cycle, compounded by nutrient loading, could make lake conditions more suitable for algal blooms that degrade water quality and pose health risks for humans, fish and animals.

Water Temperature & Quality Vulnerability

Many Thurston County lakes struggle today with algal blooms — a rapid increase in photosynthetic algae and cyanobacteria when water temperatures are warm and nutrients such as nitrogen and phosphorous are present. In Thurston County, common sources of such pollutants include septic systems and fertilizers applied at homes and farms.

Algal blooms can be harmful when they starve a waterbody of sunlight and oxygen [*Figure 33, below*]. Some algae even produce toxins that can poison people and animals that go near the water, consume the water, or swim in the water (CDC, 2016).

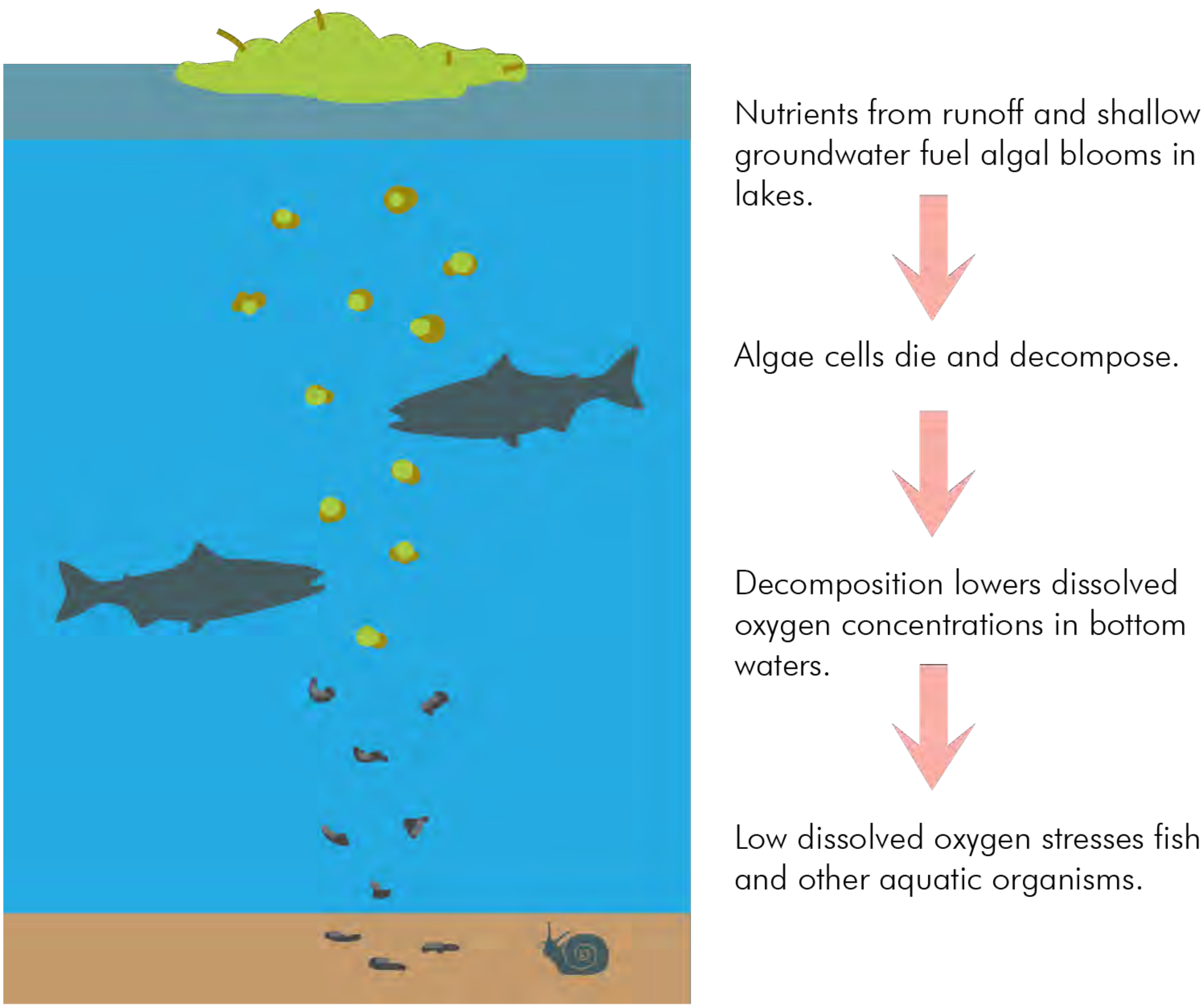


Figure 33: Algal blooms block sunlight and reduce dissolved oxygen essential for fish and other aquatic organisms.
Source: *TRPC*

Warmer surface water may shift earlier in the year lake thermal stratification and the spring plankton bloom, a critical piece of the freshwater food web (Mauger et al., 2015). Higher water temperatures may also support the growth of algae in lakes (WDFW, 2011).

Water temperature strongly influences the growth of cyanobacteria and harmful algal blooms (USGCRP, 2016). Water temperatures of at least 77°F favor cyanobacteria over less-harmful types of algae.

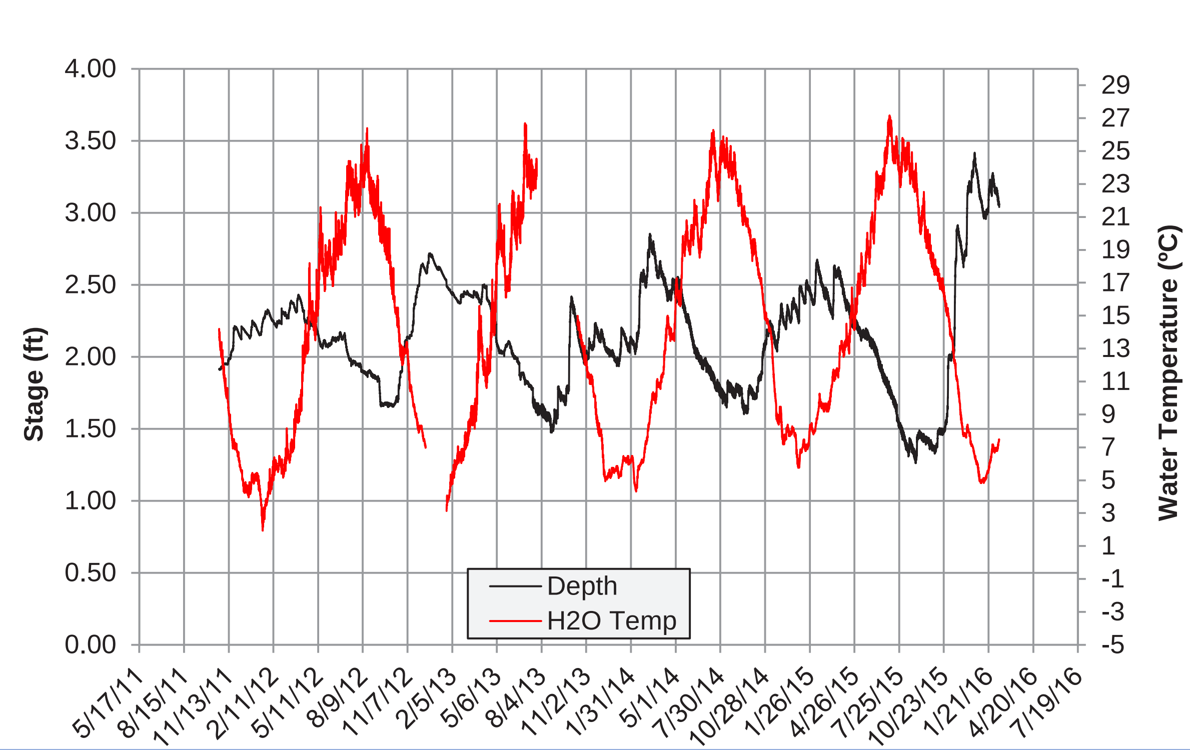
Several lakes within the project area already struggle with this issue. Toxic blue-green algal blooms occurred in 2004 and 2010/11 in Lake Lawrence, which is on Washington State's Clean Water Act Section 303(d) list of impaired water bodies for total phosphorus (Roberts et al., 2012).

Toxic blue-green algal blooms also occurred in Long and Pattison lakes, amid a stretch of unseasonably warm and dry weather last spring, prompting Thurston County to advise people to temporarily avoid the popular swimming, boating and fishing sites [*Figure 34, below*]. Lake water samples taken April 4, 2016, detected the algae toxin *Anatoxin* — which affects the nervous system — at about 20 micrograms per liter (µg/L), well above the state standard of 1 µg/L (Thurston Talk, 2016). The toxin level at Pattison Lake was 21.82 µg/L, and the level at Long Lake was 19.27 µg/L (King County, 2016).

Figure 34: Swimmers enjoy a July 2016 dip in the water at Long Lake Park, a hot spot for summer recreation activities.
Source: *TRPC*

Figure 35 [*on pg. 47*] shows that, historically, Long Lake's water temperature rises as its depth decreases. Given this relationship, the projected increase in summer temperature and decrease in summer precipitation could raise the risk of algal blooms in coming years.

Figure 35. The graph below shows the inverse relationship between the water depth and temperature amid Long Lake, as recorded at Holmes Island, during the October 2011-February 2016 period. ***Source:*** *Thurston County*



3.3: Wetlands

Wetlands — which provide critical habitat for amphibians, waterfowl and other organisms — would also be vulnerable to changes in precipitation volume, sea level, and air and water temperature in the decades ahead.

Thurston County's wetlands [*Figure 36, on pg. 48*] include tidal and non-tidal marshes that are continually or frequently inundated by surface water and/or groundwater. Non-tidal marshes are mostly freshwater wetlands on poorly drained soils or near lakes or streams (EPA, 2016); tidal marshes include freshwater, brackish and saltwater wetlands near the Puget Sound coast.

There have been very minor observed changes (within the margin of error) in wetland extent and type within the project area in the past 20 years. Thurston County was approximately 6.65 percent covered by wetlands in 1996, according to NOAA's Coastal Change Analysis Program (C-CAP) Land Cover Atlas tool, which analyzes general land cover change trends across coastal areas in the United States. By 2010, the figure dropped to approximately 6.63 percent. Of the changes observed, there was a 0.13 percent increase in freshwater (palustrine) wetlands, and a 1.22 percent decrease in saltwater (estuarine) wetlands.

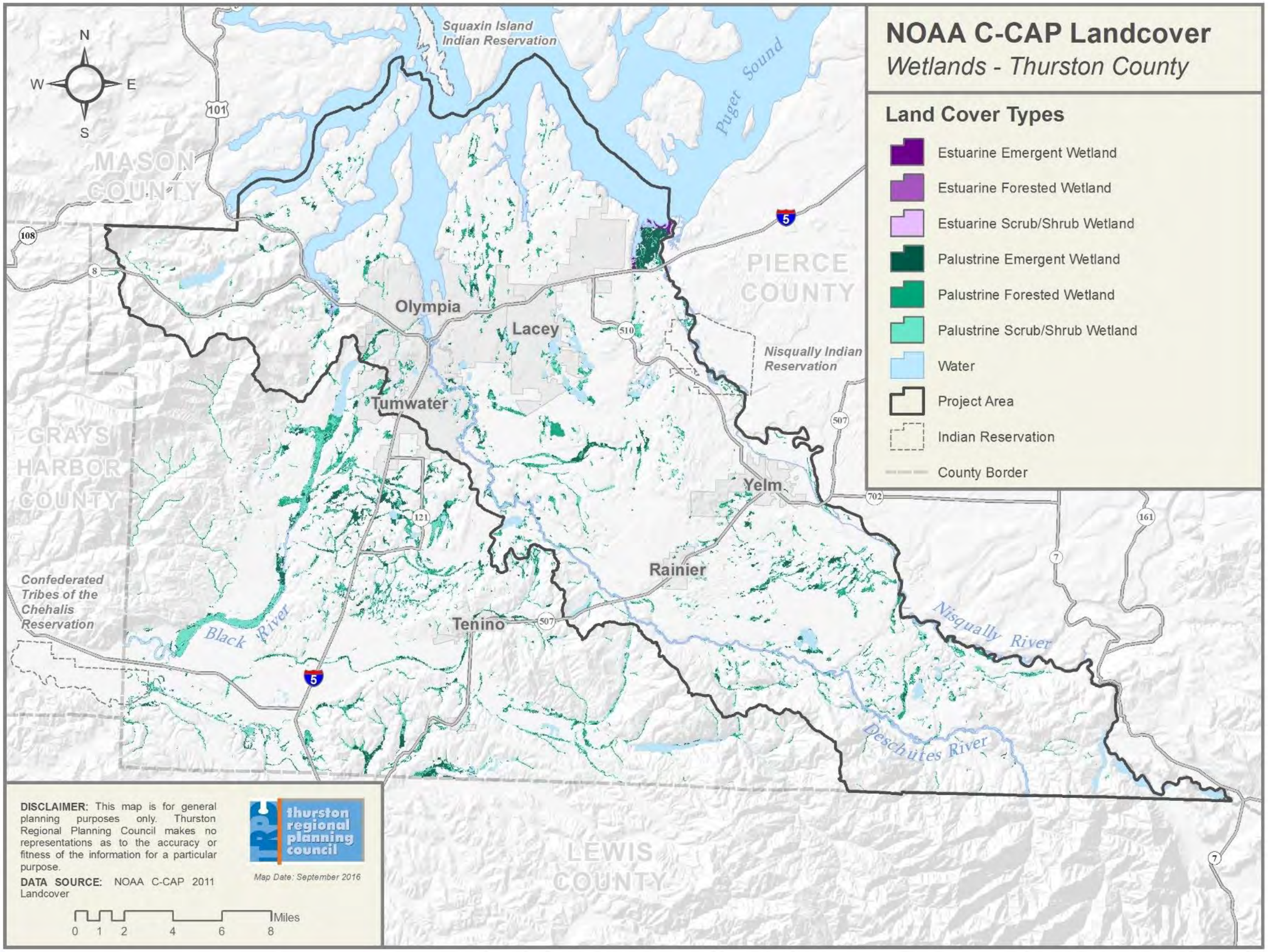


Figure 36: This map shows the current extent of freshwater (palustrine) and saltwater (estuarine) wetlands in Thurston County. ***Source:*** *TRPC, using NOAA C-CAP data*

The projected impacts of sea-level rise on Thurston County's tidal wetlands and other coastal habitat have been studied extensively and are summarized in this assessment's next section, Marine Ecosystems [*See Section 4.1, on pg. 54*]. Non-tidal wetlands farther inland are vulnerable to changes in precipitation and air temperature, which could reduce the amount of water replenishing and cooling wetlands.

If Thurston County's freshwater wetlands decrease in extent, as some models project [*Figure 47, on pg. 64*], frogs and other cold-blooded amphibians would be among species affected most. Some populations may be able to adapt to temperature changes — e.g., shifting in latitude and elevation (Mauger et al., 2015). Other populations will become too warm or dry, resulting in less growth or death.

Thurston is one of five Washington counties with the Oregon spotted frog [*Figure 37, right*], which is listed as threatened under the federal Endangered Species Act (USFWS, 2016). The amphibian prefers large marshes with abundant plants that provide opportunities for basking or taking cover.

Figure 37: Oregon spotted frog
Source: *Thurston County*

In addition to providing frog habitat, local wetlands provide ecosystem services such as water purification, flood protection, shoreline stabilization, groundwater recharge, and streamflow maintenance (WDOE, 2016). Thurston County's nearly 34,000 acres of wetlands provide between $109 million and $3.7 billion in ecosystem service benefits to the region's economy annually (Flores, et al., 2012).

3.4: Groundwater

Bigger winter storms and high groundwater flooding can result in less infiltration into the soil and aquifers, and more runoff into streams and Puget Sound. Summer droughts, in turn, could spur more groundwater pumping when surface water is scarce. Such direct and indirect climate impacts, coupled with sea-level rise, could make Thurston County's coastal freshwater aquifers more vulnerable to water quality and quantity risks. The following section examines the vulnerability of groundwater — the main source of drinking water in Thurston County — to saltwater intrusion and inundation, pathogen and pollution contamination, and drought and overconsumption.

Saltwater Intrusion & Inundation Vulnerability

The boom and bust cycle of precipitation described above could leave coastal freshwater aquifers more vulnerable to the intrusion of denser saltwater from Puget Sound as sea levels rise by an estimated 24 inches this century [*See Section 4.1, on pg. 54*]. Salty water can be unhealthy for people sensitive to sodium (e.g., those with high blood pressure) (Hayes, 2016).

The direct impacts of saltwater intrusion and inundation on groundwater are likely to be greatest in places with low topographic relief and very low hydraulic gradients between freshwater and saltwater (e.g., downtown Olympia, Nisqually Valley, Steamboat Island area) (Pitz, 2016). Increases in near-shore pumping rates when less surface water is available during summer months (an indirect response to climate change) could exacerbate the risk of saltwater intrusion in such places.

Some Thurston County municipalities and tribes have already begun adapting to climate-related threats. In 1995, Olympia applied to the state Department of Ecology to transfer its municipal water rights from McAllister Springs and Abbott Springs to a new McAllister Wellfield upgradient of the springs. Engineers had deemed McAllister Springs — the City's primary drinking water source at the time — susceptible to saltwater intrusion from nearby Puget Sound, as well as vulnerable to hazardous transportation spills and microbial contamination (City of Olympia, 2010).

In 2012, Ecology issued Olympia water rights for McAllister Wellfield, which now serves as the City's primary water source, supplemented seasonally by six Group A[21] water system wells (City of Olympia, 2015). Two of these wells, located at Allison Springs, are the City's only drinking water sources deemed at risk of saltwater intrusion due to their proximity (about 1,000 feet) to Eld Inlet (Buxton, 2016). The City characterizes the near-term risk as "low" and monitors Allison Springs' groundwater regularly, looking for changes in conductivity and chloride concentration that may indicate influence of saltwater.

The Nisqually Indian Tribe eventually intends to draw water from the McAllister Wellfield to meet future demand. Three wellfields (Cuyamaca, Leschi, and Nisqually), on the Nisqually Indian Reservation, meet the Tribe's current needs. Saltwater intrusion is not deemed a risk for these water sources (Cushman, 2016).

The Tribe plays a leadership role in resources management within the Nisqually watershed to protect water quality and quantity in the Nisqually River. The Tribe recently bought out several properties near the river and discontinued production from their shallow, low-producing wells (Cushman, 2016).

The City of Lacey has 20 wells that draw from three aquifers beneath the city and its unincorporated urban growth area. None of the wells is currently deemed vulnerable to saltwater intrusion (Rector, 2016). However, significant sea-level rise, exacerbated by high tide events, could spur seawater to inundate two of the City's shallow (100 feet deep) wells amid the Nisqually Valley, near where Old Pacific Highway crosses the Nisqually River.

Lacey also has three deep (450-550 feet) active production wells in Hawks Prairie that are screened below sea level. The City manages pumping at the wells to avoid causing saltwater intrusion of the underlying aquifer and operates a monitoring network to provide early warning detection.

While Lacey has not seen any indication of saltwater intrusion in this aquifer, a significant change (+1 foot or more) in sea level would likely affect the City's pumping strategies (Rector, 2016). Going forward, Lacey officials contend that the diversity in water supply and ability to pump water between pressure zones — coupled with demand-side strategies such as reducing water consumption — should enable the City's water system to adapt to changes in precipitation patterns and sea levels.

The City of Tumwater's primary water sources are its Palermo Wellfield — immediately west of the Tumwater Valley Municipal Golf Course and Deschutes River — and its Bush Wellfield, located just east of Interstate 5, near Bush Middle School. During the peak summer demand period, five other wells located throughout the incorporated city help meet increased water demand (Tumwater, 2016). All of the wells are comparatively shallow, averaging about 100 feet deep.

Tumwater officials consider sea-level rise a low near-term risk for the City's wells, which are several hundred feet above sea level and several miles south of Budd Inlet (Smith, 2016). However, as part of

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[21] Group A water systems include community water providers with at least 15 residential connections (e.g., the municipal-run water systems in Thurston County); Group B water systems have fewer than 15 residential connections (e.g., small homeowners' associations).

the water systems planning cycle that begins in 2017, the City will begin looking at whether saltwater intrusion could pose a greater risk if sea levels rise and affect the upper Deschutes River (Smith, 2016). The other cities within the project area, Rainier and Yelm, get their water from wells within city limits — far enough away from Puget Sound so as to not be vulnerable to saltwater intrusion or inundation as a result of sea-level rise, according to officials from both cities (Beck, 2016; Van Every, 2016).

Thurston County owns several Group A water systems near the Puget Sound shoreline, including the Tamoshan system, on the low-lying Cooper Point peninsula, and the Boston Harbor system, across Budd Inlet. The County regularly tests the water quality of the community systems' wells — which are more than 500 feet deep — and has detected no signs of saltwater intrusion (Patching, 2016). Even so, as part of a nascent drought-planning effort, County staff members have begun to consider the long-term risks of drinking water contamination associated with climate change.

The Thurston Public Utility District (PUD) also runs several Group A water systems with wells close to Puget Sound. The PUD owns the Lew's 81st well, near Boston Harbor, and tests it regularly for chloride, as required by the State. The PUD has detected no signs of saltwater intrusion (Gubbe, 2016).

The PUD does not conduct such tests for the other Group A water systems it manages near Puget Sound — including Beverly Beach, on Cooper Point; Edgewater and Olympic View, near Steamboat Island; and, Dana Passage, north of Boston Harbor (Gubbe, 2016). The PUD, which provides water to about 3,500 homes, businesses and schools, has not conducted a formal assessment of how climate change could affect its water systems, but the issue has generated interest among the PUD's elected commissioners.

The issue has also generated interest at the state level, and additional guidance to water system managers is coming. The Washington Department of Health's (DOH) Source Water Assessment Program (SWAP) assesses the vulnerability of roughly 6,800 water sources (wells, springs, surface water) operated by about 4,100 Group A water systems across the state. The DOH program looks for potential sources of contaminants, such as oil and chemicals from commercial and industrial sites, but doesn't currently assess the risks of saltwater intrusion or changes in precipitation. The agency acknowledges the risk of saltwater intrusion into the source waters of community water systems near Puget Sound, so in coming years DOH will encourage such system operators to evaluate their vulnerability and consider how they would respond to risks (Hayes, 2016).

Pathogen & Pollution Vulnerability

Prolonged drought, or even reduced seasonal streamflow, can make contaminants more concentrated in wells — the source of drinking water for many rural and urban Thurston County residents. Conversely, extreme rain events and runoff can overwhelm wastewater, septic and stormwater conveyance systems and cause problems such as sewer overflows, basement backups and localized flooding (USGCRP, 2016).

Contamination occurs when microbial pathogens (e.g., bacteria from animal and human waste) and nutrients (e.g., nitrogen and phosphorous from fertilizers) are carried from farms, ranches, suburban neighborhoods, and urban centers into surface and groundwater [*Figure 38, on pg. 52*]. Stormwater is already the leading contributor of pollution of Washington's urban waterways, and such runoff endangers sensitive species and habitats (Adelsman & Ekrem, 2012).

Concentrated contaminants are not a risk for municipal water systems that draw water from deep wells and purify it. However, private water systems that rely on shallow wells (less than 50-100 feet deep) —

especially those at risk for saltwater intrusion or those with low productivity — are likely to be more vulnerable to contamination during drought conditions (Mauger et al., 2015).

Small community or private groundwater wells or other drinking water systems where water is untreated or minimally treated are also highly susceptible to water-borne disease outbreaks in the wake of extreme precipitation events (USGCRP, 2016). For example, increased rainfall and peak streamflow during the winter months could make conditions more suitable for water-borne parasites that cause Cryptosporidiosis, a diarrheal disease that occurs when humans ingest the cysts of *Cryptosporidum parvum* or *Cryptosporidum hominis* (Mauger et al., 2015).

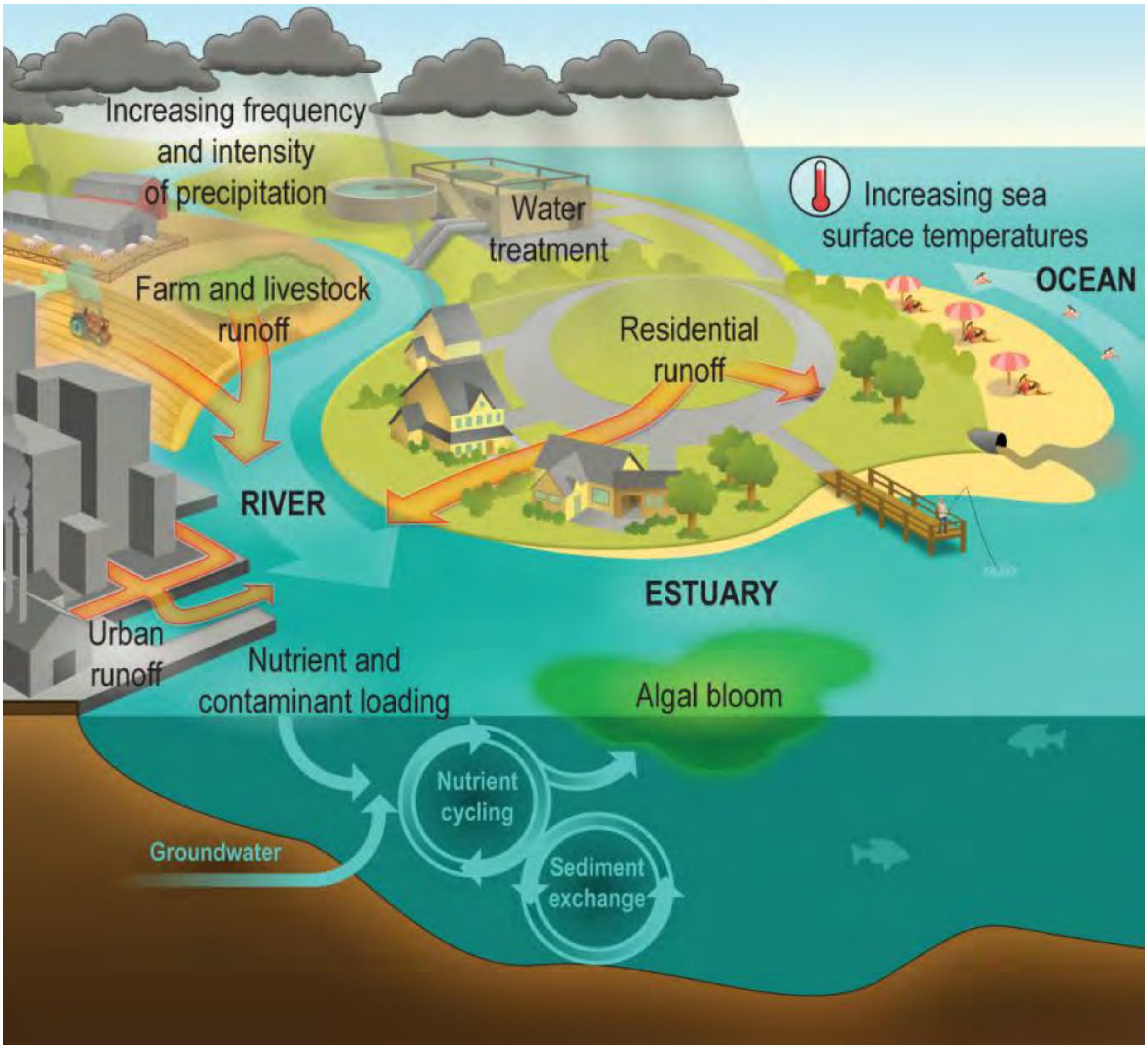

Figure 38: Precipitation and temperature changes affect fresh and marine water quantity and quality primarily through urban, rural, and agricultural runoff, which affects human exposure to water-related illnesses primarily through contamination of drinking water, recreational water, and fish and shellfish. ***Source:*** *USGCRP, 2016*

Water Quantity Vulnerability

As noted in the previous section, a future with warmer, drier summers could spur growing communities around the state to increase their groundwater withdrawals when surface water is limited (Pitz, 2016). This could exacerbate water quantity and affordability vulnerabilities.

Water quantity (supply-and-demand) vulnerability will likely to be highest in snow-influenced watersheds with existing conflicts over water resources (e.g., fully allocated watersheds with little management flexibility) (Snover et al, 2013). Vulnerability will be lowest where hydrologic change is smallest (i.e., existing rain-dominant watersheds), where there are simple institutional arrangements, and where current water demand rarely exceeds supply.

As noted previously in this assessment [*See Section 3.1, on pg. 32*], the Nisqually Watershed is projected to shift this century from a mixed rain-and-snow watershed (i.e., a watershed that receives 10-40 percent of its precipitation as snow) to a rain-dominant watershed (i.e., a watershed that gets less than 10 percent of its precipitation as snow); the Deschutes and Kennedy-Goldsborough watersheds will remain rain-dominant systems.

Studies conducted in Everett, Tacoma and Seattle and noted in UW CIG's 2015 assessment find that the reliability of municipal water supplies — that is, the probability of meeting demand in a given year — is largely unaffected by projected changes precipitation (Mauger et al., 2015). The report did not reference any Thurston County communities.

Communities and homes that rely on wells for water could see their costs rise if seasonal overconsumption lowers groundwater levels and forces wells to pump from greater depths (Pitz, 2016). A potential risk is that such a decrease in groundwater levels, coupled with an increase in energy prices, could make pumping from wells too expensive for some users. Another potential risk is there could be less water available to support new development.

4: Marine Ecosystems

Increasing greenhouse emissions and rising air temperatures over the 21st century are projected to affect the world's marine ecosystems in significant ways, from increasing ocean temperatures and acidity to melting ice sheets and raising sea levels. Such changes would impact both estuaries and residential and urban development along Thurston County's Puget Sound coastline. The following section explains how changes in the ocean's volume, acidity and temperature are expected to affect the Puget Sound region's built and natural environments.

…

4.1: Sea-Level Rise

Throughout the 21st century, the Puget Sound region is expected to experience continued, and possibly accelerated, sea-level rise as a result of melting ice sheets and warmer oceans. This may result in permanent inundation of some low-lying areas, and increased frequency, depth, and duration of coastal flooding due to increased reach of tides and storm surges (Mauger et al., 2015). Sea-level rise may also exacerbate river flooding by slowing the ability of water to drain into Puget Sound, as well as degrade drinking water sources [*See Section 3.4, on pg. 51*].

Globally, average sea level rose about 8 inches — roughly the same level recorded at the Seattle tidal gauge — during the 20th century (Mauger et al., 2015). The Puget Sound region's sea level is projected to rise another 24 inches (range: +4 to +56 inches) by the end of this century, relative to 2000 (NRC, 2012).[22] Levels could be higher or lower than this range, however, depending on the rate that the local coastline is sinking or rising due to geologic factors and the rate that polar ice is melting. The analysis below examines how built and natural assets are vulnerable to coastal flooding and erosion associated with sea-level rise.

Coastal Infrastructure Vulnerability

Most Thurston County shorelines are stable. However, Olympia City Hall in downtown is subsiding by about 2.5 millimeters (0.9 inch) per decade (Pacific Northwest Geodetic Array, 2016). Thus, City of Olympia engineers estimate that sea-level rise could be 11 inches greater amid low-lying downtown — much of which is built atop fill — than the surrounding shoreline areas (Christensen, 2016).

The City of Olympia established a policy in 2010 to protect downtown from flooding resulting from high runoff combined with a high tide [*Figure 39, right*] that inundates the gravity-fed stormwater drainage system. Downtown Olympia generally experiences nuisance

Figure 39. A March 2016 king tide event inundated downtown Olympia's Percival Landing and Sylvester Street. Sea-level rise is expected to raise the risk of coastal flooding associated with such high-tide events. ***Source:*** *TRPC*

[22] The National Research Council (NRC) projections noted in this assessment are based on global climate models and extrapolations of historical trends, as well as account for rapid changes in the behavior of ice sheets and glaciers that have been observed recently.

flooding[23] just once or twice a year — sometimes more during periodic El Niño events — but the risk rises with the sea [*Figure 41, on pg. 56*] (Christensen, 2016):

- With 1 foot of sea-level rise, Olympia could expect nuisance flooding 30 times annually, affecting approximately 261 structures and inundating up to 163 acres;
- With 2 feet of sea-level rise, Olympia could expect nuisance flooding 160 times annually; affecting approximately 328 structures and inundating up to 252 acres;
- With 4 feet of sea-level rise, Olympia could expect nuisance flooding 440 times annually or during more than half of its high-tide events, affecting approximately 402 structures and inundating up to 368 acres.

Downtown Olympia's importance to the region cannot be understated. The densely built area is the home of dozens of businesses, the Port of Olympia marine terminal, Olympia City Hall, LOTT Budd Inlet Treatment Plant, and other important facilities. Fortunately, most of the area's shoreline is owned by or under the control of local or state government agencies [*Figure 40, below*].

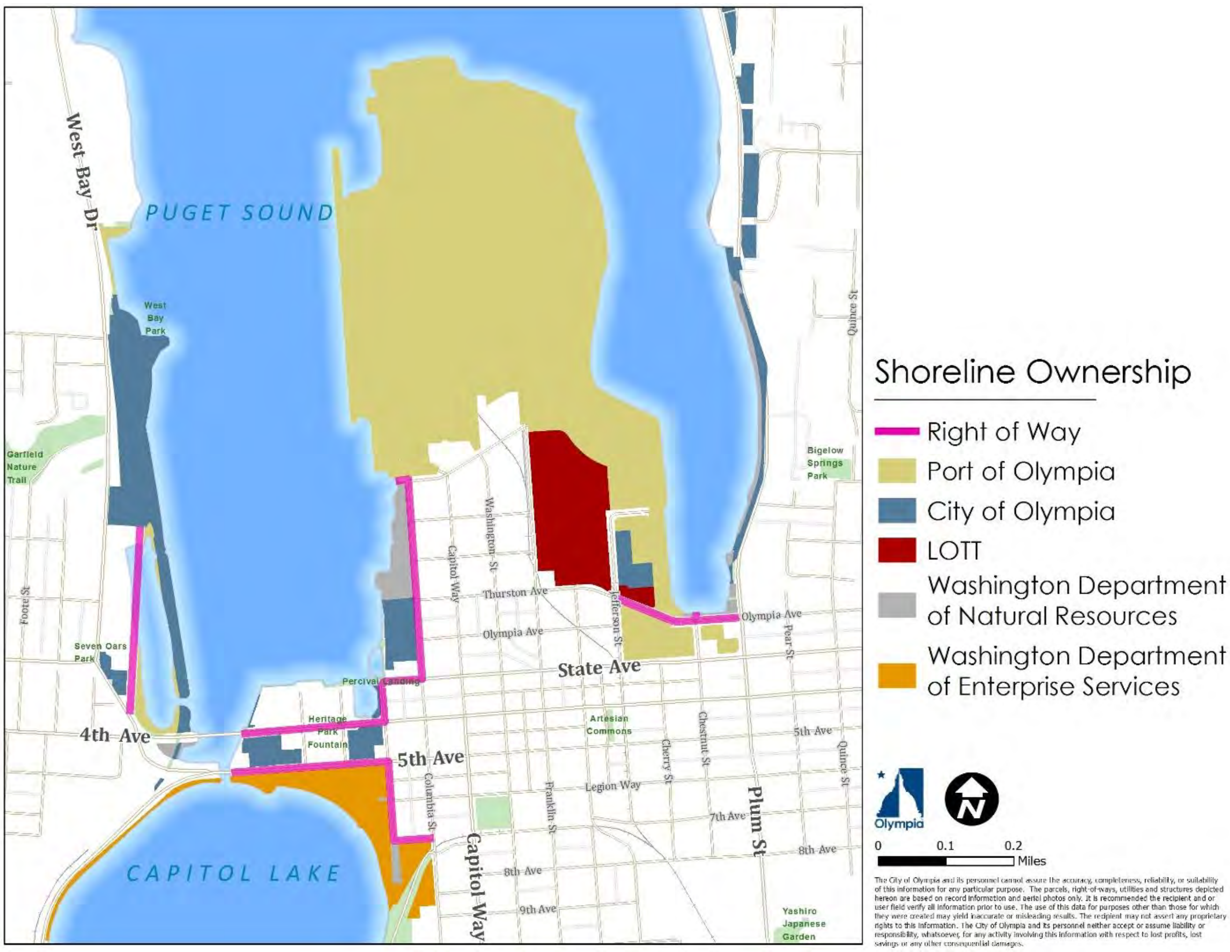

Figure 40. Most of downtown Olympia's shoreline is public ownership, which could simplify future efforts to adapt to sea-level rise. ***Source:*** *City of Olympia*

[23] Nuisance flooding events are tides in excess of 17 feet mean lower low water (MLLW) — the average height of the lowest tide recorded at a tide station each day during a recording period. Generally, this is when downtown Olympia streets flood.

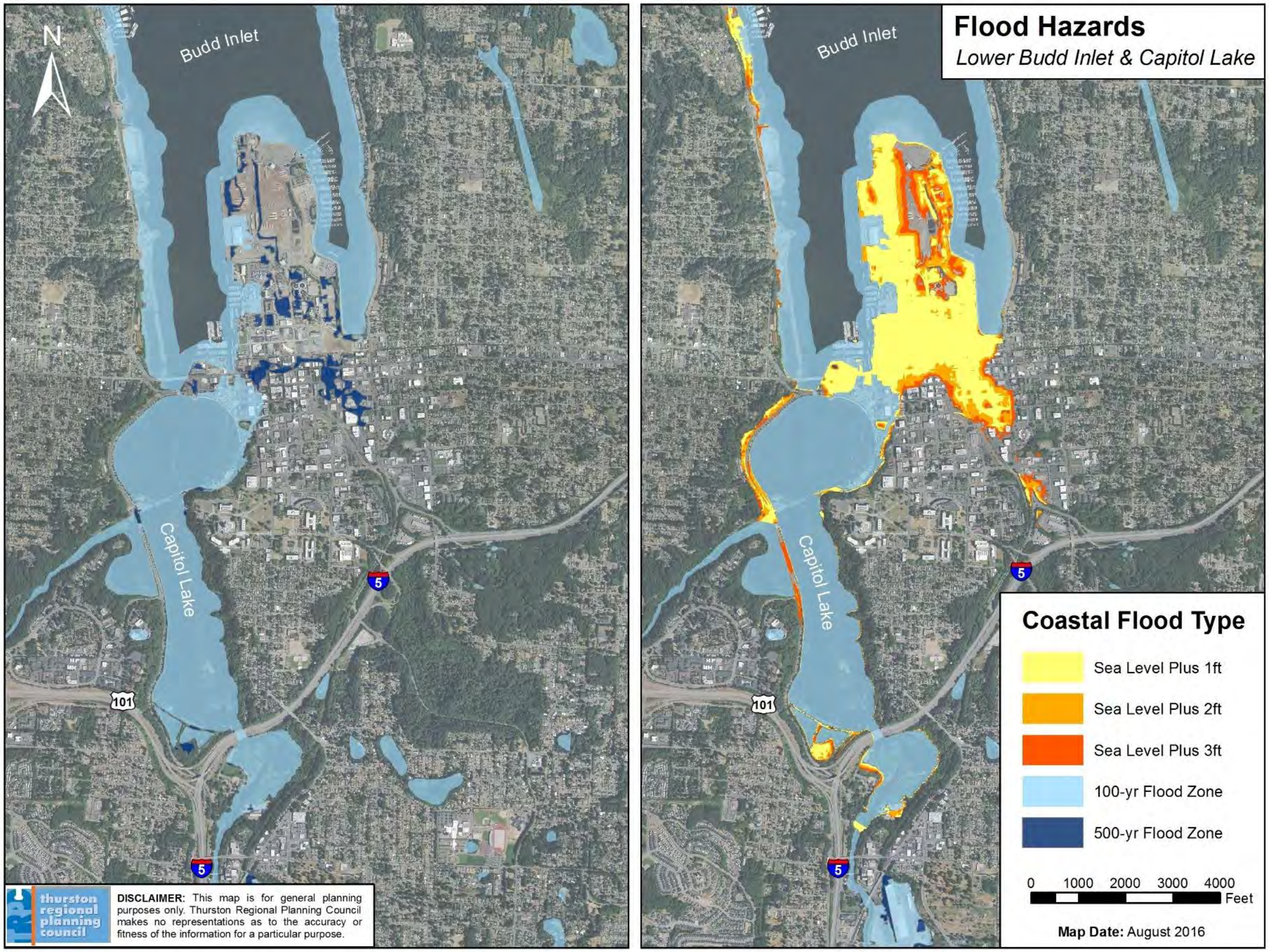

Figure 41: These maps show the extent of 100- and 500-year flood events coupled with 1-3 feet of sea-level rise throughout lower Budd Inlet and the Capitol Lake complex. ***Source:*** *Federal Emergency Management Agency (FEMA) preliminary 2016 flood data*

In addition to potentially disrupting commerce and damaging billions of dollars in public and private property, flooding amid the greater downtown Olympia area could pose temporary safety risks (e.g., inhibiting the movement of emergency service vehicles), as well as long-term health risks (e.g., mobilizing toxic chemicals amid former industrial sites and inundating sewer lines and treatment facilities). To prepare for and cope with such risks, the City will begin work in 2017 on a sea-level rise management plan and funding strategy with assistance from partners including the State of Washington, Port of Olympia, and LOTT Clean Water Alliance (Hoey, 2016).

City staff are considering a wide range of strategies (City of Olympia, 2016), including some that were identified in a 2011 technical report (Simpson, 2011).

- Require that the finished floors of new buildings accommodate 1 foot of sea level rise
- Install flood gates on stormwater outfalls that are connected to Budd Inlet and Capitol Lake and susceptible to backflow flooding; eventually, consolidate drainage systems and install pumping stations to get Moxlie Creek and stormwater runoff out of downtown
- Build barriers (e.g. floodwalls) around critical facilities and along shorelines
- Regrade low-elevation areas (e.g., Heritage Park east of Capitol Lake and Percival Landing east of Columbia Avenue)
- Elevate roadways

The LOTT Clean Water Alliance also hired a consultant to evaluate the vulnerability of its Budd Inlet Treatment Plant — a critical facility that handles wastewater from almost 90,000 residential, commercial and industrial customers served by the sewer utilities of Lacey, Olympia, and Tumwater. The 2014 assessment, prepared by the consultant firm Brown and Caldwell, used five scenarios that incorporated UW CIG sea-level rise projections — including combinations of sea-level rise, 100-year tidal flooding, and storm surge flooding — so as to identify inundation areas and high-level vulnerabilities at the treatment plant.

Under the three higher scenarios, critical infrastructure, including the effluent pump station, main utilidors (underground access tunnels), and a Puget Sound Energy substation, would be inundated (Polda & Brown and Caldwell, 2014). In the two most extreme scenarios, the headworks building, administration building, multiple substations, and backup generators would also be inundated.

Any failure of these core services would likely shut down key sections of the plant, resulting in potential backup. If shutdown or failure of the core infrastructure were to occur, flow would back up through the collection system and exacerbate flooding throughout the sewer system, downtown Olympia, and possibly areas farther upstream (Polda & Brown and Caldwell, 2014).

The assessment recommended a variety of adaptation actions, most of which focus on raising electrical distribution panels above the projected high-water line, and preparing methods to seal off critical areas from water in the event of a flood.

Low-lying sections of Interstate 5 and U.S. Route 101 also could be vulnerable to the combined effects of flooding and sea-level rise in the future [*Figure 42, on pg. 58*]. These highways are critical to ensuring that commercial trucks, commuter cars, emergency service vehicles and other automobiles are able to move within and through the Thurston County region.

McAllister Creek occasionally floods I-5 on- and off-ramps south of the Nisqually National Wildlife Refuge (area of Milepost 114), and this would be made worse by sea-level rise, according to a recent Washington Department of Transportation vulnerability assessment of transportation infrastructure

(WSDOT, 2011). The embankment atop which I-5 sits was never evaluated for open water at its toe. The levee removal at the Nisqually delta and the rising sea level means that the toe of the slope is now exposed to potential wave action (Maurer, 2016).

Similarly, along U.S. Route 101, as it crosses Mud Bay west of Olympia, water currently backs up in culverts and floods the highway's median during high tides. There is the potential for water to flood travel lanes temporarily due to sea-level rise (WSDOT, 2011).

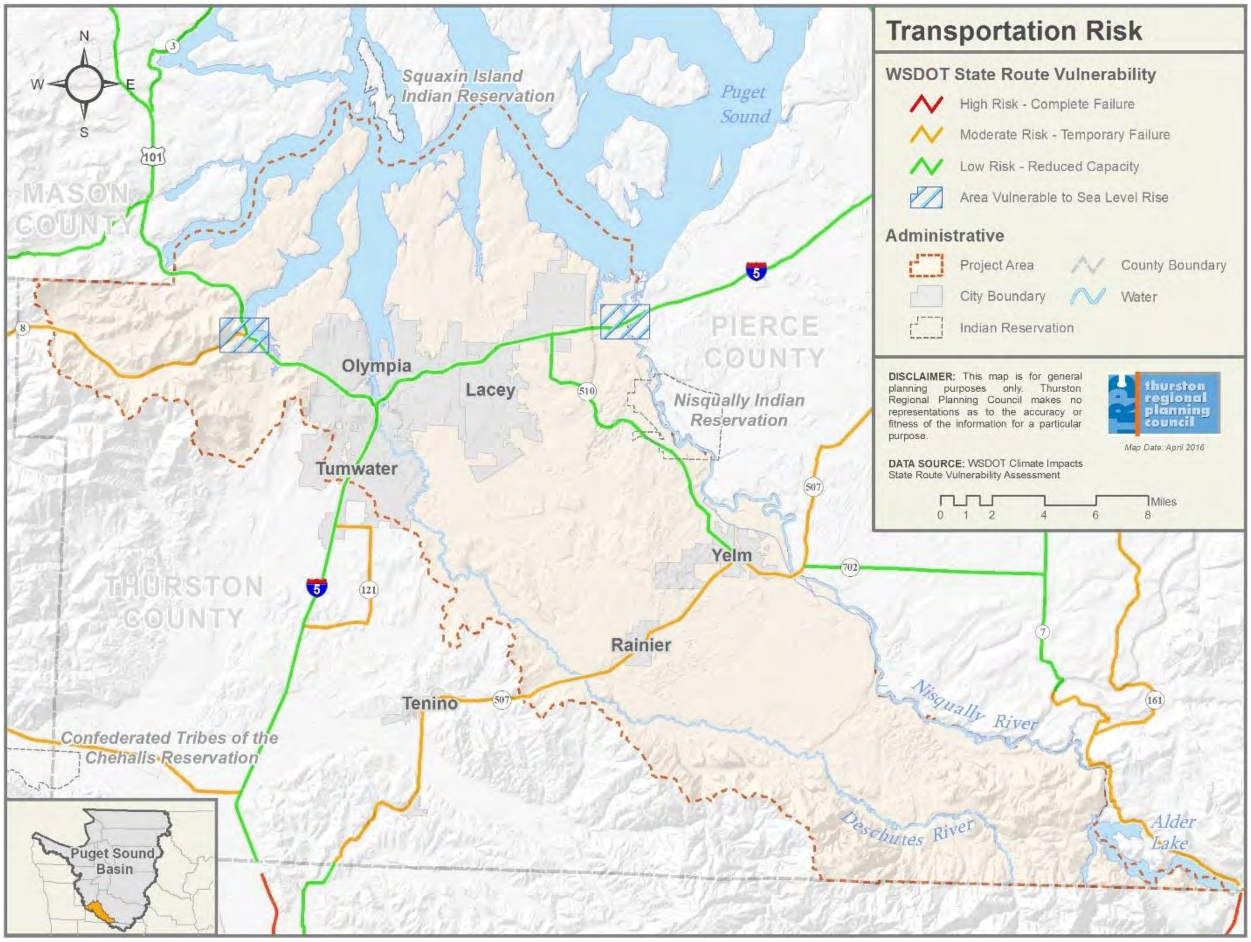

Figure 42. The map above shows sections of U.S. Route 101 and Interstate 5 that are currently vulnerable to coastal flooding, which could be exacerbated by rising sea levels. ***Source:*** *TRPC, adapted from WSDOT map*

The following maps [*Figures 43-46, on pgs., 59-62*] use preliminary Federal Emergency Management Agency (FEMA) data to show the projected reach of 100- and 500-year coastal flood events[24] compounded by sea-level rise of 1-3 feet (12-36 inches). As the draft maps show, some homes and commercial buildings near low-lying coastal areas such as the Nisqually Estuary, Henderson Inlet and Mud Bay would be vulnerable to sea-level rise.

[24] The 100-year floodplain includes lands subject to a 1% chance of flooding in a given year. The 500-year floodplain includes lands subject to a 0.2% chance of flooding in a given year.

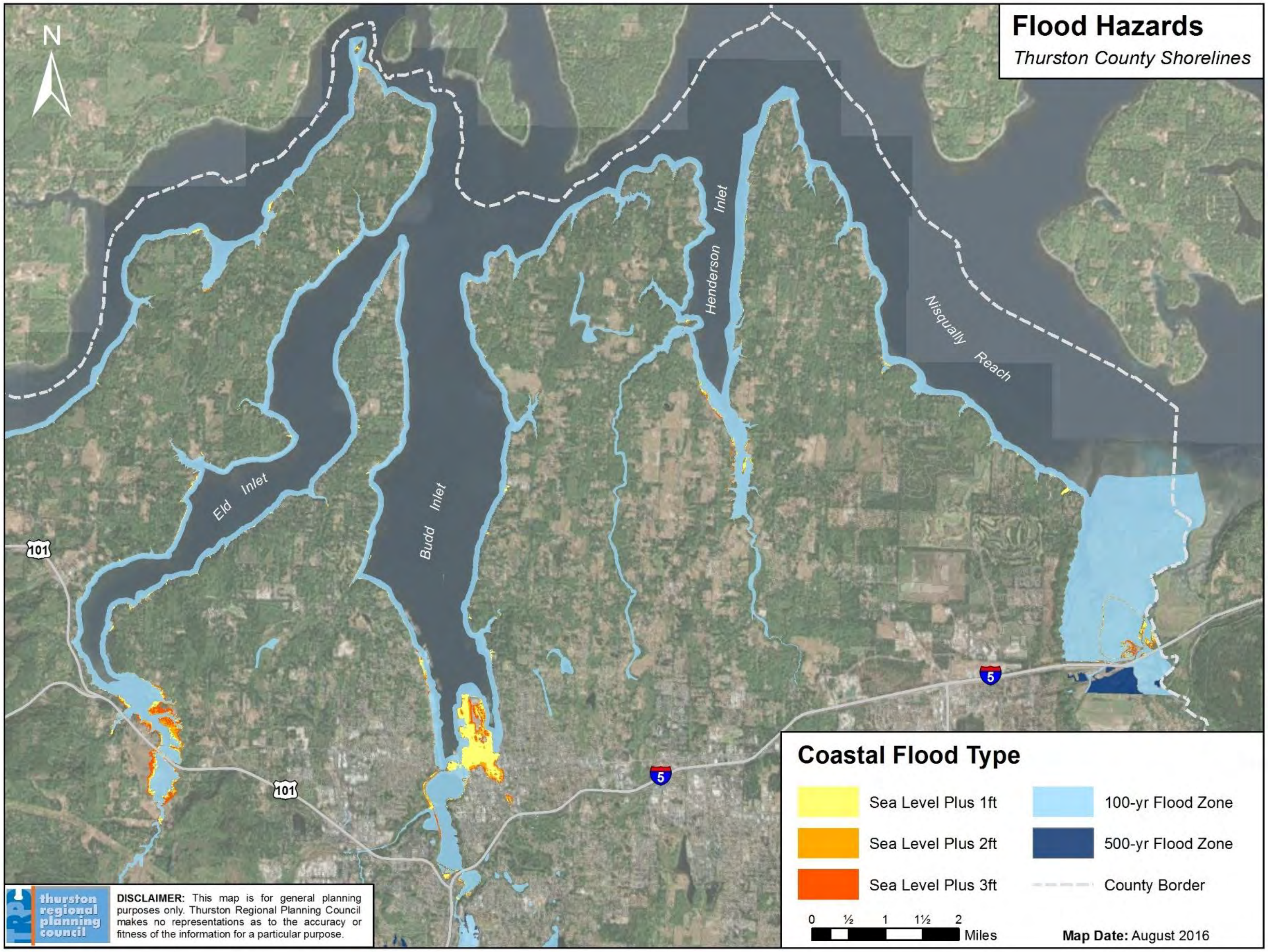

Figure 43: This map shows the extent of 100- and 500-year flood events, coupled with 1-3 feet of sea-level rise, throughout north Thurston County. ***Source:*** *Federal Emergency Management Agency (FEMA) preliminary 2016 flood data*

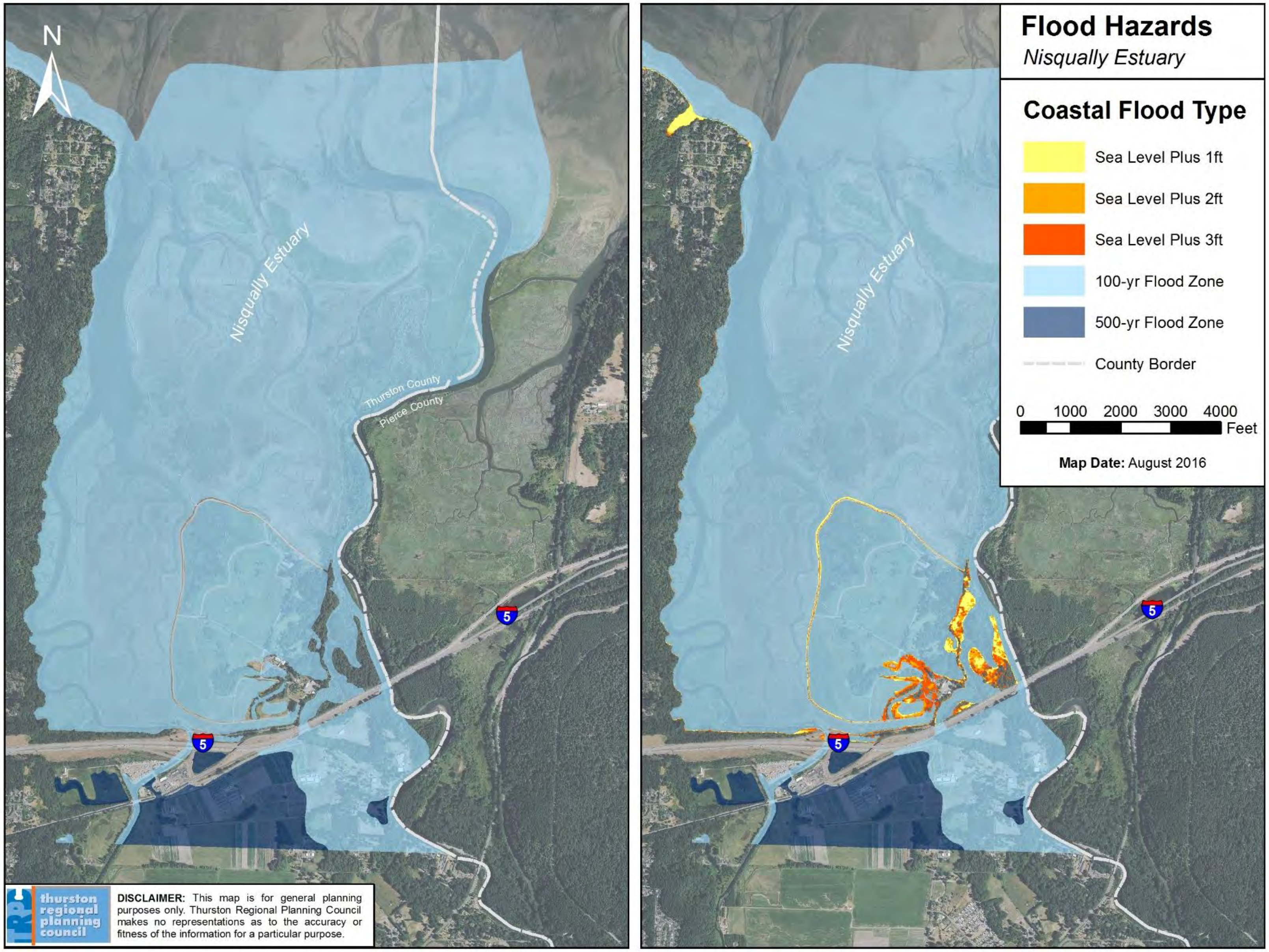

Figure 44: These maps show the extent of 100- and 500-year flood events, coupled with 1-3 feet of sea-level rise, throughout the Nisqually Estuary. ***Note:*** *Data shown only for Thurston County.* ***Source:*** *Federal Emergency Management Agency (FEMA) preliminary 2016 flood data*

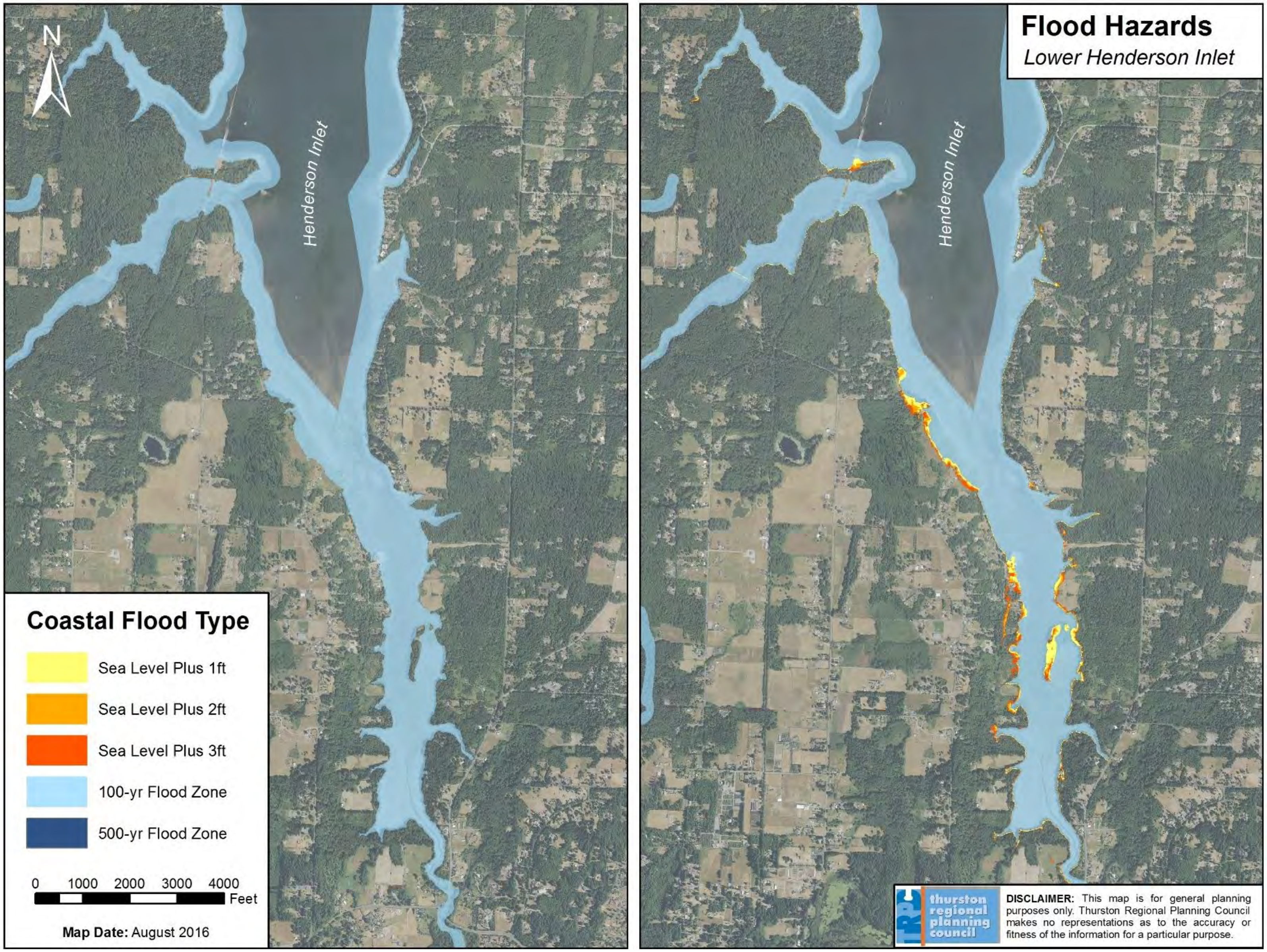

Figure 45: These maps show the extent of 100- and 500-year flood events, coupled with 1-3 feet of sea-level rise, throughout lower Henderson Inlet. ***Source:*** *Federal Emergency Management Agency (FEMA) preliminary 2016 flood data*

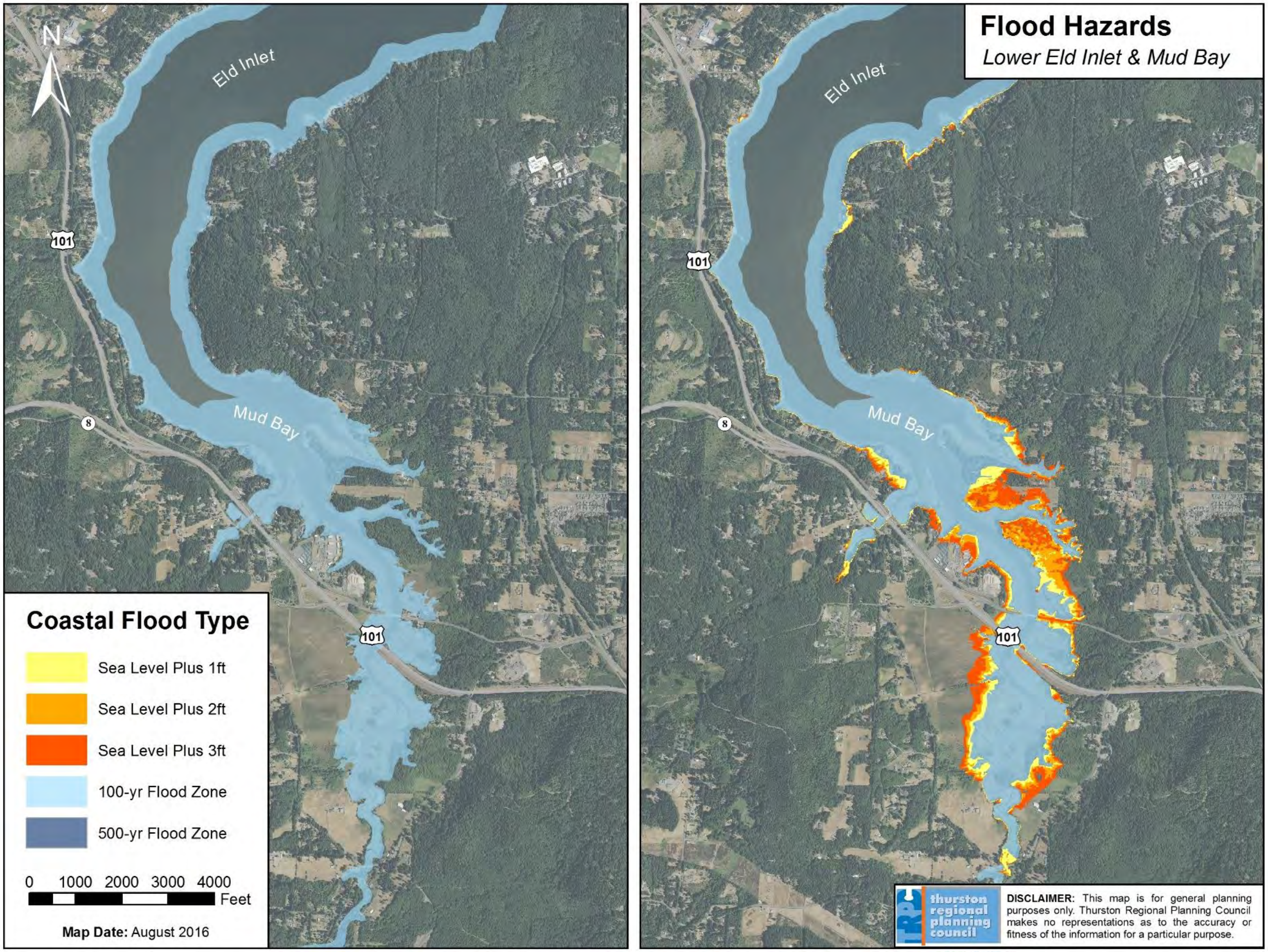

Figure 46: These maps show the extent of 100- and 500-year flood events, coupled with 1-3 feet of sea-level rise, throughout lower Eld Inlet and Mud Bay.
Source: *TRPC, using preliminary FEMA flood hazard data as of August 2016*

Increased exposure to water and wave energy as a result of sea-level rise is expected to erode unprotected coastal bluffs, which may have both detrimental and beneficial impacts: Coastal bluff erosion may threaten nearby buildings and occupants, yet this naturally occurring process also may contribute sand and gravel that would allow for down-drift shores to become higher and move landward, thereby maintaining the beach profile (Johannessen and MacLennan, 2007).

More than a quarter of Puget Sound's shoreline is armored with rock revetments, seawalls and other materials (PSP, 2016) that are built to protect homes, roads and other infrastructure. Such barriers do not guarantee that the land behind them is invulnerable to the sea's growing reach, however.

Seawalls and revetments are usually designed for a particular set of conditions. If rising sea levels continue to magnify the effects of high tides and waves, the original freeboard will be exceeded by seawater gradually and overtopping will become more frequent (NRC, 2012). This would increase the probability of structural damage.

Coastal Species Vulnerability

Increased erosion and inundation associated with sea-level rise is expected to affect the type and extent of coastal habitat (Mauger et al., 2015). This could be most acute in areas that are low-lying, with highly erodible soils, and where inland migration is hindered by bluffs for infrastructure (e.g., roads).

A 2007 National Wildlife Federation study used a model[25] to project the effects of sea-level rise on 11 Pacific Coast and Puget Sound sites — including north Thurston County, from the Nisqually Reach to the Cooper Point peninsula (NWF, 2007). Figure 47 [*below*] shows projected changes in marsh habitat amid the Thurston County study area — which included northern Olympia and Lacey, unincorporated peninsulas north of the cities and Puget Sound shorelines.

North Thurston County			
Habitat Type	**Baseline**	**Projected Change**	
	2007 *(Initial Conditions)*	**2100** *(+27" of sea level)*	**2100** *(+59" of sea level)*
Inland Freshwater Marsh	1,614 acres	-154 acres (-10%)	-208 acres (-13%)
Tidal Freshwater Marsh	47 acres	+2 acres (+4%)	+2 acres (+4%)
Brackish Marsh	672 acres	-69 acres (-10%)	-101 acres (-15%)
Saltwater Marsh	133 acres	+574 acres (+432%)	+670 acres (+504%)

Figure 47: Projected change in north Thurston County tidal and non-tidal marsh (wetland) habitat in 2100 as a result of sea-level rise. ***Source:*** *TRPC, adapted from NWF, 2007*

A more recent study by U.S. Geological Survey and Oregon State University researchers evaluated elevation, vegetation, mineral and organic matter buildup (accretion), and water level and salinity characteristics at 60 acres of the Nisqually Estuary and eight other sites along the Oregon and Washington coasts in order to model differences in tidal marsh vulnerability to sea-level rise (Thorne, Dugger, & Takekawa, 2015). Under the "mid" sea-level rise scenario used in the study (about 25 inches by 2100), the Nisqually Estuary would lose all of its high-marsh habitat and most of its mid-marsh

[25] The NWF study's Sea Level Affecting Marshes model (SLAMM 5.0) used a projected a 27-inch and 59-inch rise in global sea level by 2100, relative to 1980-1999, per the A1B maximum greenhouse gas scenario. The AIB scenario is similar to the RCP 6.0 scenario — described as "moderate" in the UW CIG's 2015 assessment — in which greenhouse gas emissions increase gradually until stabilizing during the final decades of this century.

habitat by the end of the century. Under the “high” sea-level rise scenario (about 56 inches), however, sea-level rise would drown all of the estuary’s marsh habitats and turn them into mudflats [*Figure 48, below*].

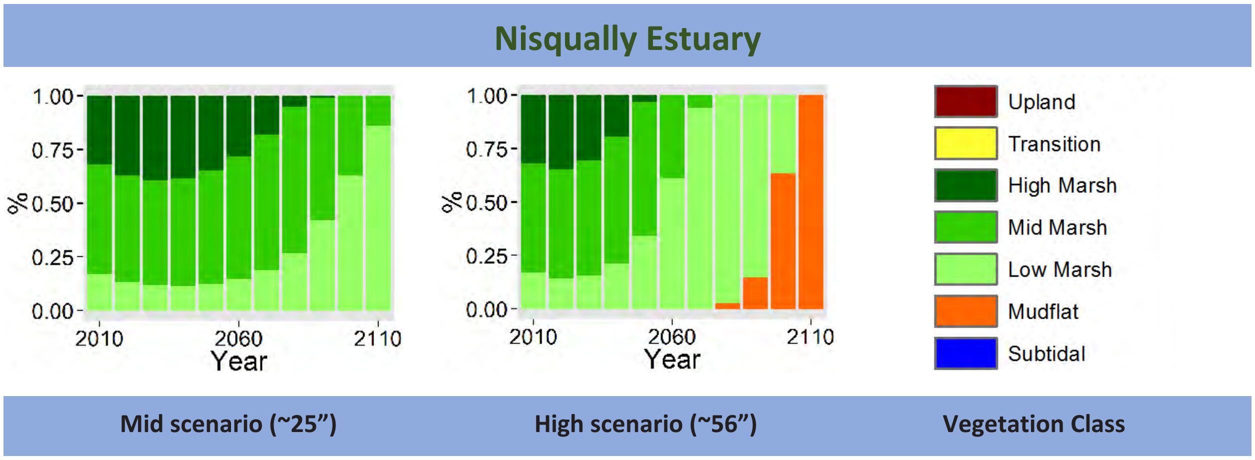

Figure 48: The figure above shows the projected percent change in vegetation class amid the Nisqually Estuary per mid and high emissions scenarios. ***Source:*** *TRPC, adapted data from USGS, 2015*

Such changes could have negative effects on birds, amphibians, and other wildlife that use less frequently inundated tidal marsh [*Figure 49, below*] for cover, foraging and nesting (Thorne, Dugger, & Takekawa, 2015). Conversely, the changes could increase habitat for marine algae, estuarine fish, and shellfish.

The Billy Frank Jr. Nisqually National Wildlife Refuge at the mouth of the river is rich in biodiversity today, attracting more than 200 species birds (and many more bird-watchers) throughout the year. Otters, clams, crabs, salmon and many other land and sea creatures also live amid the refuge’s seven distinct habitats, which include riparian forest, coniferous forest, river, seasonal freshwater wetlands, permanent freshwater wetlands, estuary and open saltwater (USFWS, 2016).

Figure 49. The Nisqually delta (*pictured*) was restored in 2009 by removing dikes and reconnecting 762 acres of former farmland with Puget Sound’s saltwater tides. This was the largest estuary restoration project in the Pacific Northwest (USFWS, 2016). ***Source:*** *TRPC*

The climatic ranges of more than 100 bird species across Washington are projected to decline by 50 percent or more (relative to 1971-2000) by the 2080s (Mauger et al, 2015). Such “climate-sensitive” bird species include the bald eagle and western grebe (Langham et al., 2015), which are found in the Nisqually Estuary and the broader Puget Sound region.

The persistence of tidal marshes along Puget Sound and other parts of the Pacific Northwest coast will depend largely on future sediment supply and marsh productivity (Thorne, Dugger, & Takekawa, 2015). A local barrier not noted in the report is Tacoma Power’s hydroelectric dam complex at Alder Lake, which limits the movement of sediment down the Nisqually River and accretion at the Nisqually Estuary [*Also see Section 3.1, on pg. 36*]. Interstate-5 provides yet another barrier, which could limit the estuary’s ability to migrate upstream as the sea level rises.

4.2: Ocean Acidification & Pollution

Ocean acidification occurs when seawater absorbs atmospheric carbon dioxide — the main greenhouse gas — causing chemical reactions that reduce the water’s pH (a measure of acidity ranging from 0-14) (NOAA, 2016). As the seawater acidity increases, it becomes harder for clams, oysters, crabs and other calcifying marine organisms to make and maintain shells.

Ocean acidification is projected to increase the frequency, magnitude and duration of harmful pH conditions throughout Puget Sound (Mauger et al, 2016), which could affect the entire food web. For example, a decline in the population of plankton would reduce food available for salmon, resulting in lower growth rates in seawater with higher acidity. Fewer salmon would reduce the food available for both predatory marine mammals (e.g., resident orca whales and seals) and humans. Perhaps the biggest casualty would be water-filtering shellfish — which hold significant cultural, environmental and economic value in the region.

Figure 50: The Olympia oyster, *Ostrea lurida*, is a native edible oyster of Puget Sound that has been harvested by generations of coastal residents. ***Source:*** *Wikimedia Commons.*

For centuries, Squaxin, Nisqually and other tribal peoples have harvested shellfish, including the Olympia oyster [*Figure 50, right*], for subsistence and trade. Shellfish continue to be a major income source for tribal and non-tribal communities: Washington leads the nation in production of farmed clams, oysters and mussels, and shellfish growers directly and indirectly employ more than 3,200 people and contribute $270 million to state economy (State of Washington, 2011).

Today, fecal material, nutrients and other polluted runoff from land-based sources (e.g., farms, septic tanks, stormwater, wastewater) limit recreational and commercial shellfish growing and harvesting along many parts of the South Puget Sound shoreline [*Figure 51, on pg. 66*].

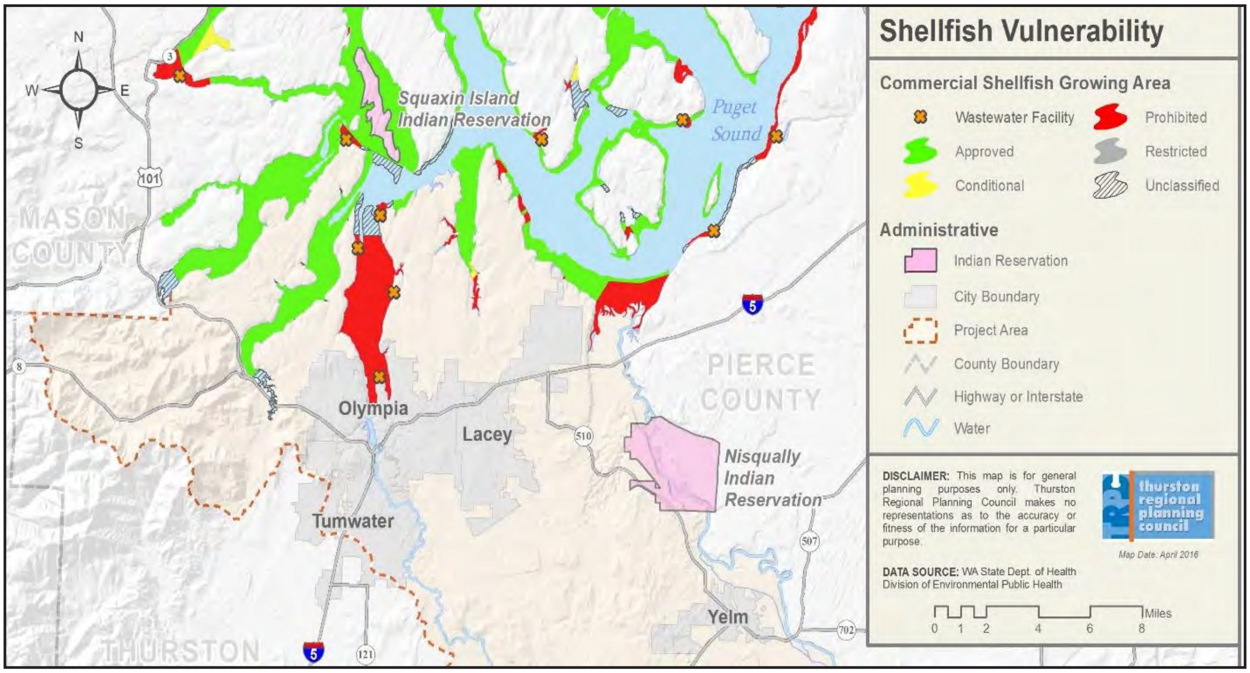

Figure 51: The Washington State Department of Health keeps a statewide database on commercial and recreational shellfish growing areas, including their overall health risk and proximity to wastewater treatment plants. The map above shows the current status of the commercial shellfish growing area within South Puget Sound. ***Source:*** *TRPC, adapted from DOH map*

Combined, changes in ocean temperature, chemistry and pollution could exacerbate risks to marine creatures and those that consume them.

For example, greater inflows of warmer freshwater — which holds less oxygen — raises the risk of marine water stratification and hypoxia and can alter the timing of spring plankton blooms that support the food web, including salmon and other economically important fish (Mauger et al., 2015). Warmer waters are also projected to increase the spread of *Vibrio parahaemolyticus* and *Vibrio vulnificus*, bacteria strains that can cause illness in people who eat raw or undercooked shellfish — specifically oysters [*See Figure 66, on pgs. 85-86*].

Precipitation will be the primary climate driver affecting the flow of enteric viruses from sewage (e.g., noroviruses and hepatitis A) to shellfish areas in coming decades (USGCRP, 2016). Heavy rainfall events could increase the load of such contaminants, organic matter (e.g., plant debris that releases CO2 as it decomposes) into South Puget Sound, increasing the persistence of enteric bacteria and viruses and contributing to acidification.

Rising air and sea temperatures are also projected to increase the magnitude and frequency of harmful algal blooms, often called “red tides,” in marine waters (Mauger et al., 2015).

Warming is projected to increase the Puget Sound seasonal window of growth for red tide-causing *Alexandrium* toxic organisms by about 30 days by 2040, enabling algal blooms to start earlier in the year and last longer (USGCRP, 2016) [*Also see Figure 66, on pgs. 85-86*]. People who swim in Puget Sound or eat fish and shellfish from its waters — particularly, children, older adults, pregnant women and immunocompromised individuals — face the highest health risks (USGCRP, 2016) [*Also See Section 6.4, on pg. 86*].

5: Terrestrial Ecosystems

The following section examines how climate change is likely to impact the Puget Sound region's terrestrial ecosystems — the land and the species that live upon it. The first half of the section looks at climate change impacts on farms and ranches, including economically important agricultural crops and livestock (e.g., berries and dairy cows); the second half of the section looks at climate change impacts on forests and prairies, including economically and environmentally important trees (e.g., Douglas fir and Garry oak). As noted previously, climate change impacts on humans are noted throughout this assessment and summarized in Section 6 — Human Health & Welfare.

…

5.1: Farms & Ranches

Puget Sound's agricultural sector is expected to be relatively resilient to climate change (warmer, wetter winters and hotter, drier summers), and some crops may even benefit from a longer growing season and more atmospheric carbon dioxide (Mauger et al., 2015). However, climate change-exacerbated drought and flood events, as well as invasive pests and plants, will still pose risks for local farms and ranches.

Drought & Flood Vulnerability

Drier summers would exacerbate temperature-driven declines in summer water availability (Mauger et al., 2015). Periodic drought is an issue that already affects the state and region — particularly the agricultural and industrial sectors — and adaptation is already taking place to protect the economy and environment.

The Department of Ecology, for example, provides emergency water permits, financial assistance and temporary transfer of water rights during a state-declared drought emergency, such as during 2015, when water supplies were below 75 percent of normal (WSU, 2016). The state agency also provides grants and loans for emergency water supply projects in declared drought areas to help irrigated crops and fisheries survive (TRPC, 2009).

Sustained periods of low or no precipitation could cause crops to wither and soil to blow away, causing economic losses and air-quality threats (e.g., PM_{10} in airborne dust) (CARB, 2009). Further, scarcer surface water could force farmers and ranchers to rely more heavily on groundwater for irrigating agricultural crops and watering livestock (Adelsman & Ekrem, 2012). As noted previously, however, consuming more groundwater during dry periods could exacerbate the risks of saltwater intrusion of coastal water supplies [*Also Section 3.4, on pg. 49*].

Conversely, heavy rain events (in any season), coupled with sea-level rise, could reduce the ability of drainage ditches and other infrastructure to handle flood events in near-coastal agricultural lands (Mauger et al., 2015). An analysis evaluating the expected annual damages from Skagit River flooding puts the estimate at roughly $1.5 million annually, with more than $86 million of farm property defined as at-risk within the Skagit River Basin (Mauger et al., 2015). Such figures provide useful context for calculating potential flood damage costs (e.g., lost or damaged agricultural crops, equipment and buildings) amid the Thurston Region's near-coastal farmlands, such those near Mud Bay and the Nisqually Estuary.

Crop & Livestock Vulnerability

Thurston County has more than 1,300 farms, spread across more than 75,000 acres, according to the U.S. Department of Agriculture's most recent census (USDA, 2012). The county's top crops, as measured in annual sales, are: nursery plants, greenhouse plants, floriculture and sod grasses ($43 million); poultry and eggs ($22 million); milk from cows ($22 million); and, aquaculture ($18 million).

Changes in precipitation and air temperature — as well as atmospheric carbon dioxide (CO_2) levels — are expected to influence which crops Puget Sound region farmers cultivate in the decades ahead. For example, emitting more carbon dioxide into the atmosphere may result in increased biomass productivity of some crops, such as beans and grasses (Korner et al., 2007). Assuming sufficient water is available during the growing season, the benefits of this process, known as "CO_2 fertilization," could outweigh the negative effects of warming temperatures (Mauger et al., 2015).

Increased CO_2, however, is also projected to reduce the nutritional quality of forage and pasture lands for livestock and wild animals, the largest of which (e.g., dairy cows and horses) would be more vulnerable to heat stress or flooding as a result of seasonal warming temperatures (Mauger et al., 2015). Such stressors could also benefit thistle and other invasive plant species and allow them to outcompete native grasses and crops (Dalton et al., 2013). Forage land used for hay, grass silage and greenchop is by far Thurston County's top-acreage crop — almost 16,000 acres (USDA, 2012).

Among other agricultural crops that have been studied specifically, berries, tree fruit, and tubers could experience a production decline due to climate change stressors — most notably, drought [*Figure 52, right*] (Mauger et al., 2015). Conversely, some types of wine grapes could thrive under the region's increasingly warm climate (Sorte et al., 2013).

Figure 52: Blueberries wilt in Thurston County's summer heat. Increasingly warmer and drier summers amid the region could cause a decline in berries and other agricultural crops in the decades ahead. ***Source:*** *TRPC*

A key cause of changes in crop vigor is that the frost-free season has been lengthening across the Puget Sound region. Added to that, the number of "growing degree days," which measures heat accumulation in plants[26], is projected to increase throughout the project area — especially in lower-elevation areas [*Figure 53, on pg. 69]*.

Too much warmth at lower elevations could be problematic for vintners, however, by eliminating the microclimate necessary for premium wine production. Growers could be forced to choose between producing lower-quality grapes or starting over with a grape that is better suited for warmer, lower-elevation conditions (Dalton et al., 2013). In addition to such direct effects on grape vines, climate may also impact grapes by affecting their pests and pathogens.

[26] Grapevine development is influenced strongly by air temperature, so average heat accumulation is often used to compare regions and vine-growing condition (WSU, 2016). Average heat accumulation is often referred to as Growing Degree Days (GDD), which is calculated by subtracting 50 from the average daily temperature (°F). If the resulting value is less than 0, then it is set to 0. Thus, daily GDD units are always positive.

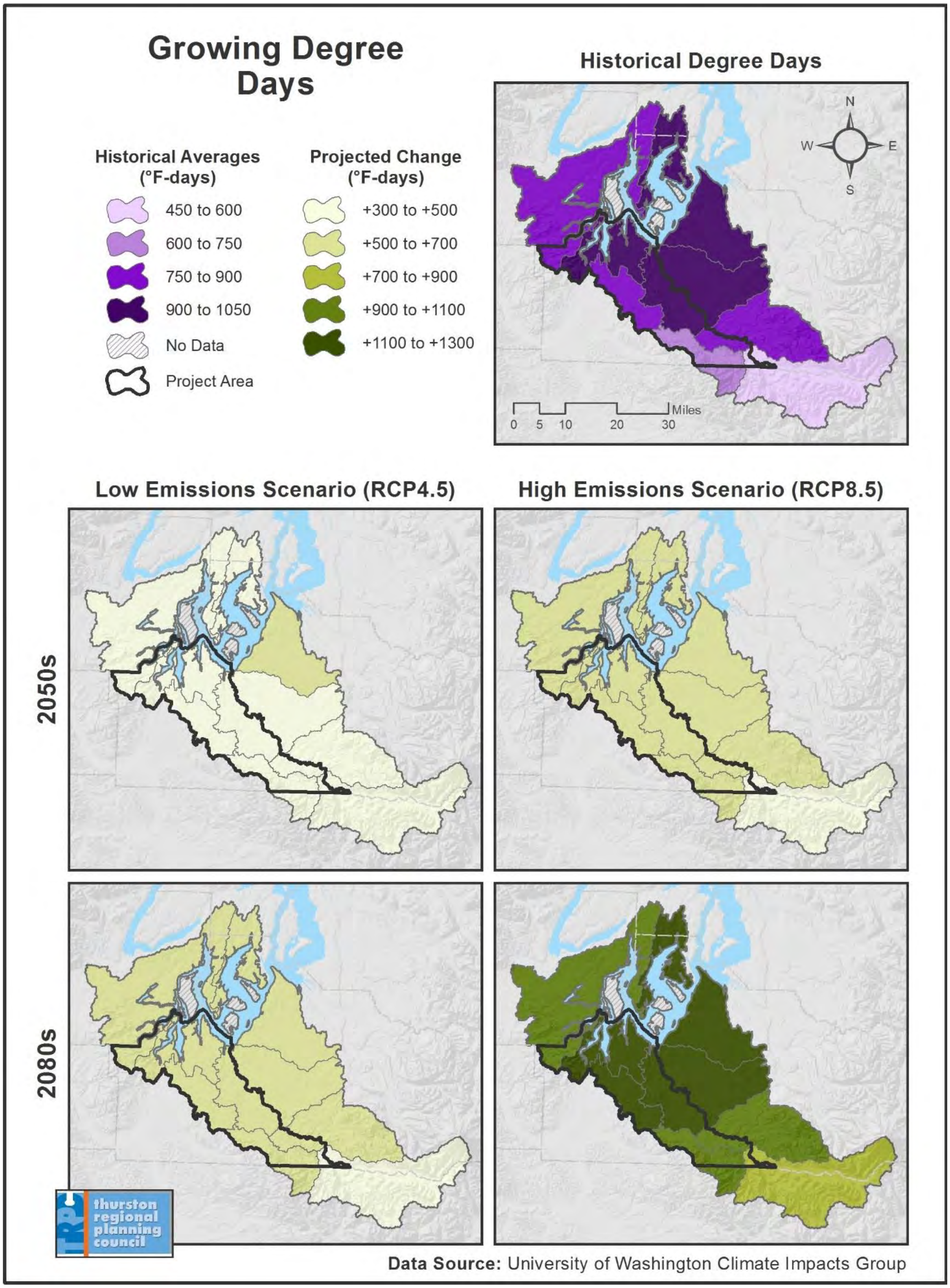

Figure 53: Projected changes in Growing Degree Days, which measures heat accumulation in plants, amid South Puget Sound watersheds. ***Source:*** *Adapted from Figure 3b in Appendix B of Mauger et al., 2015.*

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Among the factors that will help the broader Puget Sound region adapt to climate change in the decades ahead are its diversity of crops, temperate climate (compared to Eastern Washington), and access to urban markets (Mauger et al., 2015). Within Thurston County specifically, other beneficial factors include comparatively small farms with more intensive agricultural practices (Kinney, 2016); the average farm size in the county is 57 acres (USDA, 2012).

Water will be a factor limiting agricultural productivity for the reasons explained above, but shifting crop irrigation practices could help local farmers adapt in the decades ahead (Mauger et al., 2015). Other limiting factors include the costs of transitioning to new agricultural practices and crops, as well as the availability of subsidies and conservation programs that may discourage such changes.

5.2: Forests & Prairies

As a whole, there will likely be continued changes in forest growth, productivity and range, greater risks of wildfire, and changes in the prevalence and location of disease, insects and invasive species (Mauger et al., 2015). The following section looks at how such changes are expected to affect lowland forest and prairie areas, Thurston County's dominant terrestrial ecosystems.

Prairie Species Vulnerability

Prairies amid South Puget Sound lowlands range from open savanna-type landscapes with flowers such as the Golden Paintbrush, White-topped Aster and Rose Checker-Mallow (CNLM, 2016) to scattered woodlands that include Garry oak [*Figure 54, right*], Douglas-fir, Oregon ash, bigleaf maple, and Pacific madrone trees (WDFW, 2011). Within Thurston County, prairies and other open areas provide important habitat for the following federal Endangered Species Act-listed wildlife: Mazama pocket gopher, Taylor's checkerspot butterfly and Streaked horned lark (Thurston County, 2016).

Figure 54: A grove of Garry oak near McAllister Creek, east of Lacey. ***Source:*** *TRPC*

Prairie ecosystems, which historically covered 10 percent of the landscape in the South Puget Sound lowlands, have been reduced by 90 percent during the past 150 years, due largely to settlement activities such as land fragmentation, construction and agriculture (WDFW, 2011). Such ecosystems have also been degraded by invasive species such as Scotch Broom, which forms dense stands and crowds out native vegetation.

Climate change is expected to result in further shifts in the composition of prairie ecosystems. For example, warmer, wetter winters may lead to an increase in the area of wetland prairies on poorly drained soils (Bachelet et al., 2011), such as the glacial till and clay common amid South Puget Sound. Climate change, as well as stressors such as invasive species and land fragmentation, will also affect the extent of Garry oak woodlands. One study, which assessed the potential impacts of climate change on the distribution Garry oak in British Columbia, Washington and Oregon, concluded that climate suitability in areas that currently support the oak will decline in coming decades (Bodtker, 2009).

The shifts in seasonal temperature and precipitation noted above may also lead to shifts in timing of flowering (phenology) and the abundance of insect pollinators amid prairies (WDFW, 2011). This, in turn, could lead to the decline of some species of flowering plants if bees and other pollinators are absent during times of peak flowering (Halofsky et al, 2011).

Thurston County's more than 25,000 acres of prairie — including oak groves and grasslands — provide $12 million-$19 million in ecosystem service benefits to the economy annually (Flores, et al., 2012).

Forests with other deciduous trees and conifers — totaling about 236,000 acres in Thurston County — provide between $448 million and $1.9 billion annually in such benefits, including erosion control, climate regulation and pollination.

Forest Species Vulnerability

More than half of Washington's 43 million acres are classified as forestlands (WDOE, 2006), which provide economic activities (e.g., revenue from timber production, hiking and camping) and ecosystem services (e.g., wildlife habitat, carbon storage). Douglas-fir, western hemlock and other softwood tree species constitute about 73 percent of the live-wood volume (about 95 billion net cubic feet of wood volume total) on these forestlands, which are presently a net sink for CO_2 (Campbell et al., 2010); hardwood species such as alder, maple, and oak constitute 7 percent of the live-tree volume. Such species are found in Thurston County, which contains the state-managed Capital State Forest in the northwest and privately-owned working forests in the southeast [*Figure 56, on pg. 72*].

Climate change is expected to impact such forestlands directly (e.g., by affecting tree growth and extent) and indirectly (e.g., through pest and fire damage). Hotter, drier summers will likely decrease the extent of suitable habitat for Douglas-fir trees, especially amid the southern Olympic Peninsula and South Puget Sound lowlands. Models project the range of Douglas-fir — one of the most commercially important tree species west of the Cascade Range — may decline by as much as 32 percent in Washington by the 2060s, relative to 1961-1990, per a medium emissions scenario (Snover et al., 2013). Conversely, western hemlock, white bark pine, and western red cedar may expand in range.

Increased water stress associated with such hotter, drier summers may in turn lead to higher tree mortality (in forests and landscaped urban areas) and more intense fires [*See Section 6.1, on pg. 73*] (Greene & Thaler, 2014). These disturbances may be compounded by more pest and disease outbreaks (Dalton et al., 2013).

Armillaria root disease, which affects conifers and hardwoods in the region, will likely have more impact due to stress induced by hotter and drier summers. Swiss needle cast, a disease caused by *Phaeocryptopus gaeumannii,* has also been associated with such temperature and precipitation changes [*Figure 55, right*]. The foliar pathogen is projected to have more capacity to affect Douglas-fir (Dalton et al., 2013).

Figure 55: Swiss needle cast, which causes Douglas-fir tree crowns to look yellow–brown in spring, now affects trees in Oregon, Washington and British Columbia. ***Source:*** *Shaw et al., 2014*

Mountain pine beetles, a significant natural disturbance in the area today, may experience a long-term decline in extent at lower elevations as air temperatures rise. However, short-term trends indicate that both lower and higher elevations are becoming more suitable for the beetles (Greene & Thaler, 2014).

Such direct and indirect climate change impacts may increase the region's volume of organic waste, as well as offset any potential economic benefits from timber yield increases associated with higher temperatures and CO_2 concentrations (Dalton et al., 2013). The UW CIG assessment (Mauger et al., 2015) underscores, however, that more research is needed to determine specifically how invasive and non-native species currently within the Puget Sound region will respond to climate change, and which new species may emerge as invasive.

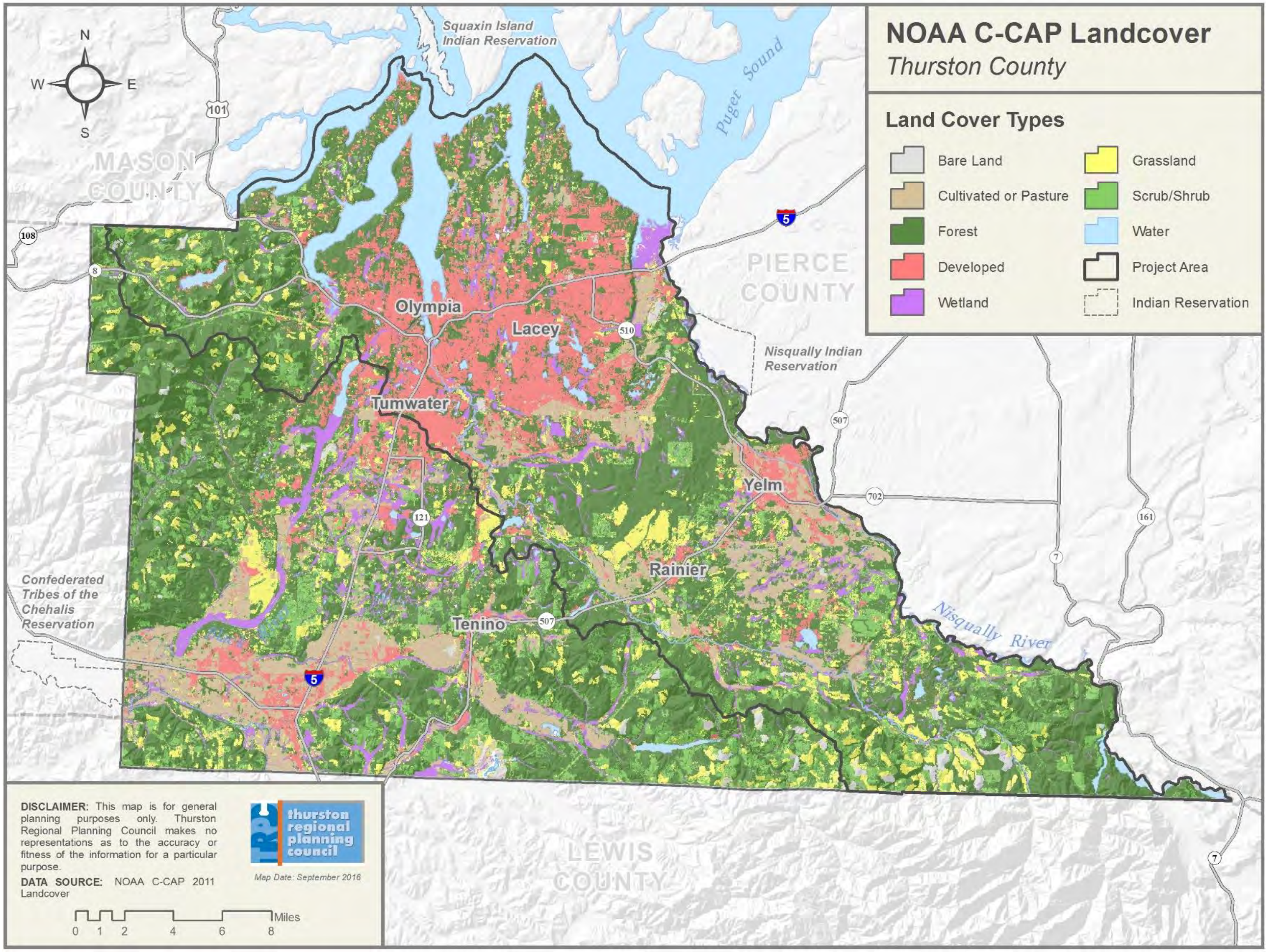

Figure 56: This map shows land cover types in Thurston County**.** ***Source:*** *TRPC, using* National Oceanic and Atmospheric Organization (NOAA) Coastal Change Analysis Program (C-CAP) data

6: Human Health & Welfare

The following section explores how climate change is expected to increase the incidence of wildfires floods and landslides — hazards that affect Thurston County's human and natural systems in myriad ways. The section concludes by exploring the projected effects of indirect climate change exposure pathways — changes in infectious disease agents and population displacement.

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6.1 Wildfires

Over its recorded history, Thurston County has experienced comparatively small wildland fires, or "wildfires," most of which were started by human activities such as burning debris and lighting fireworks (TRPC, 2009). About two-thirds of the county's wildfires (roughly 2,500 between 1972 and 2007) were between July and September, when the climate is typically warmest and driest.

The historical frequency of local wildfires suggests that such hazards have a "high" probability of occurrence, but about 97 percent of future fires will be small — five acres or less — concluded the *Natural Hazards Mitigation Plan for the Thurston Region* (TRPC, 2009). The plan did not factor in climate change but cautioned that it may create more suitable conditions (e.g., warmer, drier summers) for bigger, more frequent wildfires.

One set of fire models for the broader Pacific Northwest projects that total area burned by wildfire could more than double — from 0.5 million acres historically (1916-2006) to 1.1 million acres for the 2040s, per a moderate emissions scenario (Littell et al., 2010). While these and other models are limited in their ability to capture unique Puget Sound conditions associated with wildfires, the region is still expected to experience greater wildfire frequency and severity associated with changes in air temperature and precipitation (Mauger et al., 2015).

Wildfires can pose acute or long-term health and welfare risks for firefighters and residents: incurring stress as a result of property losses; suffering burns and death; and, breathing in smoke and particulate matter (PM_{10}). Such fires may also disrupt energy transmission by downing power poles and damaging other infrastructure, as well as burn trees and other vegetation that prevent soil from eroding.

Presumably, damages associated with fires will go up if those fires occur in or spread to the wildland-urban interface [*Figure 58, on pg. 75*]. This is where most of the county's wildfires have occurred in recent decades (TRPC, 2009) [*Figure 59, on pg. 76*].

In 2014, there were about 30,500 residents and 12,900 dwelling units in Thurston County's wildland-urban interface area, according to TRPC data; the value of all buildings and contents was more than $2.9 billion. In 2040, about 38,100 residents and 16,200 dwelling units are expected in this area. This represents a 25 percent and 26 percent increase, respectively.

In addition to temperature and precipitation, conditions that influence the severity and extent of wildfires include soil and vegetation type, slope grade, and road access. Based on these criteria, the hazards plan deemed the following communities most vulnerable to wildland fires [*Also see Figure 60, on pg. 77*]:

- Steamboat Island Peninsula;
- Boston Harbor/Fishtrap Loop/Woodard Bay/South Bay Peninsula;
- Johnson Point Peninsula;
- Nisqually River Valley, south of Yelm
- Lake Lawrence, western shore vicinity;
- Tenino, upland vicinity south of town;
- Grand Mound/Rochester/Confederated Tribes of the Chehalis Reservation;
- Capitol State Forest vicinity.

The prospect of more frequent and intense wildfires would have economic consequences. The Washington Department of Natural Resources (DNR) projects that statewide direct costs for fire preparedness and response would rise from more than $18 million in the 2040s to $24 million in the 2040s (WDOE, 2006). The total economic impacts of wildfire — including lost timber value, lost recreational expenditures, and health and environmental costs associated with air pollution and other forest changes — could be many times higher than DNR's projected preparedness and response costs.

To reduce the risk of wildfires, Thurston County currently imposes an outdoor burn ban during summer [*Figure 57, right*]. Outdoor burning is prohibited year-round for residents within the cities of Olympia, Tumwater and Lacey, as well as for county residents within the Urban Growth Area (UGA) boundary.

Figure 57: A sign near Yelm announces that a summer burn ban is in effect. ***Source:*** *TRPC*

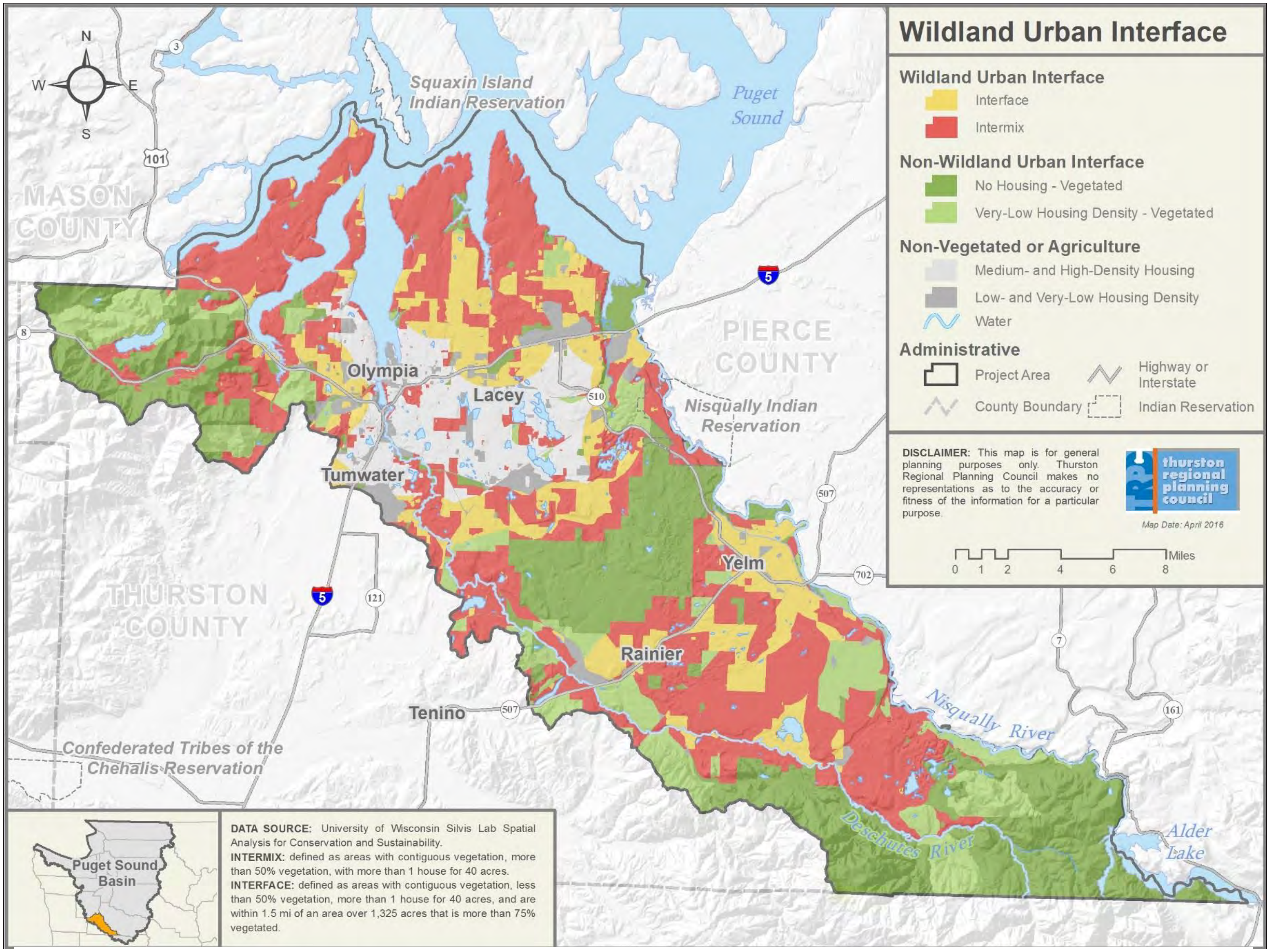

Figure 58: The project area's Wildland-Urban Interface (*shown*) is the zone of transition between unoccupied land and human development.

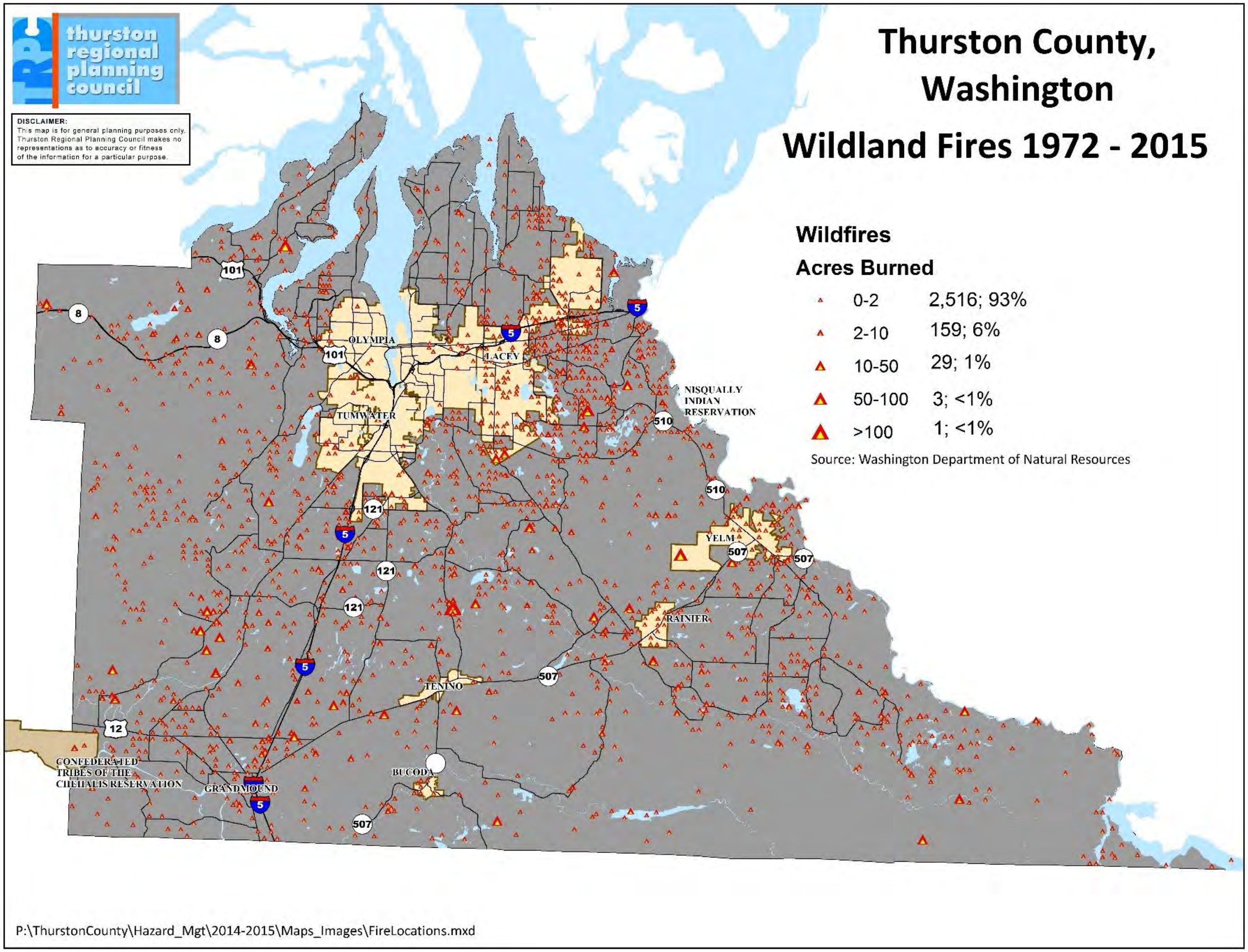

Figure 59: The map shows the location and size of wildland fires that burned in Thurston County between 1972 and 2015. As icons indicate, most of these wildfires were less than 10 acres. ***Source:*** *TRPC*

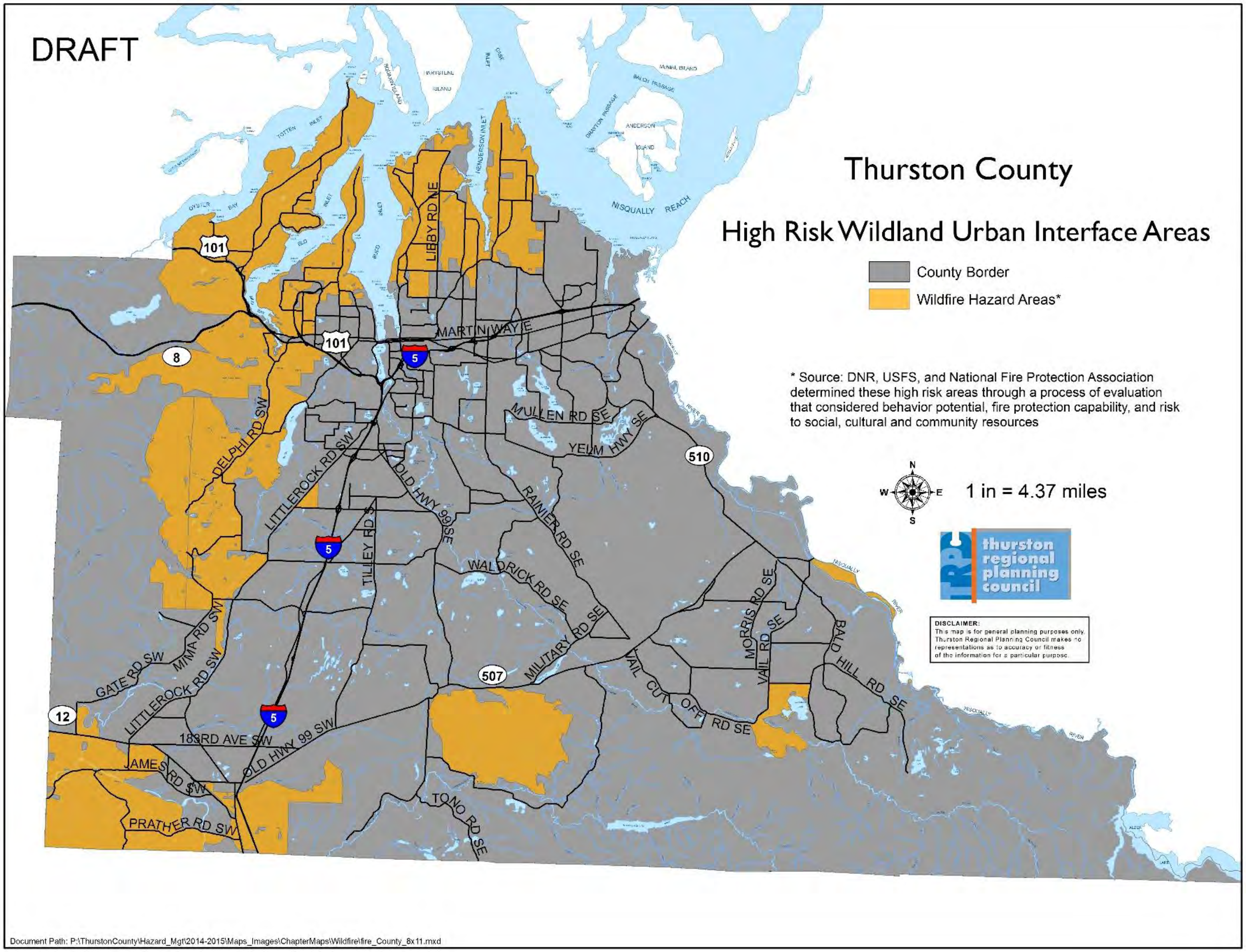

Figure 60: The map shows Thurston County wildland-urban interface areas with the highest risk of wildfires

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6.2 Floods & Landslides

As noted previously in this assessment, the frequency and intensity of today's heaviest 24-hour rain events is projected to increase during the 21st century [*See Section 2.3, on pg. 23*]. An increase in these top 1 percent heavy rain events and winter precipitation would raise the risk of floods and landslides — natural hazards that degrade water quality and threaten public safety. The following section examines which Thurston County areas and assets are most vulnerable to such hazards.

Flood Vulnerability

Flooding can come from swollen rivers, high groundwater and other sources and threaten human health and welfare in several ways, ranging from drowning in rising waters, to consuming contaminated water, to breathing in mold that grows after waters recede. Swift-moving flood water, as well as the woody debris and other detritus left behind, can pose obstruction hazards for culverts, roads and bridges that are critical transportation routes for school and transit buses, fire trucks, ambulances and other vehicles (TRPC, 2009). Inundation, erosion and sediment deposits can also damage homes and businesses, as well as disrupt communication, electric, gas and water utility infrastructure.

In its *Natural Hazards Mitigation Plan for the Thurston Region*, TRPC used more than 40 years of stream gauge data to calculate the probability and frequency of flooding in local rivers. Based on this analysis of the past, the hazards plan concluded that a "major"[27] flood event occurred on at least one county river about every 2.3 years — a "high" probability of occurrence. The Nisqually River has an estimated 12 percent chance of major flooding in a given year, or about one major flood every eight years, according to the analysis (TRPC, 2009); the Deschutes River has an estimated 22 percent chance of major flooding in a given year, or about one major flood every 4.5 years.

The hazards plan also concluded that there is a "high" probability of groundwater flooding[28] associated with a high water table and persistent heavy rains. Additionally, the hazards plan concluded that there is a "moderate" probability of tidal flooding along the county's Puget Sound coastline, and a "high" probability of urban flooding associated with stormwater runoff exceeding the conveyance capacity of drainage systems. The hazard plan's assessment, which concluded that there is a "high" overall risk of all types of flooding, did not factor in projected climate change impacts.

As noted above, heavy rainfall events are projected to become more intense and result in higher peak river flows and runoff during winter months. Adding to this, rising sea levels could increase the potential for higher tidal/storm surge and coastal flooding. More than 65,000 acres and $1.5 billion in buildings and contents are currently within Thurston County's flood hazard areas (TRPC, 2009). Such lands have high groundwater or are within the 100-year or 500-year floodplains[29] [*Figure 61, on pg. 79*].

Several stretches of local roadway are within these flood hazard areas and flood on a regular basis [*Figure 58, on pg. 68*]. Regional stretches of highway have also flooded several times in recent decades, snarling traffic and endangering motorists. In 1996, for example, riverine flooding forced the temporary closure of I-5 at the border of Thurston and Lewis counties (TRPC, 2009). The Washington Department of Transportation's climate change vulnerability assessment (WDOT, 2011) deemed this low-lying stretch of I-5, adjacent to the Chehalis River in Lewis County, "high vulnerability" and at risk of "complete failure" in the event of a major flood [*See Figure 42, on pg. 58*].

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[27] The *Natural Hazards Mitigation Plan for the Thurston Region* defines "major" flooding as follows: Neighborhoods and communities are threatened and evacuation is recommended for residents living on specified streets, in specified communities or neighborhoods, or along specified stretches of river. Major thoroughfares may be closed and major damage is expected.

[28] This occurs when impermeable hard pan prevents infiltration and causes standing water on land below the water table.

[29] The 100-year floodplain includes lands subject to a 1% chance of flooding in a given year. The 500-year floodplain includes lands subject to a 0.2% chance of flooding in a given year.

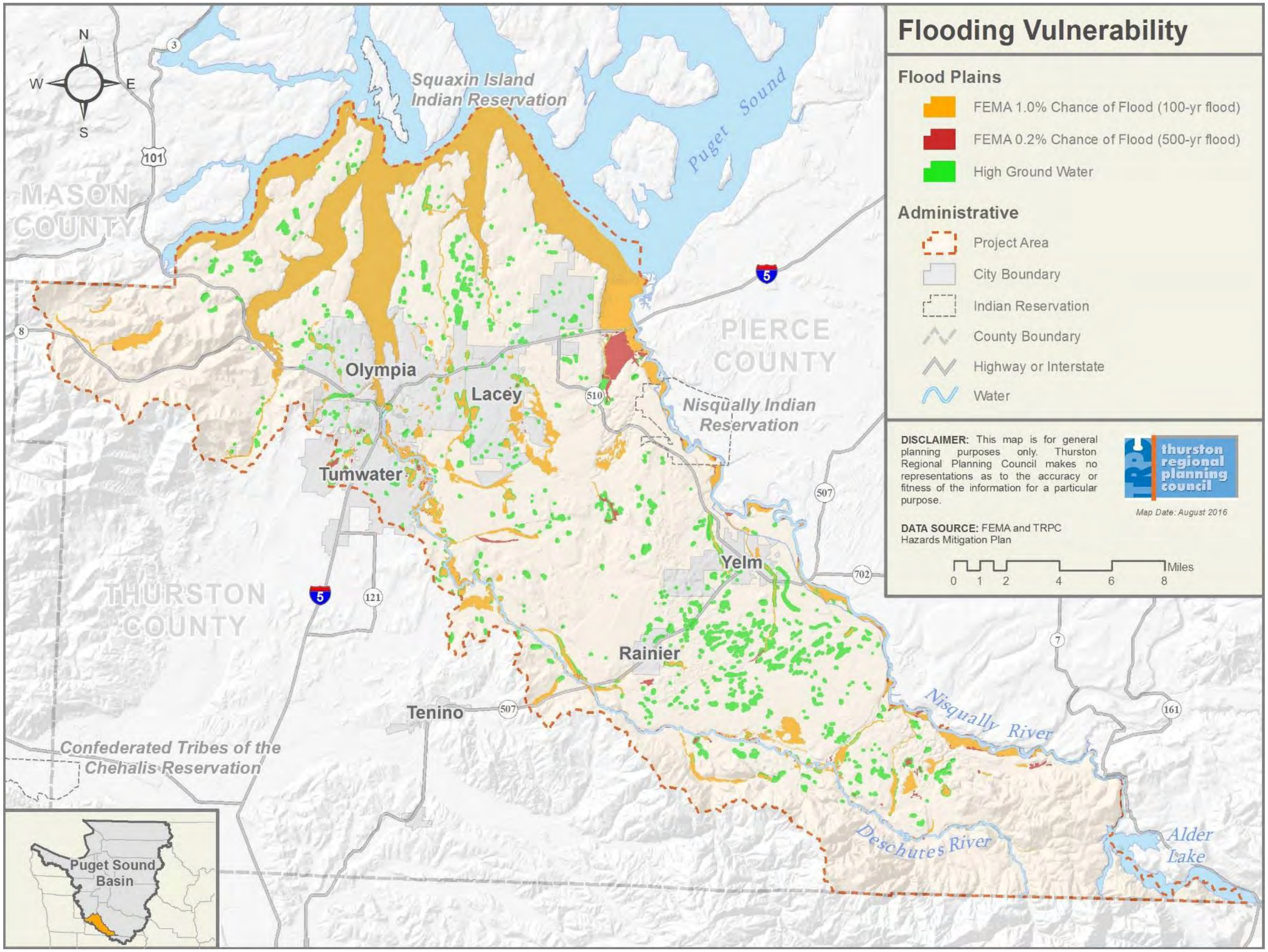

Figure 61: The map shows floodplain and high groundwater areas within the project area that are deemed most vulnerable to flooding.

Landslide Vulnerability

Heavy rain events can compromise the stability of hillsides by raising the water table quickly and boosting drainage through the soil to lower layers (Mauger et al, 2015). As explained previously in this assessment, this can cause flooding amid areas with high groundwater, as well as trigger landslides or significant sediment runoff from steep slopes where the soil is unprotected by vegetation or snow.

Such hazards can have lasting effects on salmon, which, as noted previously in this assessment, are an important part of this region's environment and cultural traditions. For example, winter storms in the 1990s, compounded by logging activity, triggered landslides in the Deschutes River and decimated the stream's Coho salmon population [*Figure 62, below*].

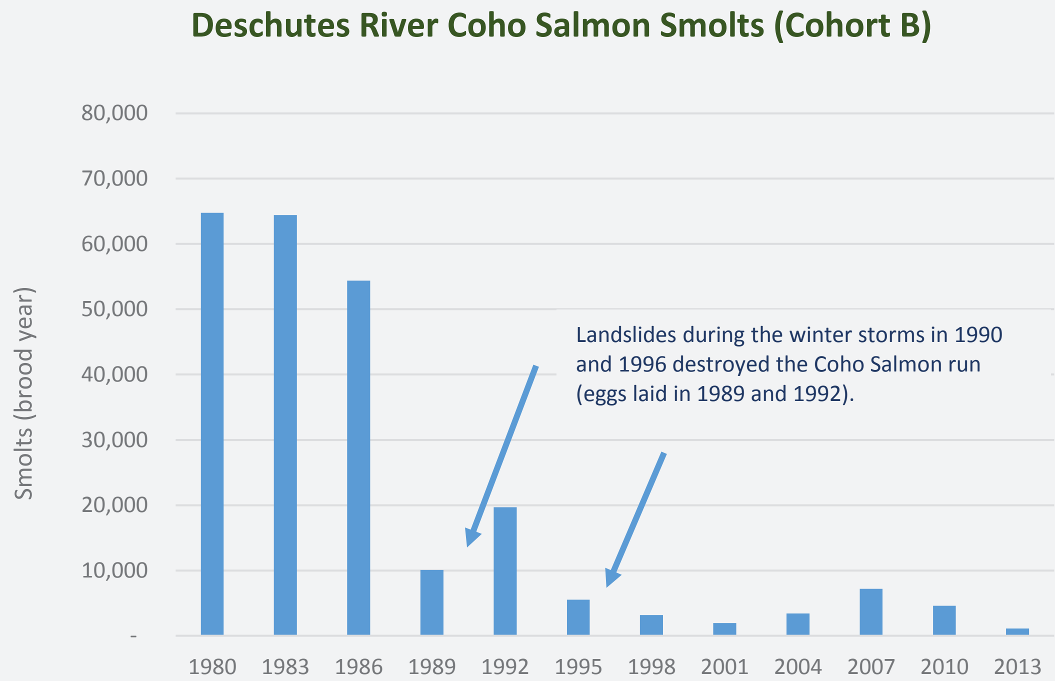

Figure 62: Coho salmon return to spawn three years after emerging. Cohort B, which includes eggs which were laid in 1980 and their descendants, has not recovered from landslides that decimated habitat in the Deschutes during the winters of 1990 and 1996. ***Source:*** *Washington Department of Fish & Wildlife*

Landslides can also topple trees and affect the transmission of electricity across the region. PSE has more than 1,500 miles of overhead distribution lines, 1,200 miles of underground cable, 30 distribution substations, and six transmission substations within Thurston County (Puget Sound Energy, 2012).

Landslides can also exact a costly toll on homes and roads built adjacent to sleep slopes. Landslides on the northeastern shore of Eld Inlet during the winter of 1998-1999, for example, resulted in $24 million in damages and response and recovery costs (TRPC, 2009). More than 30 homes amid the Carlyon Beach community, south of Hunter Point, [*Figure 63, on pg. 81*] were destroyed by the landslides, which followed three years of above-average rainfall (Slaughter, 2016).

The Thurston Region hazards plan (TRPC, 2009) assessed the risk of future landslides as "moderate," after factoring in the high probability of landslides occurring in the area, coupled with their history of destructive, but localized, impacts. The hazards plan's risk assessment did not factor in projected climate change impacts.

Currently, more than 12,000 Thurston County residents and 4,400 acres are within landslide hazard areas — locations where the slope is greater than 40 percent [*Figure 64, on pg. 82*]. The value of buildings and goods within the county's landslide hazard is more than $1.1 billion, according to TRPC data.

Figure 63: Photo of Carlyon Beach property damaged by the '98-'99 winter landslides. ***Source:*** *Slaughter, 2016*

In coming decades, shifts in Puget Sound region air temperature, precipitation and streamflow are expected to increase the frequency of landslides and rate of erosion during winter and spring but reduce such processes during summer (Mauger et al, 2015). For example, modeling projects winter soil water content — an indicator of landslide hazard — is projected to increase up to +35 percent for the 2040s (relative to the 1970-1999 period) along Cascade Range slopes.

The increase would be due, in part, to the mountains getting less snowpack, which absorbs rain and protects slopes from raindrop erosion. The UW CIG report cautioned that such quantitative projections are limited, however, because it is difficult to distinguish between impacts exacerbated by climate change and human activities such as logging and land development (Mauger et al., 2015).

In preparation for increasing frequency of these natural hazards, TRPC and its partners are creating a spatial database of road segments that have been affected by landslides and floods or are most likely to be affected by these hazards in the future [*Figure 65, on pg. 83*]. For each road segment, the database identifies potential triggers (e.g., slope grade or groundwater seepage), alternative routes, and mitigation measures taken.

The goal of this online database, which also includes road segments vulnerable to flooding, is to help catalogue and prioritize problem spots that may warrant additional actions (e.g., slope stabilization, debris containment; stormwater management, road relocation, culvert replacement) as the region's climate changes.

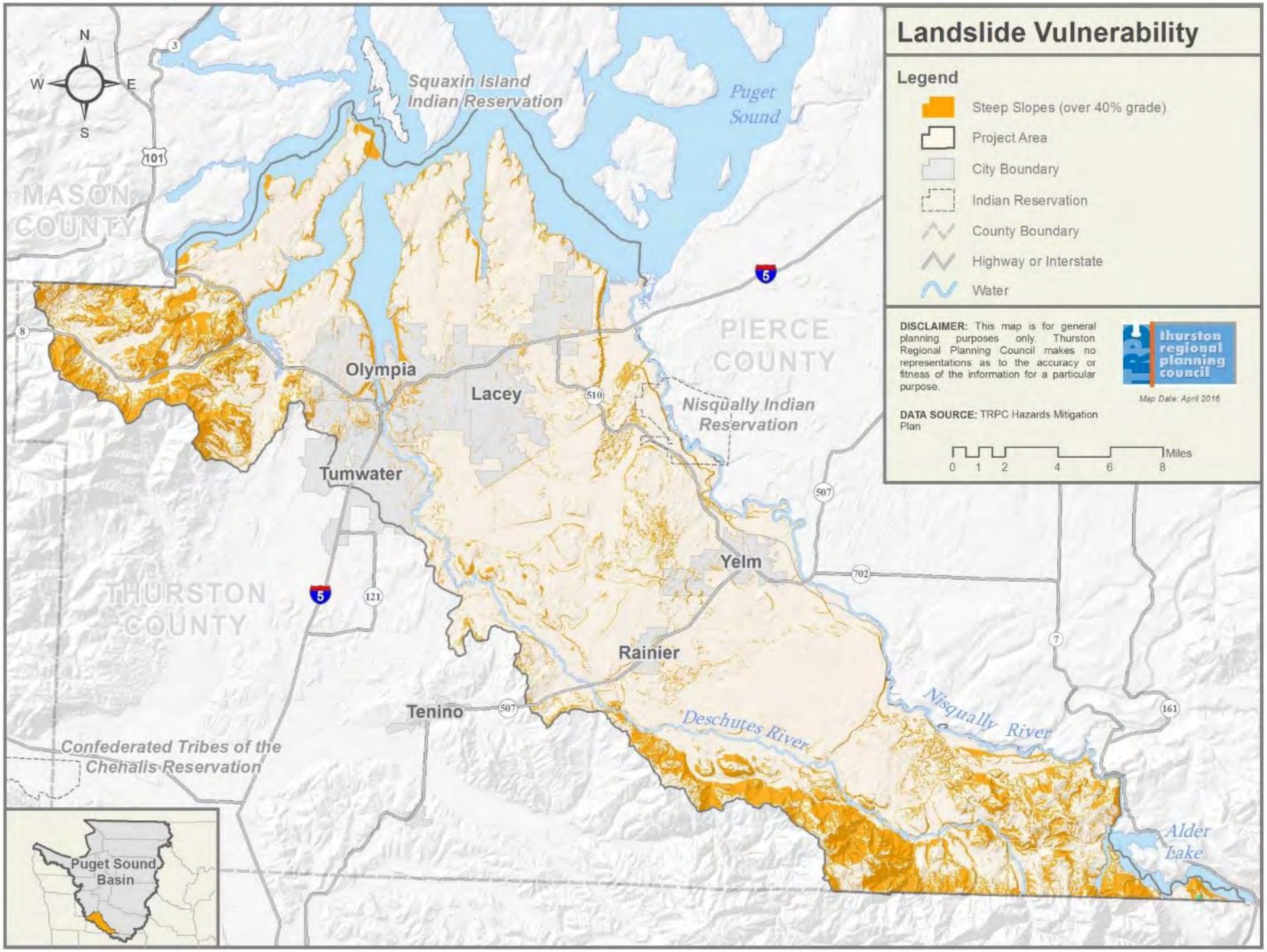

Figure 64: Coastal bluff and forested hillsides are among Thurston County lands most vulnerable to landslides.

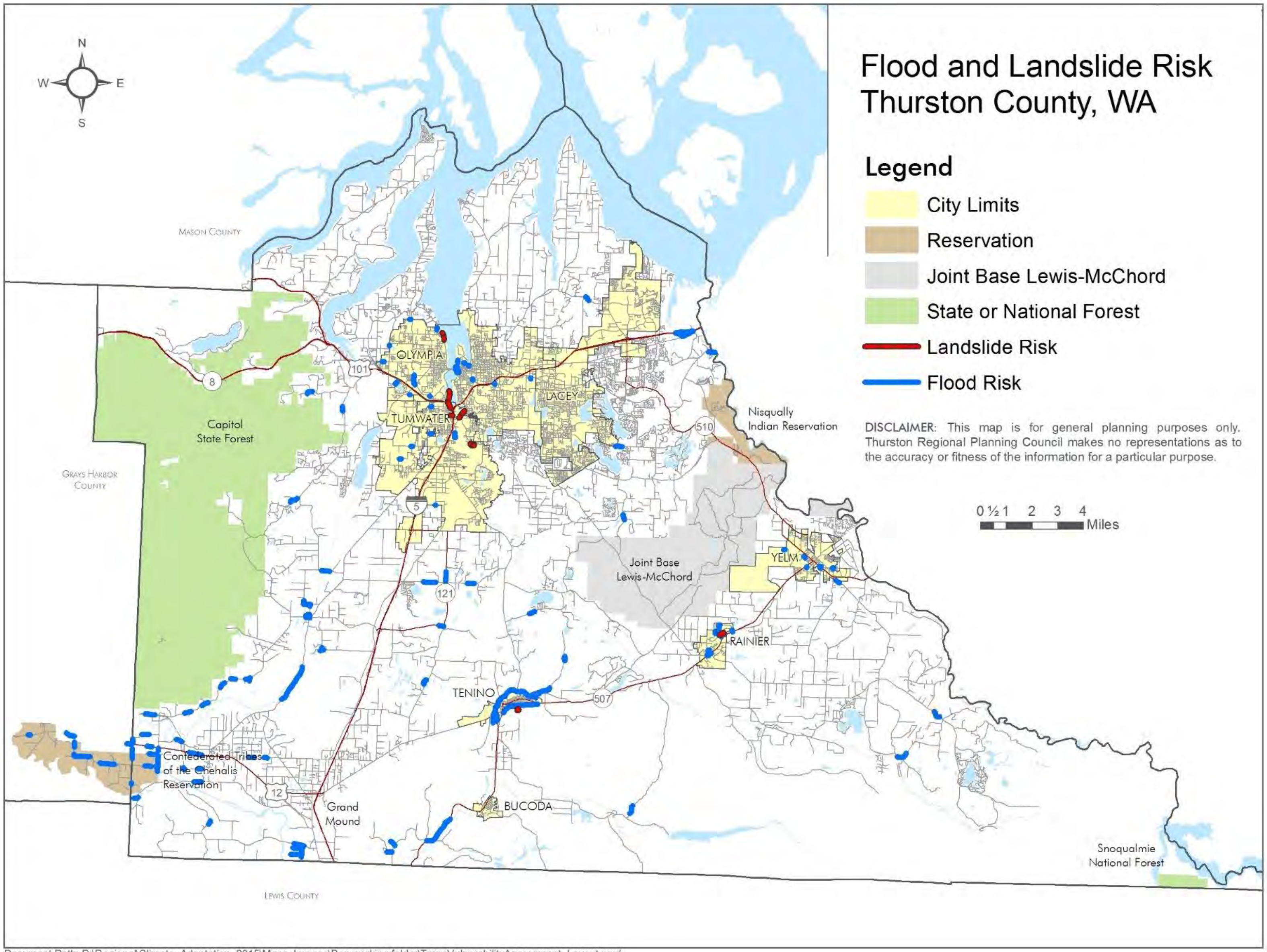

Figure 65: This map shows the locations of road segments that have been affected by floods and landslides historically and are deemed most vulnerable to such natural hazards in the future. ***Source:*** *TRPC, using information provided by local government jurisdictions*

6.4: Diseases & Other Health Threats

As explained throughout this assessment, climate change is projected to exacerbate or introduce a wide range of health threats, including infectious diseases from exposure to viruses and bacteria, which would affect human health outcomes in Thurston County and the broader Puget Sound region. Exposure pathways include food, water, air, soil, trees, insects and animals [*Figure 66, pgs. 84 and 85].*

Human Health Threat	Exposure Pathway	Outcomes & Symptoms	Climate Driver
Algae: Toxigenic marine species of *Alexandrium, Pseudo-nitzschia, Dinophysis, Gambierdiscus; Karenia brevis*	Shellfish; Fish Recreational waters (aerosolized toxins)	Gastrointestinal and neurologic illness caused by shellfish poisoning or fish poisoning. Asthma exacerbations, eye irritations caused by contact with toxins.	Temperature (increased water temperature), ocean surface currents, ocean acidification, hurricanes [*See Section 4.2, on pg. 64*]
Cyanobacteria (multiple freshwater species producing toxins including microcystin)	Drinking water; Recreational waters	Liver and kidney damage, gastroenteritis (diarrhea and vomiting), neurological disorders, and respiratory arrest.	Temperature, precipitation patterns [*See Section 3.2, pg. 45*]
Enteric bacteria & protozoan parasites: *Salmonella enterica; Campylobacter* species; Toxigenic *Escherichia coli; Cryptosporidium*; *Giardia*	Drinking water; Recreational waters; Shellfish	Enteric pathogens generally cause gastroenteritis. Some cases may be severe and may be associated with long-term and recurring effects.	Temperature (air and water; both increase and decrease), heavy precipitation, and flooding [*See Section 3.4, on pg. 49*]
Enteric viruses: enteroviruses; rotaviruses; noroviruses; hepatitis A and E	Drinking water; Recreational waters; Shellfish	Most cases result in gastrointestinal illness. Severe outcomes may include paralysis and infection of the heart or other organs.	Heavy precipitation, flooding, and temperature (air and water; both increase and decrease) [*See Section 4.2, on pg. 65*]
Bacteria: *Vibrio* species	Recreational waters; Shellfish	Varies by species but include gastroenteritis, septicemia (bloodstream infection) through ingestion or wounds, skin, eye, and ear infections.	Temperature (increased water temperature), sea level rise, precipitation patterns (as it affects coastal salinity) [*See Section 4.2, on pg. 65*]

(Table continued on pg. 85)

Human Health Threat	Exposure Pathway	Outcomes & Symptoms	Climate Driver
Fungi: *Cryptococcus gattii*	Soil; Trees	Inhaling the tropical organism may cause cryptococcosis pulmonary disease, with symptoms such as headache, fever, cough and chest pain (CDC, 2010).	Temperature and precipitation (hotter, drier summers, and warmer, wetter winters)
Vector-borne viruses: West Nile Virus	Mosquitos	Minor symptoms such as fatigue, fever and headache; in severe cases, brain inflammation (CDC, 2015).	Temperature and precipitation (hotter, drier summers, and warmer, wetter winters)
Heat Stress (hyperthermia)	Air	Extreme heat can cause cramps, loss of consciousness, weakness and stroke — and, in extreme cases, death	Temperature (hotter, drier summers) [*See Section 2.1, on pg. 15*]
Air Pollution: surface ozone; particulate matter ($PM_{2.5}$)	Air	Surface ozone can increase allergy symptoms; fine particulate matter can enter lungs and cause symptoms including coughing, sneezing, runny nose and shortness of breath	Temperature and precipitation (hotter, drier summers, and warmer, wetter winters) [*See Section 2.2, on pg. 22*]

Figure 66: The table above shows the connections between climate change drivers (shifts in air temperature and precipitation) and exposure pathways (food, water, air, and vectors such as biting insects) for viruses, bacteria and other human health threats. ***Source:*** *TRPC, adapted from table in USGCRP, 2016*

Tribal Vulnerability

Members of local tribes, which are rooted in place and utilize the land and waters for cultural traditions, are particularly vulnerable to climate change impacts (TNC, 2016). According to one study, tribal and Asian and Pacific Islander community members consume 3-10 times the amount of fish and shellfish of average U.S. consumers (Judd et al., 2016). Continuing to consume traditional seafood staples may increase health risks from contamination (e.g., *Vibrio* in shellfish), but replacing such traditional foods may involve the loss of cultural practices tied to their harvest (USGCRP, 2016).

Squaxin Island Tribe members are already thinking about these and other climate risks and considering strategies to support current and future generations. In 2015, a team of Pacific Northwest researchers worked with the Squaxin and several other tribes to develop indicators that reflect tribal definitions of health and wellbeing. Squaxin-specific indicators included (Donatuto et al., 2015):

- Physical Health — including maintaining body strength and nutrition and being free of illness and pollution;
- Community Connection — including actively participating in community functions, such as harvesting, and looking out for family and tribal elders;
- Natural Resources Security — including having abundant and accessible land, plants, water and animals to support a healthy ecosystem and human community;
- Cultural Use — including being able to harvest local natural resources (e.g., clams and salmon) and carry forth cultural traditions;
- Education — including passing on knowledge, values and beliefs to future generations;
- Self-Determination — including maintaining the ability to exercise treaty rights and define and enact the Tribe’s chosen environmental or habitat restoration programs;

- Balance — including maintaining homeland connections and ensuring that the wellbeing and health of future generations are not at risk due to environmental changes and relationships with others.

Based on interviews with Squaxin officials, the researchers summarized potential actions and opportunities. Ideas with climate change mitigation and adaptation benefits include (Donatuto et al., 2016): building river turbines and enhancing riparian buffers; removing the Fifth Avenue dam at Capitol Lake; educating people about climate change and health; repairing septic systems to protect water quality; and, working with the State of Washington to repair roads and bridges susceptible to failure associated with more extreme temperature changes.

Assessing Adaptive Capacity

New health threats may emerge and others may worsen in coming years, necessitating the need for both flexible and durable strategies in the Thurston County region. The vulnerability of the community's health and welfare will depend largely on peoples' sensitivity and exposure to threats and capacity to adapt (USGCRP, 2016). Thus, it will be important for our local and state public health professionals to consider a wide range of social and behavioral factors [*Figure 67, below*] as they assess communities' and individuals' adaptive capacity and develop strategies.

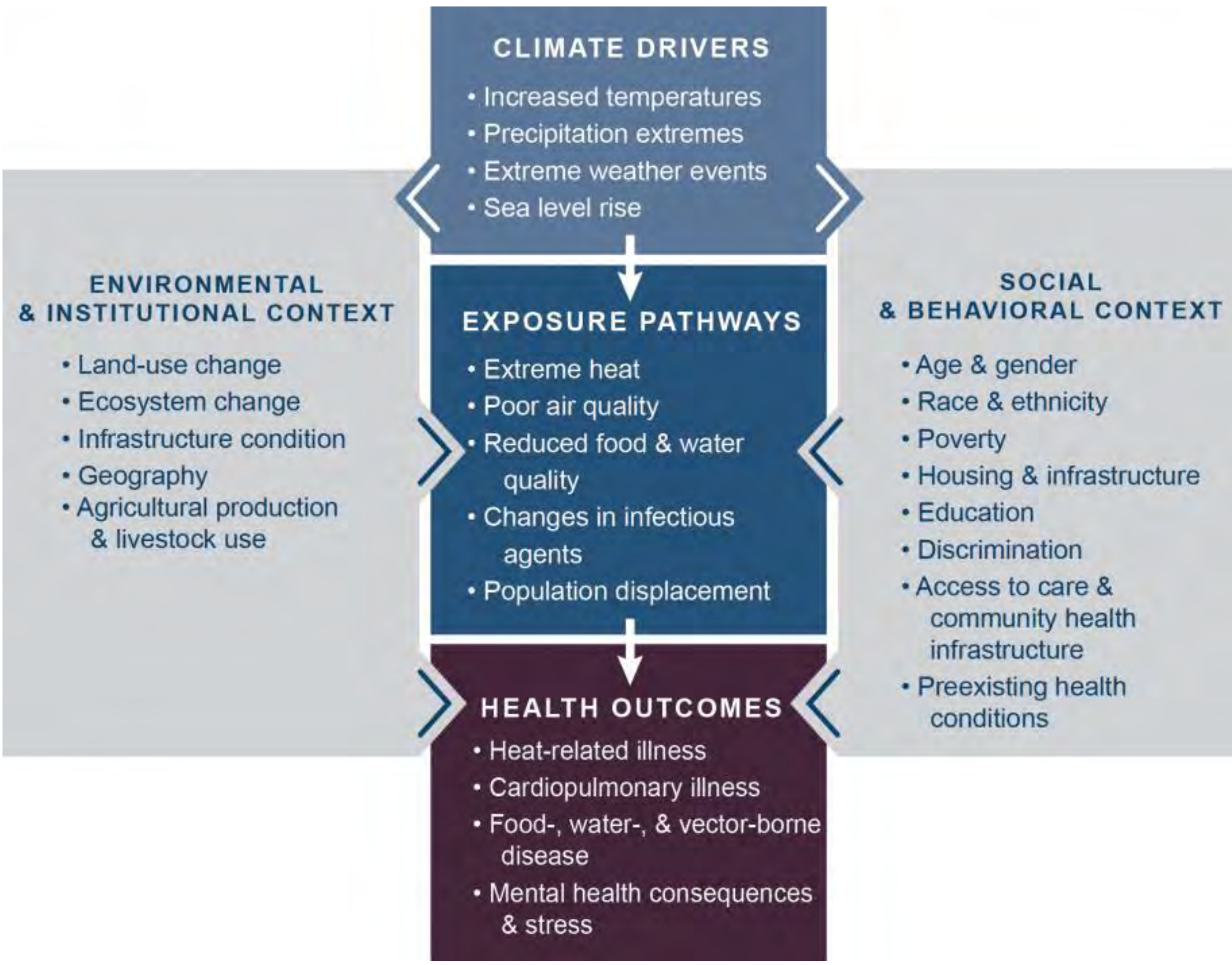

Figure 67: This diagram illustrates climate drivers and exposure pathways that affect human health outcomes. The gray boxes show factors, such as socio-economic status and land use change, which can affect a person's or a community's vulnerability and adaptive capacity. ***Source:*** *USGCRP, 2016*

Our region has a solid foundation for such efforts. The Thurston Thrives initiative, which grew out of TRPC's Sustainable Thurston project, uses a systems approach to identify priority health outcomes and implement cross-sector strategies to achieve community targets related to climate change, clean energy, food and other topics (Thurston Thrives, 2016).

Thurston Thrives' website includes strategy maps and tracks measures of progress for such topics. Similarly, the Washington State Department of Health's Washington Tracking Network website tracks indicators affected by climate change (e.g., heat stress, air quality, wildfire occurrence, flood risks).

The DOH interactive online tool's Social Vulnerability of Hazards map, for example, rates the social vulnerability of census block groups (1 = "low" social vulnerability; 10 = "high" social vulnerability) by factoring in criteria, including: educational attainment; English language proficiency; disability; age; housing type and household size; access to a private vehicle; and, unemployment and poverty rates.

Based on such criteria, the Thurston County census tracts [*Figure 68, below*] with the highest social vulnerability to hazards (rating of 9 or 10) include: 012411 (North Yelm); 012320 (Nisqually Valley); 011550 (Tanglewilde-Thompson Place); 011200 (Central Lacey/Woodland District); 011621 (South Lacey/Smith Lake); 010510 (Southwest Olympia/Capital Mall).

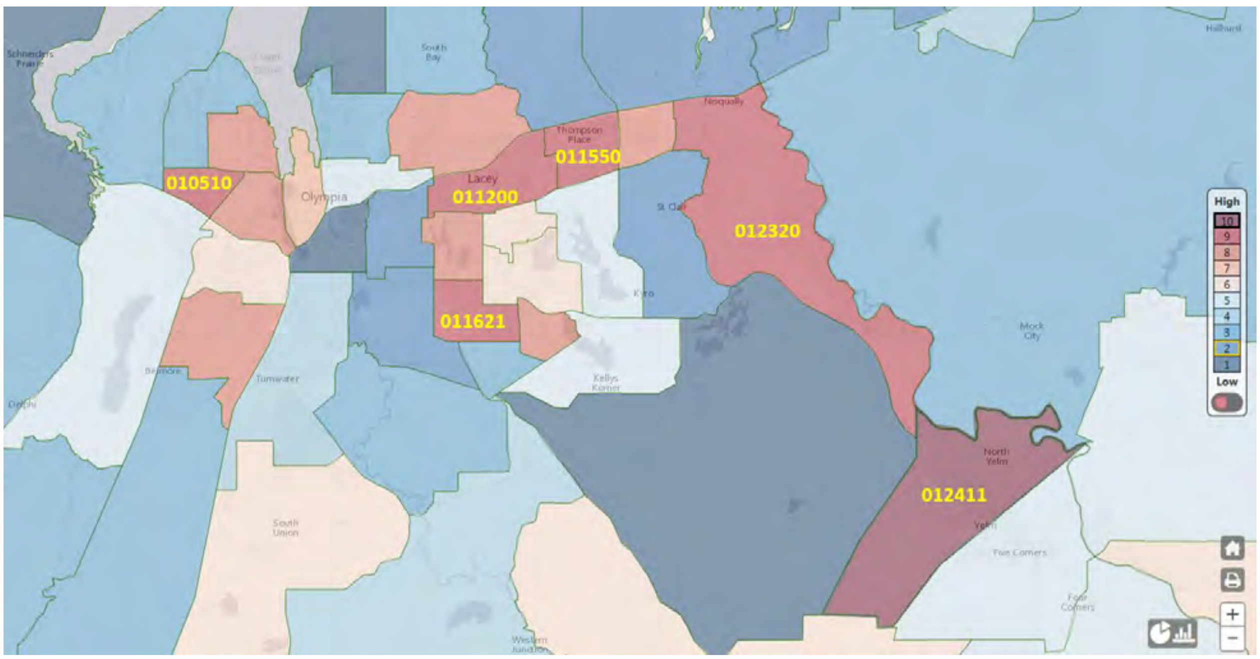

Figure 68: The map above shows the Thurston County areas (census tracts) that are most vulnerable to natural hazards, as ranked by the Washington State Department of Health's Washington Tracking Network. TRPC and its partners could use such tools to assess the adaptive capacity of communities and to develop strategies to prepare for and cope with climate change impacts. ***Source:*** *DOH; census track numbers added by TRPC*

6.5: Population Displacement

As the project's *Science Summary* explains, climate change is projected to affect other parts of the nation in myriad ways — including more frequent and intense hurricanes in the Southeast, droughts in the Southwest, and heat waves in the Northeast. This raises the provocative idea that the comparatively temperate Pacific Northwest will become a refuge from climate change in the decades ahead.

Cliff Mass, who teaches atmospheric science at the University of Washington, concluded as much after analyzing how climate change could exacerbate the effects of natural hazards on other parts of the nation. "A compelling case can be made that the Pacific Northwest will be one of the best places to live as the earth warms — a potential climate refuge," Mass wrote recently on his widely read weather blog (Mass, 2015). Others caution that adaptation is still essential amid the Puget Sound region, given the breadth and severity of projected climate change impacts.

Social scientists have already observed how environmental, social and economic stressors accompanying sudden "pulse" events (e.g., Hurricane Katrina) [*Figure 69, below*] and sustained "pressure" events (e.g., the Dust Bowl) spur people to migrate both voluntarily and involuntarily to new communities. Whether such migration is temporary or permanent depends on several factors, including a migrant's economic status, educational attainment, and social and cultural connections (Saperstein, 2015).

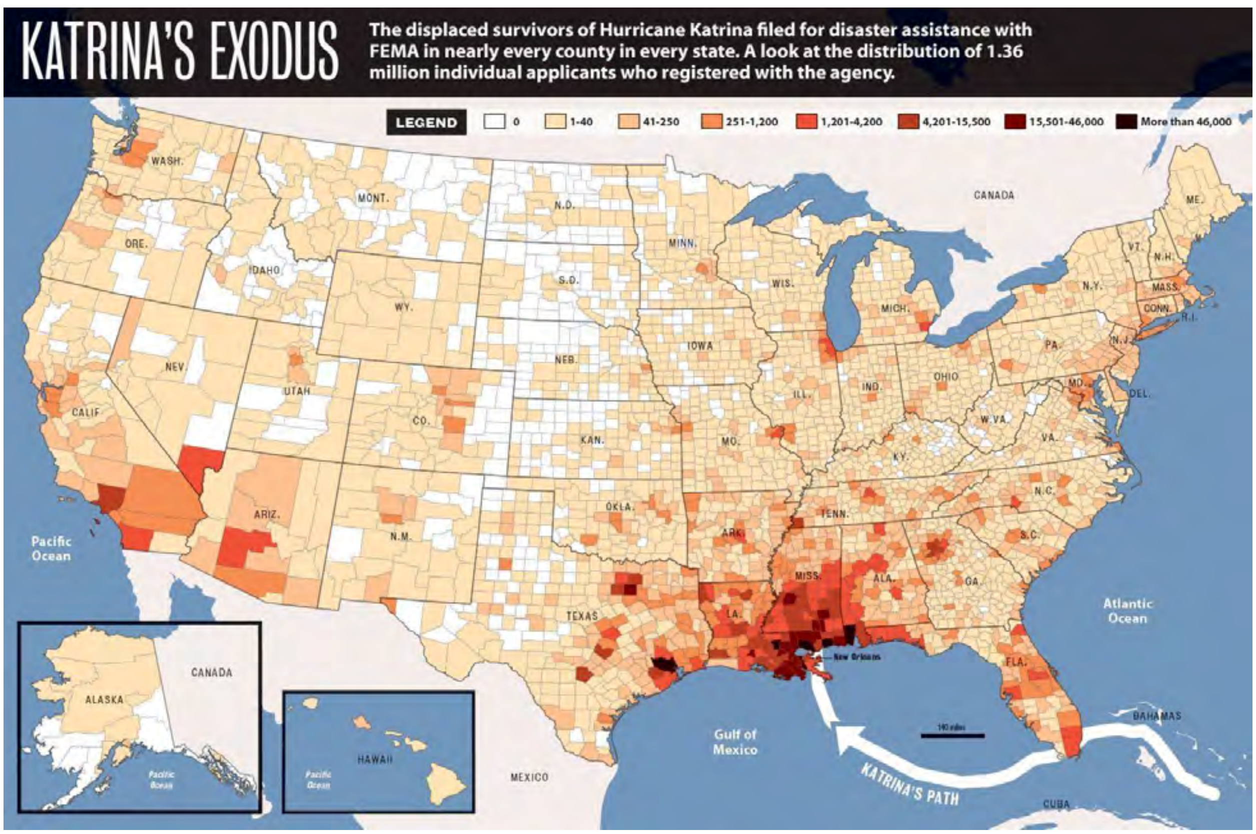

Figure 69: The map shows where Hurricane Katrina survivors moved to after the storm, as recorded by FEMA disaster-assistance applications. ***Source:*** *New Orleans Times-Picayune/NOLA.com, using information from FEMA, U.S. Census Bureau, The New York Times and Queens College*

Climate change-induced migration is the subject of a small-but-growing body of research — yet the fact remains that it is impossible to predict how many people might move to or within Thurston County — or when — as a result of climate change. This doesn't mean we can't or shouldn't begin preparing today for how climate change could shape local population growth and its impacts.

This vulnerability assessment marks a first adaptation step, as it begins to show what areas and assets of the Thurston County region are most vulnerable to climate-exacerbated threats. Subsequent assessments could take a closer look at which of the region's residents are most vulnerable to displacement (e.g., low-income or socially isolated residents who may be forced to move because of coastal or upland flooding) and what resources they might need. Depending on their circumstances, displaced residents may require shelter, food, clothing, health care, and job-placement assistance (TRPC, 2010).

Potential risks and opportunities of climate change impacts on the region's growth include:

- Increases pressure on rural lands to develop, yet also presents an opportunity to focus growth in existing urban areas, consistent with the Sustainable Thurston vision;
- Increases demand for food, water, energy and other resources;
- Increases pressure on existing parks and open spaces;
- Increases pressure on transportation infrastructure (e.g., roads, transit);
- Increases demand for local goods and services and supports job creation/demand;
- Increases cost to provide social services;
- Increases pollution related to development (e.g., more septic systems and impervious surfaces);
- Increases solid and organic waste creation;
- Increases demand on schools (e.g., unplanned influx of students)

Going forward, local government agencies and their partners could study who is most likely to move here from other parts of the state, nation and world (e.g., by studying "chain migration," the tendency of migrants to follow those of similar ethnicity or job skillset). Researchers could also assess how to accommodate potential newcomers in ways consistent with community values (e.g., by evaluating where and what type of growth should occur so that it is consistent with local comprehensive plans). A recent paper published by Portland State University provides an approach for such work using U.S. Census Bureau data analysis and collaborative planning strategies (Ahillen et al., 2011).

7: Next Steps

The following section provides a brief description of the next steps TRPC and its partners will take to craft a Thurston Climate Adaptation Plan with a vision, goals and strategies to help the region prepare for and cope with climate change impacts. As the United Nations Intergovernmental Panel on Climate Change underscored in its fourth assessment report, adaptation is "necessary to address impacts resulting from the warming that is already unavoidable" due to past emissions (Klein et al., 2007).

7.1: Overview of Plan Components

In coming months, the project team will work with its Stakeholder Advisory Committee to complete a risk assessment — modeled after a U.S. Environmental Protection Agency approach — which considers the probability and consequence of local climate change impacts identified in the vulnerability assessment. The risk assessment will help the Stakeholder Advisory Committee to develop and prioritize project-area adaptation strategies — many of which may also be applicable to others parts of Thurston County and the Puget Sound region with similar built and natural assets. For more information about the U.S. EPA risk-assessment methodology, please visit: www.epa.gov/sites/production/files/2014-09/documents/being_prepared_workbook_508.pdf.

Earth Economics will conduct a detailed benefit-cost analysis (BCA) of at least two priority strategies that are selected by the Stakeholder Advisory Committee. The Tacoma-based firm's analysis will evaluate the economics of natural ecosystems, including the ecosystem services that are produced or protected by a particular land cover type [*Figure 70, below*].

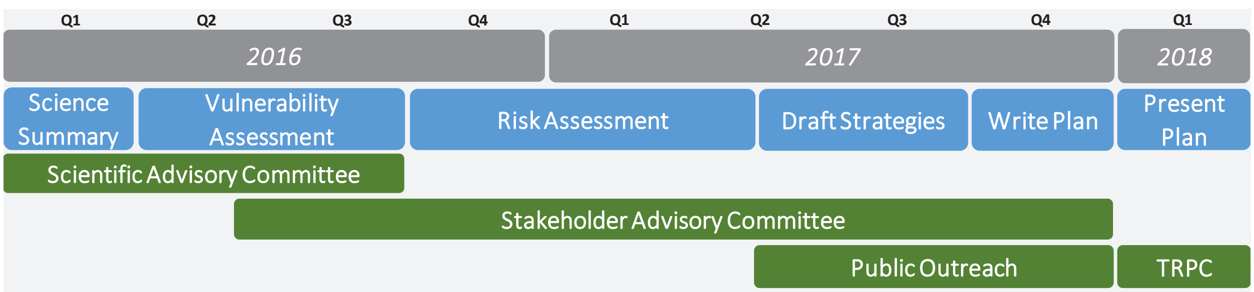

Figure 70: The process diagram above shows key Thurston Climate Adaptation Plan dates and components, including the vulnerability and risk assessments. ***Source:*** *TRPC*

As this vulnerability assessment shows, climate change is projected to exacerbate the risk of natural hazards (e.g., storms, floods, landslides, etc.) that already affect the region and may introduce new risks (e.g., disease vectors) to built and natural systems. Thus, during the final action-planning phase, the Stakeholder Advisory Committee will consider how adaptation strategies can address multiple risks or have co-benefits such as mitigating (reducing) greenhouse gas emissions or protecting air and water quality.

> **"A prudent way to cope with invisible but inevitable dangers … is to build resilience into all systems critical to our well-being. A resilient system can absorb large disturbances without changing its fundamental nature."**
>
> — Thomas Homer-Dixon, *The Upside of Down: Catastrophe, Creativity and the Renewal of Civilization*

This planning approach, which is consistent with the project's vision and guiding principles, will help the Thurston Region's built and natural environments remain resilient in the decades ahead. For more information about the project's process, vision and documents, please visit www.trpc.org/climate.

8: Appendix

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8.2: Explanation of Figures

Watershed Delineation

Per the requirements of TRPC's National Estuary Program (NEP) grant, the Thurston Climate Adaptation Plan's project area includes the extent of three Water Resource Inventory Areas (WRIAs) within Thurston County: WRIA 11 (Nisqually), WRIA 13 (Deschutes), and WRIA 14 (Kennedy-Goldsborough). WRIAs are watershed units defined by the Washington State Department of Ecology. WRIAs and HUCs are similar except for small differences in basin groupings, as well as the fact that HUCs extend beyond the state's borders into Canada, Idaho and Oregon. Both were digitized using 1:24,000 scale hydrography and topography maps and data.

Below is a list of other useful information about vulnerability assessment figures that incorporate data from UW CIG or other sources. These descriptions are adapted from the UW Climate Impacts Group's 2015 Report *State of Knowledge: Climate Change in Puget Sound* (Mauger et al, 2015).

University of Washington Climate Impacts Group Figures

In Mauger et al., 2015, the University of Washington Climate Impacts Group (CIG) used 10 global climate models and statistical downscaling to assess climate change impacts for the Puget Sound region. The models incorporate the "low" RCP 4.5 and "high" RCP 8.5 emissions scenarios used by the International Panel on Climate Change its fifth assessment report (IPCC, 2013).

UW CIG used hydraulic unit codes (HUCs), defined by the U.S. Geological Survey, to delineate the data for the Puget Sound region watersheds. The Thurston Regional Planning Council (TRPC) then used these data in a geographic information system (GIS) to spatially analyze historic and projected climate trends amid the South Puget Sound sub-region, which includes the project area.

Such maps show the historical and projected change in temperature, in Fahrenheit (°F). Such maps also compare watershed averages for historical conditions (1970-1999) and the projected change for current climate models. Projections are shown for the 2050s (2040-2069) and 2080s (2070-2099), and projections are included for two greenhouse gas scenarios: one low (RCP 4.5) and one high (RCP 8.5).

With the exception of the air temperature maps, all of the maps show projected changes (relative to historical averages) in percent ranges rather than absolute values. The UW CIG took the same approach in its Puget Sound climate impacts assessment (Mauger et al., 2015) because the percent ranges are more reliable numbers than absolute values.

The UW CIG modelers showed percent changes for variables that vary widely across the region. For example, annual precipitation varies by a factor of 10 from the driest to the wettest parts of the Puget Sound region. Absolute changes in precipitation, however, are not easily distinguishable from that pattern (Mauger, 2016).

U.S. Forest Service - NorWeST Projected Stream Temperature Figures

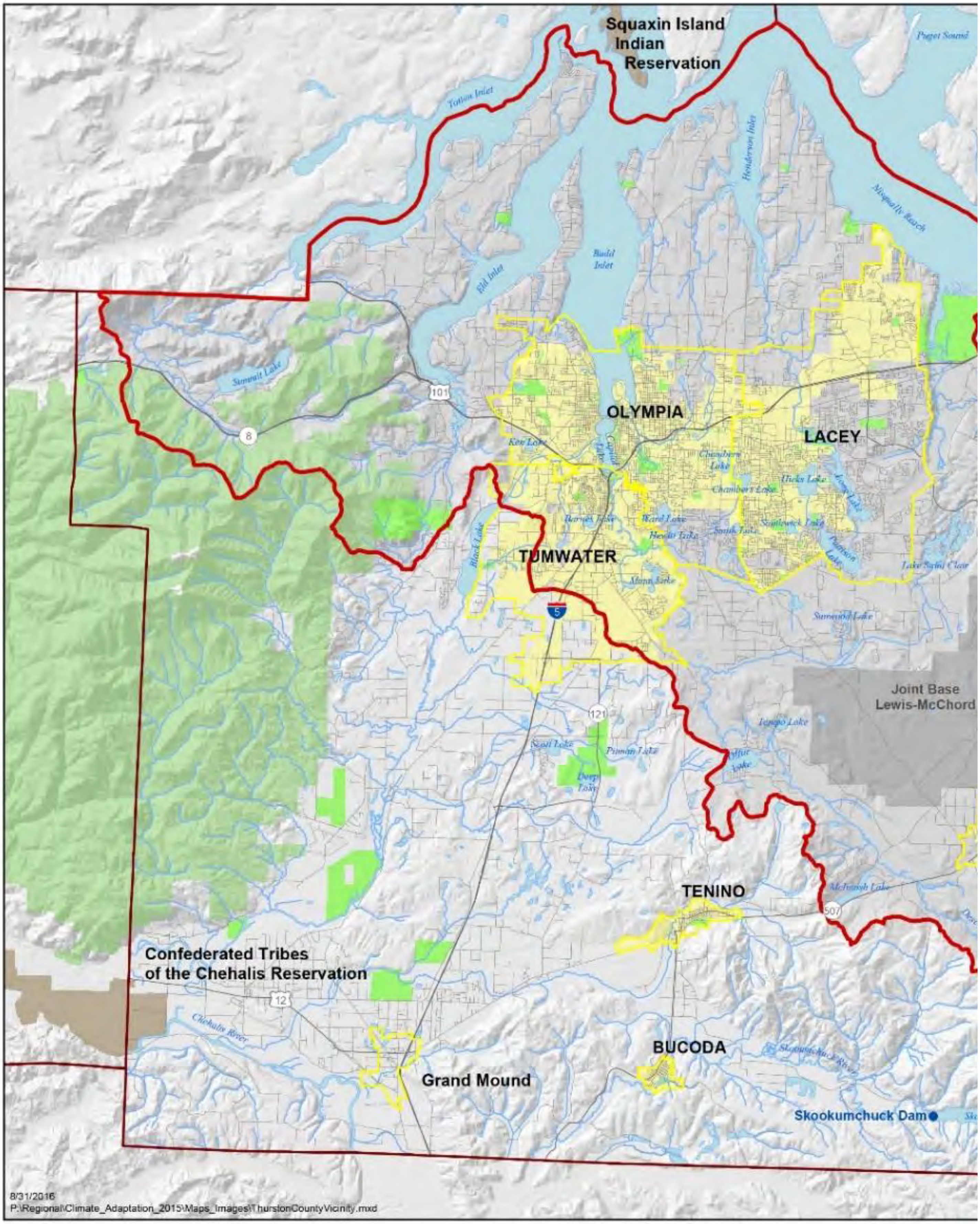
The NorWeST Stream Temperature data set contains three temporal extents based on historic and projected stream temperature data. The descriptions below are from the metadata contained within the GIS dataset. It should be noted that while the University of Washington Climate Impacts Group data utilized the most recent IPCC climate scenarios, the NorWeST dataset is based on 2007 scenarios.

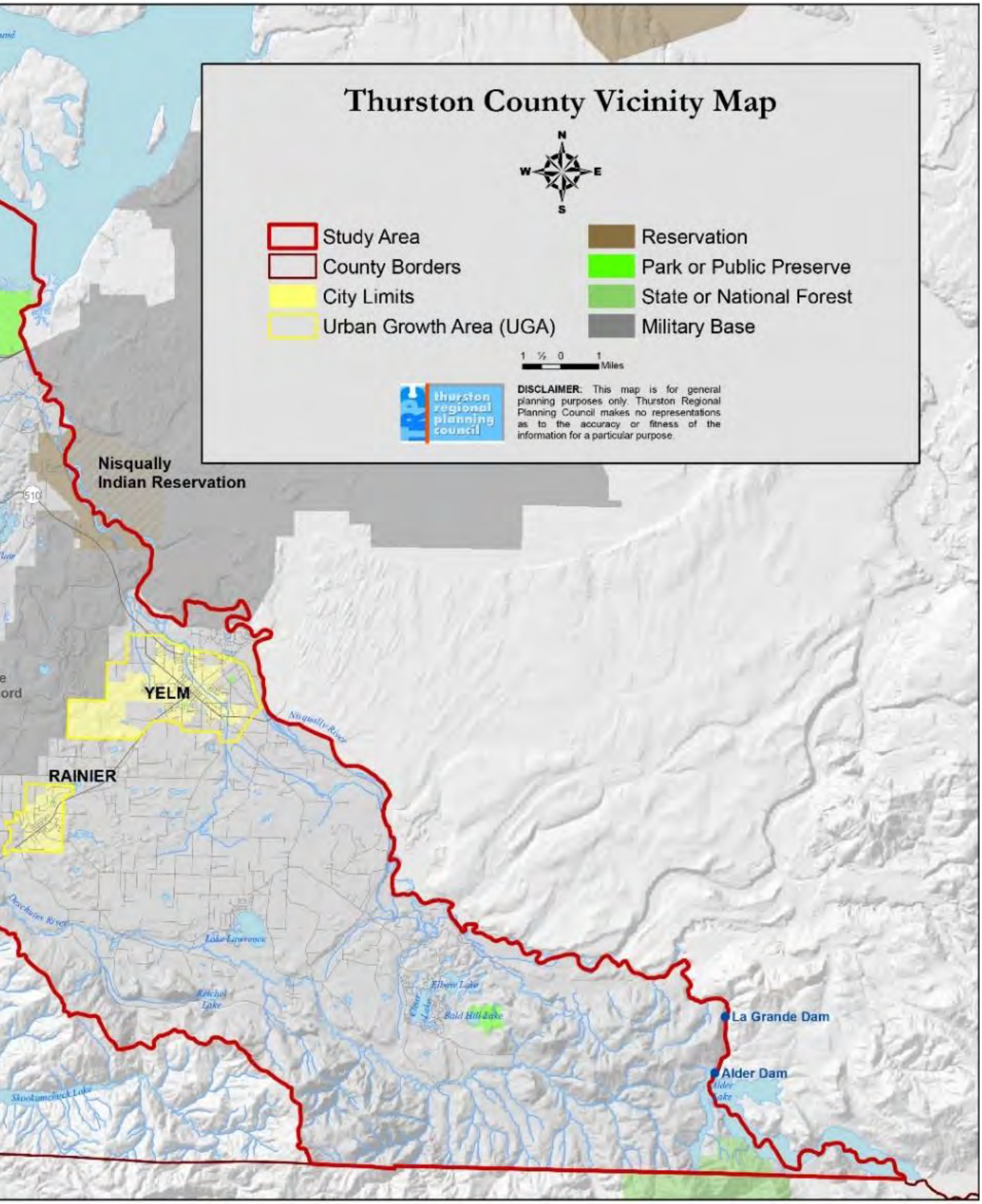
Mean August Stream Temperature - Historical composite scenario representing 19-year average of August mean stream temperatures for 1993 – 2011.

Modeled Future Scenario 2040 - Future scenario based on global climate model ensemble averages that represent the A1B warming trajectory for 2040s (2030 - 2059). Future stream deltas within a processing unit were based on similar projected changes in August air temperature and stream discharge, but also accounted for differential warming of streams by using historical temperatures to scale temperature increases so that cold streams warm less than warm streams.

Modeled Future Scenario 2080 - Future scenario based on global climate model ensemble averages that represent the A1B warming trajectory for 2080s (2070 - 2099). Future stream deltas within a processing unit were based on similar projected changes in August air temperature and stream discharge, but also accounted for differential warming of streams by using historical temperatures to scale temperature increases so that cold streams warm less than warm streams.

8.3: Reference Map





Thurston County Vicinity Map
N
W
E
S
Study Area
County Borders
City Limits
Urban Growth Area (UGA)
Reservation
Park or Public Preserve
State or National Forest
Military Base
1 ½ 0 1
Miles
thurston regional planning council
DISCLAIMER: This map is for general planning purposes only. Thurston Regional Planning Council makes no representations as to the accuracy or fitness of the information for a particular purpose.
Nisqually Indian Reservation
510
YELM
RAINIER
Nisqually River
Deschutes River
Lake Lawrence
La Grande Dam
Alder Dam

Appendic C

Goal Risk Report

Goal-Risk Report

Goal 1: Create vibrant centers, corridors, and neighborhoods while accommodating growth.

		Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
1	Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).	High	High	Increasing Drought	Place	0-10 years	Low	Take Action
16	Warmer winters increase the range and survival of invasive species, pests, and diseases that threaten native flora and fauna.	Medium	High	Warmer Winter	Extensive	10-30 years	Medium	Take Action
4	Warmer summers cause urban heat islands, which could affect livability/health in heavily developed centers and corridors.	Low	Medium	Warmer Summer	Place	More than 30 years	Medium	Take Action

Goal 2: Preserve environmentally sensitive lands, farmlands, forest lands, prairies, and rural lands and develop compact urban areas.

		Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
7	Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.	High	High	Intensifying Precipitation	Extensive	0-10 years	High	Take Action
8	Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.	High	High	Increasing Drought	Extensive	0-10 years	High	Take Action
10	Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.	High	High	Increasing Drought	Extensive	0-10 years	High	Take Action
11	Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.	Medium	High	Warmer Winter	Place	0-10 years	High	Take Action
12	Sea-level rise increases the frequency, depth, and duration of inundation of low-lying coastal areas, which could turn marshes, estuaries, and other upland areas into mudflats (dams limit sedimentation and 1-5 berms limit vegetation adaptation in the Nisqually Estuary).	High	High	Sea-level Rise	Place	0-10 years	Medium	Take Action
13	Warmer summers stress sensitive plants and habitat (including urban landscaping), which could leave them vulnerable to extreme heat, pests, or pathogens.	High	High	Warmer Summer	Extensive	0-10 years	High	Accept
14	Warmer winters cause salmon to remain active during winter and deplete their store of energy/health.	Medium	High	Warmer Winter	Extensive	10-30 years	Medium	Accept
16	Warmer winters increase the range and survival of invasive species, pests, and diseases that threaten native flora and fauna.	Medium	High	Warmer Winter	Extensive	10-30 years	Medium	Take Action
20	Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.	Medium	High	Sea-level Rise	Extensive	10-30 years	Medium	Take Action
22	Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.	High	High	Increasing Drought	Place	10-30 years	High	Take Action
15	Warmer summers decrease climatic suitability of areas that currently support Garry oak and prairie habitat.	Medium	Medium	Warmer Summer	Extensive	More than 30 years	Medium	Accept
18	Warmer winters shift the timing of flowering and abundance of pollinators, which could reduce some species of plants throughout the region.	Medium	Medium	Warmer Winter	Extensive	0-10 years	Medium	Accept
19	Warmer water expands the range for invasive aquatic species.	Medium	Medium	Warmer Water	Extensive	More than 30 years	Medium	Take Action
23	Population change increases pressure on existing parks and open space.	Medium	Medium	Population Change	Extensive	10-30 years	Medium	Accept

Goal 2: Preserve environmentally sensitive lands, farmlands, forest lands, prairies, and rural lands and develop compact urban areas.

	Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
139 Warmer summers decrease climatic suitability of areas that currently support Douglas fir.	Medium	Medium	Warmer Summer	Extensive	0-10 years	Medium	Accept
113 Population change increases pressure to develop rural areas, which could reduce, fragment and/or degrade farms, forests, and prairies.	Low	Low	Population Change	Extensive	10-30 years	Low	Accept

Goal 3: Create a robust economy through sustainable practices.

		Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
1	Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).	High	High	Increasing Drought	Place	0-10 years	Low	Take Action
26	Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).	High	High	Sea-level Rise	Place	10-30 years	High	Take Action
27	Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).	High	High	Intensifying Precipitation	Extensive	0-10 years	High	Take Action
29	Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.	Medium	High	Increasing Drought	Extensive	More than 30 years	Medium	Take Action
30	Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.	Medium	High	Intensifying Precipitation	Place	0-10 years	High	Take Action
32	Sea-level rise raises the cost of new development and redevelopment.	Medium	High	Sea-level Rise	Place	0-10 years	High	Take Action
90	Population change increases strain on social and emergency services.	Medium	High	Population Change	Extensive	0-10 years	Low	Take Action
36	Population change puts more strain on transportation (roads, transit, etc.).	Medium	Medium	Population Change	Extensive	More than 30 years	Low	Take Action
38	Warmer summers raise the risk of low crop yields or failure due to warmer temperature, reduced summer precipitation, and increased pest prevalence.	Low	High	Warmer Summer	Extensive	More than 30 years	Medium	Accept
41	Ocean acidification reduces food available for and survival of salmon and other marine life.	Low	High	Ocean Acidification	Extensive	More than 30 years	Medium	Accept
42	Warmer winters reduce snowpack and alter stream volume and temperature, impacting long-term productivity of anadromous fish populations and fisheries.	Low	High	Warmer Winter	Extensive	More than 30 years	High	Accept
45	Warmer water increases the risk of marine water stratification and hypoxia, which could alter the timing of spring plankton blooms that support the marine food web (including salmon and other economically important fish).	Low	Medium	Warmer Water	Extensive	More than 30 years	Medium	Accept
50	Intensifying precipitation raises the cost of development (flooding and runoff mitigation measures).	Medium	Low	Intensifying Precipitation	Site	0-10 years	Medium	Accept
51	Warmer summers increase extreme heat events, which could result in project delays and higher costs (e.g., in the construction industry).	Low	Low	Warmer Summer	Site	10-30 years	Low	Accept

Goal 4: Protect and improve water quality, including groundwater, rivers, streams, lakes, and the Puget Sound.

	Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
52 Increasing drought reduces groundwater recharge (drinking water and in-stream flows).	High	High	Increasing Drought	Place	0-10 years	Medium	Take Action
55 Warmer water increases the growth and reach of pathogens (e.g., cyanobacteria and algal blooms) harmful to humans, fish, and other water users.	High	High	Warmer Water	Extensive	0-10 years	High	Take Action
56 Increasing drought increases the concentration of pollutants in first-flush runoff.	High	Medium	Increasing Drought	Place	10-30 years	Medium	Take Action
57 Intensifying precipitation contaminates water (turbidity and sedimentation) due to landslides.	High	Medium	Intensifying Precipitation	Extensive	10-30 years	Medium	Take Action
58 Sea-level rise increases coastal flooding of downtown Olympia and LOTT wastewater treatment plant assets, which could threaten the ability to treat and discharge water and increase the energy consumed to operate pumps.	High	High	Sea-level Rise	Place	10-30 years	Medium	Take Action
59 Ocean acidification decreases marine pH and -- when coupled with increases in ocean temperature and land-borne pollution -- threatens marine water quality.	High	High	Ocean Acidification	Extensive	0-10 years	Medium	Take Action
61 Intensifying precipitation contaminates water (nutrients) from septic systems due to high groundwater flooding.	Medium	High	Intensifying Precipitation	Site	0-10 years	High	Take Action
62 Sea-level rise inundates former industrial sites, which could mobilize pollutants in the soil and degrade water quality.	High	High	Sea-level Rise	Place	More than 30 years	High	Take Action
63 Intensifying precipitation contaminates water (bacteria, pathogens) due to a greater incidence of combined stormwater/sewer system overflows.	Medium	High	Intensifying Precipitation	Place	10-30 years	Medium	Take Action
65 Population change increases transportation-related energy consumption, CO2 emissions, and other pollutants related to buildings and transportation.	High	High	Population Change	Extensive	More than 30 years	Low	Take Action
60 Population change increases pollution related to development (e.g., more septic systems and impervious surfaces).	High	Low	Population Change	Extensive	More than 30 years	Low	Take Action
64 Warmer water increases periods of low dissolved oxygen and hypoxic conditions in lakes and other freshwater areas.	Medium	Medium	Warmer Water	Extensive	10-30 years	Medium	Take Action
66 Increasing drought raises the risk of wildfires, which could contaminate water (turbidity and sedimentation).	Low	Medium	Increasing Drought	Place	10-30 years	Medium	Accept
67 Warmer summers increase recreational activity in waterbodies and the risk of boat fuel spills.	Low	Low	Warmer Summer	Place	10-30 years	Low	Take Action

Goal 5: Plan and act toward zero waste in the region.

	Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
27 Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).	High	High	Intensifying Precipitation	Extensive	0-10 years	High	Take Action
68 Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.	Low	Medium	Sea-level Rise	Place	More than 30 years	Medium	Accept
71 Population change increases solid waste generation.	Low	Low	Population Change	Extensive	More than 30 years	Low	Take Action
72 Warmer summers increase the use of parks, which could raise waste volume and disposal costs.	Low	Low	Warmer Summer	Site	More than 30 years	Low	Accept
74 Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.	Low	Low	Increasing Drought	Site	10-30 years	Medium	Accept

Goal 6: Ensure that residents have the resources to meet their daily needs.

		Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
1	Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).	High	High	Increasing Drought	Place	0-10 years	Low	Take Action
26	Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).	High	High	Sea-level Rise	Place	10-30 years	High	Take Action
27	Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).	High	High	Intensifying Precipitation	Extensive	0-10 years	High	Take Action
78	Warmer summers introduce or exacerbate disease vectors (carriers), which could harm human health (warmer, wetter winters also exacerbate exposure to pathogens and other health threats).	Medium	High	Warmer Summer	Extensive	0-10 years	Medium	Take Action
82	Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.	Medium	High	Increasing Drought	Extensive	0-10 years	High	Take Action
85	Warmer winters shift the life cycle of fish and wildlife, which could reduce populations that support subsistence and recreational hunting.	High	Medium	Warmer Winter	Extensive	0-10 years	Medium	Accept
87	Intensifying precipitation puts more strain on services (social, emergency, etc.).	High	Medium	Intensifying Precipitation	Extensive	0-10 years	Medium	Take Action
90	Population change increases strain on social and emergency services.	Medium	High	Population Change	Extensive	0-10 years	Low	Take Action
91	Warmer summers increase summer peak energy demand and costs for cooling residential and commercial buildings (e.g., buying and operating air conditioners), which could place more demand on the grid and reduce energy security.	High	Medium	Warmer Summer	Extensive	0-10 years	High	Take Action
92	Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.	Medium	High	Warmer Summer	Extensive	0-10 years	Medium	Take Action
117	Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).	High	Medium	Population Change	Extensive	0-10 years	High	Take Action
36	Population change puts more strain on transportation (roads, transit, etc.).	Medium	Medium	Population Change	Extensive	More than 30 years	Low	Take Action
80	Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.	Medium	Medium	Increasing Drought	Place	10-30 years	Medium	Take Action
89	Population change puts more strain on schools (e.g., unplanned influx or loss of students).	Medium	Medium	Population Change	Extensive	10-30 years	Low	Take Action

Goal 6: Ensure that residents have the resources to meet their daily needs.

		Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
93	Warmer winters reduce snowpack that supports winter recreation activities.	Low	High	Warmer Winter	Site	10-30 years	High	Accept
98	Sea-level rise reduces shoreline recreation opportunities.	Low	High	Sea-level Rise	Place	0-10 years	Low	Accept
94	Increasing drought raises the risk of wildfires, which could damage utility infrastructure.	Low	Medium	Increasing Drought	Place	0-10 years	Medium	Take Action
95	Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.	Low	Medium	Increasing Drought	Place	0-10 years	Medium	Take Action
99	Increasing drought raises the risk of wildfires, which could result in personal injury or death.	Low	Low	Increasing Drought	Place	0-10 years	Low	Take Action

Goal 7: Support local food systems to increase community resilience, health, and economic prosperity.

		Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
1	Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).	High	High	Increasing Drought	Place	0-10 years	Low	Take Action
27	Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).	High	High	Intensifying Precipitation	Extensive	0-10 years	High	Take Action
102	Warmer water threatens the survival of salmon, which support cultural and economic practices and ecosystem services.	High	High	Warmer Water	Extensive	0-10 years	High	Take Action
103	Ocean acidification makes it harder for calcifying organisms to form shells, and it ultimately harms commercial and recreational fisheries.	High	High	Ocean Acidification	Extensive	0-10 years	High	Take Action
104	Ocean acidification reduces the food available for and survival of salmon and other marine life.	High	High	Ocean Acidification	Extensive	10-30 years	Medium	Accept
105	Increasing drought raises the risk of lower crop yield or failure.	Medium	Medium	Increasing Drought	Extensive	10-30 years	Medium	Take Action
106	Warmer winters increase the range and survival of pests and diseases that affect crops.	Medium	Medium	Warmer Winter	Extensive	10-30 years	High	Take Action
107	Warmer summers accelerate the risk of food spoilage before it reaches market.	Medium	Medium	Warmer Summer	Extensive	10-30 years	Low	Take Action
109	Sea-level rise pushes saltwater farther into estuaries, which may inundate near-coastal farms and ranches.	Low	High	Sea-level Rise	Site	10-30 years	Medium	Accept
110	Warmer summers increase the heat stress risk for dairy cows and other large livestock.	Low	Low	Warmer Summer	Place	10-30 years	Medium	Accept
111	Warmer summers increase atmospheric CO2, which decreases the nutritional quality of forage and pasture lands for livestock and wild animals.	Low	Medium	Warmer Summer	Extensive	10-30 years	Medium	Accept
113	Population change increases pressure to develop rural areas, which could reduce, fragment and/or degrade farms, forests, and prairies.	Low	Low	Population Change	Extensive	10-30 years	Low	Accept

Goal 8: Ensure that the region’s water supply sustains people in perpetuity while protecting the environment.

	Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
1 Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).	High	High	Increasing Drought	Place	0-10 years	Low	Take Action
114 Sea-level rise makes coastal groundwater more vulnerable to saltwater intrusion and inundation.	High	High	Sea-level Rise	Place	10-30 years	High	Take Action
117 Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).	High	Medium	Population Change	Extensive	0-10 years	High	Take Action
116 Increasing drought raises pollutant concentrations in shallow wells and surface waters.	High	Low	Increasing Drought	Extensive	10-30 years	Low	Take Action
118 Warmer winters increase plant transpiration (root uptake and leaf release of water) during winter months, which could lower water table.	Low	Low	Warmer Winter	Extensive	More than 30 years	Low	Accept
119 Intensifying precipitation increases volume of urban runoff and flooding, which decrease groundwater recharge.	Low	Low	Intensifying Precipitation	Extensive	0-10 years	Low	Take Action

Goal 9: Move toward a carbon-neutral community.

	Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
65 Population change increases transportation-related energy consumption, CO_2 emissions, and other pollutants related to buildings and transportation.	High	High	Population Change	Extensive	More than 30 years	Low	Take Action
122 Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.	Low	High	Increasing Drought	Place	0-10 years	Medium	Accept
123 Intensifying precipitation causes erosion and loss of organic materials (e.g., plants) that build up in reservoirs (e.g., Alder Lake), decay, and emit greenhouse gases (e.g., methane).	Low	High	Intensifying Precipitation	Site	0-10 years	Low	Accept
124 Warmer summers accelerate the release of carbon stored in soils.	Low	Medium	Warmer Summer	Extensive	0-10 years	Medium	Accept
125 Increasing drought lowers reservoir levels, which exposes organic materials and causes them to decay and emit greenhouse gases.	Low	Medium	Increasing Drought	Site	0-10 years	Low	Accept
129 Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).	Low	Low	Increasing Drought	Extensive	10-30 years	Medium	Accept

Goal 10: Maintain air quality standards.

	Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
65 Population change increases transportation-related energy consumption, CO_2 emissions, and other pollutants related to buildings and transportation.	High	High	Population Change	Extensive	More than 30 years	Low	Take Action
132 Warmer summers increase production of surface ozone (VOCs interacting with NOx) and accumulation of fine particulate matter (PM2.5).	Medium	Medium	Warmer Summer	Extensive	0-10 years	Medium	Take Action
135 Increasing drought parches farm fields and other open spaces, which could erode and release windblown dust (e.g., PM10) that degrades air quality.	Low	Low	Increasing Drought	Place	10-30 years	Medium	Take Action
136 Intensifying precipitation increases use of polluting generators following storm-induced power outages.	Low	Low	Intensifying Precipitation	Extensive	0-10 years	Low	Accept

Goal 12: Make strategic decisions and investments to advance sustainability regionally.

		Consequence	Likelihood	Stressor	Spatial Extent	Horizon	Confidence	Strategy
1	Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).	High	High	Increasing Drought	Place	0-10 years	Low	Take Action
138	Intensifying precipitation necessitates retrofitting stormwater and wastewater infrastructure to mitigate flooding and backups that threaten water quality and human health and welfare.	Medium	High	Intensifying Precipitation	Place	0-10 years	High	Take Action

Appendix D

Public Engagement Strategy

THURSTON CLIMATE ADAPTATION PLAN

Public Engagement Strategy

Thurston Regional Planning Council

2017

I. Community Forum & Online Survey (Spring):

1) Forum Format: Hosted April 17 community forum (5:30-8PM @ SPSCC, 4220 6th Ave. SE, Lacey)

- Open House [30 mins]: Enabled people to get project literature, visit stations [*See #2*]
- Presentation [15 mins]: Welcome and brief project overview
- Presentation [20 mins]: Climate change impacts in Puget Sound/Thurston County
- Small-groups [85 mins]: Asked people to visit the tables, learn more about the climate impacts, ask questions, and fill out index cards with adaptation actions [*See #2*]

2) Forum Stations: Project staff facilitated five stations organized by theme: Flooding & Erosion; Plants & Animals; Transportation & Energy; Water Use & Drought; and, Wildfire & Extreme Heat.

- **Poster 1**: Each station had a thematic poster with a succinct description of 3-4 relevant climate risks and 3-4 general examples of actions we can take to improve our adaptive capacity.
- **Reference Materials:** Each station had a reference copy of the Vulnerability Assessment and a draft Action-Risk Report, so people could read more about specific risks and draft actions.
- **Index Cards:** Each station had a stack of cards pre-printed with two questions:
  - 1) What actions should individuals take to reduce the risk of (_*station theme*_) and prepare for and cope with its impacts? ________________________.
  - 2) What actions should the region's municipalities and/or other stakeholders take? _______.
- **Poster 2**: After people filled out their index cards, staff taped them on Poster 2 to be seen by all.
- **Survey:** Told people they could also offer action ideas via online survey thru May 8.

3) Forum Photos:

- Had small chalk boards written with the words: "A resilient community is _____." Asked attendees to finish the sentence. Took photo of attendees holding chalkboard.
- Took photos of the forum (presenters, audience, small-group discussions, etc.).

4) Online Survey: Created widget on the project webpage with a short survey to elicit adaptation ideas.

- Promoted the survey at the forum and via e-mail, TRPC website carousel, social media, etc.
- Hosted the survey during all of April and first week of May.

5) Next Steps: Reviewed and incorporated public input

- Transcribed and posted online the public comments received via the forum and survey.
- Drafted and revised actions based on community input and presented them to the Stakeholder Advisory Committee for evaluation and prioritization.

II. Project Marketing & Promotion (Spring-Fall):

1) Project website:

- Created video that describes project, promotes April public forum and project materials.
- Promoted project materials and meetings on TRPC homepage.

2) News Media:

- Wrote press release and sent to local media (The Olympian, Cooper Point Journal, Thurston Talk, Tenino Independent, Nisqually Valley News, South Sound Green Pages).
- Attended *The Olympian*'s April 5 editorial board meeting to discuss the project and forum.

3) E-mail & Social Media:

- Created e-mails and project listserv to alert interested parties about plan materials and meetings.
- Promoted materials and meetings via TRPC's Facebook and Twitter feeds, Nextdoor, etc.

4) Print materials:

- Developed a 2-page project overview to hand out at meetings and other public events.
- Developed and posted eye-catching fliers to promote major public-engagement events (forum, Art of Change, etc.), and posted the flier at public buildings and other busy places.

4) In-person outreach: (2017)

- Engaged more than 20 community organizations. This included handing out and e-mailing project literature, hosting information tables, and giving presentations. The organizations included:
    1) South Thurston Economic Development Council;
    2) Nisqually River Council;
    3) Climate Shepherds;
    4) Thurston Thrives Climate & Clean Energy Workgroup;
    5) WSU Thurston County Agricultural Extension — forum on agriculture and climate change;
    6) Thurston Conservation District WRIA 13 workgroup;
    7) TRPC Technical Advisory Committee;
    8) TRPC Council;
    9) South Sound Climate Action Convention;
    10) The Olympian Editorial Board;
    11) Black Lake Audubon chapter;
    12) South Sound Sierra Club chapter;
    13) Thurston County Fire Chiefs Association;
    14) The Evergreen State College (TESC) — Indigenous Climate Justice Forum;
    15) TESC class — *Community Resilience: Social Equity and Environmental Issues*;
    16) Olympia Arts Walk;
    17) Northwest Climate Conference;
    18) Sustainability in Prisons Project — climate symposium at Stafford Creek Corrections Center;
    19) Olympians for People-Oriented Places.
    20) Thurston County Board of County Commissioners
    21) Thurston County Planning Commission

III. Plan Development & Outreach (Summer-Winter):

1) August 2017:

- Sent draft actions to community stakeholders (cities, county, tribes, fire agencies, etc.), elicited feedback, and revised actions as needed.
- Wrote draft plan text and incorporated edits recommended by project team

2) September 2017:

- Designed and printed draft plan
- Developed "Resilience Road" climate adaptation board game and poster for fall outreach [*See IV*]

3) October 2017:

- Posted draft plan online, elicited feedback from public via e-mail/social media/website, made changes as needed.
- Brought draft plan, board game and poster to "Art of Change" event (Oct. 6) [*See V*] and Northwest Climate Conference (Oct. 10) [*See IV*] to generate additional interest, input

4) November 2017:

- Incorporated changes, as needed, based on community input
- Presented climate risks and draft actions to Thurston County Planning Commission and Board of County Commissioners (Nov. 1)
- Wrote a story about the project in the 2017 *Main Street Journal* newsletter and presented at TRPC meeting (Dec. 1)
- Presented final draft of plan to project's Stakeholder Advisory Committee (Nov. 29)

5) December 2017:

- Presented final draft of plan to TRPC council (Dec. 1)

6) January 2018:

- Sought TRPC council approval of plan via consent calendar (Jan. 5)

IV. Northwest Climate Conference Presentation (Fall)

1) Poster: The Northwest Climate Conference planning committee accepted TRPC's proposal to present a project poster — and companion board game — at the annual climate conference, Oct. 10-11, in Tacoma.

- **Poster Title:** *(logo)* Thurston Climate Adaptation Plan: *(subtext)* A Climate Change Preparedness & Response Plan for Thurston County
- **Description:** TRPC's poster featured an illustrated map of Thurston County and a winding road with the following eight project components (steps): Science Summary; Vulnerability Assessment; Risk Assessment; Public Engagement; Action Evaluation; Economic Analysis; Plan Development; Plan Implementation. Small text boxes described each component on the poster:
  - **Science Summary:**
    - Summarizes observed and projected climate change impacts at the global, national, and regional scales
    - Describes emissions scenarios and climate models used in this project's vulnerability and risk assessments
  - **Vulnerability Assessment:**
    - Explains how South Puget Sound region's climate has changed historically, how it is projected to change this century, and how such changes affect the vulnerability of human and natural systems
    - Describes how the region's human health and welfare and built and natural "assets" (e.g., roads and rivers) are vulnerable to the collective impacts of natural hazards (e.g., wildfires, landslides, floods) and human-caused stressors (e.g., water pollution) exacerbated by climate change
  - **Risk Assessment:**
    - Uses a U.S. EPA methodology to evaluate how 85 risks identified in the vulnerability assessment affect the region's ability to achieve the 12 project goals
    - Selects a strategy for each risk — either Take Action or Accept — based on the risk's relative likelihood and consequence of occurrence
  - **Public Engagement:**
    - Uses face-to-face meetings, social media posts, online video, survey, board game, pop-up library, and other tools to educate the community about the plan and elicit input
  - **Action Evaluation:**
    - Drafts 90 actions — many with mitigation co-benefits — to respond to the region's most severe climate risks
    - Prioritizes 25 actions using evaluation criteria (effectiveness, durability, equity, etc.)
  - **Economic Analysis:**
    - Performs benefit-cost analyses of representative plan actions, including protecting and expanding riparian buffers and incentivizing infill development in urban areas
    - Incorporates the value of local ecosystem services (e.g., forests, grasslands, and riparian shorelines) to produce "benefits" data that can be applied to a wide range of climate adaptation and mitigation actions and can aid decision-making efforts

- **Plan Development:**
  - Creates online climate "Resilience Toolkit" with resources for community climate preparedness, planning and education efforts
  - Incorporates "energy map" and "carbon wedge" analyses to show pathways to hitting regional greenhouse gas emissions targets (mitigation)
- **Plan Implementation:**
  - Seeks TRPC regional policymaker adoption of plan in early 2018
  - Encourages entire community — neighborhoods, municipalities, tribes, etc. — to take actions and track progress

- **Text box at the end of the road:** "Want to learn more about what you can do? Please read the plan or play the game."

2) Reference Materials:

- A reference copy of the draft plan included the full list of actions and additional information about each component.
- A two-page handout provided a brief project overview, website, and contact information.

3) Board Game

- **Title:** *Resilience Road: A Game of Climate Change & Chance*
- **Overview:** TRPC brought to the NW climate conference and Arts Walk a playable version *"Resilience Road,"* a fun and educational board game that explores the *Thurston Climate Adaptation Plan's* stressors, risks, and actions. Game Rules introductory text:

  Storms, floods, droughts, wildfires … We face these natural hazards today, and climate change stressors will worsen them tomorrow. Fortunately, we can prepare for and adjust to adverse climate impacts and become a more resilient region.

  Grab a few friends and consider what steps — "adaptation" actions — you can take down Resilience Road. But be careful: You'll be buffeted by rising seas and other setbacks. Cooperation will be key to reaching the road's end — Resilience Ridge — together. Good luck!
- **Game Goal:** Players reach the road's end *("Resilience Ridge"*) as close together as possible by taking actions from the *Thurston Climate Adaptation Plan* and working together: If a player surges ahead or falls behind, the player may give or receive a turn or card.
- **Game Design:**
  - **The Board:** The 22" x 34" game board is an illustrated map of Thurston County with a winding road of colorful footsteps, climate stressors, and familiar landmarks (*State Capitol Building, Mount Rainier, Deschutes Falls, etc*).
    - **Roadway:** The board's roadway features about 70 spaces, each space with 2 footsteps.
    - **Grants Pass:** The board includes one "Grants Pass" that links two spaces. If a player lands on this space, he/she may skip ahead to the space at the end of the mountain pass: *"Congrats: You've received a grant to work on climate actions of your choice!"*
    - **Deschutes Falls:** The board includes one "Deschutes Falls" that links two spaces. If a player lands on this space, he/she must "fall" backward down the river to the end of the falls: *"Sorry: You've been swept downstream. Shake it off, and get back on your feet!"*

- **The Draw Pile:**
  - The draw pile features 114 cards:
    - 90 action cards
    - 16 stressor cards
    - 8 eight wild cards

- **Game Rules:**
  - **Players & Turns:**
    - 1) Up to 5 people may play concurrently.
    - 2) Each player chooses a game pawn (*red, blue, green, yellow, black*) and lines up at "Start."
    - 3) The player with the next birthday goes first, then players draw clockwise
    - 4) Each player takes a card from the draw pile during his/her turn.

  - **Cards:**
    - **Action Cards:** The draw pile includes 90 "Action" cards. Each card features:
      - Two or four colorful footsteps (*Priority Actions = 4 steps; Secondary Actions = 2 steps*) and the corresponding text of one of the plan's 90 adaptation actions (simplified actions from the *Thurston Climate Adaptation Plan*) within 6 thematic categories:
        - — General (**Gold**)
        - — Drought & Water Quality (**Navy**)
        - — Flood & Erosion (**Teal**)
        - — Plants & Animals (**Green**)
        - — Transportation & Energy (**Orange**)
        - — Wildfire & Extreme Heat (**Red**)
      - Players should keep track of their drawn cards, so they can be played to exit a stressor spot.
    - **Stressor Cards:** The draw pile includes 16 climate "Stressor" cards. Such stressors pose climate risks to that threaten the region: *For example, the stressor "Intensifying Precipitation" will raise flood and erosion risks; we can take actions — such as restoring and protecting riparian vegetation along shorelines (Action F-01) — to respond to such risks.*
      - A player who draws a stressor card must keep his/her pawn in place. On the player's next turn, he/she may play an action card or wildcard to move again.
      - If the player lacks an appropriate card to play, another player may give him/her such a card during the turn.
      - When playing a card, the player should read it aloud and then place it at the bottom of the draw pile.
      - The objective of this is two-fold: All players must consider how to cooperate and learn about the links between climate stressors, risks, and actions.
    - **Wild Cards:** The draw pile also includes 8 "Wild" cards that a player may use if no suitable action has been drawn to respond to a stressor:
      - Wild Card Text: *"Stuck? Well, you're in luck. … Please create an adaptation action for a climate stressor of your choosing."*

Concept:

- **An All-ages Approach:**
  - TRPC designed the game so it could be played by adults and children anywhere. The rules and board are simple. The illustrations are fun and engaging. The game is fun: Cards require players to make connections between real climate risks and actions, create their own actions (via wild cards), and cooperate with each other.
- **A Replicable Approach:**
  - The actions on the cards are simplified versions of real *Thurston Climate Adaptation Plan* actions, which are often more detailed and technical.
  - TRPC will make this game available for other communities, so they could replicate actions and educate residents.

V. Art of Change outreach event (Fall)

1) Overview: The Thurston Regional Planning Council, City of Olympia, Timberland Regional Library (TRL), Puget Sound Estuarium, and local artist Carrie Ziegler collaborated on a climate change public-engagement project, "Art of Change," which combined art, science, policy, and literacy.

2) Details: The partners hosted the Art of Change climate information station during the first night of fall Arts Walk (Oct. 6) at the Puget Sound Estuarium (309 State Ave. NE), which featured a new mural representing plankton (which are affected by ocean acidification). Project partners included: Michael Burnham, TRPC; Andy Haub, City of Olympia; Sara Pete, TRL; Carrie Ziegler, local artist; and Taisha McFall, Estuarium.

- The Art of Change information station included the following:
- Ziegler, the mural's artist, was on hand to discuss the mural and her nascent "Climate Action Through Art" project.
  - A "pop-up" library hosted by a TRL librarian:
    - TRPC developed a pamphlet that features links to TRL's climate literacy materials: videos, books, periodicals, online courses, etc.
    - Arts Walk participants who stopped by the pop-up library could sign up for a library card on site, grab a pamphlet, browse/check out TRL climate resources.
  - Information tables hosted by TRPC and City of Olympia staff:
    - Arts Walk participants who visited the tables could learn about planned and ongoing climate work by local governments, including TRPC's regional climate adaptation plan and Olympia's sea-level rise management strategy.
- In addition to designing and printing the pamphlet noted above, TRPC developed a *Resilience Toolkit* brochure: This six-page handout included information about climate change books, films, and educational courses available through the Timberland Regional Library, as well as information about community climate planning, preparedness, and art resources. Additional information is available via the online version of the *Resilience Toolkit*, www.trpc.org/climate/resiliencetoolkit.
    - The information station also included posters, reports and other materials (e.g. TRPC's "*Resilience Road*" adaptation board game). Main poster wording: *Art of Change: A climate action, art and information station*

Appendix E
Action Risk Report

Action-Risk Report

General

ACTION A-01

Update the regional climate adaptation plan periodically with new information, evaluate implementation efforts and effectiveness, amend strategies and actions as necessary, and enhance community climate literacy (e.g., by working with schools, libraries, and other partners to enhance the public's understanding of climate change causes, impacts, and responses).

TRPC should update the plan every five years with new climate data (observed and projected) and community input to ensure the plan remains a relevant reference tool for local policymakers, residents, and other stakeholders. As part of its adaptive management process, TRPC should track where, when, and how the community implements actions, as well as consider new actions to address unforeseen impacts and overcome implementation barriers.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.

General

ACTION G-01

Direct government staff members to develop their technical expertise and skills to prepare for and respond to climate change impacts.

With clear policy direction from local and tribal government policymakers, staff members could invest in professional development that enhances their understanding of projected changes in the region's climate (e.g., air temperature and precipitation) and their impacts on municipal services and infrastructure. Staff members could use the skills and knowledge to protect human health and welfare, as well as adequately plan, design, build and maintain roads, culverts, and other assets.

- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.
- Warmer winters increase the range and survival of invasive species, pests, and diseases that threaten native flora and fauna.
- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Intensifying precipitation necessitates retrofitting stormwater and wastewater infrastructure to mitigate flooding and backups that threaten water quality and human health and welfare.
- Population change puts more strain on transportation (roads, transit, etc.).
- Warmer winters increase the range and survival of pests and diseases that affect crops.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.

ACTION G-02

Create hazard recovery plans and prioritize the restoration of vital public safety facilities and other essential community assets (e.g., hospitals and major bridges).

As part of this action, ensure that all appropriate personnel — including municipal public works, planning, and public health workers — have adequate training and gear (e.g., reflective vests, hard hats, and agency vehicles) to respond to emergencies.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise increases coastal flooding of downtown Olympia and LOTT wastewater treatment plant assets, which could threaten the ability to treat and discharge water and increase the energy consumed to operate pumps.
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Sea-level rise pushes saltwater farther into estuaries, which may inundate near-coastal farms and ranches.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION G-03

Pursue funding to implement highest-priority actions identified in the adopted Hazards Mitigation Plan for the Thurston Region.

This action would improve the region's resilience, its ability to recover more quickly and fully from hazards. Visit trpc.org/hazards to view a list of countywide and local partner actions.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Warmer summers introduce or exacerbate disease vectors (carriers), which could harm human health (warmer, wetter winters also exacerbate exposure to pathogens and other health threats).
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION G-04

Factor climate impacts into the planning of operations and the coordination of disaster response and recovery activities among first-responders, including public health, law enforcement, fire, and emergency medical services personnel.

Examples of activities include: updating emergency services communications equipment; enhancing training of emergency personnel and other responders; taking regular inventory of emergency facility needs (e.g., cooling centers and temporary shelters); assessing and improving the adaptive capacity of people who are most vulnerable to climate change-exacerbated hazards (e.g., people who are homeless, elderly, socially isolated, and/or live in high-risk areas).

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Warmer summers cause urban heat islands, which could affect livability/health in heavily developed centers and corridors.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION G-05

Assess potential climate change-induced population migration within and to the Thurston Region, and evaluate response strategies.

This action could entail assessing who in the region is most vulnerable to temporary or permanent displacement (e.g., low-income or socially isolated residents who may be forced to move because of climate-exacerbated hazards) and what resources they might need. This action also could entail assessing who is most likely to move to the region and how to accommodate them in ways consistent with community values. For example, this could be done by studying "chain migration" (the tendency of migrants to follow those of similar ethnicity, language or job skillset), as well as by evaluating such migrants' needs and where/how much growth should occur so that it's consistent with local comprehensive plans. TRPC could integrate such analysis into its periodic population and employment forecasts. For more information, visit: http://www.trpc.org/236/Population-Employment-Forecasting.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Population change increases transportation-related energy consumption, CO_2 emissions, and other pollutants related to buildings and transportation.
- Population change increases strain on social and emergency services.
- Population change increases pressure on existing parks and open space.
- Population change puts more strain on transportation (roads, transit, etc.).
- Population change increases pollution related to development (e.g., more septic systems and impervious surfaces).
- Population change puts more strain on schools (e.g., unplanned influx or loss of students).
- Population change increases solid waste generation.
- Population change increases pressure to develop rural areas, which could reduce, fragment and/or degrade farms, forests, and prairies.

ACTION G-06

Create a household preparedness plan and store of food, water, and other supplies (lanterns, bicycles, etc.) to use in case a flood or other hazard cuts off access to goods, services, and emergency responders.

Municipalities, neighborhood associations, and their partners (e.g., the American Red Cross) can encourage these household preparedness practices by enhancing outreach and incentives. See TRPC's online Resilience Toolkit (trpc.org/climate/resiliencetoolkit) for links to preparedness resources.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.

ACTION G-07

Identify a neighborhood site (e.g., a school, house of worship, or other location that's safe, accessible, and well-known) to serve as a temporary coordination center for local hazard response and recovery efforts, and publicize the hub's location widely.

This action could help increase household and neighborhood resilience, in the event that police and fire personnel cannot provide immediate assistance. Households and their broader neighborhoods could work with municipal agencies (e.g., through neighborhood and sub-area plans) and nonprofits (e.g., the American Red Cross) to plan, select, and publicize emergency coordination sites.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.

ACTION G-08

Encourage neighborhoods to become familiar with residents who have skills and tools to assist others with special needs (e.g., elderly or disabled), should residents need to provide emergency response in the event that police and fire personnel cannot provide immediate assistance.

Programs such as "Map Your Neighborhood" are effective ways to develop maps and inventories/directories of neighborhood assets. [Thurston County Emergency Management Map Your Neighborhood: http://www.co.thurston.wa.us/em/MYN/MYN.htm]

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.

ACTION G-09

Encourage residents to organize or participate in regular emergency preparedness, response, and recovery planning and training events.

Such events could include neighborhood potlucks with disaster drills, skills sharing, and discussions about hazards (extreme heat, wildfires, etc.) with local emergency responders.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Population change increases strain on social and emergency services.
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.

ACTION G-10

Increase the number of residents who receive Community Emergency Response Team (CERT) training to improve local hazard preparedness, response, and recovery efforts. Ensure such efforts are ongoing.

This action would help increase household and neighborhood resilience, in the event that police and fire personnel cannot provide immediate assistance.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.

ACTION G-11

Factor climate impacts into the full life-cycle costs of roads, buildings, parks, and other assets — from their initial siting and design to their ongoing operations and maintenance.

The Thurston Climate Adaptation Plan, which should be updated periodically by TRPC [See Action A-01], will serve as a regional reference guide for understanding local climate impacts and asset risks. By considering such impacts (e.g., projected sea levels), public- and private-sector property owners will be better able to protect their assets and reduce operations and maintenance costs.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Intensifying precipitation necessitates retrofitting stormwater and wastewater infrastructure to mitigate flooding and backups that threaten water quality and human health and welfare.
- Population change puts more strain on transportation (roads, transit, etc.).
- Intensifying precipitation raises the cost of development (flooding and runoff mitigation measures).
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).

ACTION G-12

Increase incentives to make urban infill and redevelopment projects more viable financially.

Incentives could include, but are not limited to, tax credits and fee waivers for infill and redevelopment projects, as well as stormwater control transfer programs (e.g., Redmond, Washington's stormwater mitigation banking program).
Infill and redevelopment projects within urban centers and corridors inside of the urban growth areas enhance residents' resilience by providing better access to transportation options and services (e.g., food stores, hospitals, and emergency responders). Such projects also have potential climate mitigation benefits, enabling residents to drive fewer miles and reduce their transportation-related greenhouse gas emissions.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Intensifying precipitation contaminates water (nutrients) from septic systems due to high groundwater flooding.
- Population change increases transportation-related energy consumption, CO2 emissions, and other pollutants related to buildings and transportation.
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Population change increases strain on social and emergency services.
- Population change puts more strain on transportation (roads, transit, etc.).
- Population change increases pollution related to development (e.g., more septic systems and impervious surfaces).
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.
- Population change increases pressure to develop rural areas, which could reduce, fragment and/or degrade farms, forests, and prairies.

ACTION G-13

Align land use, hazard mitigation, transportation, capital improvement, and other plans so that they take into account climate change and work toward the same goals.

This action, in which TRPC could take the lead as a coordinating body, would help ensure consistent interjurisdictional and interagency planning and policymaking with regard to climate change mitigation and adaptation.

- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.
- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Intensifying precipitation necessitates retrofitting stormwater and wastewater infrastructure to mitigate flooding and backups that threaten water quality and human health and welfare.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.

ACTION G-14

Expand ability to predict drought and flood events by tracking soil moisture, streamflow, precipitation, groundwater levels, tide levels, well levels, reservoir levels, and weather forecasts.

The City of Olympia proposes working with the Port of Olympia and the U.S. Geological Survey (USGS) to establish a tide gauge in Olympia. Additionally, the National Oceanic & Atmospheric Administration (NOAA) hosts the online Water Resources Dashboard — which includes maps and data that can help local resource managers monitor for the potential for extreme precipitation and drought events: https://toolkit.climate.gov/topics/water-resources/water-resources-dashboard.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.
- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Warmer winters reduce snowpack and alter stream volume and temperature, impacting long-term productivity of anadromous fish populations and fisheries.
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought raises the risk of lower crop yield or failure.
- Sea-level rise pushes saltwater farther into estuaries, which may inundate near-coastal farms and ranches.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.
- Warmer summers increase the heat stress risk for dairy cows and other large livestock.
- Increasing drought parches farm fields and other open spaces, which could erode and release windblown dust (e.g., PM10) that degrades air quality.

ACTION G-15

Create a website that details health risks exacerbated by climate change and provides information that helps residents prepare for and respond to drought, poor air quality, extreme heat, disease vectors, and other threats.

This action would improve the region's climate literacy and resilience.

- Warmer water increases the growth and reach of pathogens (e.g., cyanobacteria and algal blooms) harmful to humans, fish, and other water users.
- Sea-level rise increases coastal flooding of downtown Olympia and LOTT wastewater treatment plant assets, which could threaten the ability to treat and discharge water and increase the energy consumed to operate pumps.
- Intensifying precipitation contaminates water (nutrients) from septic systems due to high groundwater flooding.
- Sea-level rise inundates former industrial sites, which could mobilize pollutants in the soil and degrade water quality.
- Warmer summers introduce or exacerbate disease vectors (carriers), which could harm human health (warmer, wetter winters also exacerbate exposure to pathogens and other health threats).
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Increasing drought raises pollutant concentrations in shallow wells and surface waters.
- Warmer summers increase production of surface ozone (VOCs interacting with NOx) and accumulation of fine particulate matter (PM2.5).
- Warmer summers cause urban heat islands, which could affect livability/health in heavily developed centers and corridors.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.
- Increasing drought parches farm fields and other open spaces, which could erode and release windblown dust (e.g., PM10) that degrades air quality.

ACTION G-16

Develop a countywide disaster debris management plan with actions to dispose of or recycle materials (organic and artificial) efficiently after a disaster.

This action would improve the region's resilience, its ability to recovery quickly and fully from hazards.

- Warmer summers stress sensitive plants and habitat (including urban landscaping), which could leave them vulnerable to extreme heat, pests, or pathogens.
- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Population change increases solid waste generation.
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION G-17

Advocate for expanding the eligibility of federal disaster-assistance funding to allow for the replacement or relocation of aging or vulnerable infrastructure before it fails.

This includes facilities such as water infrastructure, fire stations, transportation infrastructure, emergency coordination shelters, and buildings that are used as emergency shelters.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Sea-level rise increases coastal flooding of downtown Olympia and LOTT wastewater treatment plant assets, which could threaten the ability to treat and discharge water and increase the energy consumed to operate pumps.
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Sea-level rise makes coastal groundwater more vulnerable to saltwater intrusion and inundation.
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION G-18

Limit access to parks, lakes, and other outdoor recreation areas when natural hazards (e.g., algal blooms, wildfires, floods) pose risks to public safety.

This action would help protect public health and welfare.

- Warmer winters increase the range and survival of invasive species, pests, and diseases that threaten native flora and fauna.
- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Warmer water increases the growth and reach of pathogens (e.g., cyanobacteria and algal blooms) harmful to humans, fish, and other water users.
- Sea-level rise increases coastal flooding of downtown Olympia and LOTT wastewater treatment plant assets, which could threaten the ability to treat and discharge water and increase the energy consumed to operate pumps.
- Sea-level rise inundates former industrial sites, which could mobilize pollutants in the soil and degrade water quality.
- Intensifying precipitation contaminates water (bacteria, pathogens) due to a greater incidence of combined stormwater/sewer system overflows.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION D-01

Develop and implement a comprehensive drought-response strategy that sets action levels for different drought stages.

Thurston County experienced moderate or more extreme drought conditions in the summer months nine out of the last sixteen years, including the last three consecutive years. Climate change and population growth will exacerbate these water shortages.
A possible funding source for this action is the Washington Department of Ecology's Watershed Planning Implementation and Flow Achievement grant; the next funding cycle is 2019-2021.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.
- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Increasing drought increases the concentration of pollutants in first-flush runoff.
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought raises the risk of lower crop yield or failure.
- Increasing drought raises pollutant concentrations in shallow wells and surface waters.
- Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.
- Increasing drought raises the risk of wildfires, which could contaminate water (turbidity and sedimentation).
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.
- Increasing drought lowers reservoir levels, which exposes organic materials and causes them to decay and emit greenhouse gases.
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).
- Increasing drought parches farm fields and other open spaces, which could erode and release windblown dust (e.g., PM10) that degrades air quality.

ACTION D-02

Evaluate and secure sustained funding to support enhanced long-term monitoring of ground and surface water quality and quantity.

This action includes enhancing monitoring of water volume, temperature, and pollution in streams, lakes, and Puget Sound. Existing resources include:
The state Department of Ecology measures changes in the Puget Sound lowland streams and urban shoreline areas as a result of stormwater management: http://www.ecy.wa.gov/programs/wq/stormwater/municipal/rsmp/status.html.
Thurston County conducts data analysis and regular monitoring of specific lakes, rivers, and streams: http://www.co.thurston.wa.us/health/ehswat/swater.html.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Warmer water increases the growth and reach of pathogens (e.g., cyanobacteria and algal blooms) harmful to humans, fish, and other water users.
- Increasing drought increases the concentration of pollutants in first-flush runoff.
- Intensifying precipitation contaminates water (turbidity and sedimentation) due to landslides.
- Sea-level rise increases coastal flooding of downtown Olympia and LOTT wastewater treatment plant assets, which could threaten the ability to treat and discharge water and increase the energy consumed to operate pumps.
- Ocean acidification decreases marine pH and -- when coupled with increases in ocean temperature and land-borne pollution -- threatens marine water quality.
- Intensifying precipitation contaminates water (nutrients) from septic systems due to high groundwater flooding.
- Sea-level rise inundates former industrial sites, which could mobilize pollutants in the soil and degrade water quality.
- Intensifying precipitation contaminates water (bacteria, pathogens) due to a greater incidence of combined stormwater/sewer system overflows.
- Warmer summers introduce or exacerbate disease vectors (carriers), which could harm human health (warmer, wetter winters also exacerbate exposure to pathogens and other health threats).
- Sea-level rise makes coastal groundwater more vulnerable to saltwater intrusion and inundation.
- Warmer water increases periods of low dissolved oxygen and hypoxic conditions in lakes and other freshwater areas.
- Warmer water increases the risk of marine water stratification and hypoxia, which could alter the timing of spring plankton blooms that support the marine food web (including salmon and other economically important fish).
- Increasing drought raises the risk of wildfires, which could contaminate water (turbidity and sedimentation).
- Warmer summers increase recreational activity in waterbodies and the risk of boat fuel spills.

ACTION D-03

Increase reuse of reclaimed water for irrigating plants, supplementing low streamflow, and other purposes.

In the north Thurston County area, the LOTT Clean Water Alliance produces reclaimed water. LOTT's partner cities — Lacey, Olympia, and Tumwater — operate reclaimed water utilities and purvey the water to customers for reuse.

LOTT develops reclaimed water production capacity based primarily on the need for additional treatment capacity in the wastewater system. Other community needs, such as climate resilience, can influence planning for additional reclaimed water.

Because reclaimed water must be conveyed in a separate purple pipe network, distribution and reuse is generally limited to areas within close proximity to existing reclaimed water pipelines. Decisions about the expansion of the distribution line network are generally made by the partner cities' utilities. Significant cost is involved in adding reclaimed water production capacity and expanding the distribution system. Local and outside funding commitments may be necessary.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).
- Increasing drought parches farm fields and other open spaces, which could erode and release windblown dust (e.g., PM10) that degrades air quality.

ACTION D-04

Conduct benefit-cost analyses (BCAs) of adaptation actions that conserve water resources.

Benefit-cost analyses, also commonly called cost-benefit analyses, would provide Thurston Region policymakers an important economic tool for evaluating water-conservation actions, including those in this plan [See Drought & Water Quality actions].

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).

ACTION D-05

Increase the number of water rights that are transferred to a trust, temporarily or permanently.

This action would be measurable and could involve a variety of leads and partners. Washington's Trust Water Rights Program provides a way for the State to legally hold water rights for future uses without the water right relinquishing. Water rights holders may sell, lease, or donate their unused capacity to the program. The Department of Ecology, guided by RCW 90.42.40, holds the water rights in a trust to support instream flows and other beneficial uses. Water rights that are donated or leased temporarily to Ecology retain their original priority date while held in the trust. Water rights that are sold permanently to Ecology are retired. For more information, visit ecy.wa.gov/programs/wr/market/waterbank.html.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).

ACTION D-06

Set up a water bank in Thurston County's watersheds to enable water rights trading that supports conservation.

Thurston County does not currently have an active water bank for its watersheds. Under RCW 90.42.40, however, communities in the Yakima River, Columbia River, Dungeness River, and Walla Walla River watersheds have set up water banks for buying and selling water rights. In Walla Walla's water bank, for example, the Walla Walla Watershed Management Partnership buys water rights and then divides them into exempt well mitigation credits for sale to prospective water users. Thurston County could explore creating a similar partnership.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).

ACTION D-07

Implement tiered water pricing.

This action, in which municipal water customers pay more per gallon as they use more, would provide a clear price signal and support conservation.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).

ACTION D-08

Increase incentives for water conservation during dry months.

This action would investigate and implement additional incentives that could be offered, including for outdoor use and for properties on private water systems or wells.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought raises the risk of lower crop yield or failure.
- Increasing drought raises pollutant concentrations in shallow wells and surface waters.
- Increasing drought lowers reservoir levels, which exposes organic materials and causes them to decay and emit greenhouse gases.
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).
- Increasing drought parches farm fields and other open spaces, which could erode and release windblown dust (e.g., PM10) that degrades air quality.

ACTION D-09

Incentivize new commercial construction to include on-site rainwater harvesting facilities.

This action would reduce runoff and provide a source of water for irrigating plants and flushing toilets.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Intensifying precipitation contaminates water (bacteria, pathogens) due to a greater incidence of combined stormwater/sewer system overflows.
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Intensifying precipitation necessitates retrofitting stormwater and wastewater infrastructure to mitigate flooding and backups that threaten water quality and human health and welfare.
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Intensifying precipitation increases volume of urban runoff and flooding, which decrease groundwater recharge.

ACTION D-10

Install efficient plumbing fixtures and equipment in buildings so as to conserve water.

The Uniform Plumbing Code, part of the Washington State Building Code, sets maximum water consumption levels for new faucets, toilets, showerheads, and other plumbing fixtures in buildings.
The LOTT Clean Water Alliance provides free water-saving kits (showerheads, leak-detection kits, etc.) to rate-payers within its Lacey, Olympia and Tumwater service area. LOTT also provides rebates to residential, commercial, industrial, and institutional rate-payers who install water-saving toilets, appliances, and other equipment. For more information, visit http://lottcleanwater.org/programs.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).

ACTION D-11

Evaluate and offer new incentives for residents to install rain gardens on well-draining soils and plant drought-tolerant landscaping (e.g. xeriscaping) to adapt to changes in seasonal precipitation.

Incentives could include utility rebates or credits.
[U.S. EPA has published a handbook with "Water-Smart" landscaping tips for rain gardens and other parts of the yard: https://www3.epa.gov/watersense/docs/water-efficient_landscaping_508.pdf]

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Warmer summers stress sensitive plants and habitat (including urban landscaping), which could leave them vulnerable to extreme heat, pests, or pathogens.
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Intensifying precipitation contaminates water (bacteria, pathogens) due to a greater incidence of combined stormwater/sewer system overflows.
- Intensifying precipitation increases volume of urban runoff and flooding, which decrease groundwater recharge.

ACTION D-12

Construct new water-storage systems (e.g., large cisterns, water towers, and reservoirs) to provide back-up water supplies during droughts.

Per state law (RCW Title 90), a municipality or other party would need state approval to store and withdraw water that exceeds its allocated water rights.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).

ACTION D-13

Expand Thurston County's septic system operation and maintenance education and outreach programs.

Climate models project more frequent and intense rain storms, which could oversaturate drain fields around septic tanks and cause them to flood, overflow, and release pollutants into surface waters. A 2016 report by Thurston County and TRPC — Deschutes Watershed Land Use Analysis: Scenario Development Report — estimated that it would cost about $43,000 annually to administer a voluntary septic system operation and maintenance program in the Deschutes Watershed alone.

- Warmer water increases the growth and reach of pathogens (e.g., cyanobacteria and algal blooms) harmful to humans, fish, and other water users.
- Intensifying precipitation contaminates water (nutrients) from septic systems due to high groundwater flooding.
- Population change increases pollution related to development (e.g., more septic systems and impervious surfaces).

ACTION D-14

Reduce zoning density for parcels (i.e., "downzone") and lower limits for impervious surfaces near streams and lakes with nutrient-loading problems.

When considering whether to take this action, which would mitigate the combined impacts of water pollution and warming, government agencies should consider whether it would result in more impervious surfaces elsewhere.

- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.
- Warmer water increases the growth and reach of pathogens (e.g., cyanobacteria and algal blooms) harmful to humans, fish, and other water users.
- Increasing drought increases the concentration of pollutants in first-flush runoff.
- Intensifying precipitation contaminates water (nutrients) from septic systems due to high groundwater flooding.
- Population change increases pollution related to development (e.g., more septic systems and impervious surfaces).

ACTION D-15

Facilitate new residential water and sewer connections to municipal sources, where feasible.

This action would help protect water quality and quantity.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).

ACTION D-16

Incentivize water metering for all wells.

Metering all wells, either through voluntary or regulatory means, would help fill water usage data gaps and provide water managers with information they can use to ensure there is sufficient supply to meet demand (water for people, fish, and other users).

Every municipal water supplier in Washington — i.e., Group A water systems with at least 15 service connections — must install a source meter that shows total system production, as well as install service meters that show authorized consumption for each connection (e.g., a single-family home). All new Group B water systems — those with multiple, but fewer than 15 connections, often in less-urbanized areas — must install a source meter as well.

Most of Thurston County's Group B systems have source meters, in compliance with state law, but such systems are not required to report their production data to state and local governments. Few of Thurston County's Group B systems have individual service meters, which are not required by state law.

About a quarter of Thurston County's wells are considered "permit-exempt" and are not in a Group A or B water system. Washington’s groundwater permit exemption (RCW 90.44.050) allows for single or group domestic well water use up to 5,000 gallons per day without first obtaining water right permits.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).

ACTION D-17

Establish a local non-regulatory entity to provide technical assistance to private well owners regarding conserving water and detecting leaks and pollution.

This action would help protect water quality and quantity.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Sea-level rise makes coastal groundwater more vulnerable to saltwater intrusion and inundation.
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought raises pollutant concentrations in shallow wells and surface waters.
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).

ACTION F-01

Evaluate and secure sustained funding to restore and protect riparian vegetation along freshwater and marine shorelines.

Plant buffers stabilize banks, provide shade and flood storage, slow and filter polluted runoff, store carbon emissions, and enhance air quality. A local government, for example, could add a vegetation surcharge to its stormwater utility rate to fund restoration of these riparian areas.

- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.
- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Warmer water increases the growth and reach of pathogens (e.g., cyanobacteria and algal blooms) harmful to humans, fish, and other water users.
- Increasing drought increases the concentration of pollutants in first-flush runoff.
- Warmer water threatens the survival of salmon, which support cultural and economic practices and ecosystem services.
- Warmer water expands the range for invasive aquatic species.
- Warmer winters reduce snowpack and alter stream volume and temperature, impacting long-term productivity of anadromous fish populations and fisheries.
- Warmer water increases periods of low dissolved oxygen and hypoxic conditions in lakes and other freshwater areas.

ACTION F-02

Incorporate projected sea-level rise and flooding information into the designation of regulatory hazard areas.

Development and activities typically are required to be set back and/or buffered from regulated hazard areas, such as floodplains, marine shorelines, and high groundwater areas, which are determined by historic water level information. This action could involve updating regulations to better reflect projections about how water levels may change (e.g., the Ordinary High Water Mark [OHWM], the 100-year floodplain or channel migration area) in order to ensure new homes and other development are located and/or designed appropriately for future conditions.

- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION F-03

Design new and replacement stream culverts and other drainage infrastructure to accommodate projected higher peak flows associated with more frequent and intense heavy precipitation events.

This action would improve fish passage and reduce flooding that occurs when debris blocks culverts. Additional funding could help Thurston County address problematic culverts more quickly.

- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Intensifying precipitation contaminates water (bacteria, pathogens) due to a greater incidence of combined stormwater/sewer system overflows.
- Intensifying precipitation necessitates retrofitting stormwater and wastewater infrastructure to mitigate flooding and backups that threaten water quality and human health and welfare.
- Intensifying precipitation raises the cost of development (flooding and runoff mitigation measures).

ACTION F-04

Install flood gates and pumps on stormwater outfalls connected to Puget Sound to mitigate back-ups during high tides and heavy rains exacerbated by rising seas.

This action, to be considered as part of the City of Olympia's sea-level rise response strategy for downtown (2018), would help reduce flooding and its impacts on public budgets and mobility.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation contaminates water (bacteria, pathogens) due to a greater incidence of combined stormwater/sewer system overflows.
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION F-05

Build floodwalls or other protective structures around critical facilities located in areas vulnerable to flooding as a result of sea-level rise and heavy precipitation.

This action will be considered as part of the City of Olympia's sea-level rise response strategy for downtown (2018). Local policymakers could utilize best available science to evaluate site-specific responses, which could include walls, berms, or other "hard" or "soft" structures. As a follow-up to this action, policymakers could identify and set aside areas to receive critical facilities that could be moved at the end of their useful lifespan.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise reduces shoreline recreation opportunities.
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION F-06

Require that new or renovated buildings utilize flood-protection measures (such as raised finished-floor levels and temporary flood barriers) to accommodate projected sea-level rise over the structures' lifespan.

Chapter 16.80 of the Olympia Municipal Code, which focuses on reducing damage from sea-level rise, requires that all new buildings have the lowest floor (including basement) protected from flooding or elevated to 16 feet or greater. Other parts of the county could replicate this requirement.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise raises the cost of new development and redevelopment.
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION F-07

Increase education and enforcement efforts to ensure that commercial and residential building owners properly maintain low-impact development (LID) facilities that treat stormwater runoff on site.

Washington's municipal stormwater permit directs recipients to make LID the "preferred and commonly used approach to site development," where feasible. Such facilities, even those on private property, must be maintained properly to reduce stormwater runoff, flooding, and water pollution.

- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Increasing drought increases the concentration of pollutants in first-flush runoff.
- Intensifying precipitation contaminates water (bacteria, pathogens) due to a greater incidence of combined stormwater/sewer system overflows.
- Population change increases pollution related to development (e.g., more septic systems and impervious surfaces).
- Intensifying precipitation raises the cost of development (flooding and runoff mitigation measures).
- Intensifying precipitation increases volume of urban runoff and flooding, which decrease groundwater recharge.

ACTION F-08

Assess drinking water wells' vulnerability to saltwater intrusion and inundation from rising sea levels, and develop adaptation measures (e.g., relocating wells).

This action would help ensure the protection of the region's drinking water supplies.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise raises the cost of new development and redevelopment.
- Sea-level rise makes coastal groundwater more vulnerable to saltwater intrusion and inundation.

ACTION F-09

For sites where elevating or relocating a building is not a viable option in response to flood risks, acquire the property, use the land for appropriate uses (e.g., flood storage or agriculture), and help the occupants resettle in the community.

This action would help protect public welfare and physical assets while mitigating flood risks.

- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).

ACTION F-10

Implement brownfield clean-up strategies/planned actions for low-lying sites that are most vulnerable to sea-level rise.

This action would reduce the risk of water contamination from polluted coastal sites that become inundated with seawater.

- Sea-level rise inundates former industrial sites, which could mobilize pollutants in the soil and degrade water quality.

ACTION F-11

Protect important historical or cultural sites that are at risk of coastal or inland flooding, erosion, and wildfires.

Options could include allowing inundation of the site, relocating the site to higher ground, or stabilizing the site's shoreline with vegetation, rip-rap or other materials.

- Sea-level rise increases the frequency, depth, and duration of inundation of low-lying coastal areas, which could turn marshes, estuaries, and other upland areas into mudflats (dams limit sedimentation and 1-5 berms limit vegetation adaptation in the Nisqually Estuary).
- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise reduces shoreline recreation opportunities.
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION F-12

Limit construction of buildings and roads in areas where flood and landslide risks are highest.

This action would reduce the risk of infrastructure damage from floods and landslides exacerbated by changes in precipitation timing, type, and volume.

- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise raises the cost of new development and redevelopment.
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION F-13

Identify where and how the region could support the natural inland transition of coastal lowlands to estuaries as sea levels rise.

Supportive actions could include modifying artificial barriers such as roads, as well as purchasing vulnerable properties (e.g., low-lying agricultural lands) that could transition to estuaries over time.

- Sea-level rise increases the frequency, depth, and duration of inundation of low-lying coastal areas, which could turn marshes, estuaries, and other upland areas into mudflats (dams limit sedimentation and 1-5 berms limit vegetation adaptation in the Nisqually Estuary).
- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise raises the cost of new development and redevelopment.
- Sea-level rise pushes saltwater farther into estuaries, which may inundate near-coastal farms and ranches.
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION F-14

Construct flood-storage facilities (e.g., wetlands or artificial ponds) upstream of concentrated development areas that are at risk of flooding.

This action would reduce the risk of flooding and protect downstream built and natural assets.

- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Intensifying precipitation raises the cost of development (flooding and runoff mitigation measures).

ACTION F-15

Minimize development, disturbance, and vegetation removal on or near steep slopes (>25% gradient) adjacent to waterbodies.

This action would reduce the risks of landslides and sediment runoff.

- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation contaminates water (turbidity and sedimentation) due to landslides.
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION F-16

Retrofit or reroute pedestrian/bicycle trails and bridges in areas that are subject to repetitive flooding and/or landslides.

This action would help protect public welfare.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise reduces shoreline recreation opportunities.

ACTION F-17

Decouple remaining combined storm and sewer systems, where cost-effective, so as to add capacity and mitigate back-ups and water-borne disease outbreaks.

This action would help protect the LOTT Clean Water Alliance's downtown Olympia treatment plant from marine water inundation during coastal flood events exacerbated by rising seas and heavy rains. Marine water would kill the plant's biological water-treatment process.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Intensifying precipitation contaminates water (bacteria, pathogens) due to a greater incidence of combined stormwater/sewer system overflows.
- Intensifying precipitation raises the cost of development (flooding and runoff mitigation measures).

ACTION P-01

Increase funding, education, and incentives for private landowners to manage lands in ways that enhance ecological and economic resilience (e.g., protecting and restoring forests, prairies, and shoreline/riparian areas).

Incentives could include expanding Thurston County's Transfer of Development Rights (TDR) program, conservation easement funding, as well as expanding market-based approaches for ecosystem service payments or credits (e.g., for water quality, carbon sequestration, and flood management).

- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.
- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.
- Warmer winters increase the range and survival of invasive species, pests, and diseases that threaten native flora and fauna.
- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Ocean acidification decreases marine pH and -- when coupled with increases in ocean temperature and land-borne pollution -- threatens marine water quality.
- Warmer winters shift the life cycle of fish and wildlife, which could reduce populations that support subsistence and recreational hunting.
- Warmer summers decrease climatic suitability of areas that currently support Garry oak and prairie habitat.
- Warmer water expands the range for invasive aquatic species.
- Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.
- Warmer summers decrease climatic suitability of areas that currently support Douglas fir.
- Population change increases pressure to develop rural areas, which could reduce, fragment and/or degrade farms, forests, and prairies.

ACTION P-02

Use best-management practices, such as installing large woody debris in rivers, to improve water temperature, streamflow, and channel conditions.

Placing large woody debris in rivers alters the flow of water, digs out cooler pools for fish to rest, and creates sediment-free riffles for fish to spawn. It will be necessary to choose proper sites and structures that do not cause flooding.

- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.
- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.

ACTION P-03

Create/Update basin plans that integrate climate impacts, and include goals and targets for protecting natural resources and habitat.

This action would ensure that region continues to assess how climate change affects watersheds and takes measurable steps to protect the water, plants (e.g., riparian areas), and animals within.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.
- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.
- Warmer summers stress sensitive plants and habitat (including urban landscaping), which could leave them vulnerable to extreme heat, pests, or pathogens.
- Warmer winters cause salmon to remain active during winter and deplete their store of energy/health.
- Warmer winters increase the range and survival of invasive species, pests, and diseases that threaten native flora and fauna.
- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Warmer water threatens the survival of salmon, which support cultural and economic practices and ecosystem services.
- Ocean acidification makes it harder for calcifying organisms to form shells, and it ultimately harms commercial and recreational fisheries.
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Warmer summers decrease climatic suitability of areas that currently support Garry oak and prairie habitat.
- Warmer summers raise the risk of low crop yields or failure due to warmer temperature, reduced summer precipitation, and increased pest prevalence.
- Warmer winters reduce snowpack and alter stream volume and temperature, impacting long-term productivity of anadromous fish populations and fisheries.
- Increasing drought raises the risk of lower crop yield or failure.
- Warmer winters increase the range and survival of pests and diseases that affect crops.
- Sea-level rise pushes saltwater farther into estuaries, which may inundate near-coastal farms and ranches.
- Warmer summers decrease climatic suitability of areas that currently support Douglas fir.
- Warmer summers increase the heat stress risk for dairy cows and other large livestock.
- Population change increases pressure to develop rural areas, which could reduce, fragment and/or degrade farms, forests, and prairies.

ACTION P-04

Implement monitoring practices that provide early detection of invasive species on land and in water, and expand biological control and manual removal of such plants and insects.

This action would help halt the spread of invasive plant and insect species that thrive in a warmer climate.

- Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.
- Warmer winters increase the range and survival of invasive species, pests, and diseases that threaten native flora and fauna.
- Warmer water expands the range for invasive aquatic species.
- Warmer winters increase the range and survival of pests and diseases that affect crops.

ACTION P-05

Evaluate additional assisted migration of vulnerable plant and animal species to suitable habitat.

This action would help ensure species survival as changes in temperature and precipitation shift the location of suitable habitat.

- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.
- Warmer winters degrade critical habitat (rivers and streams) due to greater winter runoff.
- Warmer summers stress sensitive plants and habitat (including urban landscaping), which could leave them vulnerable to extreme heat, pests, or pathogens.
- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Warmer summers decrease climatic suitability of areas that currently support Garry oak and prairie habitat.
- Warmer summers decrease climatic suitability of areas that currently support Douglas fir.

ACTION P-06

Expand efforts to monitor the cause and extent of changes in native and invasive plant distribution.

This action would help land managers select and implement effective actions to ensure the survival of native plants.

- Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.
- Warmer summers stress sensitive plants and habitat (including urban landscaping), which could leave them vulnerable to extreme heat, pests, or pathogens.
- Warmer winters increase the range and survival of invasive species, pests, and diseases that threaten native flora and fauna.
- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Warmer summers decrease climatic suitability of areas that currently support Garry oak and prairie habitat.
- Warmer water expands the range for invasive aquatic species.
- Warmer summers decrease climatic suitability of areas that currently support Douglas fir.

ACTION P-07

Increase organic matter content and water retention in soils within urban and agricultural settings.

Integrating perennials into cropping systems such as grass forages, cover cropping, compost application and conservation tillage helps improve water infiltration and storage, as well as increases soil organic matter content and carbon sequestration.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought stresses sensitive plants and habitat, which could reduce long-term viability of preserved and restored areas.
- Warmer summers stress sensitive plants and habitat (including urban landscaping), which could leave them vulnerable to extreme heat, pests, or pathogens.
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Increasing drought reduces groundwater recharge (drinking water and in-stream flows).
- Warmer summers raise the risk of low crop yields or failure due to warmer temperature, reduced summer precipitation, and increased pest prevalence.
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.

ACTION P-08

Increase urban agriculture and biointensive farming methods to maximize crop yields and ecosystem services.

Municipalities and their partners could encourage such practices by providing technical support and incentives.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Warmer summers stress sensitive plants and habitat (including urban landscaping), which could leave them vulnerable to extreme heat, pests, or pathogens.
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Warmer summers raise the risk of low crop yields or failure due to warmer temperature, reduced summer precipitation, and increased pest prevalence.
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought raises the risk of lower crop yield or failure.
- Warmer winters increase the range and survival of pests and diseases that affect crops.
- Warmer summers accelerate the risk of food spoilage before it reaches market.
- Population change increases pressure to develop rural areas, which could reduce, fragment and/or degrade farms, forests, and prairies.

ACTION P-09

Protect and enhance marine vegetation, such as eelgrass, so as to help clean water, sequester carbon dioxide, and improve fish habitat and survival.

The Nisqually Estuary has Thurston County's only significant eelgrass beds.

- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Ocean acidification decreases marine pH and -- when coupled with increases in ocean temperature and land-borne pollution -- threatens marine water quality.
- Ocean acidification makes it harder for calcifying organisms to form shells, and it ultimately harms commercial and recreational fisheries.
- Ocean acidification reduces the food available for and survival of salmon and other marine life.
- Ocean acidification reduces food available for and survival of salmon and other marine life.

ACTION P-10

Educate waterfront property owners about the benefits of voluntary oyster seeding and other shellfish production, and encourage such practices.

This action would help improve water quality and sustain the region's shellfishery, which are threatened by ocean acidification and land-borne pollution.

- Increasing drought increases the concentration of pollutants in first-flush runoff.
- Sea-level rise increases coastal flooding of downtown Olympia and LOTT wastewater treatment plant assets, which could threaten the ability to treat and discharge water and increase the energy consumed to operate pumps.
- Ocean acidification decreases marine pH and -- when coupled with increases in ocean temperature and land-borne pollution -- threatens marine water quality.
- Ocean acidification makes it harder for calcifying organisms to form shells, and it ultimately harms commercial and recreational fisheries.
- Warmer water increases the risk of marine water stratification and hypoxia, which could alter the timing of spring plankton blooms that support the marine food web (including salmon and other economically important fish).

ACTION P-11

Support Voluntary Stewardship Program (VSP) implementation to encourage conservation of agricultural lands and critical areas (e.g., riparian stream buffers) that provide ecosystem services.

Under the VSP program, which was created via state law, Thurston County works with landowners to develop voluntary, site-specific plans to protect critical areas on agricultural lands.

- Intensifying precipitation increases the frequency and intensity of the heaviest 24-hour rain events and the overall volume of winter streamflow, which could degrade sensitive riparian areas.
- Increasing drought degrades critical habitat (lakes, rivers and streams) due to changes in water volume and temperature.
- Warmer winters reduce snowpack and alter stream volume and temperature, impacting long-term productivity of anadromous fish populations and fisheries.

ACTION P-12

Grow woody perennial crops that help conserve water, store carbon, and provide other ecosystem services.

This action, which includes planting fruit trees and other crops whose woody stems and branches don't die off each winter, has both climate adaptation and mitigation co-benefits.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Warmer summers raise the risk of low crop yields or failure due to warmer temperature, reduced summer precipitation, and increased pest prevalence.
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Increasing drought raises the risk of lower crop yield or failure.
- Warmer winters increase the range and survival of pests and diseases that affect crops.
- Warmer summers accelerate the risk of food spoilage before it reaches market.
- Warmer summers accelerate the release of carbon stored in soils.
- Increasing drought parches farm fields and other open spaces, which could erode and release windblown dust (e.g., PM10) that degrades air quality.

ACTION T-01

Expand and retrofit the region's energy distribution, monitoring, and storage infrastructure to support more on-site renewable energy generation.

Bolstering the region's electricity distribution, monitoring, and storage infrastructure to handle more on-site renewable energy generation (e.g., solar panels on residential rooftops) would provide a hedge against the risk of service disruptions as a result of storms and blackouts.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.
- Warmer summers increase summer peak energy demand and costs for cooling residential and commercial buildings (e.g., buying and operating air conditioners), which could place more demand on the grid and reduce energy security.

ACTION T-02

Provide additional utility incentives to support energy efficiency and renewable energy investments in buildings.

Thurston County's electric utility, Puget Sound Energy, could offer new incentives to help building owners cover the cost of investing in energy efficiency (e.g., installing new windows and insulation) and installing solar panels, small-scale wind turbines, and other equipment that generates electricity on site from clean, renewable resources.
Washington state law allows "on-bill" financing, for example, in which an electric utility provides a loan to the owner of a commercial or residential building to invest in on-site renewable energy generation and efficiency upgrades. The borrower, which pays back the loan on its electric bill, saves money over time as it reduces its need for utility-provided electricity. This, in turn, reduces pressure on the utility to invest in generation from new sources (e.g., coal and natural gas power plants).

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.
- Warmer summers increase summer peak energy demand and costs for cooling residential and commercial buildings (e.g., buying and operating air conditioners), which could place more demand on the grid and reduce energy security.

ACTION T-03

Offer additional utility rebates or bill credits to induce residents to buy and install energy-efficient appliances and other equipment.

Thurston County's electric utility, Puget Sound Energy, could provide residential rate-payers additional financial incentives to buy and install energy-efficient light bulbs, clothes dryers, air conditioners, and other equipment that saves energy and lowers bills. To enhance equity, PSE could increase incentives for low-income renters and homeowners.

- Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.
- Warmer summers increase summer peak energy demand and costs for cooling residential and commercial buildings (e.g., buying and operating air conditioners), which could place more demand on the grid and reduce energy security.
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Warmer summers cause urban heat islands, which could affect livability/health in heavily developed centers and corridors.

ACTION T-04

Evaluate strategies to protect important electrical equipment that is within critical areas at risk of flooding and/or landslides.

Examples of such critical electrical equipment include underground power lines and low-elevation substations near the Puget Sound shoreline. Strategies could include elevating, reinforcing, or relocating such equipment.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).

ACTION T-05

Map transportation infrastructure that is vulnerable to repeated floods and/or landslides, and designate alternative travel routes for critical transportation corridors when roads must be closed because of natural hazards.

Integrate this lifeline transportation route map's data into the Thurston County Emergency Operations Plan and other local planning efforts.

- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).

ACTION T-06

Relocate or retrofit low-lying roads vulnerable to coastal or inland flooding.

This action, for example, could include relocating or raising Interstate 5 at the Nisqually Estuary and U.S. Highway 101 at Mud Bay (e.g., building taller, longer bridges). Such near-shore areas are vulnerable to coastal flooding exacerbated by sea-level rise and heavy precipitation.

- Sea-level rise increases the frequency, depth, and duration of inundation of low-lying coastal areas, which could turn marshes, estuaries, and other upland areas into mudflats (dams limit sedimentation and 1-5 berms limit vegetation adaptation in the Nisqually Estuary).
- Sea-level rise increases wave-action exposure, which could increase the erosion rate of coastal bluffs, degrade coastal wildlife habitat, and threaten the property and safety residents.
- Sea-level rise raises the risk of coastal inundation, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Sea-level rise raises the cost of new development and redevelopment.
- Sea-level rise raises the risk of coastal inundation and landslides, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.

ACTION T-07

Increase the energy efficiency of the region's water infrastructure.

This action includes replacing pumps and other drinking water, wastewater, and stormwater systems that consume large amounts of energy.

- Sea-level rise increases coastal flooding of downtown Olympia and LOTT wastewater treatment plant assets, which could threaten the ability to treat and discharge water and increase the energy consumed to operate pumps.
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Increasing drought necessitates moving water farther distances, which consumes more energy and may increase greenhouse gas emissions (depending on the energy fuel source).

ACTION T-08

Build additional large-scale renewable energy projects (e.g., utility-scale solar arrays and wind farms) in Thurston County.

Such clean-energy projects offset demand for electricity from polluting fossil fuels (coal and natural gas) and hydropower — which is vulnerable to less summer precipitation/lower streamflow.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.
- Warmer summers increase summer peak energy demand and costs for cooling residential and commercial buildings (e.g., buying and operating air conditioners), which could place more demand on the grid and reduce energy security.

ACTION T-09

Establish energy goals/benchmarks (e.g., LEED) for new buildings, and adopt permitting practices and building code and/or design guidelines that support clean and efficient energy practices and technologies (e.g., passive design, rooftop solar panels, electric vehicle charging stations).

This action, which could be taken by tribal, state or local governments, would reduce building electricity consumption and demand/costs for utility-provided power.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.
- Warmer summers increase summer peak energy demand and costs for cooling residential and commercial buildings (e.g., buying and operating air conditioners), which could place more demand on the grid and reduce energy security.
- Intensifying precipitation increases use of polluting generators following storm-induced power outages.

ACTION T-10

Expand utility outreach to and education of commercial and residential power customers about the benefits of clean and efficient energy technologies and practices.

Generating electricity from clean, renewable resources (e.g., the wind and sun) — and using electricity more efficiently — helps reduce the region's greenhouse gas emissions that contribute to global climate change. Such actions also offset demand for electricity Puget Sound Energy gets from polluting fossil fuels (coal and natural gas) and hydropower — which is vulnerable to less summer precipitation/lower streamflow.

- Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.
- Warmer summers increase summer peak energy demand and costs for cooling residential and commercial buildings (e.g., buying and operating air conditioners), which could place more demand on the grid and reduce energy security.

ACTION T-11

Develop and adopt policies that require residential and commercial properties to undertake an energy audit at the time of sale or during a substantial remodel.

Tribes or local governments could require such energy audits. If the energy audits identify deficiencies, regulators could recommend energy retrofits to upgrade properties to a specified level.

- Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.
- Warmer summers increase summer peak energy demand and costs for cooling residential and commercial buildings (e.g., buying and operating air conditioners), which could place more demand on the grid and reduce energy security.

ACTION T-12

Generate additional energy from waste products (e.g., woody biomass and sewage) in Thurston County.

LOTT's wastewater-treatment plant, located in downtown Olympia, already captures methane to generate heat and electricity on site. Such projects offset demand for electricity from polluting fossil fuels (coal and natural gas) and hydropower — which is vulnerable to less summer precipitation/lower streamflow.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Increasing drought reduces summer hydropower production, a comparatively clean and inexpensive electricity source for commercial and residential customers.
- Warmer summers increase summer peak energy demand and costs for cooling residential and commercial buildings (e.g., buying and operating air conditioners), which could place more demand on the grid and reduce energy security.

ACTION T-13

Increase resources to monitor air quality, and enforce regulations to reduce the health risks of air pollution (e.g., surface ozone and particulate matter) exacerbated by warmer temperatures and automobile emissions.

This action would help reduce air pollution that threatens the region's residents.

- Population change increases transportation-related energy consumption, CO_2 emissions, and other pollutants related to buildings and transportation.
- Increasing drought raises the risk of wildfires and elevated levels of PM_{10} (coarse particulate matter) from smoke.
- Warmer summers increase production of surface ozone (VOCs interacting with NO_x) and accumulation of fine particulate matter ($PM_{2.5}$).
- Warmer summers cause urban heat islands, which could affect livability/health in heavily developed centers and corridors.
- Increasing drought parches farm fields and other open spaces, which could erode and release windblown dust (e.g., PM_{10}) that degrades air quality.

ACTION W-01

Create and maintain a map of the region's high-risk wildland urban interface communities and locations of wildfires.

Such a map would be used to regulate Firewise development practices (e.g., requiring building fire-suppression sprinklers and setbacks), as well as to educate property owners about wildfire risks.

- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.
- Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.
- Increasing drought raises the risk of wildfires, which could contaminate water (turbidity and sedimentation).
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION W-02

Require new developments in high-risk wildfire areas to submit a fire-protection plan during site plan review.

This action would help reduce the risk of wildfire spreading to and damaging buildings.

- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.
- Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.
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- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION W-03

Provide private forestland owners and residents living in Wildland-Urban Interface (WUI) areas information about fire prevention/Firewise practices, and encourage the application of such practices.

Firewise is a program of the National Fire Protection Association (NFPA) and co-sponsored by the USDA Forest Service, the US Department of the Interior and the National Association of State Foresters. Firewise practices include limiting vegetation near homes and building such structures with flame-resistant materials.

- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.
- Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.
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- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION W-04

Plant drought- and pest-resistant trees, shrubs, and grasses in parks, landscaping strips, and other urban areas.

Such vegetation reduces the need for watering, provides cooling shade, improves air and water quality, and supports flood storage/infiltration.

- Increasing drought makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation increases the volume of urban runoff and flooding, which could render inadequate some stormwater/flood-control facilities.
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Population change increases strain on social and emergency services.
- Warmer summers increase extreme temperatures that could cause heat-related illnesses (e.g., hyperthermia) -- a major risk for elderly, homeless, and other vulnerable populations.
- Population change makes it harder to balance competing demands for water (for housing, industry, energy, agriculture, and the environment).
- Population change increases pressure on existing parks and open space.
- Increasing drought reduces aquifer recharge and could spur more groundwater pumping when surface water is scarce, all of which could lower well levels and raise the cost of pumping water from greater depths.
- Warmer summers increase production of surface ozone (VOCs interacting with NOx) and accumulation of fine particulate matter (PM2.5).
- Warmer summers cause urban heat islands, which could affect livability/health in heavily developed centers and corridors.
- Intensifying precipitation raises the cost of development (flooding and runoff mitigation measures).
- Warmer summers increase atmospheric CO2, which decreases the nutritional quality of forage and pasture lands for livestock and wild animals.

ACTION W-05

Adopt wildfire hazard overlay districts with development regulations (for new structures) based on factors such as slope, structure, and fuel hazards.

This action would help reduce the risk of wildfire spreading to and damaging buildings.

- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.
- Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.
- Increasing drought raises the risk of wildfires, which could contaminate water (turbidity and sedimentation).
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION W-06

Lower the density of development allowed in areas with the highest risk of wildfire.

Downzoning rural, unincorporated areas within the region's Wildland-Urban Interface (WUI), the zone where natural areas and development meet, would decrease the number of homes and businesses at risk of fire damage. Downzoning areas within city and town urban growth areas, however, may be in conflict with state Growth Management Act and local density goals.

- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.
- Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.
- Increasing drought raises the risk of wildfires, which could contaminate water (turbidity and sedimentation).
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION W-07

Extend and enforce the rural burn ban when wildfire risks are high.

This action would lower the risk of wildfires during periods of extreme heat and drought.

- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.
- Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.
- Increasing drought raises the risk of wildfires, which could contaminate water (turbidity and sedimentation).
- Increasing drought raises the risk of wildfires, which could damage public- and private-sector infrastructure (homes, businesses, roads, etc.) and create waste that cannot be reused or recycled.
- Increasing drought raises the risk of wildfires, which could damage utility infrastructure.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION W-08

Modify local building codes, where necessary, to require fire sprinkler systems and enable emergency access/egress in all new residential and commercial construction.

This action would help mitigate the risks of wildfires spreading.

- Intensifying precipitation raises the risk of floods and landslides, which could damage private property and public infrastructure, endanger lives, and cut off access to goods and services (affects agriculture, buildings, roads, bridges, cultural sites, and other assets).
- Intensifying precipitation puts more strain on services (social, emergency, etc.).
- Population change increases strain on social and emergency services.
- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

ACTION W-09

Account for the inclusion of defensible spaces into future developments (e.g., designing roads, pathways, sidewalks, and landscaping to create firebreaks) in areas where there is high wildfire risk.

This action would reduce the risk of wildfires spreading to and damaging homes.

- Increasing drought raises the risk of wildfires, which could damage forests and other sensitive lands that provide wildlife habitat, economic resources (e.g., timber), and recreation opportunities.
- Increasing drought raises the risk of wildfires and elevated levels of PM10 (coarse particulate matter) from smoke.
- Increasing drought raises the risk of wildfires, which could destroy forests that serve as a net carbon sink.
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- Increasing drought raises the risk of wildfires, which could close roads and cut off access to vital goods and services.
- Increasing drought raises the risk of wildfires, which could result in personal injury or death.

Appendix F

Action Benefit-Cost Analyses

October 2017

Benefit-Cost Analysis of Selected Actions from the Thurston Climate Adaptation Plan

Earth Economics

http://www.eartheconomics.org/
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Report Version 1.2

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Cover Photo: Pioneer Park in Tumwater, Source: Orin Blomberg

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Executive Summary

The *Thurston Climate Adaptation Plan* is an important step toward ensuring community resilience and economic sustainability. As part of this plan, the Thurston Regional Planning Council is considering several actions to prepare for climate change impacts.

This report provides a holistic benefit-cost analysis (BCA) for two climate adaptation actions identified in the *Thurston Climate Adaptation Plan*, going beyond traditional economic measures (e.g., capital costs, acquisition costs) to take nature's services into account. Action F-01 evaluates and secures sustained funding to restore and protect riparian vegetation along freshwater and marine shorelines. Action G-12 aims to increase incentives for targeted urban development, ensure that redevelopment projects are financially viable. The benefit-cost ratio (BCR) is the dollar value of benefits produced by each dollar of related costs; in other words, the return on investment for every $1 in expenditures or forfeited revenue. Our BCA results show that both of these adaptation actions will provide significantly greater ecosystem service benefits that should be taken into account when considering whether to take other actions. Highlights include:

- The BCR for Action F-01 ranges from 1.73 (based on low estimates of the value of ecosystem services) to 9.34 (based on high estimates).
- The BCR for Action G-12 ranges from 14.78 (low estimates) to 18.15 (high estimates).
- Ecosystem services in restored riparian areas will produce between $2,644 and $8,311 per acre, every year.

Additional community benefits, such as expanded employment opportunities and associated income have not been included in this analysis. Even without these benefits, investing in climate adaptation in Thurston County offers exceptionally good returns.

Introduction

Watersheds within the Thurston Region and around the Puget Sound face a range of threats from natural hazards, including droughts, floods, and fires. In the coming years, climate change will intensify these natural hazards and, subsequently, their effects on underprepared populations. With funding from the National Estuary Program (NEP), the Thurston Regional Planning Council (TRPC) is working to better prepare communities for future threats through regional planning efforts.

TRPC is developing "a watershed-based climate adaptation plan with actions the Thurston County region could take to prepare for and adjust to climate change impacts in the decades ahead."[i] This plan includes 90 actions, split into six broad categories that include drought and water quality; flood and erosion; and, transportation and energy.[ii] An additional component of plan development is the use of benefit-cost analysis (BCA) to evaluate possible actions. In this report, Earth Economics presents a more holistic assessment of the benefits and costs of two proposed climate adaptation actions to Thurston County, including the benefits provided by ecosystem services, as well as more conventional metrics of benefits and costs.

BCA is a proven economic tool for developing environmental, health, and safety regulations.[iii] Traditional BCAs include economic benefits and costs occurring within the market, like acquisition and maintenance costs. A holistic BCA includes these traditional market measures, but also incorporates non-market benefits and costs, such as ecosystem services and social impacts. Environmental and social benefits are often just as tangible as economic benefits. For example, families displaced by flooding experience a social cost. Incorporating economic, environmental, and social benefits and costs into policy analysis provides a more holistic perspective of what people value, whether or not a market transaction occurs. Ecosystems are vital to economies, providing essential goods and services that enable cities, communities, households, and their residents to thrive. However, society has largely undervalued the importance of functioning ecosystems, leading to the degradation or destruction of natural assets. This loss of natural assets translates to tangible economic costs. For example, the loss of free flood protection provided by natural wetlands necessitates replacements. The ecosystem function that generates flood risk reduction must be replaced with costly levees, and flooded houses must be fixed.

To avoid ecosystem losses, it is important to include ecosystem service benefits in decision making. Economic value can be assigned by employing ecosystem services valuation, a method that economists use to ascribe monetary value to ecosystem services. For example, in 2012, Earth Economics assessed Thurston County's ecosystems, finding that they provide at least $608 million in economic benefits to the regional economy *every year*.[xii] These economic benefits come from ecosystem services such as flood reduction, habitat, and water supply.

Use of Ecosystem Services in BCAs

While far from fully recognized, ecosystem service values have been included in local and federal policy discussions in recent decades. This section highlights environmental and public health policy decisions that incorporated non-market benefits, including ecosystem services.

In 1995, Meyer et al. conducted a BCA that relied heavily on people's willingness to pay for preservation and use of the Elwha River.[iv] This study found that non-market benefits exceeded market benefits by a factor of over 100. The results of this analysis influenced the decision to restore the Elwha River by removing two dams.

On a broader scale, the U.S. Forest Service incorporated non-market benefits into forest management decisions in 1996. One USFS report found that accounting for the non-market benefits of federal land aligned with the economic objectives of federal land management, which require that lands are managed to "maximize net public benefits".[v] Non-market methods used by environmental economists can be adapted by economists working in other policy contexts. For example, revealed and stated preference valuations are used to estimate the benefits of health hazard reduction, such as willingness to pay for fire alarms, automobile safety, or an improvement in quality of life.[vi] Given the efficacy of non-market benefit estimation in a variety of policy contexts, policy decisions with a significant impact on natural capital or ecosystem services-producing land should incorporate non-market benefits into policy analysis.

Prior use of Ecosystem Services by Earth Economics

In Seattle, the $6.4 million Thornton Creek Confluence Project, an urban stream daylighting and floodplain expansion project, relied on a holistic BCA for approval. During the planning phase, Seattle Public Utilities produced a BCA that included not only flood risk reduction and infrastructure operations and maintenance cost reduction outcomes, but also habitat improvement benefits.[vii] These economic benefits, calculated by Earth Economics, helped demonstrate that the project would have a positive net return. The project was subsequently approved by the Asset Management Committee, Seattle Public Utilities' decision-making body.

Mojica et al. conducted a BCA of four dams on the Lower Snake River, correcting an earlier cost benefit analysis that didn't account for non-market benefits. When lost recreation benefits were incorporated into a BCA of the dams, the benefit-cost ratio of the dams sank to 0.15, indicating that every dollar spent provided a benefit of 15 cents.[viii]

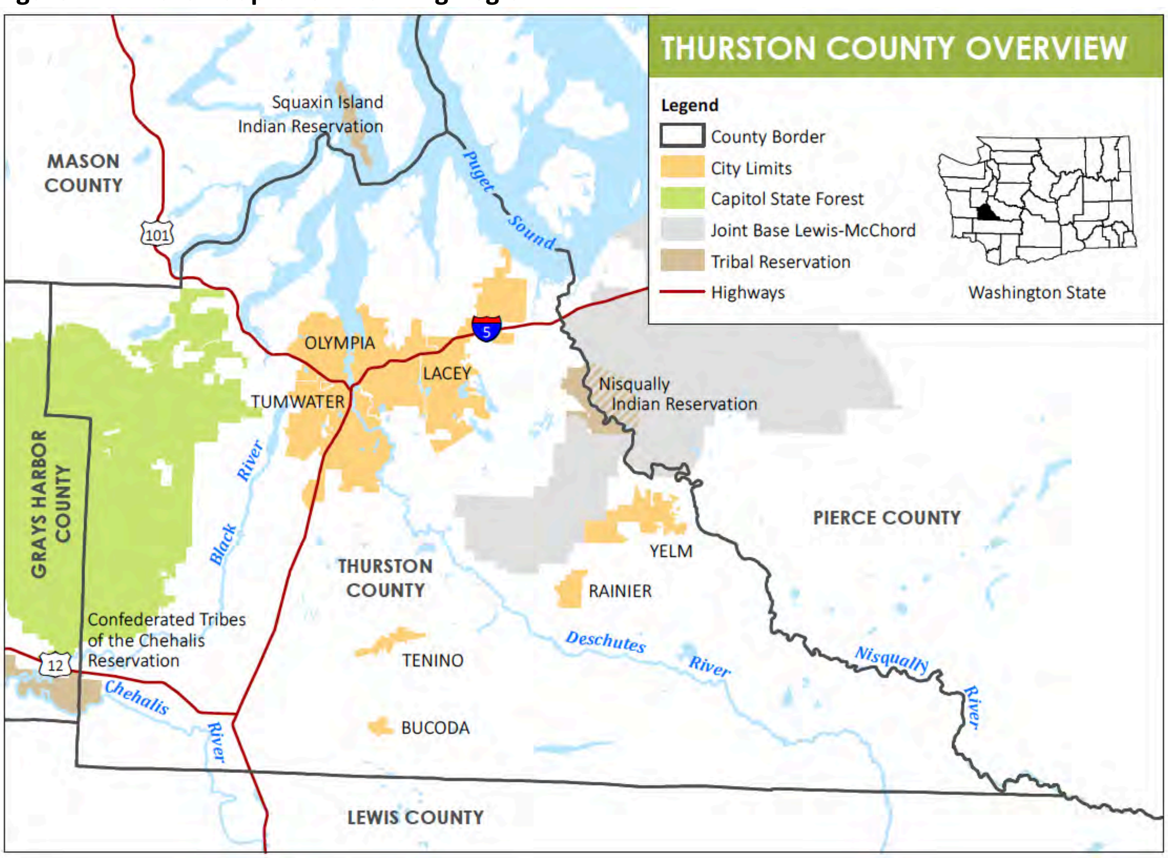
Earth Economics specializes in the valuation of non-market benefits provided by natural landscapes. Recently, Earth Economics and Royal Engineering conducted an ecosystem services valuation of Louisiana's coastal wetlands, projecting future land cover types.[ix] These projections were based upon changes in hydrology resulting from installation of sediment diversions near the mouth of the Mississippi River. The change in ecosystem services value between different scenarios was viewed as the benefit in a BCA of sediment diversion installation.

The Federal Emergency Management Agency (FEMA) requires all applicants to its hazard mitigation grant programs to demonstrate a benefit-to-cost ratio greater than one to qualify. In 2013, FEMA became the first federal agency to adopt ecosystem services valuation in formal policy. The policy was approved using values and concepts provided by Earth Economics. Faced with rising natural disaster costs and climate uncertainty, FEMA approved Mitigation Policy FP-108-024-01, which allows the inclusion of ecosystem services in BCA for flood-related acquisition projects. In 2016, FEMA adopted additional values provided by Earth Economics that added ecosystem services values for drought and wildfire mitigation. Today, leaders are able to make more informed decisions, leading to stronger, more cost-effective projects that take nature into account and save taxpayer dollars.

Study Overview

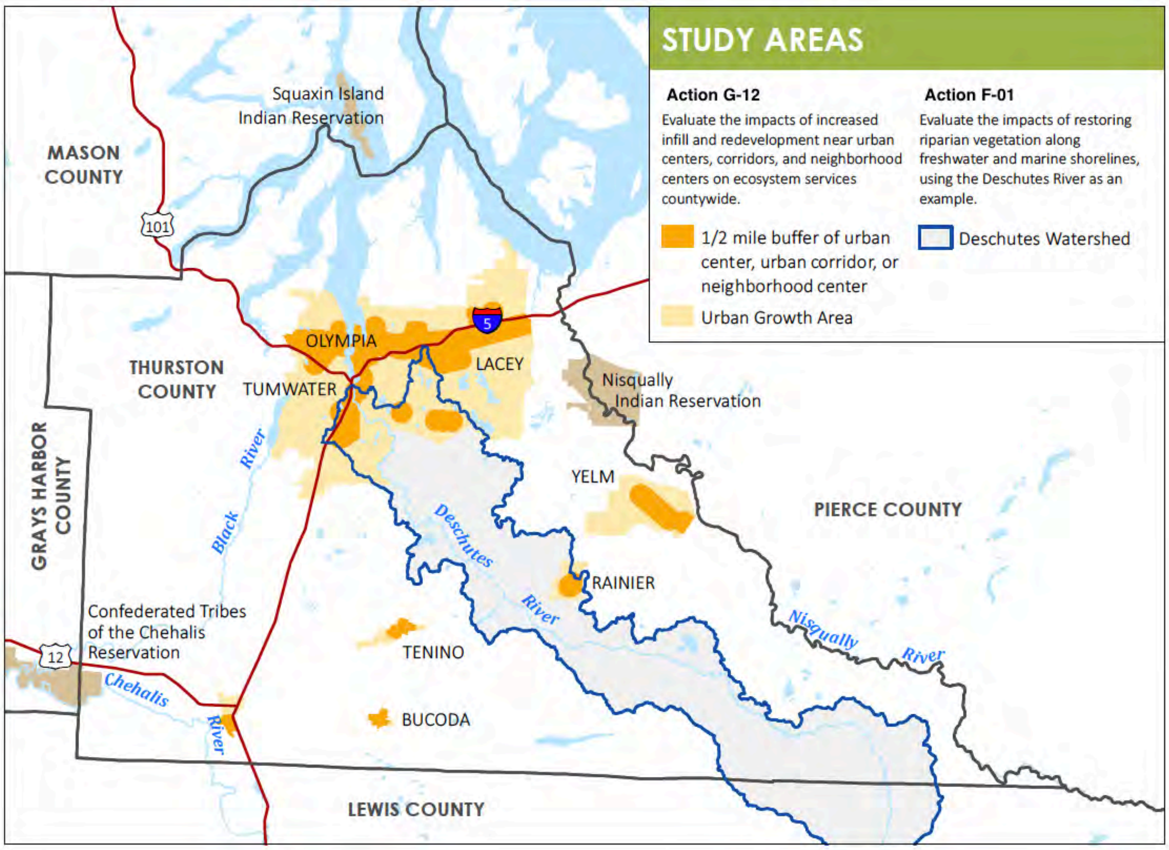
This analysis develops BCAs for two proposed climate adaptation actions within TRPC's climate adaptation plan to serve as examples of how to conduct a holistic BCA. The plan targets actions to implement in the Thurston County portion of three watersheds (the Nisqually, Deschutes, and Kennedy/Goldsborough (WRIA 11, 13, and 14)). Situated directly along Southern Puget Sound, this region offers a diverse landscape of coastal lowlands, prairie flatlands and foothills of the Cascade mountain range. The population centers of Olympia, Lacey, and Tumwater, with a combined 100,000+ residents, also fall within the planning area (see Figure 1).

Figure 1. Climate Adaptation Planning Region



As determined in agreement with TRPC and the stakeholder group, Action F-01 and Action G-12 were selected for sample BCAs.[ii] To illustrate benefits and costs, specific planning scenarios are associated with each action. As depicted in Figure 2, the planning scenario for each action in this analysis focuses on only a portion of the larger study region. These sample planning scenarios provide quantitative inputs for a holistic BCA that can be adjusted or replicated as other implementation scenarios or actions are considered. The two BCAs developed in this analysis provide a model for the inclusion of ecosystem services and additional non-market benefits into assessments of climate adaptation actions. Details of Action F-01 and Action G-12 are provided below.

Figure 2. Actions F-01 and G-12 Scenario Geographies

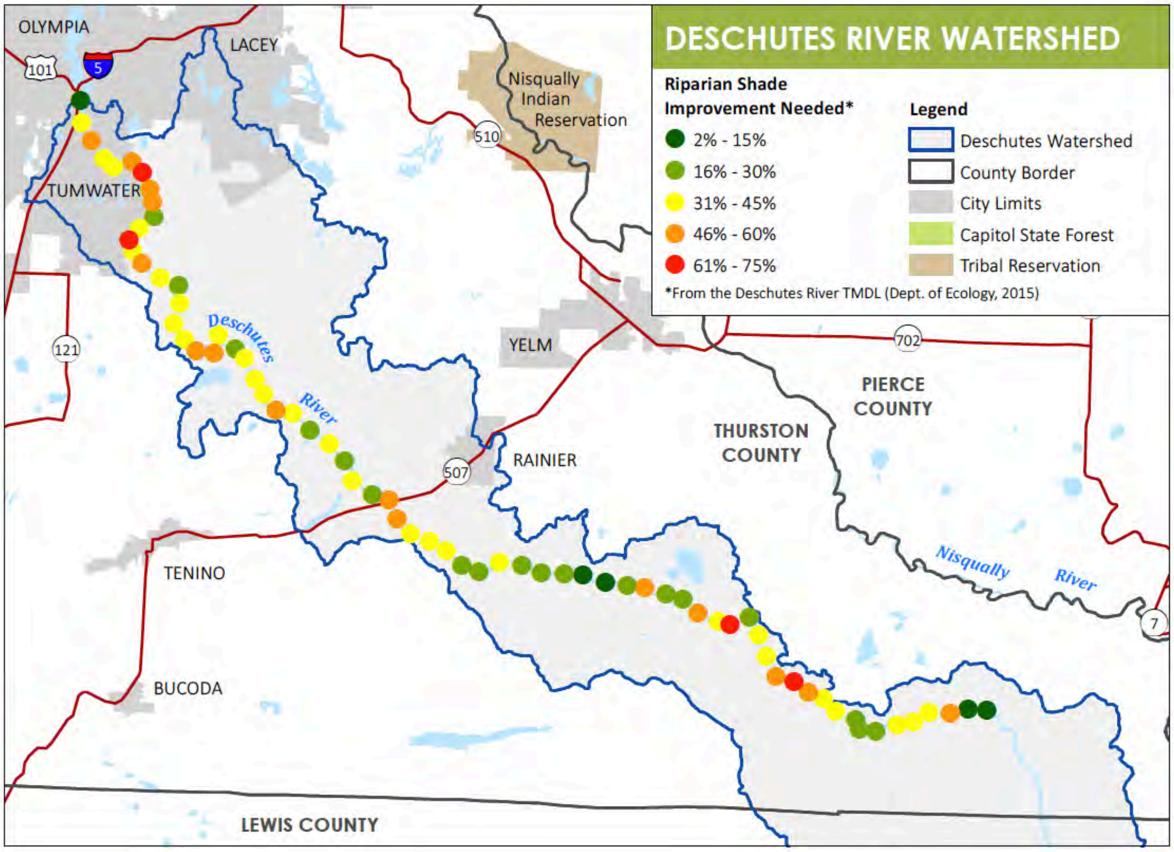


Action F-01

Action F-01 proposes to evaluate and secure sustained funding to restore and protect riparian vegetation along freshwater and marine shorelines. Restoration along the Deschutes River is the planning scenario utilized to demonstrate the benefits and costs of Action F-01. Extensive planning has been completed in this watershed, related to multiple Total Maximum Daily Load (TMDL) studies and other impairments. TRPC used the shade allocation targets identified in the Deschutes River TMDL to estimate the change in land cover under a restoration and conservation scenario.

Similar scenario development in other watersheds could be used in additional Action F-01 BCAs. The degree of riparian restoration needed along stretches of the Deschutes River is highlighted in Figure 3.

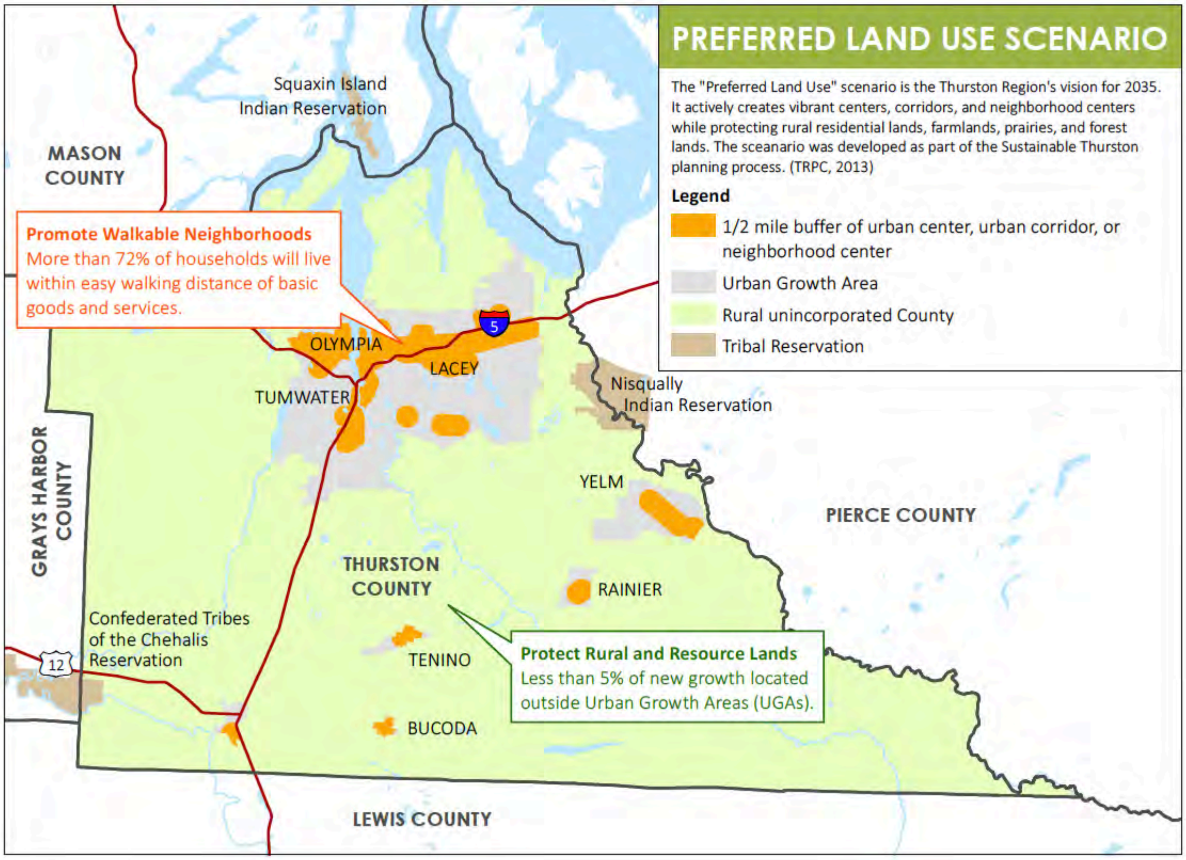
Figure 3. Deschutes Watershed with Proposed Restoration Sites under Action F-01



Action G-12

Action G-12 proposes to increase incentives to improve the financial viability of targeted urban development and redevelopment projects in designated centers, corridors, and neighborhood centers. This action can both preserve rural natural assets by avoiding development and enhance residents' resilience by shortening their distance to services. The implementation scenario of Action G-12 used in this analysis is region-wide, and was developed as the Preferred Land Use scenario of the Sustainable Thurston project, a region-wide visioning project completed in 2013. The Preferred Land Use scenario represented a "compact" growth scenario compared to the Baseline scenario – or adopted land use plans projection. The targets from the Preferred Land Use Scenario[xi] are shown in Figure 4.

Figure 4. Zones of Future Development within Thurston Region



Holistic BCA Methods

Ecosystem Services Valuation

Ecosystem service benefits are included in the BCA for both actions. The derivation of ecosystem service values follows the methodology presented in Earth Economics' 2012 report, *The Natural Value of Thurston County, A Rapid Ecosystem Service Valuation*.[xii] Updates were made to 2012 values based on improved valuation literature. The per-acre ecosystem service values used in the following BCAs are presented in Appendix B.

Action F-01 Benefit and Cost Methods

This particular action requires restoration of riparian lands, converting currently developed, agricultural, or non-optimal vegetated lands to forests. The benefit from Action F-01 is expressed as the difference between ecosystem services values of current baseline land cover and projected land cover under successful implementation. TRPC provided data on project costs, including restoration and the acquisition of easements on private land, based on 40 Thurston County riparian restoration projects listed in the Washington State Recreation and Conservation Office's PRISM database.[xiii] Projects were funded between 1999 and 2016.

Please note that not all expected costs and benefits were included in this analysis (e.g., benefits of improved or restored salmon runs due to riparian restoration).

Action G-12 Benefit and Cost Methods

The evaluation of this action is based upon the expected benefits and costs associated with incentivizing downtown development and redevelopment, as an alternative to continuing current suburban expansion rates. The benefits of Action G-12 are based upon the difference in ecosystem services provided by the Baseline (i.e., adopted land use plans) and Preferred Land Use scenarios. Additional benefits are experienced by county, city, and town governments in the form of avoided service provisioning costs. The costs of Action G-12 include foregone government revenues from impact fee decreases and tax exemptions. Details on the methods used to evaluate Action G-12 are provided in Appendices D and E.

Holistic BCA Results

Action F-01 Results

Action F-01 provides a benefit-cost ratio ranging from 1.73 to 9.34, based on the low and high ecosystem services estimates, respectively. Appendix B (Table 4) details the per land cover ecosystem service values utilized to represent benefits. The total and per-acre costs of restoration on both public and private land are displayed in Table 1**.** The net present costs and benefits of restoration and the associated benefit-cost ratios are shown in Table 2.

Table 1. Action F-01: Per-Acre and Total Costs

	Program Costs	
	Private Land	**Public Land**
Acreage of Converted Land	510	35
Avg. Restoration Cost ($/acre)	$13,866	$13,866
Avg. Easement Cost ($/acre)	$9,457	$0
Total Cost ($/acre)	$23,323	$13,866
Costs (2016$)	$11,894,730	$485,310
Public + Private (2016$)	**$12,380,040**	

Table 2. Action F-01: Fifty Year Net Present Value and Benefit-Cost Ratios

	Net Present Value	
	Low	**High**
2.875% Discount Rate	$21,382,000	$115,633,000
Benefit-Cost Ratio	1.73	9.34

Action G-12 Results

Action G-12 provides a BCR ranging from 14.78 to 18.15 when ecosystem service benefits are included, based on the low and high estimates of the value of these nonmarket benefits, relative to a baseline of continued suburban growth. In other words, Thurston County can expect between $14.78 and $18.15 in benefits for every dollar it invests in targeted urban development and redevelopment. The Preferred Land Use scenario preserves 6,175 acres of rural land, ensuring the yearly production of $12-$17 million in ecosystem services over the baseline (2016$).

The net present value over a 50-year period (2.875% discount rate) for all ecosystem service benefits (see Appendix B) and avoided public service provisioning costs (see Appendix D) is between $1.05 billion and $1.29 billion.

Reducing impact development fees for multifamily projects in urban areas, such as downtown Olympia, Lacey's Woodland District, and Tumwater's Town Center, Capitol Corridor, and Brewery District, results in a one-time loss of $260,000. Additional tax incentives for urban development under the Preferred Land Use scenario would reduce city, county, and state revenue by a total of $71 million (see Appendix E for further details). Net present costs, benefits, and BCRs associated with Action G-12 are presented in Table 3. The land cover changes on which these net present values are based are shown in Appendix B in Table 5.

Table 3. Action G-12: 50-Year Net Present Values and Benefit-Cost Ratios

	Low	**High**
NPV of Ecosystem Services*	$343,260,000	$582,072,000
Avoided Public Service Costs*	$703,498,000	
Total Benefits	**$1,046,758,000**	**$1,285,570,000**
	Costs	
Foregone Impact Fees	$260,000	
Tax Exemptions	$70,581,000	
Total Costs (2016$)	**$70,841,000**	
Benefit-Cost Ratios	14.78	18.15

* 2.875 discount rate, over 50 years.

Conclusions and Recommendations

This report provides a benefit-cost analysis of two actions from the *Thurston Climate Adaptation Plan* and highlights the importance of including ecosystem services and social impacts in the region's decision-making process. Earth Economics' earlier work revealed that Thurston County provide goods and services are valued at least $608 million every year. Any decision with the potential to affect the value of the goods and services provided by ecosystems must consider the entire range of benefits and costs to ensure that a course of action will maximize net public benefits.

Understanding the immense value of ecosystem services, which ultimately shape the regional economy, is a critical first step in developing policies, investing public dollars, and making decisions regarding natural resource management and flood mitigation.

Earth Economics recommends the following next steps:

- **Include Ecosystem Services and Social Benefits in Future Benefit-Cost Analyses.** As local governments consider courses of action to address floodplain management and climate adaptation needs in the region, officials should consider the costs and benefits of their actions with regard to ecosystem services. BCAs that incorporate ESV can provide governments, organizations, and private landowners a way to calculate the true rate of return on conservation and restoration investments. Including ecosystem services values also allows for the full consideration of green and grey alternatives to infrastructure projects. A handful of state and federal agencies, including FEMA, already include ESV in their formal BCAs (Mitigation Policy FP-108-024-01, 2013). Thurston County jurisdictions should join the ranks of these leading agencies and include ESV in future BCAs.

- **Engage Stakeholders to Expand Benefits and Costs Under Action Scenarios.** Ultimately, a holistic BCA for all action items in the *Thurston Climate Adaption Plan*, that involves land use changes, would support jurisdictions' decision-making processes and base decisions on what people value, as opposed to solely the market transactions that take place.

- **Protect and Restore Natural Capital.** Farmland preservation, salmon habitat restoration, and flood damage mitigation are priorities for the Thurston Region. TRPC partners can help accelerate this work by advocating for the acceptance and application of ecosystem service valuation, and a holistic approach to benefit-cost analysis, in the jurisdictions' planning processes. Taking this approach will lead to additional conservation efforts throughout the Thurston Region, and support long-term economic growth.

Glossary of Terms

Benefit-cost analysis: A common tool that compares the present-day cost of a project with its long-term benefits, often used by decision makers to determine whether or not a project will be funded.

Benefit-cost ratio: The dollar value of benefit per dollar of associated cost. If a ratio number is higher than 1, then the project is typically funded. A project with a benefit-cost ratio greater than 1 indicates that the project benefits outweigh the costs. A project with a benefit-cost ratio less than 1 indicates that the project's costs outweigh the benefits.

Discount rate: The rate at which people value current consumption or income, compared with later consumption or income. It determines the present value of future cash, due to uncertainty, productivity, or time preference for the present.

Ecosystem goods and services: Benefits obtained from ecosystems. Goods are tangible, and often traded in markets (e.g., potable water, fish, timber). Services provide less tangible, often non-market benefits (e.g., flood protection, water quality, climate stability).

Market-based valuation: Value estimates based on observed willingness-to-pay for a given good or service (i.e., market pricing).

Natural capital: Earth's stock of organic and inorganic materials and energies (renewable and nonrenewable) and living biological systems (ecosystems) which constitute the biophysical context for the human economy and human wellbeing.

Net present benefits: The measure of the total benefits in today's dollars, including future benefits which have been annually discounted over a pre-determined period of time (e.g., project period).

Net present cost: The costs expressed in discounted present values. Future costs which have been annually discounted over a pre-determined period of time (e.g., project period).

Net present value: The measure of the total value in today's dollars, including future contributions which have been annually discounted over a pre-determined period of time (e.g., project period).

Non-market value: A value recognized by people but not usually expressed in prices because the valuable thing either is not currently, or cannot conceivably, be traded in markets.

Riparian areas: Habitat which is immediately adjacent to freshwater areas (e.g. marshes, forests, etc.).

Appendix A – BCA Limitations

BCA Limitations

The BCAs conducted for this report do not provide a complete estimation of all potential benefits arising from these actions. For example, the riparian restoration in Action F-01 may be associated with increased levels of recreation, which improves the health of the local population. This increase in health is not accounted for within the analysis. Similarly, Vehicle Miles Traveled (VMT) in Action G-12 are excluded, which could be expected to reduce local air pollution, greenhouse gas emissions and total commuting time. The change in ecosystem services brought about by Actions F-01 and G-12 may result in a change in consumer behavior. The increased density of downtown and urban centers will increase the number of businesses that can be supported within the areas and may encourage employers to move in and take advantage of an expanded market. These unquantified benefits were outside the scope of the report and would require a great deal more data and time to incorporate into the analysis in a quantitative manner.

Appendix B – Ecosystem Service Tables

Land cover acreages for each scenario were developed by Thurston Regional Planning Council. Methodology is described in Appendix F.

Table 4. Action F-01 Acreage and Value Change

Land Cover	Acres			Annual Value			
	Baseline Scenario	Restoration Scenario	Change	Low $/acre	High $/acre	Change (Low)	Change (High)
Developed							
Barren Land	2.2	0	-2.2	$0	$0	0	0
Developed, High Intensity	1.4	0.02	-1.3	$0	$0	0	0
Developed, Medium Intensity	11.0	0.06	-11	$0	$0	0	0
Developed, Low Intensity	78.2	0.2	-78	$0	$0	0	0
Developed, Open Space	45.2	2.0	-43	$0	$0	0	0
Shoreline	11.6	0	-12	$0	$0	0	0
Cultivated							
Field Crops	9.3	0	-9.3	$719	$1,959	($6,683)	($18,196)
Pastures	82	0	-82.1	$2,334	$2,345	($191,636)	($192,532)
Forest							
Deciduous	115	229	114.5	$2,787	$8,311	$318,961	$951,213
Evergreen	298	596	298.5	$2,644	$8,235	$789,166	$2,458,032
Mixed	132	264	132	$2,648	$8,172	$349,676	$1,079,263
Grasslands	84	0.10	-84	$4,972	$5,430	($418,848)	($457,461)
Shrublands	223	0.7	-222.1	$606	$1,153	($134,512)	($256,163)
Wetlands							
Forested/Woody	395	395	-0.05	$16,006	$19,847	($815)	($1,011)
Totals						**$705,308**	**$3,563,145**

Note: This analysis includes the value of both carbon storage and carbon sequestration (i.e., the additional carbon stored each year). Only the latter are reflected in Table 4. The change in carbon stock value from baseline to restoration ranges from a low of $2,261,000 to a high of $19,039,000.

Table 5. Action G-12 Acreage and Value Change

Land Cover	Acres			Annual Value			
	Baseline Scenario	Preferred Land Use Scenario	Change	Low $/acre	High $/acre	Change (Low)	Change (High)
Cultivated							
Field Crops	5,910	6,052	142	719	1,959	$101,944	$277,579
Pastures	34,272	35,517	1,245	2,334	2,345	$2,905,868	$2,919,454
Forest							
Deciduous	26,108	26,843	735	2,563	4,057	$1,883,871	$2,981,950
Evergreen	135,334	136,847	1,513	2,420	3,981	$3,662,480	$6,024,718
Mixed	46,553	47,518	965	2,424	3,918	$2,339,311	$3,781,395
Grasslands	35,946	36,519	574	1,052	1,454	$603,669	$834,505
Shrublands	67,190	68,191	1,001	543	551	$543,638	$551,596
Wetlands							
Forested/Woody	26,645	26,645	0	15,587	19,709	$0	$0
Grass/herbaceous	289	289	0	9,201	10,056	$0	$0
Totals	**378,247**	**384,422**	**6,175**			**$12,040,782**	**$17,371,197**

Note: This analysis includes the value of both carbon storage and carbon sequestration (i.e., the additional carbon stored each year). Only the latter are reflected in Table 5. The change in carbon stock value from baseline to restoration ranges from a low of $16,842,000 to a high of $111,149,000.

Appendix C – Ecosystem Services Benefit Transfer References

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Appendix D – Action G-12 Benefit, Avoided Cost of Service Provision

Shifting patterns of urban and suburban development affect regional resiliency in multiple ways, but perhaps the most immediately evident are changes to cost of providing public services to residents. This analysis looks specifically at these changes to county, town, and city government expenditures in Thurston County.

This analysis considers development expected to occur from 2017 to 2040, under two Sustainable Thurston project scenarios, the Baseline of "business as usual," and another known as Preferred Land Use, which seeks to incentivize targeted urban development and redevelopment. The associated service provisioning costs have been projected through 2065, for consistency with our earlier assessment of net present values over a 50 year planning horizon.

Different patterns of development (e.g., urban vs. rural) and dwelling types (e.g., single-family vs. multifamily), lead to varying costs for the provision of public services. For instance, the per-household cost to extend power lines to homes in urban areas is far less than for rural or suburban homes. To estimate these cost differences, this analysis draws from a report of development patterns in Halifax, Nova Scotia,[xv] using their estimates of the differential costs of providing public services to various dwelling types to estimate similar Thurston County, city, and town government expenditures.

Using the per-household cost of service for varying development patterns and rates of development, this analysis compares the baseline scenario to the preferred land use scenario. Calculations and sources are detailed below.

Dwelling types

After adapting the classification of dwelling types in the Halifax study to those in the Sustainable Thurston project, the following development patterns were provided by TRPC for the baseline year, 2016, as well as the two development scenarios.

Distribution of dwelling types, provided by TRPC (aggregated multiple categories from Sustainable Thurston Plan)

Dwelling Types	2016 Units	2040 Baseline Units	2040 Preferred Land Use Units
Pattern B	34,652	42,045	36,858
Pattern D	43,134	72,942	69,203
Pattern E	12,557	13,550	13,849
Pattern F	18,676	32,451	31,858
Pattern G	6,219	9,486	14,226
Total	115,238	170,475	165,994

Thurston County 2016 Cost of Service by Dwelling Type

2016 Thurston County/Town/City Public Service Expenditures[xvi] = $538,749,979

b = Cost of service provision per household, pattern B

Solve for b, then adjust other development patterns (D,E,F,G) according to Halifax Percent of Pattern B service cost

Cost = (b x number of B units)

+ ((b x (Halifax cost per unit Pattern D / Halifax cost per unit Pattern B)) x (number of D units))

+ ((b x (Halifax cost per unit Pattern E / Halifax cost per unit Pattern B)) x (number of E units))

+ ((b x (Halifax cost per unit Pattern F / Halifax cost per unit Pattern B)) x (number of F units))

+ ((b x (Halifax cost per unit Pattern G / Halifax cost per unit Pattern B)) x (number of G units))

$538,749,979= 34,652b + (b x ($3,088/$4,112) x 43,134) + (b x ($1,914/$4,112) x 12,557) + etc.

$538,749,979= 34,652b + 32350.5b + 5901.8b + etc.

$538,749,979= 84,917.03b

b = $6,344.43

Table 6. Projected Service Provision Costs per Household

Dwelling Types	Cost/Household (CAN 2004)	Percentage of Pattern B Service Cost	Thurston County Units 2016	Projected Thurston County Cost/Household (2016$)
Pattern B	$4,112.00		34,652	$6,344.43
Pattern D	$3,088.00	75%	43,134	$4,758.32
Pattern E	$1,914.00	47%	12,557	$2,981.88
Pattern F	$2,172.00	53%	18,676	$3,362.55
Pattern G	$1,413.00	34%	6,219	$2,157.11

Rate of Development

To calculate total service costs associated with development, the rate of development was assumed constant over the analysis period, 2017 to 2040. Year 2016 is excluded, assuming that the first additional units will be completed in 2017 and final units finished in 2040. This enables the calculating of annual costs of service provision, accounting for the increase in units over time.

Dwelling Types	Change in units 2040 Baseline	Change in units 2040 Preferred	Rate of Development Baseline (2017-2040) (Units/year)	Rate of Development Preferred (2017-2040) (Units/year)
Pattern B	7,393	2,206	308.04	91.92
Pattern D	29,808	26,069	1,242.00	1,086.21
Pattern E	993	1,292	41.38	53.83
Pattern F	13,775	13,182	573.96	549.25
Pattern G	3,267	8,007	136.13	333.63

Annual Service Provision Costs

Annual increase in cost of services is calculated based on the number of dwellings completed from the 2016 baseline. Additional dwellings of each type are multiplied by the respective annual service costs. From 2041 to 2065, no additional development is assumed, but annual service costs of dwellings built from 2017 to 2040 are continued through 2065. This allows for a 50-year net present value calculation for total service provision costs under each scenario. The difference in service provision cost, represents the savings by the county.

$$\begin{aligned} &Thurston\ County\ Savings \\ &\qquad = Total\ Baseline\ Service\ Provision\ Costs \\ &\qquad - Total\ Preferred\ Land\ Use\ Service\ Provision\ Costs = \$703{,}497{,}600 \end{aligned}$$

Appendix E – Action G-12 Cost, Impact Fees and Tax Exemption

Impact Fees

Subsidizing development and redevelopment in urban centers, urban corridors, and other residential centers results in a loss to city, county, and state revenue, through lowered fees and revenues. The dollar values in this analysis (2016$), were derived from a comparison of impacts fees for two Olympia development projects, one within the subsidized downtown zone, and one outside.

$$Transportation\ Impact\ Fee\ Per\ Unit, Non\ Subsidized = \$2{,}293$$

$$Parks\ Impact\ Fee\ Per\ Unit, Non\ Subsidized = \$3{,}196$$

$$Transportation\ Impact\ Fee\ Per\ Unit, Subsidized = \$0$$

$$Park\ Impact\ Fee\ Per\ Unit, Subsidized = \$2{,}614$$

Baseline Scenario

Number of New Multifamily Units in Targeted Development Zone = 3,267 units

Number of New Multifamily Units Outside of Targeted Development Zone = 13,775 units

$$\begin{aligned} &Baseline\ Revenue\ Per\ Unit \\ &\qquad = Transportation\ Impact\ Fee, non\ subsidized \\ &\qquad + Park\ Impact\ Fee, non\ subsidized = (\$2{,}293 + \$3{,}196) = \$5{,}489\ per\ unit \end{aligned}$$

$$Total\ Baseline\ Revenue = \$5{,}489\ per\ unit * 17{,}042\ units = \$93{,}543{,}538$$

Future Development Scenario

Number of New Multifamily Units in Targeted Development Zone = 8,007 units

Number of New Multifamily Units Outside of Targeted Development Zone = 13,182 units

$$\begin{aligned} &Future\ Development\ Revenue\ Per\ Unit\ in\ Targeted\ Development\ Zone \\ &\qquad = Transportation\ Impact\ Fee, subsidized + Park\ Impact\ Fee, subsidized \\ &\qquad = (\$0 + \$2{,}614) = \$2{,}641\ per\ unit \end{aligned}$$

$$\begin{aligned} &Future\ Development\ Revenue\ Per\ Unit\ Outside\ of\ Targeted\ Development\ Zone \\ &\qquad = Transportation\ Impact\ Fee, non\ subsidized \\ &\qquad + Park\ Impact\ Fee, non\ subsidized = (\$2{,}293 + \$3{,}196) = \$5{,}489\ per\ unit \end{aligned}$$

$$\begin{aligned} &Total\ Future\ Development\ Revenue \\ &\qquad = (\$2{,}614\ per\ unit * 8{,}007\ units) + (\$5{,}489\ per\ unit * 13{,}182\ units) \\ &\qquad = \$93{,}286{,}296 \end{aligned}$$

Difference Between Scenarios

$$Reduced\ Impact\ Fee\ Revenue = \$93{,}543{,}538 - \$93{,}286{,}296 = \$257{,}242$$

Tax Exemption

Tax exemptions for development and redevelopment projects in urban centers, corridors, and residential centers can be significant incentives for developers. This scenario applies the average annual tax exemptions from a downtown Lacey project completed in 2008,[xvii] and assumes a constant rate of development from 2017 to 2040. Tax holidays were applied to new multifamily dwellings in the urban corridor starting the year of the expected building completion and assumed to continue for 12 years. In other words, units completed in 2040 would be tax exempt until 2051.

$$Multifamily\ Tax\ Exemption\ Per\ Unit\ Per\ Year = \$1{,}161\ per\ unit\ per\ year$$

$$Number\ of\ New\ Multifamily\ Units\ in\ Targeted\ Development\ Zone = 8{,}007\ units$$

$$Number\ of\ New\ Multifamily\ Units\ Constructed\ Annually\ in\ Targeted\ Development\ Zone = 334$$

$$Total\ Annual\ Tax\ Exemption = (\$1{,}161\ per\ unit\ per\ year) * (334\ units) = \$387{,}415.36\ per\ year$$

$$Total\ Tax\ Exemption\ (2.875\%\ Discount\ Rate\ over\ 35\ year\ period) = \$70{,}583{,}995.42$$

Appendix F – Land Cover Estimates

Action F-01 (Restoration)

2011 NOAA C-CAP land cover within a 100-foot buffer of the Deschutes River was used for the Baseline Scenario under Action F-01.

Change in land cover was estimated using the riparian shade improvement targets identified in the Deschutes River TMDL.[xvii] Shade improvement targets represent the increase in percent canopy cover needed at each river kilometer to meet water quality standards. "Total Acres to Restore" was equal to the sum of the shade improvement times the area (including the 100-foot buffer) of each kilometer segment.

Acreage in ten "unrestored" land cover classes was reduced proportionally by "Total Acres to Restore". Land cover in three forest land cover classes was increased proportionally by the same amount. Land cover classes are listed in Table 7.

Table 7. Land Cover Classes Adjusted in Action F-01 Restoration Scenario

Land Cover Classes Decreased by Total Acres to Restore	Land Cover Classes Increased by Total Acres to Restore
• Barren Land • Cultivated (Crops) • Developed, High Intensity • Developed, Medium Intensity • Developed, Low Intensity • Developed, Open Space • Grassland/Herbaceous • Pasture/Hay • Scrub/Shrub • Shoreline	• Deciduous Forest • Evergreen Forest • Mixed Forest

Action G-12 (Infill)

Using TRPC's parcel-level population estimates for 2011 and 2011 NOAA C-CAP land cover, average land cover across ten residential density categories was calculated (Table 8).

Table 8. Percent Land Cover for Residential Density Groups

Dwelling Units / Acre	High Intensity Developed	Med. Intensity Developed	Low Intensity Developed	Developed Open space	All Other Land Covers
0 to 0.1	0%	1%	3%	4%	92%
0.1 to 0.2	0%	0%	5%	7%	88%
0.2 to 0.5	0%	1%	10%	11%	78%
0.5 to 1.0	1%	2%	23%	15%	59%
1 to 2	0%	5%	35%	15%	45%
2 to 5	0%	14%	55%	8%	22%
5 to 10	2%	39%	43%	6%	10%
10 to 20	5%	45%	36%	5%	9%
20 or More	12%	47%	27%	7%	7%

For the Baseline and Preferred Land Use scenarios, percent land cover in the four developed land cover classes was calculated by demining the maximum residential density of each parcel (based on zoning, critical areas, and existing uses) and multiplying the parcel area by the respective land cover percent in Table 8. The calculated developed land cover area was added to the 2011 land cover; non-developed covers were decreased proportionately.

In situations where there was already developed land covers on the parcel, it was assumed that developed land covers would not be converted to less intensive categories.

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[xvii] WA Department of Ecology, 2016. Deschutes River Watershed Area: Deschutes River, Percival Creek, and Budd Inlet Tributaries. Water Quality Improvement Project. Retrieved from: www.ecy.wa.gov/programs/wq/tmdl/deschutes/DeschutesTributariesTMDL.html

EARTH ECONOMICS

www.eartheconomics.org

EXHIBIT 2

CLIMATE ACTION COMMITTEE

OCTOBER 2020 • FINAL REPORT

COMMITTEE MEMBERS
Tim Ellis, Chair
Debbie King, Vice Chair
Mari Atkinson
Eliza Kirk
Nicholas Ness
Ann Swadener
Allison Woodbury
Council President Richard Emery
Councilmember Riaz Khan

The Committee thanks former Council President Christine Cook for her 2019 contributions

CITY OF
MUKILTEO

LETTER FROM MAYOR GREGERSON

To begin, we acknowledge that we are gathered on Indigenous Lands, the traditional territory of the Coast Salish People, specifically the Tulalip Tribes, successors in interest to the Snohomish, Snoqualmie, Skykomish, and other allied bands signatory to the 1855 Treaty to Point Elliott.

I am proud of the work of our Climate Action Committee, and grateful to the City Council for authorizing this intiative. This issue is a crisis that deserves focus, and the Committee members have given it their all.

The Climate Action Committee's purpose was to consider recommended clean energy goals, encourage residents to be part of the solution, encourage City staff, businesses, and residents to conserve current resources, work with the Council and City administration to implement ideas, and effectively address the future impacts of climate change.

The goals of this work aligned with many in our City's Comprehensive Plan: sustainability (through innovation and optimism), promoting a high quality of life (by protecting the natural environment), and creating a healthy community (by encouraging mobility through trails, biking, and recreation programs). Their work will inspire us to expand these efforts and take concrete actions.

This committee has worked for nearly a year and a half to develop recommendations for the City to help us reach net zero, or 100% renewable electricity. This final report provides a narrative with key data to help support the recommendations. I am extremely hopeful, and this plan is a great start to being able to create a lasting impact for our environment.

Thank you for your careful consideration of these recommendations, and a special thanks to the Climate Action Committee for the dedication and commitment to this work. They have dedicated long hours and energy to this effort. I commend them for their wise insights, educated perspectives, and dedication. I look forward to taking action to protect our environment.

Thank You,

Jennifer Gregerson, Mayor of Mukilteo

ACKNOWLEDGEMENTS

This report involved the effort of a volunteer Mukilteo Climate Action Committee, formed by Resolution Resolution 2019-02, passed May 6, 2019, and meeting since July 2019. A heartfelt thank you to all those who assisted in this process.

Mayor Jennifer Gregerson
Tim Ellis Chair
Debbie King, Vice Chair
Mari Atkinson
Eliza Kirk
Nicholas Ness
Ann Swadener
Allison Woodbury
Council President Richard Emery
Councilmember Riaz Khan
Staff Support: Lindsey Arrington

The Committee thanks former City Councilmember Christine Cook and former city staffer Nancy Passovoy for their contributions.

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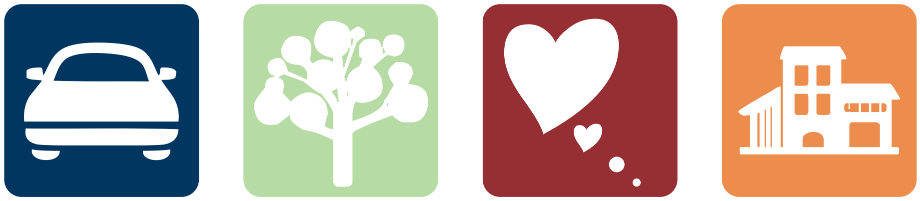


CLIMATE CHANGE AND MUKILTEO IMPACTS

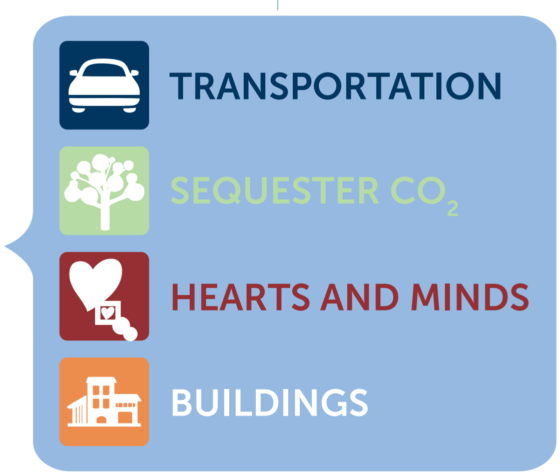
INTRODUCTION

Cities release more than 70% of energy-related CO_2 emissions worldwide, leaving an enormous carbon footprint, especially in coastal regions, which host 90% of the world's urban areas and are at high risk for climate change devastation.[1]

Two-thirds of the world's population will reside in urban areas by 2050,[2] putting additional stress on coastal communities due to unprecedented sea-level rise, coastal storms, and food shortages. Because coastal cities are at the highest risk of suffering the bulk of climate change impacts, they present the opportunity to identify and measure emission levels, develop strategies for emissions reduction, and set measurable reduction goals.[3]

Mayors, city councils, and community leaders are in a strong position to take the lead in combatting climate change because they understand local needs and resource constraints. They can put measures in place to track the performance of city services, guide change, and set appropriate regulations regarding land use, transportation, infrastructure, and building codes.

Climate change mitigation refers to actions that reduce and stabilize GHG emissions. The Mukilteo Climate Action Committee recommends actions that will reduce Mukilteo Greenhouse Gas (GHG) emissions to achieve a net-zero by 2040—net-zero being the balance between GHG emissions produced and emissions removed from the atmosphere. The committee identified four categories as having the most potential for attaining net-zero status: **Transportation**, **Sequester CO2**, **Hearts and Minds**, and **Buildings**.



COMMITTEE GOALS

According to Resolution 2019-02, the Climate Action Committee's goals are to:

- *Identify the benefits and costs of adopting policies and programs that promote the long-term goal of greenhouse gas emission reduction while maximizing economic and social benefits of such action.*
- *Provide input and independent analysis regarding the City's interest in making a clean energy commitment, as well as identifying a goal for renewable energy usage.*
- *Develop an action plan, including options, methods and financial resources needed and an associated timeline and milestones to achieve the renewable energy goals.*

1 Why Cities," C40 Cities, accessed September 26, 2020, https://www.c40.org/why_cities

2 "2018 Revision of World Urbanization Prospects," United Nations—Department of Economic and Social Affairs, May 16, 2018, https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

3 "Global Protocol for Community-Scale Greenhouse Gas Emission Inventories," NLC National League of Cities, March 08, 2017, https://www.nlc.org/resource/global-protocol-for-community-scale-greenhouse-gas-emission-inventories

CURRENT IMPACTS

According to the Northwest Chapter of Fourth National Climate Assessment, the warming climate is impacting the Pacific Northwest's natural resource economy, cultural heritage, built infrastructure, recreation, and the health and welfare of Northwest residents.[4]

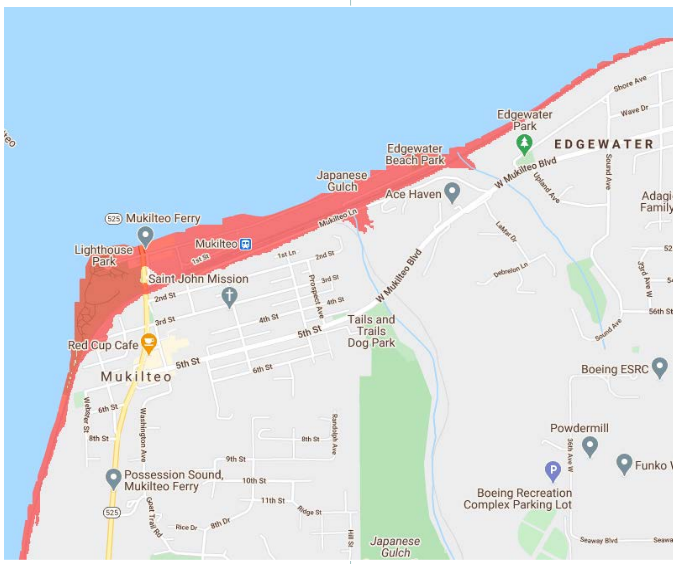


Figure 1: Land projected to be below 100-year flood level in 2100

For decades, the burning of fossil fuels has been releasing excess greenhouse gases into the atmosphere, including CO2 and methane, blanketing the earth in a cumulative layer of heat. Ninety-three percent of this heat is absorbed into the ocean, resulting in expanding water vapor and precipitation, more acidic waters, sea-level rise, and shifts in the marine ecosystem. Toxic algal or algae blooms and oxygen-depleted dead zones threaten our salmon and shellfish industries, especially Dungeness crab and krill, organisms vital to the marine food chain. Warming rivers and streams and the decreasing snowpack interfere with salmon spawning sites, leading to a loss of habitat and an inability to migrate.

Sea-level rise from melting glaciers and snowpack puts high-population coastal areas at risk from flooding, landslides, increased storm surges, and infrastructure damage. In 2003, a storm surge caused $3.5 million damage to Ivar's Restaurant, closing it for 471 days. A similar surge caused damage to Ivar's in 2012.[5]

Figure 1 estimates that sea-level rise plus a major flood event could flood the entire Mukilteo waterfront in 2100.[6]

Economic impacts such as the closing of fisheries due to algal blooms, losses in outdoor recreational revenue, depletion of the salmon and shellfish industry, and infrastructure damage from sea-level rise, increase risk of income loss, and food insecurity, particularly for low-income and minority coastal populations. In 2015, a harmful algal bloom extended from Alaska to California, closing shellfish fisheries for a prolonged period of time due to the high-level of neurotoxins in the water. An Advancing Earth and Space Science study links this algal bloom to warming, low-nutrient ocean waters.[7]

Escalating temperatures, pollution, and smoke from wildfires pose an increasing threat to both physical and mental health, including an increased risk of heart attacks, cancer, respiratory disease, and heat-related deaths. In 2020, wildfires raged through California, Oregon, and Eastern Washington, scorching nearly 4.8 million acres and killing 35. [8] A smothering, dense smoke layer settled up and down the west coast, obscuring the Seattle skyline and catapulting the air quality index to dangerous levels.

4 Fourth National Climate Assessment, Ch.24 Northwest, Volume II: Impacts, Risks, and Adaptation in the United States. https://nca2018.globalchange.gov/chapter/24/

5 Komo News, "'Geyser in the middle of the restaurant' shuts down Ivar's," 26 January 2012, https://komonews.com/archive/geyser-in-the-middle-of-the-restaurant-shuts-down-ivars

6 "Land Projected to be below 100-year flood level in 2100," Sea level rise and coastal flood risk maps—Climate Central, accessed September 28, 2020, https://coastal.climatecentral.org/

7 Ryan M. McCabe, Barbara M. Hickey et all, "An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions," Advancing Earth and Space Science, 20 Sep 2016, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL070023

8 "As wildfire smoke becomes a part of life on the West Coast, so do its health risks," The Washington Post, September 17, 2020, https://www. washingtonpost.com/nation/2020/09/16/smoke-air-west/

GREENHOUSE GASES

Greenhouse gases (GHGs) include carbon dioxide, methane, chlorofluorocarbons (CFSs), and nitrous oxide.

Methane (CH_4) is emitted during the production and transport of coal, natural gas, and oil, as well as from livestock, other agricultural practices, and the decay of organic waste in municipal solid waste landfills. While methane is one of the most potent GHG in trapping heat, it only stays in the atmosphere for a short time and accounts for only about 10% of GHG emissions. Yet, because of it's potency, methane has the power to raise sea-levels for centuries.[9]

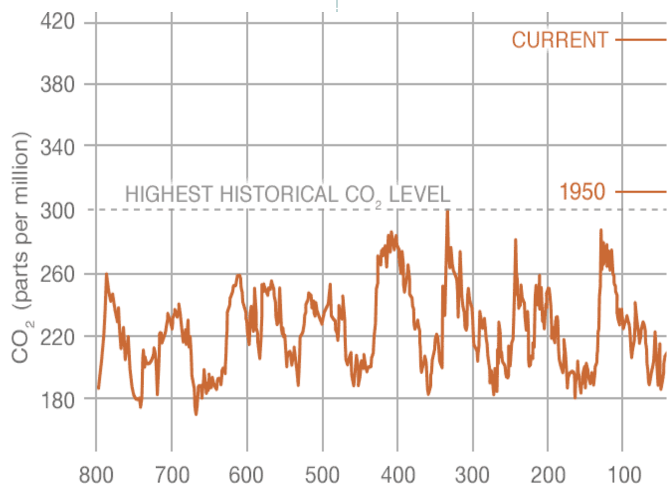


Figure 2: CO2 levels during the last three glacial cycles, as constructed from ice cores. (NOAA)

Carbon dioxide (CO_2) accounts for 81% of all GHGs released through human activities.[10] The burning of fossil fuels (coal, natural gas, and oil) releases CO_2 into the atmosphere. And while natural sources (solid waste, trees, and other biological material) also emit CO_2, human-related emissions are responsible for the harmful increase released into the atmosphere since the industrial revolution. CO_2 can stay in the atmosphere for 200 years or more. *Figure2* displays how CO_2 levels rose sharply around 1950 after several ice ages.[11]

Urban forests and plants absorb, or sequester, CO2 when absorbed by plants as part of the biological carbon cycle, removing it from the atmosphere.

Nitrous oxide (N2O) is emitted during agricultural and industrial activities, combustion of fossil fuels and solid waste, and during the treatment of wastewater.

Fluorinated GHGs—hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride—are synthetic, powerful greenhouse gases emitted from a variety of industrial processes. These gases are emitted in lesser quantities, though because they are potent GHGs, they are often referred to as High Global Warming Potential (High GWP) gases. Fluorinated gases are sometimes substituted for stratospheric ozone-depleting substances (chlorofluorocarbons (CFCs), hydrochlorofluorocarbons, halons).[12]

The Clean Energy Transformation Act (CETA) requires the transition to 100% non-GHG-emitting electricity resources by 2045 according to the following schedule:[13]

- Eliminate coal-fired electricity resources by December 2025.
- Attain GHG neutrality by January 2030.
- Transition to 100% non-GHG-emitting by January 2045.

9 Robinson Meyer, "Short-Lived' Methane Could Raise Sea Levels for Another 800 Years," The Atlantic, January 10, 2017, https://www.theatlantic.com/science/archive/2017/01/short-lived-methane-sea-levels-for-800-years-solomon/512588/

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12 "Overview of Greenhouse Gases," Greenhouse Gas Emissions, EPA, accessed October 13, 2020, https://www.epa.gov/ghgemissions/overview-greenhouse-gases

13 "Chapter 19.405 RCW: Washington Clean Energy Transformation Act," May 7, 2019, https://app.leg.wa.gov/RCW/default.aspx?cite=19.405&full=true#19.405.030

PROCESS

Following the submission of the Interim Report of the Mukilteo Climate Action Committee on December 9, 2019, the Committee was able to have two in-person meetings before COVID-19 control practices required that all meetings must be virtual.

Despite the COVID-19 restrictions, the Committee continued its full-team monthly-meeting pace, along with the addition of three-to-four member sub-team meetings to dig into more detail of what we wanted to include in this report.

In addition to a full outline of recommended climate actions, this report includes the following (click the title to access these sections of the report):

- **Prioritization Matrix**—identifies actions with the highest benefit vs. cost ratio.
- **Getting Started Plan**—for the Council to use when considering the 2021 budget.
- **GHG Emissions Dashboard**—for the City to track progress against the goal of net-zero GHG emissions by 2045 or sooner.
- **Cost Analysis**—specified actions amount to an estimated 0.5 FTE staff member—this matrix indicates that we could make good progress on these actions.

MITIGATION STRATEGIES

TRANSPORTATION

The world caught a glimpse of what a cleaner world would look like when GHG emissions dropped 17% during the early days of the coronavirus pandemic, due in part to a significant decrease in vehicular and air travel.[14]

Electric Vehicles (EVs) and charging stations garner the most attention when it comes to reducing GHG emissions. Yet the City can also support residents who wish to transition from single-vehicle transport by increasing access to public transportation and ride-sharing, bicycling and walking, and telecommuting.

The purchase of the Mukilteo Police Department's first all-electric police cruiser, a Tesla Model 3, in early 2020 sets a precedent for other city departments to replace aged gas- and diesel-powered vehicles with all-electric purchases. The City should also expedite the permitting process for installing residential charging stations and address barriers to installing chargers at garage-free homes and on rental properties.

The City should take advantage of online and print media and host community events to educate Mukilteo residents of the health benefits of moving to EVs and human-powered transportation. A city-wide transition to electric vehicles would reduce CO2 pollution, risk of oil spills and oil dependency, and health risks, including cancer and respiratory issues. Bicycling and walking can reap the benefits of reduced heart disease, obesity, and diabetes, and improved mental health.

Transition to Electric Vehicles (EVs) by 2040

Electric vehicles

- Introduce a policy to replace the city's fleet vehicles with electric options at the time of retirement, including police cruisers, fire engines, and work vehicles (trucks and vans).
- Support the continuing transition of Community Transit and Everett Transit fleets to electric vehicles.
- Work with local auto dealers to promote EV sales within the community.
- Encourage the Mukilteo School District to transition to electric school buses.

EV chargers plan

- Address options for increasing public access to EV charging stations:
    - Expedite the permitting process for installing residential charging stations.
    - Map optimal locations for chargers in commercial areas.
    - Address barriers to charging for garage-free homes and rental properties.
    - Consider integrating charging infrastructure into streetlights.
- Consider smart cable technology.
- Assess the potential to partner with third-party EV charging station providers to lower program and construction costs.

EV power storage

- Install battery storage by 2040 for EV chargers to provide vehicle-to-grid electricity from the grid.[15]

Decrease GHG Emissions from Fossil-Fuel-Powered Vehicles

No-idle zones

- Adopt a policy to limit vehicle idling; post signs at businesses and holding areas (e.g. school and ferry areas).
- Collaborate with regional partners to limit vehicle idling.
- Advocate for state and federal legislation to advance GHG reductions.

14 Le Quéré et al, Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement, Nature Climate Change, 10, 647–653 (May 19, 2020), https://doi.org/10.1038/s41558-020-0797-x

15 "Energy Storage for Transportation & Electric Vehicles (EVs): ESA," Energy Storage Association, https://energystorage.org/why-energy-storage/applications/transportation-storage/, accessed September 26, 2020

- Create a no-idle-zone toolkit for municipalities.

Shared vehicles

- Investigate regional congestion pricing, i.e. revenue created for projects and services to serve a variety of transportation modes/options.
- Explore parking management strategies:
  - Align cost of commuting by car vs transit options for sustainability goals.
  - Implement dynamic pricing.
  - Build vehicle-on-demand parking spaces.
- Promote carpooling/van-pooling and telecommuting for city employees.
- Establish car-sharing programs such as Zipcar and Car2Go.

Flexible work policies

- Educate and encourage local employers to reduce commute trips.
- Explore the options and benefits of compressed work weeks.
- Encourage businesses and organizations to continue promoting telecommuting beyond the coronavirus pandemic. Adopt a telecommuting policy for city employees.
- Allow for schedule adjustments and flex time.
- Share these program's case studies from the City's implementation of similar programs with local employers.
- Encourage home-based business opportunities.
- Update city land-use rules for home-based businesses.
- Install "smart" water meters to transmit water usage electronically.
- Shift to every-other-week garbage collection and weekly organic collection.

Enhanced support to human-powered transportation

Increased routes between commuting nodes

- Routes within Mukilteo
- Require developers to provide pedestrian connections between neighborhoods, schools, businesses, and work sites.
- Fill gaps in pedestrian and cycling routes between areas with high visitation volumes (e.g. Lighthouse Park, Mukilteo Speedway, Boeing, etc).
- Routes between Mukilteo and surrounding areas
- Examine pedestrian and bike routes in Mukilteo that could be connected to other inter-urban trails, sidewalks, or bike lanes.
  - Encourage transit agencies to install bike racks on transit vehicles to encourage partial bike commutes for those that work outside city limits.

Enhanced infrastructure and resources

- Bicycles
  - Invest in a bike-share program.
  - Increase the number of bike racks around the city, specifically at businesses, schools, and workplaces.
  - Add a municipal bike fleet for city employee use.
  - Provide incentives for businesses interested in investing in bikes for employees.
  - Create new bike paths, lanes, and trails where space is available by funding and implementing the Bike Transit Walk Plan.
  - Update current infrastructure by refurbishing cracked bike paths and repainting faded bike lanes.
- Pedestrian infrastructure
  - Refurbish existing sidewalks, paths, and crosswalks.
  - Create new sidewalks, paths, and crosswalks where they are needed by funding and implementing the Bike Transit Walk Plan.

Community engagement

- Partner with the Mukilteo School District to expand educational programs that promote walking and biking.
- Post maps of pedestrian and cycling routes in schools and other areas.
- Support a program that would organize and lead walks around Mukilteo.

Grow Public Transportation

Buses/shuttle services

- Incentivize public transit use
  - Promote benefits such as pre-tax transit passes.
  - Offer rebates to employees who give up the use of their employer's parking facilities.
  - Offer free intercity bus service
  - Add shuttle service connecting commercial and mobility hubs.

Car sharing/mobility options

- Establish a remote park-and-ride or ride-share program for the waterfront
- Work with third-party programs and businesses to increase the availability, accessibility, and convenience of other shared mobility options (e.g. bike share, scooter share, etc.)

Funding and development

- Fund continued improvement of local commercial and transportation hubs.
- Coordinate with Community Transit, Sound Transit, and WSDOT to increase transit ridership.
  - Pursue funding opportunities for transit service.
  - Improve convenience to encourage increased ridership.
- Encourage transit-oriented development standards and projects in the city's activity centers (old town, uptown).

Promote local goods and services to reduce long-distance transport

Food

- Identify property that could be used for community and home gardens.
- Promote the growth of fruits and vegetables in community and home gardens.
- Promote local farmers' markets and co-ops.
- Promote decreasing the amount of meat residents consume.
- Encourage those with private gardens to donate to local food banks.

Goods/materials recycling

- Support neighborhood events such as garage sales and community recycling.
- Collaborate with second-hand stores to promote textile collection and recycling.

Reduce air travel

- Communicate the impact of commercial air carbon emissions vs other travel options.

SEQUESTER CO_2

Planting and fostering urban forests on a global scale is one of the cleanest, most effective ways to mitigate climate change—trees have the highest capacity to capture and store atmospheric CO_2 due to their size, extensive root systems, and longevity.

During photosynthesis, trees and plants capture and store CO_2 from the atmosphere, a process known as carbon sequestration or carbon absorption. While all trees contribute to carbon sequestration, some tree species are more efficient than others in storing carbon within their woody biomass. Douglas firs, the most dominant species in the Pacific Northwest, can sequester nearly 14 tons of carbon in its first 100 years.[16]

To achieve optimal urban forest sequestration in Mukilteo, the Committee recommends planting trees and plants in city parks and parking lots that are the most drought-resistant and have a high absorption rate. An Adopt-a-tree program would encourage businesses and residents to cover the purchase cost, and planting and maintaining of tree seeds or saplings.

Rain gardens, planted with grass and flowering perennials, soak in rainwater runoff, filter out pollutants, and provide food and shelter for wildlife.[17]

Green roofs—roofs covered in vegetation and cool roofs—roofs designed to reflect sunlight— decrease surface and air temperatures and reduce energy demand.[18]

Enhance qualities of CO_2-sequestering trees

Tree planting

- Plant 100 trees per year. Work with the Snohomish Conservation District, Save Our Streams, and other organizations to obtain education and resources for tree types, seeds, and beneficial locations.
- Focus on planting other trees throughout Mukilteo neighborhoods by providing residents with free seeds and saplings.
- Implement an Adopt-a-Tree program that would encourage businesses and residents to cover the cost of purchase, planting, and maintenance of tree seeds or saplings.

Urban forests maintenance and expansion

- Assign City Public Work Crews to implement the proper planting/transplanting process of tree seeds and saplings and to maintain the City's urban forests with proper tree maintenance programs and protocols, including watering, pruning, and health checks.
- Tighten or create restrictions on tree removal by developers, or private businesses or residents.
- Purchase landmass that is currently occupied by trees/plants/forests as city land to protect from development.
- Require shade trees, drought-resistant plants, and rain gardens to be planted in public and private commercial parking lots.

Expand carbon sequestration in city parks

Identify city parks where carbon sequestration could be increased

- Plant species of trees and plants in city parks that are the most carbon-absorbing.
- Advise urban land managers to avoid trees that require a lot of maintenance—the burning of fossil fuels to power equipment like trucks and chainsaws only erases the carbon absorption gains otherwise made.

Continue to plan and develop a system of parks, open spaces, and trails throughout Mukilteo

- Create at least one new park, rain garden, or protected wetland per year.
- Create more usable green space in Mukilteo's activity centers, such as Harbour Pointe shopping center, Rosehill Community Center, Mukilteo Lighthouse Park, ferry, and train station.
- Apply for protected land status for any unprotected green spaces.

Establish green roofs throughout Mukilteo

- Install green roofs on all municipal buildings.
- Partner with Community Transit to plant green roofs on city bus stops.

16 "Evergreen Carbon Capture: Planting Trees & Carbon Sequestration" Forterra, December 19, 2016, https://forterra.org/subpage/ecc-carbon-science

17 "Soak Up the Rain: Rain Gardens," Environmental Protection Agency, July 09, 2020, https://www.epa.gov/soakuptherain/soak-rain-rain-gardens

18 "Using Green Roofs to Reduce Heat Islands," Environmental Protection Agency, June 11, 2019, https://www.epa.gov/heatislands/using-green-roofs-reduce-heat-islands

HEARTS AND MINDS

One of the most powerful yet least expensive ways to mitigate climate change is to inspire Mukilteo residents to become more aware of how they can personally take responsibility for reducing their carbon footprint. Providing education, resources, and enjoyable activities serve as a strategic yet straightforward means to this end.

Before the City can implement the actions needed to change the hearts and minds of its residents, it must establish a process and designate a staff person to implement actions, track the progress, and providing accountability for achieving the goals of the CAP. (See Intra and Inter-Government Actions to Reduce GHGs and Metrics chart in this document.)

The Committee has specified educational activities and resources that the City can use to encourage and excite residents to learn ways to care for the planet. Recycling, composting, planting vegetables, and removing food waste are a few of the most self-sufficient and easy ways to get a head start on reducing a resident's carbon footprint. A number of these recommendations are listed in the **Getting Started** actions because they are a low-cost way to achieve sizable results within a short period of time.

Resources and educational programs

Resources

- Promote Mukilteo Climate Action Committee Plan and the City website.
- Submit articles on sustainability and net-zero emissions to the Mukilteo Beacon, Mukilteo Tribune and other local publications.
- Support community organizations and events such as volunteer cleanup crews. Encourage community ownership.
- Erect "Sea Level Circa 2100" sign at the Mukilteo waterfront.

Educational programs

- Host open houses, public hearings, and presentations.
- Host booths at Lighthouse Festival and Farmers Market.
- Create an online presence on social media—Facebook, Twitter, Instagram, and setting up a YouTube channel.

Business and residential programs

- Host community events and prioritize actions to encourage local change. Encourage community "ownership."
- Encourage the Reduce/Reuse/Refuse mindset.
  - Reduce - Simply reduce your purchasing by being mindful about you need and want.
  - Reuse - Decide to reuse or repair something before tossing and buying new. Sell or donate items. Use the library to learn how to repair items.
  - Refuse - Eliminate waste by saying no to single-use materials and look into reusable alternatives.
- Encourage residents to transition to EVs.
- Encourage composting and use of clotheslines
- Encourage residents to plant trees.
- Implement city-wide recycling programs.

Take intra- and inter-governmental actions to reduce GHGs

Intra-governmental actions

- Designate a staff person to advance efforts and provide accountability and coordination between community and city efforts.
- Create a management and reporting system to monitor activities related to CAP goals, including the progress of actions that have been initiated, implementation schedule, and community and municipal GHG emissions.
- Educate all city staff members about the CAP.
- Consider initiatives that modify behavioral patterns to increase energy efficiency in municipal operations.
- Evaluate the differential impact of climate change on neighborhoods and communities.
- Develop and incorporate equity metrics into the evaluation of CAP activities.

- Prepare an annual report for the city's Planning Commission and City Council to assess the implementation of the CAP.

Inter-governmental actions

- Provide a leadership role with other local government agencies and businesses to share best practices and successes, such as Mukilteo's Green Business Certification Program.
- Work with local and regional partners to conduct a public education and outreach campaign promoting local tool-lending libraries, car share, swap events, and service and sustainability websites and Facebook groups (e.g. Buy Nothing).[19]

Modify and implement programs in support of reducing GHGs

Commercial and community programs

- Establish policies that require and assist schools, businesses, and restaurants in recycling, composting, and reducing waste, including food waste.[20]
- Educate and guide residents in implementing composting and water savings.
- Support "collaborative consumption" community projects such as tool-lending libraries and repair cafes.
- Expand and encourage community gardens, urban agriculture, community-supported agriculture, and farmers' markets.

City programs

- Educate city employees on climate-protection and develop internal programs regarding environmental issues.
- Ban polystyrene.
- Develop a city-wide Environmentally Preferable Purchasing Policy (EPP). Consider life-cycle costing as one of the decision-making tools in this process.
- Evaluate and align future development applications and the city's Capital Improvement Program with this Climate Action Plan.

19 "Snohomish County Reusable Materials Exchange," 2Good2Toss, accessed September 26, 2020, https://2good2toss.com/

20 "Carbon Footprint of Global Food Wastage," Food and Agriculture Organization of the United Nations, accessed September 26, 2020, http://www.fao.org/3/a-bb144e.pdf

BUILDINGS

An estimated 230 billion meters of new construction is expected to be built over the next 40 years worldwide.[21] Given that buildings produce 40% of energy-related carbon emissions,[22] generating and procuring 100% clean, renewable energy is imperative to offset rising energy demands by 2040 and meet the standards set by the Paris Agreement.[23]

Washington's Clean Energy Transformation Act (CETA) stipulates that electric utilities must be greenhouse gas neutral by January 1, 2030, and supplied by 100% renewable electricity by 2045.[24]

To support CETA requirements, the Committee recommends that Mukilteo reduce building GHG net emissions to zero by 2040 by applying the following standards, incentives, and certifications to both new construction and existing facilities. This should start with de-incentivizing the use of natural gas for all structures.

Establish incentives and certifications to leverage building conversions to net-zero emissions

Incentives

- Provide direct monetary rebates, aggregation purchases, or property tax abatements for energy efficiency improvements.
- Eliminate permitting fees and streamline zoning and inspection costs for businesses and residents to upgrade to solar.[25]

21 "Global Status Report 2017 - World Green Building Council," UN Environment, accessed September 26, 2020, https://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf

22 "Why the Building Sector?," Architecture 2030, accessed September 26, https://architecture2030.org/buildings_problem_why/

23 Global Status Report 2017 - World Green Building Council," UN Environment, accessed September 26, 2020, https://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf

24 "Chapter 19.405 RCW: Washington Clean Energy Transformation Act," May 7, 2019, https://app.leg.wa.gov/RCW/default.aspx?cite=19.405&full=true#19.405.030

25 "Pathways to 100—An Energy Supply Transformation Primer for U.S. Cities," Cadmus Group (formerly Meister Consultants Group), accessed September 2020, https://cadmusgroup.com/papers-reports/pathways-to-100-an-energy-supply-transformation-primer-for-u-s-cities/

- Create a city financial assistance program to aid homeowners in improving home energy efficiency, such as local financial incentives for on-site renewable energy upgrades (e.g. solar rebates, tax credits, zero-interest loans).[26]
- Partner regionally and with the state government to revise building codes to de-incentivize natural gas for heating.
- Incentivize infill and mixed-use development through alternative code compliance, fee waivers, density bonuses, investment prioritization, development impact fees, or tax benefits.
- Evaluate the effectiveness of regulations and provide incentives for Accessory Dwelling Units.
- Create an oil-heated home conversion program that provides incentives for homeowners to replace oil heating systems with electric heat pumps.
- Encourage voluntary electrification of natural gas appliances through actions such as pilot programs, process streamlining, fee reduction, and contractor/ supplier engagement.

Certifications

- Require that commercial and residential buildings meet LEED standards at the time of sale or rental, and offer financial incentives for meeting said standards.

Establish net-zero emissions building standards

- Study benefits and economic tradeoffs of regulations that require all-electric buildings.
- De-incentivize natural gas for new construction and major renovations/redevelopment.
- Work with regional energy partnerships to develop and implement an Electrification Action Plan for all city facilities.
- Change city building codes.
    - Allow for passive heat and cooling.
    - Require solar panels on new or remodeled structures.
    - Address home orientation, roof overhang, use of trees for shade.
- Require all new buildings be designed according to a certified sustainability assessment method such as LEED[27], or BREEAM[28], to include green roofs, cool roofs, and additional landscaping that is tolerant to a range of climate conditions.
- Encourage the use of green roofs, green walls, cool roofs, cool pavements, and additional landscaping that are tolerant of a range of climate conditions.
- Work with disposal companies to implement residential and commercial composting.
- Require that an independent Residential Energy Services Network rate newly built or substantially reconstructed dwellings.
- Require that demolition contractors fully deconstruct houses or duplexes so that materials can be salvaged or reused.
- Work with community partners to offer training and certification on deconstruction.

Support upgrades that reduce/eliminate building GHG emissions and reduce the City's dependence on hydroelectric and nuclear power.

- Install energy-efficient and energy-reducing upgrades in all city buildings such as occupancy-driven HVAC controls, on-demand water heaters, improved insulation, light sensors, and programmable thermostats.
- Install solar systems on all city buildings, including Rosehill Community Center, the Public Works shop, Police and Fire Stations.

26 Ibid

27 "Leadership in Energy and Environmental Design," LEED, accessed September 26, 2020, http://leed.usgbc.org/leed.html

28 "What is BREEAM?," BREEAM®, October 07, 2019, https://www.breeam.com

PRIORITIZATION MATRIX

Climate Action Plan Prioritization Matrix identifies actions with higher impact in reducing GHG emissions and lower implementation costs vs. those with less impact on GHGs and higher costs. The Committee used this matrix to determine areas of initial focus. See the **Getting Started Plan.**

MCAC CAP Priority Matrix

Implementation (Cost/feasibility)	Higher	Middle	Lower
Less	• Inform residents of resources and programs for changes toward zero emissions • Enhance quantities of trees	• No idle zones • Modify and implement GHG reduction programs • Building incentives/ certifications	• Shared Vehicles • Promote local goods/ services
Medium	• EVs by 2040	• EV Chargers plan • Flexible work policies • Grow public transportation • Intra- and Inter-government actions to reduce GHGs	• Enhance support to human-powered transportation • Expand carbon sequestration in city parks
More	• Enhance support to human-powered transportation • Net zero building standards • Upgrade buildings		• EV power storage • Reduce air travel • Green roofs

Figure 3: CAP Prioritization Matrix

GETTING STARTED PLAN

2021 ACTIONS

The Mukilteo Climate Action Committee recommends the City take the following actions beginning in 2021.

City Operations

- Implement the following processes to monitor and track the progress of the Climate Action Plan (CAP):
- Designate a staff person as Climate Coordinator to advance efforts, and provide accountability and coordination between community and city efforts.
    - Create a management and reporting system to monitor activities related to CAP goals, including the progress of actions that have been initiated, implementation schedule, and community and municipal GHG emissions.
    - Educate all city employees about the CAP and develop internal programs regarding environmental issues.
    - Develop and incorporate equity metrics into the evaluation of CAP activities.
    - Prepare an annual report for the City's Planning Commission and City Council to assess the implementation of the CAP.
- Adopt a city telecommuting policy and procedure for employees.

City Policies

- Introduce a policy to replace the City's fleet vehicles with electric options when a vehicle is ready to be retired.
- Adopt and implement a policy to limit vehicle idling. Post signs at businesses and holding areas (e.g. school and ferry areas).

Development and Buildings

- Address options for increasing public access to chargers, including expediting the permitting process for private installation of EV charging stations and mapping optimal locations for chargers in commercial areas.
- Require developers, businesses, and/or residents take measures to lower the City's carbon footprint:
    - Plant shade trees, drought-resistant plants, and rain gardens in commercial parking lots.
    - Tighten or create restrictions on tree removal by developers, private businesses, and residents.
    - Encourage the use of green roofs, green walls, cool roofs, cool pavements, and additional landscaping tolerant of a range of climate conditions.
- Encourage voluntary electrification of natural gas appliances through actions such as pilot programs, process streamlining, fee reduction, and contractor/supplier engagement.
- Begin developing a program requiring commercial and residential buildings to meet LEED standards at the time of sale or rental. Offer financial incentives for meeting said standards.

Regional Coordination

- Support the continuing transition of Community Transit and Everett Transit fleets to electric vehicles.
- Work with local auto dealers to promote EV sales within the community.
- Work with the Mukilteo School District to transition to electric buses.
- Adopt a leadership role with other local government agencies and businesses to share best practices and successes, such as the City's Green Business Certification Program.

City Infrastructure

- Plant 100 trees per year throughout the City, including City parks, according to those that are most carbon-absorbing. Work with the Snohomish Conservation District, Save Our Streams, and other organizations to obtain education and resources for tree types, seeds, and beneficial locations.
- Assign City Public Work Crews to follow through with the proper planting/transplanting process of tree seeds and saplings and to maintain the City's urban forests with proper tree maintenance programs and protocols, including watering, pruning, and health checks.
- Advise urban land managers to avoid trees that require a lot of maintenance—the burning of fossil fuels to power equipment like trucks and chainsaws only erases the carbon absorption gains otherwise made.
- Focus on planting other trees throughout Mukilteo neighborhoods by providing residents with free seeds/saplings. Implement an Adopt-a-Tree campaign for both residents and businesses.
- Work with regional energy partnerships to develop and implement an Electrification Action Plan for all city facilities. In new and existing buildings, incorporate strategies to address electricity storage, and focus on highlighting any hurdles or solutions that would apply t0 the broader community.

Communications

- Create an online presence by posting the CAP on the City's website, developing a social media strategy (Facebook, Twitter, Instagram), and setting up a YouTube channel.
- Submit articles on sustainability and net-zero emissions to the Mukilteo Beacon, Mukilteo Tribune, and other local publications.
- Support community organizations and events such as volunteer cleanup crews. Encourage community ownership.
- Initiate community events, such as open houses, public hearings, and presentations to educate the public and prioritize actions encouraging local change. Host booths at the Lighthouse Festival and Farmers Market.
- Encourage the Reduce/Reuse/Refuse mindset, including recycling, composting, using compostable dishes and utensils, and drying clothes on clotheslines.
- Erect a "Sea Level Circa 2100" sign at the beach (above the mean high-tide mark).
- Encourage residents to start or participate in Climate Action Family Groups such as Climate Action Families. Encourage businesses and residents to take a global climate pledge.
- Work with Waste Management to implement city-wide recycling programs.
- Encourage businesses and organizations to continue promoting telecommuting beyond the coronavirus pandemic.

GHG EMISSIONS DASHBOARD

The Committee recommends using the following measurable indicators for tracking the City's progress toward achieving net-zero **Greenhouse Gases** by 2045 or sooner.

Table 1: Goal: Zero/Net-Zero Greenhouse Gas Emissions by 2045

Emission Element	Measurable	2045 Goal	Notes
Gasoline/diesel	Internal combustion vehicle count	0	Could have separate goals for city, residents and businesses.
Gasoline/diesel	Gas/diesel sold annually	0	Subtract Biodiesel (a clean burning renewable fuel made using natural vegetable oils and fats)
Natural Gas	Quantity of gas utilized annually	0	100 clean electricity

Note: This table only measures CO_2 indicators as CO_2 is the most prevalent GHG in the atmosphere and the most reliable.

Table 2: Elements of the MCAC Net Zero Outline

Outline Element	Measurable	2045 Goal
Electric vehicles by 2040	Ratio of e-vehicles to internal combustion vehicles	Infinity
EV charger plan	Ratio of EV chargers to Gas/ diesel pumps	Infinity
Sequester CO2 through flora	Annual new tree count	2500 trees by 2045

COST ANALYSIS

The costs of implementing a Climate Action Plan may seem daunting and insurmountable if viewed from a 100% perspective within a short time. A goal that requires the City's entire motor pool be replaced with EVs in one year would come with a big price tag. However, a plan to replace the motor pool with EVs over the next twenty years could fit within the City's budget and planning cycles. The Mukilteo Climate Action Committee has developed a **Getting Started Plan** for easily attainable goals that would have the greatest impact for the lowest cost in 2021.

Table 3. Climate Action Plan Costs

Element	Costs	Notes
Electric Vehicles by 2040	Costs comparable to Internal combustion engine vehicles with maintenance. Equivalent to no additional costs. Consider bio-diesel.	Transition to all EVs by 2040
EV charger plan	$10-25k/(public/city) (220v) $500-2k/unit resident (220v)	Develop EV charger plan
Resources and educational programs for local changes toward achieving a goal of zero emissions	Staff time/materials—0.3 FTE*	Inform residents of resources and educational programs for local changes toward achieving a goal of zero emissions.
Sequester CO2 through flora	$30-50/tree + installation	Sequester CO2 through flora
No idle zones	Signs and installation	Establish no-idle zones
Programs supporting GHG reduction	0.05 FTE	Modify and implement programs that support GHG reduction
Establish incentives and certifications to leverage building conversions to zero emissions	0.05 FTE	Establish incentives and certifications to leverage building conversions to zero emissions
Grow public transportation	0.05 FTE	Grow public transportation
Take intra- and inter-governmental actions to reduce GHGs	0.05 FTE	Take intra- and inter-governmental actions to reduce GHGs
Flexible work policies	State COVID-19 response covers this	Flexible work policies

*FTE: Full-time equivalent of staff time. Proposal would result in a total of one half-time FTE.

CONCLUSION

Climate change impacts the planet and all who reside here more with each passing year. Many climate disasters already surpass their predecessors in terms of magnitude and impact—the 2020 wildfires on the west coast being a prime example. We must respond to climate change with the same urgency as we did with the 2020 coronavirus pandemic. If we do not invest in sustainable solutions now, the cost and damage to our planet and future generations will be irreversible.

Following the model and actions of the Mukilteo Climate Action Committee will help things move forward quickly. The City will be an example for its residents and businesses, other cities through Snohomish County, and for Washington State in securing a greener, more sustainable future for generations to come.

Being part of this Committee has been eye-opening. Weve learned a lotbut have much more to learn. It's been an honor to pull this information together, and we hope that it will prove useful in making substantial, lasting changes to decrease our greenhouse gas emissions and achieve a net-zero status by 2045 or sooner.

—Tim Ellis, Debbie King, Mari Atkinson, Eliza Kirk, Nicholas Ness, Ann Swadener, Allison Woodbury, Richard Emery, Riaz Khan, Christine Cook

The Climate Action Committee would like to thank Mayor Jennifer Gregerson, Lindsey Arrington, and Nancy Passovoy for their invaluable help and support in preparing this Climate Action Plan.

LAND USE & ECONOMIC DEVELOPMENT COMMITTEE AGENDA REPORT	
SUBJECT TITLE: Development Projects	**FOR AGENDA OF:** June 1, 2021
Contact Staff: David Osaki, Community Development Director	**EXHIBITS:** 1. Location Map - Mundorf critical areas fill and off-site mitigation
Department Director: David Osaki	

BACKGROUND
At its May 4, 2021 meeting, the Land Use & Economic Development (LU&ED) Committee expressed interest in knowing more about development activity taking place in the City.

Below is a list of certain development projects in the City. Certain projects are "In permitting"; others "Under construction". Either is noted for the project.

In this instance "In permitting" means that a permit application has been made to the City and that the application is being reviewed by staff to ensure that the development proposal adheres to applicable codes and requirements. The applicant may still need to make site, design and other clarifications, corrections and revisions in the form of a resubmittal.

The list below is not comprehensive, but is illustrative of the range of projects taking place right now.

More information about each of these and other projects, including submittal materials, is available to the public on line at: Land Use Action Notices

DEVELOPMENT PROJECTS

1. **SALINAS CONSTRUCTION CONTRACTOR LAYDOWN YARD (In Construction)**
   Location: 4007 78th St SW

   Description: Approximately 4.5-acre paved construction yard with associated grading, parking, landscaping and street frontage improvements. Japanese Gulch Creek runs along the northeast portion of the property but is not impacted by the proposed development. The contractor laydown yard will be used to facilitate the operations of Salinas' concrete paving company.

2. **FRONT PORCH COTTAGES (In Permitting)**
   Location: 7902 44th Ave W

   Description: Proposed 14-unit cottage housing development through a Planned Residential Development (PRD). The property is located in the RD 9.6 Single-Family Residential Zone. Applicant seeks land use permit approval for a conditional use permit.

3. **<u>MUKILTEO STORMWATER DECANT FACILITY</u> (In Construction)**
<u>Location:</u> 4206 78th Street SW

<u>Description:</u> Construct a new 5,560 square foot decant station and solids storage area at the City of Mukilteo Public Works Shop. Construct a new decant settling vault which will be sized to store one day's worth of material cleaned from City catch basins and sediment ponds. This material will settle overnight and will be drained each morning to the City's sanitary sewer system.

The proposal includes the construction of a roofing system to prevent stormwater runoff from becoming contaminated before it enters the on-site stormwater collection system. This proposed roofing system over the above-ground storage areas and the settling vault will also remove a significant amount of pollutants from downstream waterways.

4. **<u>MUKILTEO WAREHOUSE BY NELSON 43, LLC</u> (In Permitting)**
<u>Location:</u> 4301 78th St SW

<u>Description:</u> Construct a new, 55,820 square foot light manufacturing/warehouse facility with associated grading (approx. 13,950 cubic yards cut; approx. 17,200 cubic yards fill), parking, landscaping, right-of-way dedication and street frontage improvements.

The applicant proposes access to the facility off 78th Street SW and anticipates traffic volumes will distribute between 78th Street SW and 44th Avenue W. Finished grade of the site will be flat with the parking lot approximately 12 feet below the roadway grade at the intersection of 78th Street SW and 44th Ave W.

5. **<u>MUKILTEO PLAZA</u> (In Permitting)**
<u>Location:</u> 823 2nd Street

<u>Description:</u> Four-story, commercial mixed-use building that includes 1,475 square feet of ground floor commercial space with 14, two-bedroom dwelling units located on the three floors above. The subject property is located within the DB (Downtown Business) zoning district.

6. **<u>BEC INVESTMENTS LLC AUTOMOBILE SALES AND REPAIR</u> (In Permitting)**
<u>Location:</u> 12900 Beverly Park Road

<u>Description:</u> Construct a new car sales building with a detached car detail and repair building totaling 4,780 square feet with associated grading and street frontage improvements. The parcel is approximately 37,105 square feet in size (0.89 acres) with a Category III wetland and Type V stream located in the northern portion of the property which extends off-site to the north and west.

7. **<u>MUNDORF CRITICAL AREAS FILL AND OFF-SITE MITIGATION</u> (In Permitting)**
<u>Location:</u> Approximately 800 block of 8th St

<u>Description:</u> Fill/remove an existing, on-site 3,432 square foot Category IV wetland in the 800 block of 8th Street to allow for the future construction of a single-family residence and mitigate the wetland fill/removal by creating an off-site wetland in Japanese Gulch using the City of Mukilteo's Critical Area Mitigation Program (CAMP). **(See Exhibit 1)**

In 2017, the applicant was granted authorization by the Mukilteo City Council to move forward with permitting to fill the on-site wetland and mitigate by creating an off-site wetland in a high-value watershed identified in the City of Mukilteo's Critical Area Mitigation Program (CAMP). The applicant has since received approval from the U.S. Army Corps of Engineers to fill/remove the existing wetland.

The new off-site wetland will be located in Japanese Gulch, within the City of Everett. This work includes the creation of 5,162 square feet of wetland and enhancement of 6,649 square feet of existing wetland buffer.

8. **<u>BASEL HARBOUR POINTE TOWNHOMES DEVELOPMENT AGREEMENT AMENDMENT</u> (In Permitting)**
<u>Location:</u> 9900 Harbour Place

<u>Description:</u> Amend the existing Development Agreement and Binding Site Plan for Sector 3 Plan to change the allowed use for what is commonly known as Lot 4A (3.36 acres) from commercial to residential. If approved, this proposal would:

- Change the allowed use from commercial to residential development;
- Allow the development of 32 townhouse-style condos in four buildings with a community park; and
- Add a second entrance off Harbour Place as the primary access for the development.

Access to the site currently is available from a private, joint use roadway shared with the private pre-school (Harbour Pointe Montessori School). However, a proposed second driveway on Harbour Place would result in primary access private road for the proposed townhouse project.

9. **<u>PROGRANITE CULVERT REPLACEMENT AND STORMWATER IMPROVEMENTS</u> (In Construction)**
<u>Location:</u> 12303, 12313, and 12230 Cyrus Way

<u>Description:</u> Replace, upgrade, and straighten the existing piped stream system on 12303, 12313 and 12230 Cyrus Way to allow for better operation and maintenance and to minimize known flooding problems directly west of the site.

10. **<u>ELECTROIMPACT DEVELOPMENT AGREEMENT AMENDMENT</u> (In Permitting)**
<u>Location:</u> 4413 Chennault Beach Road

<u>Description:</u> Proposal by ElectroImpact to amend their existing Development Agreement with the following changes:

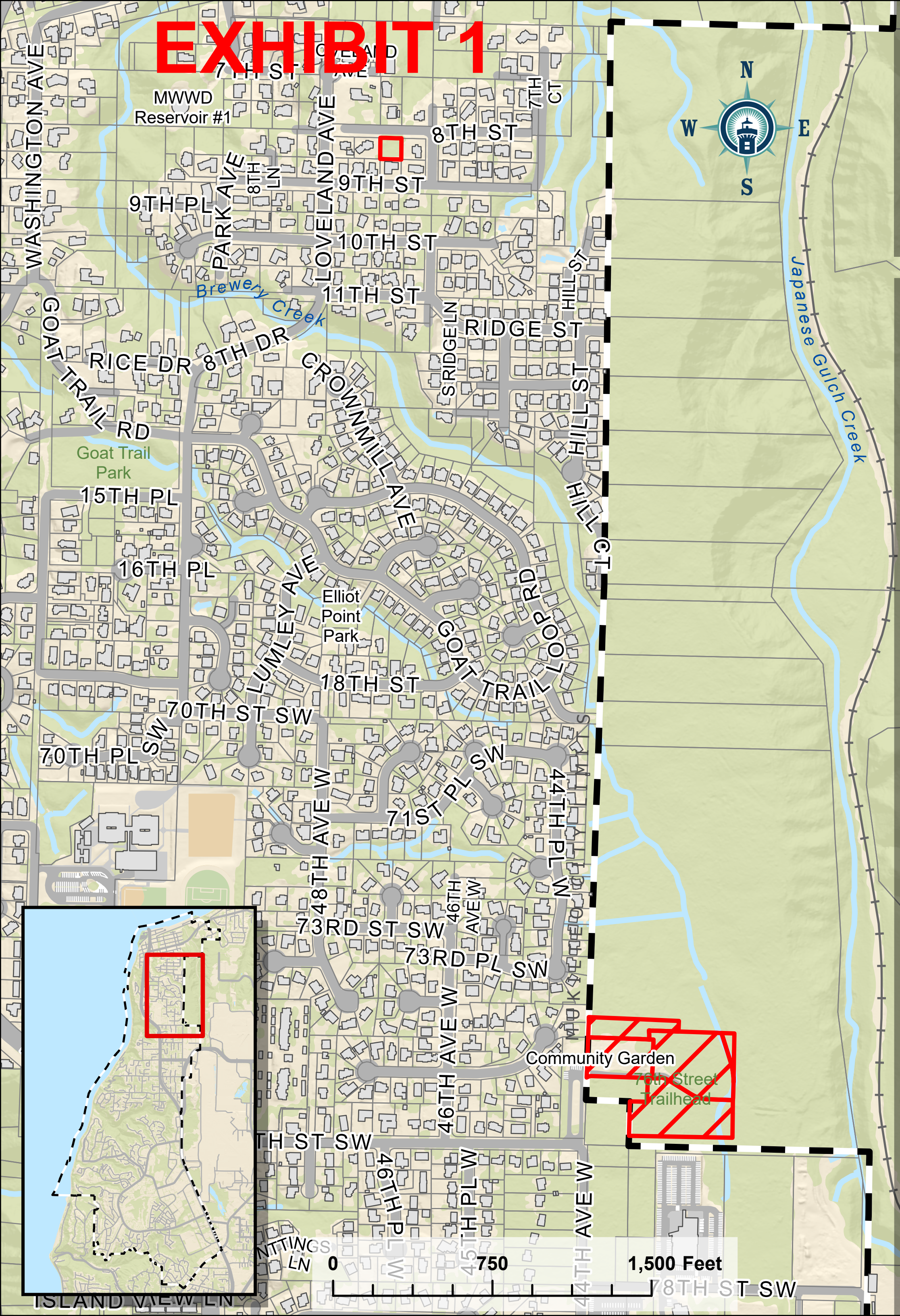
- Add Satellite Campus #5, which includes lots 30, 31, 32 and 33 of the Harbour Pointe Business Park located at 11215 47th Ave W,
- Revise the Main Campus to remove the existing Building D and add a new 29,700 square foot Building D located at 4517 Chennault Beach Road, and
- Add Building K, which is 22,000 square feet, to Satellite Campus #2 located at 4708 Chennault Beach Road.

11. **<u>LOSVAR CONDOMINIUMS EXTERIOR RENOVATION</u> (In Construction)**
610 Front Street

<u>Description:</u> Exterior renovations of their existing condominium building including:

- Exterior painting
- New code compliant guardrails and decorative metal trim elements to the windows and the roofline at the front and sides of the building (south, east and west façades)
- New wood cladding for the parking garage door on the front side of the building (south façade)
- Installation of new fencing for the front utilities (utilities boxes and meters on the south side of the building), pool and boat storage areas for better security and aesthetics (north side of the building); and
- New glass railings for the existing pool wall (north side) and private condominium unit decks to promote views (all façades).

There is no increase in the height of the building, expansion of the existing building footprint, or any in-water work.



CITY OF MUKILTEO

Mundorf Critical Area Review for Wetland Mitigation