Washington State Enhanced Hazard Mitigation Plan

2023

Approved by FEMA Region 10: October 1, 2023

About this Plan

The Washington State Enhanced Hazard Mitigation Plan (SEHMP) profiles hazards, identifies risks and vulnerabilities, and proposes strategies and actions to reduce risks to our communities and critical assets. The primary purpose of this plan is to provide the State a mechanism for mitigating vulnerabilities to hazards of all kinds by chronicling and compiling the extensive work done to analyze hazard dynamics and exposure, the likelihood of future hazard events, and our capabilities to mitigate and adapt to hazardous conditions. In essence, the SEHMP is a science-based data-driven plan to help Washingtonians understand their vulnerability to natural and human-caused hazards and more effectively mitigate those vulnerabilities through strategic projects and programs.

The Washington SEHMP is a statewide document produced by the Washington Emergency Management Division (EMD) with close partnership with the Departments of Ecology (ECY), Natural Resources (DNR), Health (DOH), Transportation (WSDOT), Commerce (COM), University of Washington (UW), and many others. A full list of planning partners can be found in Chapter 2: Statewide Planning Effort. The SEHMP incorporates best practices, programs, and knowledge from each of these stakeholders as well as local, Tribal, and Federal representatives and/or their plans. It is also used to track progress in achieving our mitigation goals through State and local programs and strategies while communicating that progress among agency partners, elected leadership, and the public. More information on the State's mitigation goals can be found in Chapter 4: Mitigation Strategy.

To be successful, the SEHMP must:

- Analyze and explain the risks to Washington from all major hazards.
- Coordinate and highlight mitigation activities across the state.
- Develop a strategy to monitor and report on annual mitigation activities throughout the state.
- Provide a resource and set an example for local-level hazard analysis and mitigation planning.
- Establish updated guidance for Hazard Mitigation Assistance Grant programs.
- Incorporate the work of an interagency Hazard Mitigation Working Group of state agencies and federal partners.
- Meet or exceed FEMA requirements in 44 CFR Part 201.

What is Hazard Mitigation?

Mitigation is taking long-term steps to reduce the risk to lives and property and ensure economic continuity in the event of a disaster. In fact, another name for hazard mitigation is disaster risk reduction. Risk can be reduced by:

- Reducing the value of exposed assets (e.g., converting developed land into a park)
- Reducing the vulnerability of an asset to a hazard (e.g., elevating a home in a floodplain)
- Reducing or eliminating the risk to an asset (e.g., replacing an undersized culvert)

A mitigation program provides resources, technical expertise, and coordination that leads to, or is the component of, the reduction of a risk or hazard identified in this plan.

Common Acronyms

This plan uses acronyms following the first complete use of a word. The following are the most used acronyms throughout this document.

- COM: Washington State Department of Commerce
- CWPP: Community Wildfire Protection Plan
- DAHP: Washington State Department of Archaeology and Historic Preservation
- DNR: Washington State Department of Natural Resources
- DOH: Washington State Department of Health
- ECY: Washington State Department of Ecology
- EMD: Washington State Emergency Management Division
- FEMA: Federal Emergency Management Agency
- HIVA: Hazard Inventory and Vulnerability Assessment
- HMA: Hazard Mitigation Assistance Grants
- HMP: Hazard Mitigation Plan
- OIC: Washington State Office of the Insurance Commissioner
- OSPI: Washington State Office of the Superintendent of Public Instruction
- SEHMP: State Enhanced Hazard Mitigation Plan
- WSDOT: Washington State Department of Transportation

Guide to the Plan

This plan meets the state mitigation planning requirements of 44 CFR Part 201 as interpreted by the Federal Emergency Management Agency in 2015 (FEMA, 2015). It is divided into chapters based on FEMA planning requirements and similar subject-matter.

Chapter 1: Washington's Hazardscape

Chapter 1 provides a general overview of the natural and human-caused hazards present in Washington and how they impact our communities, cities and towns, and environment. It helps orient the reader toward thinking about resilience holistically and provides the needed context for fully understanding subsequent chapters.

Chapter 2: Statewide Planning Effort

Chapter 2 describes the plan development process, including outreach to local jurisdictions and state agencies, the plan update schedule, the strategy development process, and the monitoring and implementation strategy. A concept of operations for the Hazard Mitigation Working Group and its role in long-term plan implementation is also described.

This chapter also includes information on the State's management of the Hazard Mitigation Assistance (HMA) grant programs and our commitment to work closely with local jurisdictions on mitigation planning and project implementation.

Chapter 3: Hazard Inventory and Vulnerability Assessment

Chapter 3 includes all the profiles for natural and human-caused hazards in the state as well as an overview of the risks associated with these hazards. This inventory details the earth and environmental system dynamics that can result in natural hazards, as well as the sources of human-caused hazards. Each profile includes detailed descriptions of how the hazard was analyzed. This section provides a statewide assessment of hazard risk (i.e., the potential for impacts) and vulnerability (i.e., how susceptible to hazard impacts a given resource may be).

Chapter 3 also provides detail on the four regional vulnerability assessments completed during this plan update (Olympic Peninsula & Southwestern, Puget Sound & Northwestern, Central, and Eastern). This regional approach to statewide vulnerability assessment is new for the 2023 SEHMP, a tactic chosen to provide local jurisdictions with more specific and downscaled information to use in their own planning efforts. Regional assessments also create an opportunity for the State to engage with local, Tribal, and non-governmental stakeholders more directly on hazard vulnerability.

Chapter 4: Mitigation Strategy

Chapter 4 details the goals, strategies, and action items developed by the Hazard Mitigation Working Group. These will be tracked over the SEHMP five-year cycle. This chapter also describes how mitigation strategies are prioritized.

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An Overview for Your Situational Awareness

Washington's hazardscape – the hazards present in the state and how they impact our communities and assets – is dynamic and changing rapidly. This rapid change is driven primarily by the interaction of our continued population growth and urban development with continued climate change. Washington has experienced more frequent and severe wildfires, storms, and floods in recent memory, many of which include secondary effects in the forms of landslides, diminished air quality, coastal erosion, and stream channel migration. We have also seen more intense heatwaves and wildfire smoke events, which cause widespread public health impacts, including deaths. Additionally, the possibility of a major earthquake, tsunami, or volcanic eruption remains persistent for much of the state.

The increase in hazard events and their magnitudes is happening while Washington's population is growing and continuing to urbanize. Our population increased about 15% between 2010 and 2020 and growth is expected to continue. Urban development is continuing as well, primarily in the Puget Sound area, and expected to increase 33% statewide by 2030 (compared to 2000) (Gao, 2017). It can be safely assumed that with population growth and urbanization comes the co-location of people, critical infrastructure, and other assets in areas exposed to various hazards**. More people and development in areas experiencing more frequent and severe hazard events creates the possibility of increasingly damaging disasters.**

The State of Washington's Enhanced Hazard Mitigation Plan (SEHMP) is one of the many mechanisms the State uses to assess its risks and vulnerabilities to the wide range of hazards here, both natural and human-caused. It is also the State's go-to resource for how we plan to reduce those risks and vulnerabilities through long-term, targeted, and strategic hazard mitigation actions. The foundation of the SEHMP is the Hazard Inventory & Vulnerability Assessment (HIVA, Chapter 3), which details the specific risks posed by each hazard as well as the characteristics of our population and critical assets that make us vulnerable to hazard impacts. Following the HIVA is our updated Mitigation Strategy (Chapter 4), which outlines the actions the State of Washington will pursue for long-term reduction of those risks and vulnerabilities identified in the HIVA. See below for a summary of findings from the HIVA update and the current list of mitigation goals informing our Strategy.

HIVA Key Findings

1. Given the severity of recent climate-related disasters and the increasing likelihood of future disasters related to climate change, we have determined that the natural hazards placing Washingtonians at the highest risk in the near-term are (1) extreme weather, (2) flooding, and (3) wildfire.
2. Extreme heat has become Washington's most deadly natural hazard after the 2021 Heat Dome event killed more than 150 Washington residents.
3. Floods and wildfires have historically been viewed as "high frequency, low severity" but are expected to transition to "high frequency, high severity" events in the future. The 2015 and 2020 wildfire seasons (DRs 4243 and 4584), as well as the 2021 and 2022 floods (DRs 4635 and 4682) indicate this transition has begun.
4. Although the probability of a catastrophic earthquake and tsunami occurring in any given year remains low, there are more people and critical assets exposed to those hazards now than ever before because of our continued population growth and development. Because it is unclear currently if the rate of seismic and tsunami resilience projects in the state is outpacing the rate of population growth and development, it is safe to assume our vulnerability to earthquakes and tsunamis remains high.

Statewide Mitigation Goals

1. Reduce the impacts of natural hazards on our community lifeline infrastructure and other critical assets;
2. Prioritize effective long-term partnerships across all levels of government;

3. Allow the risk and vulnerability assessments to drive the State's Mitigation Strategy and prioritization of mitigation actions;
4. Improve our understanding of multi-hazard environments;
5. Embed cultural understanding into our mitigation work;
6. Ensure improved and equitable access to hazards information;
7. Champion and prioritize people-centered mitigation actions in addition to property-centered ones;
8. Emphasize the role of sustainable development and climate adaptation in hazard mitigation;
9. Strategically reduce the number of repetitive loss and severe repetitive loss properties; and
10. Ensure all counties and sub-county jurisdictions in Washington understand their hazard risks and are eligible for mitigation funding opportunities.

Chapter 1: Washington’s Hazardscape

Chapter 1: Washington's Hazardscape

The landscape of hazards we face here comprise Washington's hazardscape. They include natural hazards, such as floods, wildfires, and earthquakes. They also include human-caused (i.e., technological) hazards, such as dam failure and cyberattacks. However, the primary focus of this Plan is on natural hazards. Understanding our hazardscape requires us to know where these hazards are found – their geographic distribution and regional patterns. It also requires us to determine the interaction of these hazards with the things we care about most: our people, property, infrastructure, economy, environment, and cultural resources, and how these interactions may change over time. With this knowledge, we can develop both short- and long-term hazard mitigation actions that, once implemented, will confidently reduce the risks these hazards pose and our vulnerabilities to them.

1.1. Overview

Disasters happen where Earth's natural systems intersect with human societies. A wildfire that only burns remote stretches of forestland may not be a disaster, but when a wildfire directly impacts a community by burning homes or diminishing air quality with smoke it *would* be a disaster. To understand disaster risk, we must understand both components that contribute to that risk: the earth and environmental systems that manifest our natural hazards and the built environment in harm's way. The following sections introduce these systems as well as what we can expect in the future.

1.2. Earth and Environmental Systems

Earth and environmental systems refer to the natural processes that produce our land, water, and air as well as how those processes interact with humans and other living organisms. These processes are mostly benign, happening largely unnoticed by the average person. They can, however, produce extreme events that can impact people and their communities, such as severe storms, floods, wildfires, earthquakes, landsides, and more. Climate change is a "threat multiplier" that exacerbates many of these natural hazards through its primary drivers of global temperature increases, precipitation changes, and sea level rise. Across North America climate change is impacting cities and towns through more frequent climate-induced disasters and extreme events, resulting in damaged infrastructure, economic impacts, and personal injury or loss of life (IPCC, 2022).

1.2.a. Geosphere

The geosphere refers to the rocks and minerals that comprise Earth's land surface and sub-surface. The processes of the rock cycle are driven primarily by plate tectonics, which creates mountain ranges and other land surface characteristics. In Washington, these processes also create the five active volcanoes in our state: Adams, Baker, Glacier Peak, Rainier, and St. Helens. They are also what drive the earthquakes we experience, including the potential for a catastrophic Cascadia Subduction Zone earthquake and tsunami in the future. Plate tectonics can also trigger landslides when earthquakes disturb the ground enough to cause mass movement.

1.2.b. Hydrosphere

The hydrosphere, or the water cycle, includes processes that drive the distribution of Earth's water – including precipitation, oceans, lakes, streams, and ice. Water moves through this cycle constantly, changing forms from liquid to gas to solid as it moves through the cycle's phases. The potential for extreme events is possible throughout the water cycle, including extreme rainfall, flash flooding, and drought. Climate change is influencing the rates of evaporation and precipitation around the world, causing changes in the worldwide distribution of water. In Washington, we can expect to see more frequent extreme rainfall events (such as atmospheric rivers) as well as more frequent and severe droughts because of climate change.

1.2.c. Atmosphere

The atmosphere refers to the layers of various gases that surround Earth, the majority of which are nitrogen and oxygen. The lowest layer, called the troposphere, is where most clouds and weather occur, including extreme weather such as storms. Greenhouse gases, such as carbon dioxide and methane, are also found in the atmosphere's layers and help to insulate and regulate Earth's temperature. However, greenhouse gas emissions have increased because of human activity since the early 1900s, and those extra greenhouse gases are trapping more heat than ever before, leading to global warming and its various impacts.

1.3. The Built Environment

The built environment comprises the human-made settings where people live as well as the infrastructure that supports human communities. It includes our homes, workplaces, and community lifelines (e.g., wastewater facilities, roads, dams, etc.). The primary concern of this Plan is with the impacts of disasters on Washington's built environment – including our people and the things they value most.

1.3.a. Population, Demographics, and Communities

According to the 2020 Census, Washington grew by 980,000 residents between 2010-2020, an almost 15% increase in population, making the total state population 7.7 million. Most of the state's population (approximately 52%) resides in the Greater Seattle area, including the counties of King (2.27 million), Pierce (921,000), and Snohomish (828,000). They, along with Clark and Kitsap Counties, are also the state's most densely populated counties, averaging 704 people per square mile (this density can fluctuate drastically, with much higher rates in the cities of Seattle and Tacoma and much lower rates in less populated areas of these counties). These counties also had some of the highest rates of population growth in the state (Table 1).

Median household income in Washington is $82,400 (in 2021 dollars), and the state's poverty rate is currently 9.9% (approx. 762,000 people). Poverty is a significant indicator of disaster vulnerability. Chapter 3 explains this in further detail.

Table 1. Top 10 Washington counties by 2010-2020 population growth rate.

County	2010-2020 population growth rate (%)
Clark	18.3
Benton	18.1
King	17.5
Thurston	16.9
Snohomish	16.1
Pierce	15.8
Spokane	14.5
Whatcom	12.8
Klickitat	11.9
Pacific	11.7

Washington has a diversity index of 55.9%, which represents the chance that two Washingtonians chosen at random would be from different racial and ethnic groups. This figure is slightly above the national average (54.9%), and well above Washington's 2010 rate of 45.4%, suggesting the state has become more racially and ethnically diverse since

2010. The most racially and ethnically diverse counties in Washington by diversity index are King (64.6%), Pierce (58.5%), and Yakima (57.8%). Table 2 provides a racial and ethnic breakdown for the state.

Table 2. Racial and ethnic breakdown for Washington in 2020

Race/ethnicity	Percent of state population, 2020
White alone, not Hispanic or Latino	63.8
Black or African American alone, not Hispanic or Latino	3.8
American Indian and Alaska Native alone, not Hispanic or Latino	1.2
Asian alone, not Hispanic or Latino	9.4
Native Hawaiian and other Pacific Islander alone, not Hispanic or Latino	0.8
Some other race alone, not Hispanic or Latino	0.6
Two or more races, not Hispanic or Latino	6.6
Hispanic or Latino	13.7

1.3.b. Urbanization

Although Washington continues to urbanize, it still includes vast areas of protected land (e.g., state and national parks) and other undeveloped areas relative to the most urbanized states in the US. Most of Washington's urbanization is related to already established urban areas, such as the Seattle-Tacoma metro area, as well as Spokane and the Tri-Cities. However, there is a growing trend of urban development throughout the state's wildland-urban interface, which could help drive the increase of, and our vulnerability to, wildfire-related disasters here. Urbanization also contributes to flooding when floodplains are developed or when stream dynamics are altered by bridges and culverts. And in situations where the urbanization itself doesn't change hazard potential, development in hazard-prone areas (e.g., tsunami inundation zones) increases the potential for disaster impacts.

1.4. Future Environment

Based on declared disasters in the state between 1980-2020 (Figure 1), Washington can expect around six disasters each year. This number has increased drastically since 1990, when we could expect only one disaster each year. If this upward trend continues unchanged, we can expect approximately eight disasters per year by 2030 and 10 disasters per year by 2040, with the potential for extreme variation that could include many more each year.

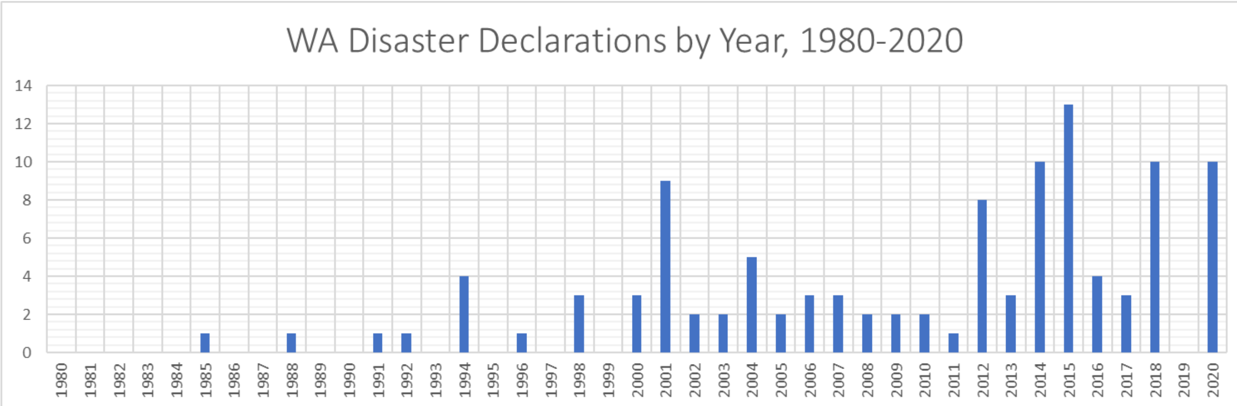

Figure 1. Disaster declarations in Washington per year, 1980-2020.

The future of Washington's hazardscape depends on a complex interaction between population growth, urban development, and climate change. For example, we know that climate change will make coastal and riverine flooding more prevalent in urban centers around the country, and that large wildfires will increasingly threaten lives, property, critical infrastructure, and natural resources (IPCC, 2022). All signs indicate this will be true for Washington as well. This section discusses the ways our hazardscape may change in terms of climate change, population growth, and urban development, and what these changes mean for our vulnerability to natural hazards.

Climate change. Washington has already experienced a 2°F increase in average temperature since the year 1900 (Frankson et al., 2022), with a continued increase highly likely and potentially as much as 10°F or more (Figure 2). Cities across the state will see increasing temperatures at varying rates but all include more days above 90°F and fewer days below 32°F compared to the average for years 1961-1990 (USGCRP, 2022). Table 3 presents observed and projected temperature data for select Washington cities.

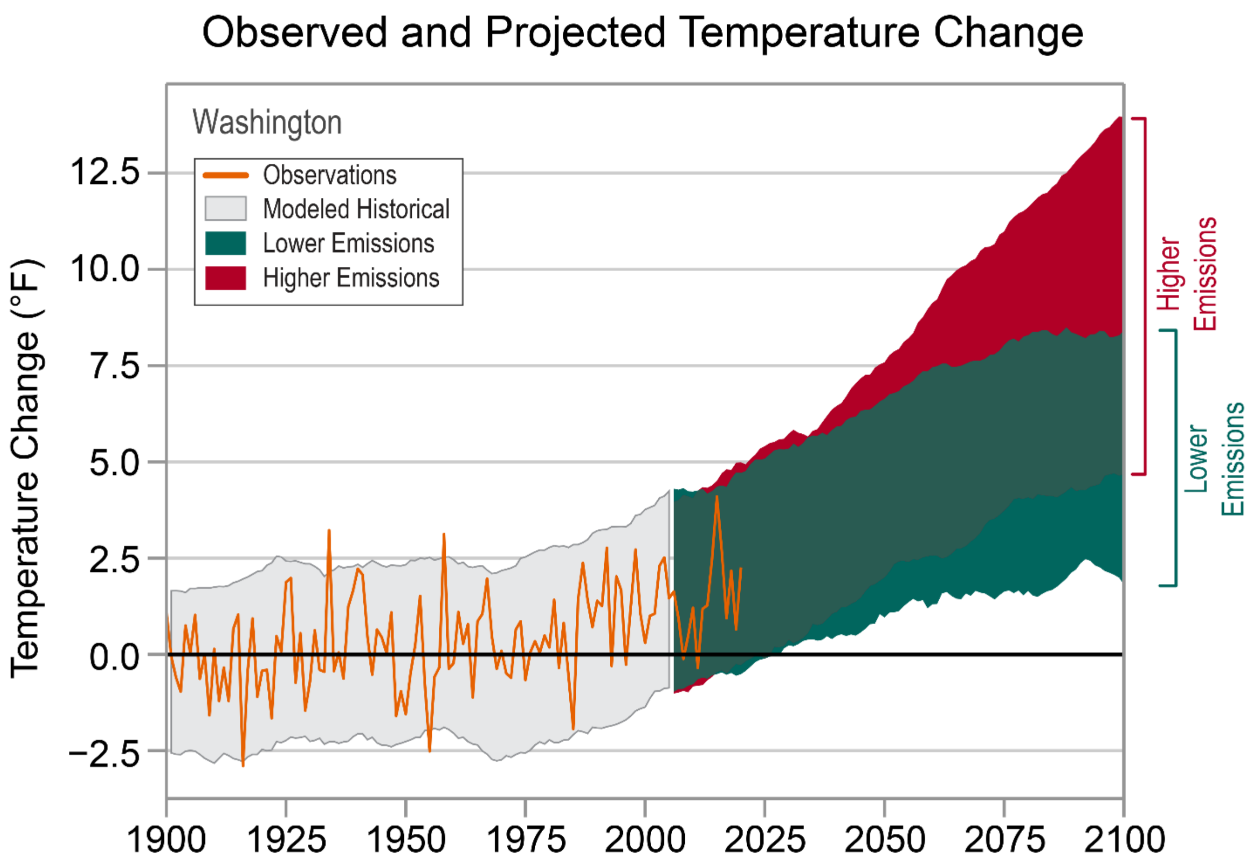

Figure 2. Statewide observed and projected temperature changes through 2100 (Source: Frankson et al., 2022).

Table 3. Observed and projected temperatures for select Washington cities. Metric used are annual averages. Cities were chosen based on location in each of the four regions used for this SEHMP update. (Source: USGCRP, 2022).

Location	Metric	1961-1990 observed avg.	2050		2090	
Aberdeen (Grays Harbor County)	Daily high temp.	51.7°F	*High emissions*	61.8°F	*High emissions*	65.4°F
			Low emissions	61.1°F	*Low emissions*	62°F
	Daily low temp.	40.1°F	*High emissions*	44.5°F	*High emissions*	48.1°F
			Low emissions	43.7°F	*Low emissions*	44.6°F
	Days with high >90°F per year	1.1	*High emissions*	5	*High emissions*	11.9
			Low emissions	3.9	*Low emissions*	4.8
	Days with low < 32°F	67.5	*High emissions*	28.3	*High emissions*	0.1
			Low emissions	31.9	*Low emissions*	0.6
Seattle (King County)	Daily high temp.	54.4°F	*High emissions*	59.8°F	*High emissions*	63.8°F
			Low emissions	58.9°F	*Low emissions*	59.9°F
	Daily low temp.	37.2°F	*High emissions*	42.1°F	*High emissions*	46°F
			Low emissions	41.2°F	*Low emissions*	42.2°F
		1.1	*High emissions*	7.8	*High emissions*	22.1

Location	Metric	1961-1990 observed avg.	2050		2090	
	Days with high > 90°F per year		*Low emissions*	5	*Low emissions*	7.2
	Days with low < 32°F	112.9	*High emissions*	64.9	*High emissions*	39
			Low emissions	71.2	*Low emissions*	63.4
Wenatchee (Chelan County)	Daily high temp.	50°F	*High emissions*	55.4°F	*High emissions*	59.8°F
			Low emissions	54.5°F	*Low emissions*	55.6°F
	Daily low temp.	27.5°F	*High emissions*	32.8°F	*High emissions*	37°F
			Low emissions	31.8°F	*Low emissions*	32.8°F
	Days with high > 90°F per year	4.9	*High emissions*	18.7	*High emissions*	37.8
			Low emissions	13.7	*Low emissions*	18.3
	Days with low < 32°F	229	*High emissions*	180	*High emissions*	144.2
			Low emissions	189.5	*Low emissions*	180.1
Spokane (Spokane County)	Daily high temp.	57.7°F	*High emissions*	63.4°F	*High emissions*	68°F
			Low emissions	62.4°F	*Low emissions*	63.6°F
	Daily low temp.	35.8°F	*High emissions*	41.4°F	*High emissions*	45.8°F
			Low emissions	40.3°F	*Low emissions*	41.4°F
	Days with high > 90°F per year	16.2	*High emissions*	46.5	*High emissions*	73.1
			Low emissions	37.7	*Low emissions*	46.5
	Days with low < 32°F	143.7	*High emissions*	87.3	*High emissions*	55.2
			Low emissions	96.3	*Low emissions*	85.9

The projected increases in temperatures in Table 3 may seem slight at first glance, however it is important to remember that with a small change in average temperature comes the potential for extreme variation around that average. Earth has warmed 1.8°F since 1900 already, and the consequences in terms of disasters is stark and apparent. Any further increase will compound those consequences, which in Washington could mean more severe and larger wildfires, more intense atmospheric rivers, more landslides, more heatwaves, and more sea level rise in some places. Remember too that Washington could see as much as 10°F increase in average temperature by 2100, with consequences that could be catastrophic. These climatic changes make us more vulnerable to the impacts of natural hazards. Without increased action to adapt to or mitigate these impacts, the people of Washington and our critical assets will be at higher risk of damage or loss.

Population growth and urban development. We expect to see Washington continue its recent population growth and rate of urban development. Based on global population projections that maintain the current trends in population growth and development (Fricko et al., 2017; Gao, 2017), Washington will likely see a steady increase in population to approximately 9.7 million by 2100 – a 25% increase over the 2020 population. Urban development will have to continue to accommodate the increasing population. Based on global urban expansion projections from NASA’s Socioeconomic Data and Applications Center (Seto et al., 2016), Washington is predicted to increase its urbanized areas by 33% by 2030, compared to the area of the state that was urbanized in year 2000. The overwhelming majority of that increase will be in the Greater Seattle region, especially in King, Snohomish, Pierce, and Kitsap Counties. The increase in population and urbanized areas will take place while simultaneously dealing with increasingly frequent and severe natural hazard events due to climate change. Although the threat of a major earthquake, tsunami, or volcanic eruption is likely to remain the same as it is today, we expect more people and property to be in areas exposed to such hazards as time goes on.

Without significant investments in hazard mitigation and resilience, the combination of more people and more critical assets in increasingly hazardous areas will present overwhelming challenges to our state and make us more vulnerable to the impacts of natural hazards. This combination of climate change, population growth, and development requires increased action to adapt to or mitigate the impacts of natural hazards, including sustainable growth and development, if we want to avoid the most severe disaster consequences.

Chapter 2: Statewide Planning Effort

Chapter 2: Statewide Planning Effort

The primary planning objectives for the 2023 SEHMP update was to come away with an improved understanding of our various hazard risks and vulnerabilities and set the stage for continued hazard analysis to drive our mitigation goals and actions. The importance of a robust state of knowledge around hazard risk and vulnerability cannot be overstated because Washington's hazardscape is so dynamic. That state of knowledge, synthesized into our Hazard Inventory and Vulnerability Assessment (Chapter 3), serves as the foundation of the Plan and informs our mitigation goals, priorities, and overarching strategy.

The development of the 2023 SEHMP was truly a statewide, comprehensive effort involving multiple State agencies. This chapter details the planning goals of the 2023 SEHMP, the State agency staff members involved in its preparation, the methods used to update it from 2018, and a discussion of the State's hazard mitigation capabilities.

2.1. Planning Team and Partners

Like the 2018 SEHMP, this update relied on the interagency Hazard Mitigation Working Group (HMWG) to ensure cross-departmental participation and information sharing. Table 4 lists the members, their job titles, and home agency of the current HMWG (current as of May 2023).

Table 4. Hazard Mitigation Working Group members (as of May 2023)

Name	Title	State Agency (unless otherwise noted)
Andy Tate	Assistant Division Manager - Community and Landowner Assistance	Natural Resources
Angie Lane	Assistant Division Manager - Plans and Information	Natural Resources
Ashley Blazina	Natural Resources Specialist	Natural Resources
Bob Frietag	Research Faculty and Co-Director of the Institute for Hazard Mitigation Planning and Research	University of Washington
Bobbak Talebi	Senior Coastal Planner	Ecology
Brandon Parsons	Associate Director	American Rivers*
Brian Terbush	Earthquake and Volcano Program Coordinator	Emergency Management Division
Carol Lee Roalkvam	Policy Branch Manager - Environmental Services Office	Transportation
Chelsea Nied	Earthquake Early Warning Program Coordinator	Emergency Management Division
Corina Allen	Chief Hazards Geologist	Natural Resources
Csenka Faborini Csorka	Senior Policy Advisor	Natural Resources
Crystal Raymond	Climate Adaptation Specialist	University of Washington
Dave Andersen	Managing Director	Commerce
Eli King	Director of Energy Emergency Management	Commerce
Elyssa Tappero	Tsunami Program Manager	Emergency Management Division

Name	Title	State Agency (unless otherwise noted)
Erin Coyle	Emergency Management Specialist	Agriculture
Garrett Jackson	Coastal Hydrologist	Transportation
Henry Bell	Coastal Planner	Ecology
Himanshu Grover	Assistant Professor and Co-Director of the Institute for Hazard Mitigation Planning and Research	University of Washington
Ian Miller	Coastal Hazards Specialist	Washington Sea Grant
Jackson Blalock	Community Engagement Specialist	Washington Sea Grant
Jenny Coe	Wildland Fire Program Coordinator	Natural Resources
Jerry Franklin	Mapping Coordinator and Analyst	Ecology
Jesi Chapin	Emergency Management Specialist	Natural Resources
Jessica Czajkowski	Assistant Director of Science and Research	Natural Resources
Joanne Markert	State GIS Coordinator	Chief Information Officer
Jodi Goodman	Dam Safety Officer	Ecology
Joel Haarstad	Mitigation & Recovery Section Manager	Emergency Management Division
Jon Culp	Drought Program Manager	Conservation Commission
Julie Dames-Ryan	Grants Administrator	Corrections
Julie Fox	Air Quality Epidemiologist	Health
Karin Bumbaco	Assistant State Climatologist	University of Washington
Kate Mickelson	Landslide Hazards Program Lead	Natural Resources
Keesha Chinn	Environmental Information Program Manager	Transportation
Kevin Scarlett	Senior Plans Reviewer	Health
Kevin Zerbe	State Mitigation Strategist	Emergency Management Division
Kimberly Moore	Legislative Coordinator and Emergency Response Planner	Health
Logan Mast	Mitigation Program Assistant	Emergency Management Division
Marnie Boardman	Climate and Health Coordinator	Health
Matt Lebens	Hazard Mitigation Program Supervisor	Emergency Management Division
Matt Stoutenburg	Emergency Management Program Specialist	Insurance Commissioner
Maximilian Dixon	Hazards and Outreach Program Supervisor	Emergency Management Division
Mike Johnson	Environmental Planning and Implementation Strategies Manager	Puget Sound Partnership
Nick Vann	Deputy State Historic Preservation Officer	Archaeology and Historic Preservation

Name	Title	State Agency (unless otherwise noted)
Ryan Chandler	Hazard Mitigation Program Supervisor	Emergency Management Division
Scott Black	Program Development Manager	Superintendent of Public Instruction
Stacey McClain	Operations Unit Manager	Emergency Management Division
Taylor Dietz	Human Services Program Manager	Emergency Management Division
Tim Cook	State Hazard Mitigation Officer	Emergency Management Division
Travis Ball	Hydraulic Engineering Chief	Army Corps of Engineers*
Tricia Sears	Geologic Planning Liaison	Natural Resources
Tristan Allen	Risk & Resilience Manager	Commerce

*Denotes non-State agency

Additional review and approval of content was performed by an EMD-based team that included the State Mitigation Strategist, State Hazard Mitigation Officer, Mitigation & Recovery Section Manager, and Operations Unit Manager. This team, referred to as the SEHMP Editors within this plan, developed and provided approval of the grant proposal, project charter, and early drafts of key sections of the 2023 Plan. Final approval of the 2023 SEHMP prior to submittal to FEMA was done by the Adjutant General and Director of the Military Department, of which EMD is a part. A copy of this approval letter can be found in Appendix A.

2.2. Planning Process and Methods

The process for the 2023 update included a review and evaluation of the 2018 SEHMP, a methodological development period to prepare the grant application for this update, validation and testing of our new hazard analysis methods, updating the HIVA and Mitigation Strategy, internal and external review, and submission to FEMA Region 10 for approval. All of this occurred during and was guided via continued meetings with our planning team, the HMWG and the SEHMP Editors.

1. **2018 SEHMP review**. Our process for 2023 began in 2019 with an EMD-led evaluative review of the 2018 SEHMP and the opportunities for improvement identified by FEMA at the time. Our evaluation determined multiple areas where the SEHMP could be strengthened – namely through better geospatial analysis to develop our HIVA as well as the development of mitigation actions with direct ties to identified risks and vulnerabilities in addition to ongoing State programs. These results were presented to the HMWG in 2020.
2. **2023 grant proposal**. We developed a draft grant proposal for the 2023 update in 2020, based largely on methods for strengthening the Plan identified by our evaluation. The contents of the draft proposal, including the initial risk assessment methodology, were presented to the HMWG in late 2020. Member feedback was used to refine the methods and proposal before finalizing it in early 2021 and submitting the grant under the DR-HMGP-4539 round in April 2021.
3. **Data collection**. Initial data collection and processing for the 2023 update began in 2020 alongside the development of the grant proposal. Data collection increased after April 2021 when the proposal was submitted and continued as the HIVA was updated throughout 2022.
4. **Project charter.** We developed a project charter to use as a tool for guiding the update progress, documentation, and keeping track of the various federal requirements the Plan must meet. We began

working on the charter in April 2021 after submitting the grant. It was finalized and signed by the SEHMP Editors on 9/21/2021.

5. **HIVA update.** Very early draft risk assessments for wildfire began in 2020 as part of the grant proposal development to validate and test the geospatial methods proposed. These preliminary results were presented to the HMWG and during the State's annual FEMA consultation in 2021. Full-scale risk assessments for natural hazards continued throughout 2022 after EMD received the grant award. Risk assessments were led by EMD with consultation and guidance from the HMWG. Vulnerabilities for State assets were incorporated into the risk assessments geospatially whenever possible. These vulnerabilities were defined as the characteristics that make the given asset susceptible to hazard impacts when they occur. We used the best available geospatial datasets for State-owned and operated structures, critical infrastructure, and populations to perform the vulnerability assessment at a statewide scale. We applied the results of the statewide HIVA to four multi-county regions to determine a finer scale assessment of vulnerability as required by federal regulation. These regional assessments, along with the entire plan draft, were reviewed by State and local partners in early 2023, prior to submission to FEMA Region 10.
6. **Mitigation Strategy update**. The 2018 Mitigation Strategy was reviewed and updated as necessary upon completion of the HIVA and regional vulnerability assessments to ensure the current state of knowledge around risk and vulnerability could be fully integrated into our mitigation actions. The review and update were completed by a collective effort of the HMWG beginning in November 2022. Some actions from 2018 were kept with minor updates, while others were removed because of programmatic changes at the State, changes in our mitigation goals and priorities, or project completion. New actions were added to the amended 2018 list as well, reflecting changes in risk and vulnerability according to the new HIVA. These changes are reflected in the updated list of mitigation actions found in Chapter 4 of this Plan.
7. **Developing a draft and review**. With all the key sections updated, the last step of our planning process was to develop a full draft of the plan and send it through the review process. This included review of key sections by the HMWG members, full internal review by the SEHMP Editors and Washington Military Department leadership, and review of the full draft by the HMWG and local partners in early 2023.

Regional Vulnerability Assessments

The regional vulnerability assessments are among the most obvious differences between the 2018 and 2023 Plans. Our reason for pursuing regional-scale vulnerability assessments is because a failure to act regionally is a well-documented factor in disaster impact. For example, activity in one part of a watershed can greatly influence flood risk in other parts of the same watershed, sometimes crossing jurisdictional boundaries. In some cases, hazard mitigation actions in one jurisdiction can lead to increased hazard risk in a neighboring jurisdiction, for example when such actions alter flood dynamics downstream (see Platt, 1982). The bottom line: hazards do not respect political borders.

Our regional vulnerability assessments were part of our effort to spur the multijurisdictional coordination needed to truly improve disaster resilience in our state. As such, we held an open solicitation period for local and tribal representatives around the state via an interest form submitted to EMD (i.e., a survey). However, we did not receive enough interested parties in some areas of the state to warrant developing regional stakeholder groups. We will revisit this approach prior to the 2028 update.

2.3. Mitigation Capabilities

The State of Washington is committed to improving its ability to mitigate natural hazards wherever possible. This includes using the National Mitigation Framework as a guide to ensure we remain focused on community resilience and the connections between economy, housing, health and social services, infrastructure, and natural and cultural resources. The below sections indicate the ways in which the State's comprehensive mitigation program follows the guiding principles of 1) fostering cooperative relationships, 2) emphasizing the planning process, 3) focusing on reducing risks, and 4) improving mitigation capabilities.

2.3.a. State Mitigation Capabilities

State laws, regulations, policies, and programs related to hazard mitigation. The responsibility for mitigating natural hazards in Washington is spread across multiple State agencies, often due to legislation that mandates certain responsibilities to these agencies. The result is a truly statewide, comprehensive effort to reduce hazard risks, but such an effort relies on fostering cooperative relationships. The primary mechanism for this coordination is the Hazard Mitigation Working Group (HMWG), although other means of interagency coordination exist. Mitigation is supported by an array of State agency programs and policies whose maintenance represents the State's commitment to mitigation and its focus on reducing risk. The following summary table (Table 5) provides an overview of the various laws, policies, and programs related to hazard mitigation in Washington, including an evaluation of these capabilities since 2018.

Table 5. Overview of laws, programs, etc. pertaining to hazard mitigation in Washington

Law, regulation, policy, or program	Relationship to hazard mitigation	Evaluation
Floodplain Management and Community Rating System	State administration of federal Risk MAP program; State coordination of NFIP; Comprehensive planning for flood hazard management	30+ communities in CRS; continued interagency involvement in Risk MAP and improved use of Risk MAP products in local planning efforts; continued reduction in number of RL/SRL properties in the state and continued encouragement to include 1 foot of freeboard and adoption of higher floodplain standards; improved strategic use of HMA funds to reduce flood risk
Floodplains by Design	Projects reduce flood risk and restore habitat along WA streams	Continued investment in FbD by State legislature. Total funding since 2018 is $101.3M, including $50.9M approved for 2021-2023 funding cycle
Shoreline Management Act	Regulates protection of shoreline environments and the creation of local shoreline master programs (SMPs)	Act applies to all 39 counties; SMPs ensure no net loss of ecological benefit, including benefits that protect the built environment, and must address potentially hazardous areas
State Building Code Act	Establishes minimum performance standards for buildings	Codes apply statewide, thereby avoiding jurisdictional variation; primary mechanism for mitigating seismic risks; 2015 adoption of stricter codes, including WUI codes
Growth Management Act	Requires jurisdictions to protect critical areas (e.g., frequently flooded areas and geological hazardous areas)	Critical areas ordinances are effective HM regulatory mechanism; Local comprehensive plans must comply; Comp plans are evaluated and updated every 8 years; Guidance developed in 2023 will help locals integrate climate resilience into comp plans
State Hazard Mitigation Program	Administers federal mitigation grants; Conducts statewide risk and vulnerability assessment; develops the SEHMP and approves local HMPs	All 39 counties are engaged in local HM planning; maintenance of "enhanced" status of the state mitigation plan; improved interagency coordination via the HMWG; comprehensive statewide HM program showcased in annual mitigation reports (Appendix D)
Dam Safety Program	Ranks dams based on environmental hazard and downstream population	Dams are assessed through risk-based analysis and dams are required to be built or retrofitted to standards based on risks; 2018 SEHMP was updated in 2020 to comply with HHPD Grant program
Drought Mitigation Program	Supports drought planning, decision-making, and response	Can request emergency drought declarations that appropriate funds for drought response; Funding being sought to increase resilience to drought in addition to drought response focus with related

Law, regulation, policy, or program	Relationship to hazard mitigation	Evaluation
		actions included in the 2023 Mitigation Strategy (Ch. 4)
Office of the Chehalis Basin	Pursues long-term flood risk reduction in the Chehalis Basin	Integrated strategy identifies actions and funding for flood reduction; Chehalis Board makes continued recommendations to Dept. of Ecology and Governor
Landslide Hazard Program	Collects LiDAR for use in landslide susceptibility mapping	LiDAR for use in landslide mapping and risk assessments has been collected in multiple counties
Tsunami Mapping Program	Conducts tsunami inundation modeling and mapping	New inundation models and associated maps were released in 2022 and will be used in various State-led planning efforts, including the tsunami hazard profile in this plan
Fuels Reduction Program	Implements wildfire fuels reduction projects	Program targets 9,000+ acres within WUI zones for fuels reduction each biennium
Chronic Environmental Deficiencies Program	Targets locations on state highways with chronic maintenance issues due to erosion, flooding, and washouts	As of Dec. 2022, 63 CED projects have been constructed with 63 remaining; Funding continued to be pursued to further address priority CEDs
Statewide Transportation Asset Management Program	Applies a risk-based approach to transportation asset management	Transportation Asset Management Plan (TAMP) includes asset inventory, risk considerations that could impact the asset, and investment strategies for asset maintenance

State administration of the National Flood Insurance Program (NFIP)

As of June 2023, there are 24,385 NFIP flood insurance policies in Washington, providing about $7 billion in insurance coverage. This is a significant decline from 2018, when there were 37,000 policies providing $9.4 billion in coverage. Private flood insurance policies are becoming increasingly more prevalent as the private market grows. Nearly 50% of NFIP insurance policies in the state are for properties located outside the special flood hazard area, an increase from 35% in 2018.

Local jurisdictions can take part in the Community Rating System (CRS) to lower NFIP premiums in their communities. While local governments participate in CRS through FEMA, the Washington Department of Ecology supports communities entering the program and maintaining good standing by providing technical assistance. Ecology staff discuss CRS during audits and have informational meetings with communities who reach out about the program. Ecology reviews flood damage prevention ordinances to ensure that communities have the class 8 freeboard requirements and maintains the Washing State Model Ordinance, which includes several provisions that help communities score points in the program. Ecology also provides technical assistance for communities to maintain CRS status, such as how to fill out Elevation Certificates properly, which are reviewed during CRS audits.

The Washington State Model flood damage prevention ordinance has several provisions above NFIP minimum requirements, including the state prohibition on new and substantially improved residential structures in the floodway (RCW 86.16) and new water supply wells in the floodway (WAC 173-160-171), one foot of freeboard above the base flood elevation, and recommended language for several other provisions such as the use of Elevation Certificates to record building construction details and enhanced standards for critical facilities. Washington State adopts the international building codes by reference with amendments, and currently requires the use of the 2018 I-Codes in all counties and cities (RCW 19.27). Separate local floodplain management regulations are required in addition to the building codes (RCW 86.16). The state's model ordinance exceeds NFIP minimums as do the 2018 I-Codes. The model ordinance notes the sections of the I-Codes that reference ASCE 24-14, Flood Resistant Design and Construction, which contains specific building elevation requirements that exceed minimum NFIP standards.

State funding capabilities for hazard mitigation projects. Washington funds most of its mitigation activity at the local level via Hazard Mitigation Assistance (HMA) grants before a declared disaster and Public Assistance (PA) Categories C-G after a declared disaster. HMA grants include those under the Hazard Mitigation Grant Program (HMGP), Building Resilient Infrastructure and Communities (BRIC), and Flood Management Assistance (FMA). It also included Pre-Disaster Mitigation grants until that program was ceased in 2020. As of January 2023, the State is administering approximately $200 million in awarded HMA grants, (65% BRIC/PDM/FMA and 35% HMGP/HMGP-Post Fire). The total amount received includes HMGP rounds for notable disasters, such as COVID-19 and the 2020 wildfires. Due to our "enhanced" status, Washington receives an additional 5% in funding for all HMGP rounds. Also as of January 2023, there is approximately $145 million of sub-applications pending submission to FEMA.

Washington also provides its own funding mechanisms for hazard mitigation unrelated to federal grant dollars. This includes funds appropriated by the State Legislature to help sub-applicants meet the cost share requirements of HMGP and BRIC/FMA grants (12.5% of cost share requirement). Since 2018, the State has also allocated $50.9 million for Floodplains by Design projects for 2021-2023. In 2021, the Governor's Office allocated funds to the Office of the Chief Information Officer to develop a natural hazards data portal for use by State agency staff involved in hazard mitigation efforts (to be completed in 2023). Also in 2021, the Office of Financial Management coordinated a task force of State agency representatives to provide the Legislature with future climate resilience funding recommendations, worth approximately $50 million, though funds have not yet been allocated.

2.3.b. Local Coordination and Capabilities

As of February 2023, all 39 counties in Washington are actively engaged in hazard mitigation planning (Figure 3). All counties except one (Adams) have completed at least one county-wide hazard mitigation plan (HMP), with many having gone through multiple comprehensive updates. As such, most of the state's population resides in a county that has assessed its natural hazard risk, developed a mitigation strategy, and is eligible for hazard mitigation grants. Prior to the next comprehensive update, we intend to do a deeper dive into the number of sub-county jurisdictions covered by an approved HMP (either stand-alone or in a multijurisdictional HMP) since we expect this number to have grown since 2018.

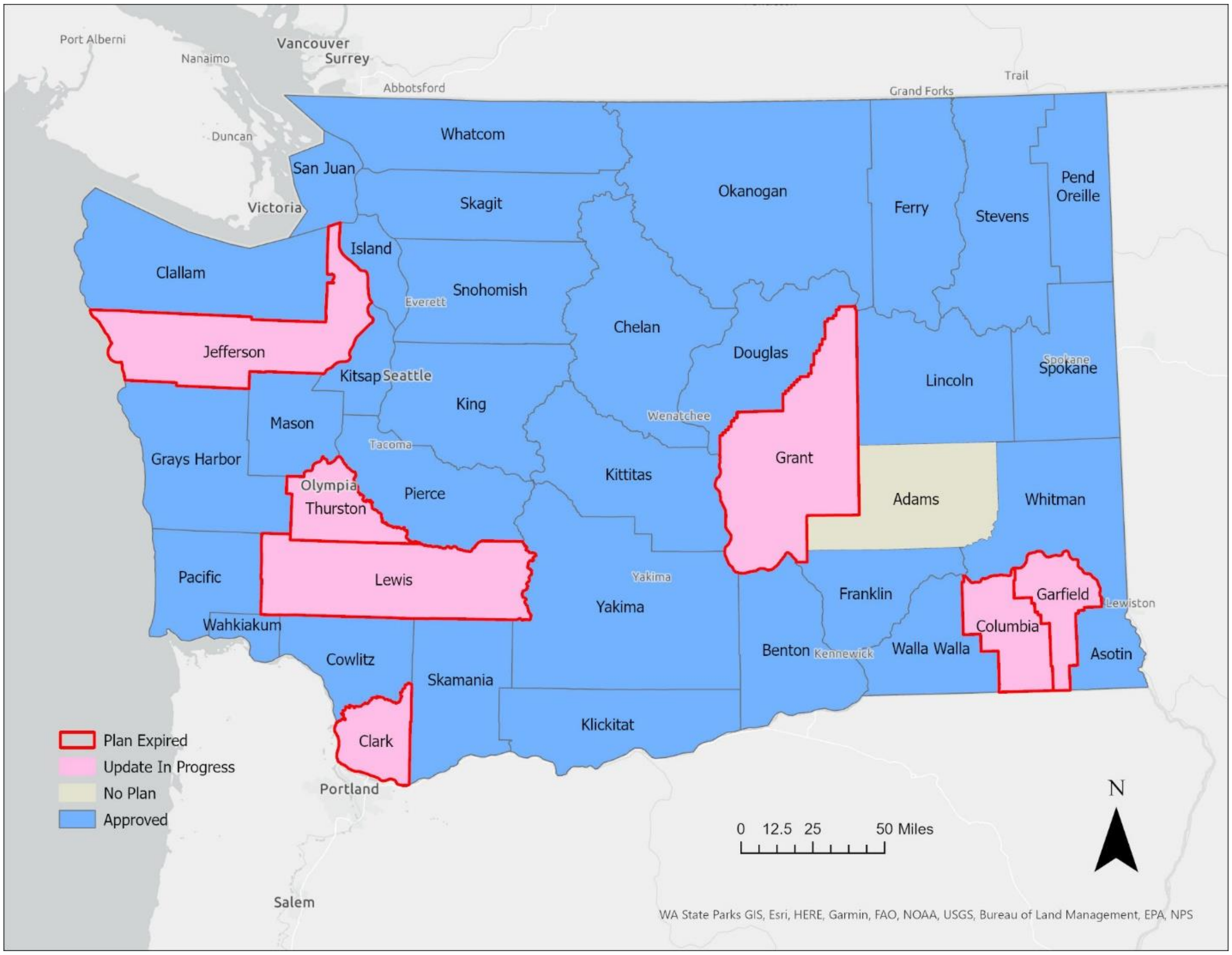

Figure 3. County-level hazard mitigation plan statuses as of Mar. 2023. Adams County is in the process of developing their first HMP.

The increase participation in mitigation planning statewide indicates an overall increase in local jurisdictions' capability to accomplish hazard mitigation. This is also reflected in the number of pre-applications EMD receives for hazard mitigation grants, which has also increased in recent years. For example, we received more than 200 pre-applications from local jurisdictions for the 2021 BRIC round and the DR-4481 HMGP round. The total estimated value of projects submitted for our review for the DR-4481 round was more than $1.4 billion.

2.4. Plan Review, Evaluation, and Implementation

The Mitigation Strategist within EMD is responsible for monitoring the relevance and implementation of the 2023 SEHMP via quarterly HMWG meetings. Intermittent updates to the 2023 SEHMP will keep the plan current and may be spurred by feedback from HMWG members, newly available hazard data and information, state and/or federal policy changes, disaster events, and so on. Updates will be reflected on an "Updates" page near the front of this plan.

Progress toward implementing the 2023 SEHMP's goals will be summarized in an annual report written by the Mitigation Strategist with input from state, local, tribal, and federal partners on their mitigation activity occurring throughout the state. This report will inform our assessment of the Plan's effectiveness at achieving its goals and objectives. Additionally, formal plan evaluation will be a standing agenda item for a minimum of one HMWG meeting each year.

Lastly, the STAPLEE methodology used to develop and prioritize the 2023 Mitigation Strategy will be used to track implementation of the specific actions included in the Strategy. Although the Mitigation Strategist at EMD will be responsible for maintaining this system of monitoring the Plan's implementation, most actions in the Strategy are not within the purview of EMD and information on their progress will be provided by HMWG members.

Chapter 3: Hazard Inventory and Vulnerability Assessment

Chapter 3: Hazard Inventory and Vulnerability Assessment

The Hazard Inventory & Vulnerability Assessment (HIVA) serves as the foundation of this Plan. Its purpose is to identify the hazards present in the state of Washington and determine how they are placing our critical assets and population at risk, as well as outline the various vulnerabilities of our critical assets and populations. By doing this, the HIVA provides a state of knowledge on current hazard risk and vulnerability across Washington. This state of knowledge is used later in the Plan to identify and prioritize mitigation actions that can be tied back to our known risks and/or vulnerabilities (see Chapter 4).

Critical assets in this plan include facilities that, if damaged or disrupted, would impact the delivery of vital services to Washington residents. They are defined according to the 2015 State Mitigation Plan Review Guide (FEMA, 2015), and include:

- State-owned and/or -leased facilities
- Health and safety infrastructure (e.g., hospitals, first responder facilities)
- Energy infrastructure (e.g., power generation facilities)
- Critical water and wastewater infrastructure (e.g., drinking water, wastewater treatment)
- Transportation infrastructure (e.g., roads, ports, airports)

The population in Washington was characterized in this HIVA by using Census data, including the 2020 Census and the 2018 Census projections since the latter are used in the social vulnerability data we used in this update (CDC, 2018).

For this update, we have emphasized the use of best available geospatial data and spatial analysis methods to identify risks and vulnerabilities. In this update, we tested the use of spatial statistical approaches for some hazards, such as wildfire, flooding, and landslides. We feel these tests prove useful in improving our understanding of *why* disasters occurred *where* they did in the past, as well as *why* vulnerabilities exist *where* they do. These approaches will eventually allow us to more accurately predict where we think disasters are most likely in the future. Although not entirely dissimilar to the approach used in the 2018 SEHMP, our use of spatial statistics is seen as an improvement over the 2018 plan in terms of characterizing previous occurrences and mapping the spatiotemporal changes in hazard events. We will build on these analyses in future updates of this plan.

What is risk and vulnerability?

Risk and vulnerability are often conflated terms or used interchangeably. However, in this Plan we are careful to use them as separate, but related, concepts.

- Risk, simply put, is the potential for adverse impacts resulting from a hazard occurrence. This potential is determined through careful analysis of exposure (i.e., what is in harm's way), extent (i.e., how severe the event could be), and probability of occurrence in a given year.
- Vulnerability refers to the characteristics of exposed assets or populations that might make them susceptible to hazard impacts. For infrastructure, this could be attributes such as age or materials used. For populations, this could be socioeconomic status or access to information.

How are they related?

Vulnerability assessments help to qualify risk analyses by providing more information about the people and critical assets in harm's way. Vulnerability becomes especially important when analyzing hazards that are widespread and could potentially impact people and assets over large geographic areas. This is because it is possible that two communities, for example, could be equally exposed to a hazard of the same extent and likelihood of occurrence, but one community may be more vulnerable to such an event than the other due to various factors that hazard mitigation practitioners and decision makers should understand.

Like the 2018 plan, we also used social vulnerability data in our assessment to create a holistic understanding of risk and identify potential disaster vulnerabilities. This data came from the Centers for Disease Control and Prevention's 2018 Social Vulnerability Index (SVI). This index combines 15 factors of social vulnerability to determine Census tract-level social vulnerability, which is expressed as a percentage of the tracts population that exhibits some or all those 15 factors. SVI "scores" range from 0 to 1 (i.e., 0% to 100%). We considered tracts with scores above 0.75 (75%) as having high social vulnerability. We also used the Department of Health's Environmental Health Disparities rankings to understand potential vulnerability. Appendix C provides a more detailed description of our risk and vulnerability assessment methodology used for this update and continued work around hazard analysis. In areas where geospatial data are not readily available, we reviewed the 2018 SEHMP material and validated that information as still applicable or updated it using non-geospatial methods, such as through secondary research or subject matter expertise.

Also new for 2023 is the use of regional vulnerability assessments to improve our understanding of jurisdictional-level risks and vulnerabilities. We sectioned the state into four regions based on shared hazards and homeland security affiliations (Figure 4). Each region received a regional vulnerability assessment found at the end of this chapter.

Data Used in this HIVA Update

As mentioned above, our 2023 HIVA emphasized the use of best available geospatial data and modern spatial analysis techniques to identify risks and vulnerabilities. Datasets integral to our assessments include:

- 2020 Census (U.S. Census Bureau, 2021)
- 2018 Social Vulnerability Index (Centers for Disease Control & Prevention, 2018)
- Environmental Health Disparities Ranking (DOH, 2022a)
- Washington State Land Use (WA DOR, 2010)
- Local Agency Public Road Routes (WSDOT, 2021)
- Global Population Projection Grids, 2000 – 2100 (Gao 2017)
- Global Urban Land Extent Projection Grids, 2000 – 2100 (Gao & Pesaresi, 2021)
- State Facilities 2021 (OFM, 2021)
- Freight Intermodal Facilities (WSDOT, 2022)
- Licensed Hospitals (DOH, 2021)
- Fire Stations (USGS, 2020)
- Local Law Enforcement Locations (ORNL, 2019)
- Electric Power Transmission Lines (ORNL, 2022)
- Railroads (FRA, 2017)
- Wellhead Protection Areas (DOH, 2022b)

Other datasets used include hazard-specific ones, such as wildfire location data from WA DNR and the National Flood Hazard Layer from FEMA, among others.

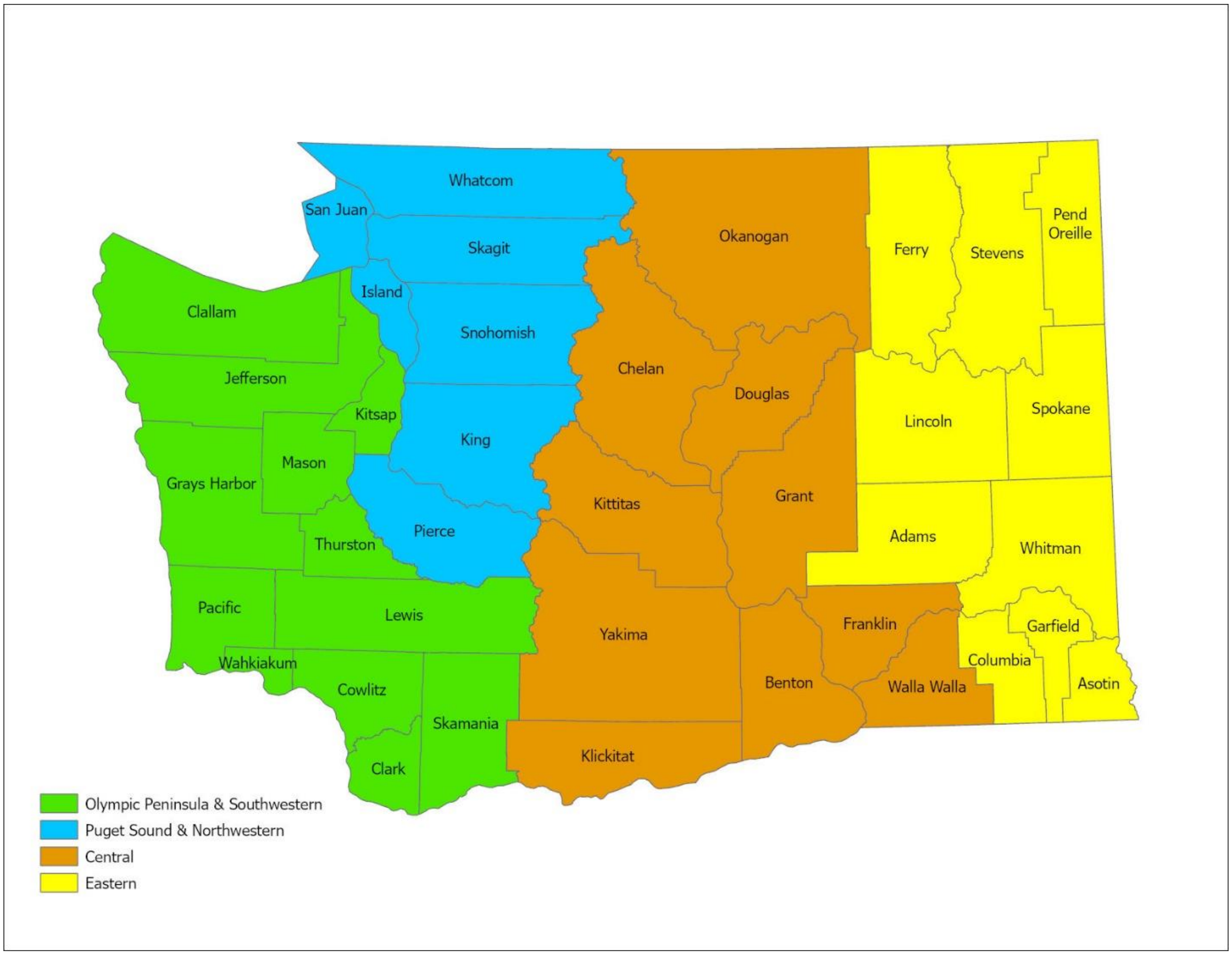

Figure 4. Regions used for the regional vulnerability assessments. These regions follow the same basic shape as the Homeland Security regions for Washington, with Olympic Peninsula & Southwestern combing HS Regions 2, 3, and 4; Puget Sound & Northwestern combining HS Regions 1, 6, and 5; and Central combining HS Regions 7 and 8 (Eastern is HS Region 9).

3.1. Natural Hazards

The sub-sections below provide summaries of each identified natural hazard in Washington that includes the locations they tend to occur based on previous occurrences, who/what is exposed to the hazard, the hazard's extent (i.e., potential magnitude or severity), and the probability of future occurrences.

Bottom line up front: The most common natural hazard events in Washington are extreme weather, flooding, landslides, and wildfires. They are also the most widespread, with each capable of having direct statewide impacts. In many previous disasters, these natural hazards triggered each other. For example, extreme rainfall triggered flash flooding and landslides in 2021 (DR-4635), and extreme heat and wind increased the potential for severe wildfires in 2020 (DR-4584). The combination of climate change and continued population growth, and subsequent urban development in hazard-prone places, has contributed to the increased frequency and severity of these natural hazard events, and therefore, the state's vulnerability to these hazards (Figure 5). For this reason, these natural hazards are often referred to as "climate-related natural hazards." These events used to be high frequency but low severity, but they are now becoming high frequency *and* high severity events. **Given the severity of recent climate-related disasters and the increasing likelihood of future disasters related to climate change, we have determined that the natural hazards placing Washingtonians at the highest risk in the near term are (1) extreme weather, (2) flooding, and (3) wildfire.**

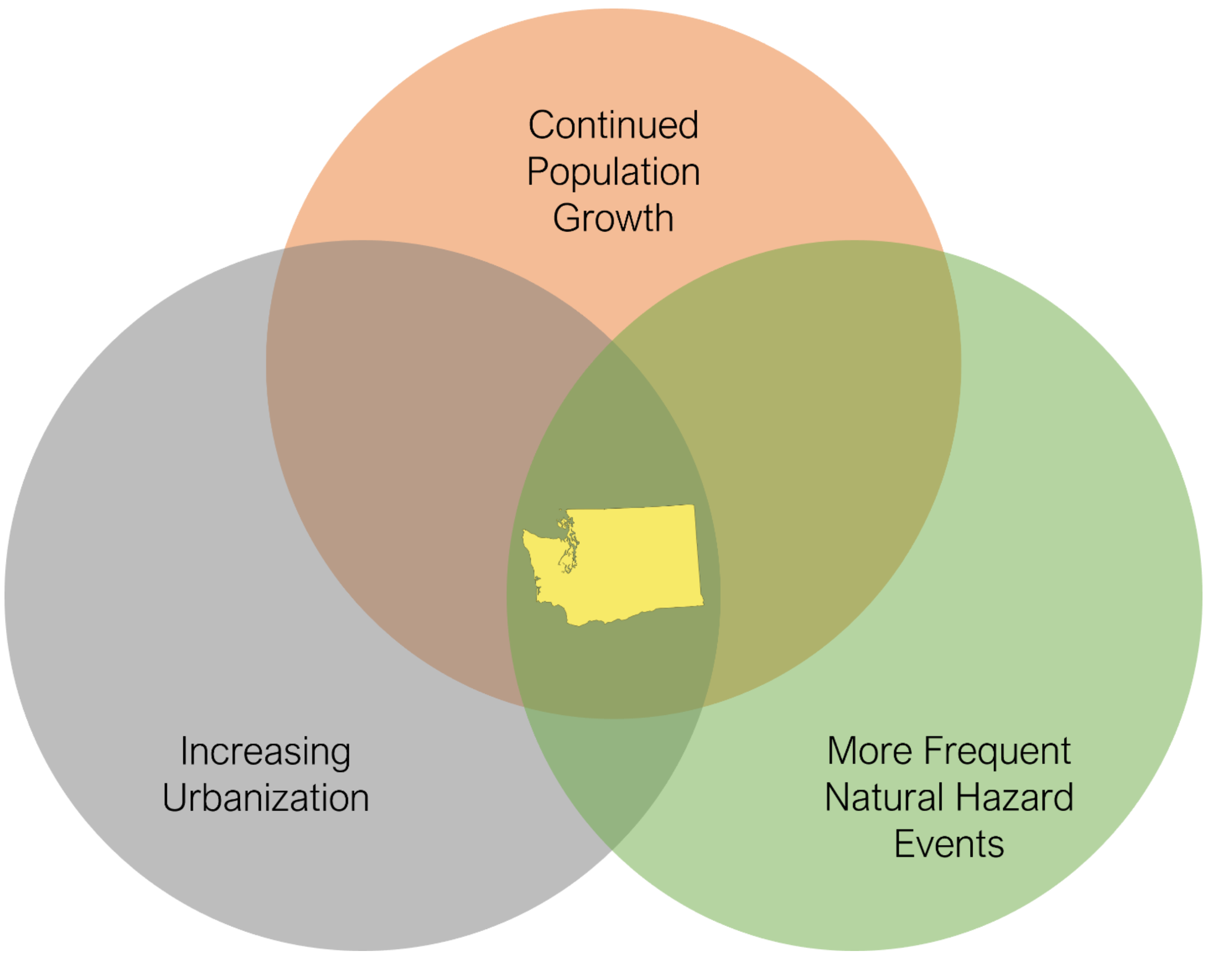

Figure 5. Washington is challenged by the co-location of people, critical assets, and natural hazard-prone areas – all three of which are increasing over time.

3.1.a. Avalanche

Situational overview

In Washington, avalanches can occur in our four mountain ranges – the Cascade Range, Olympic Mountains, Blue Mountains, and Selkirk Mountains, typically above 2,000 feet in elevation. However, for this update our avalanche hazard analysis has focused on the avalanche hazard zones identified by the Northwest Avalanche Center (NWAC, 2022) (Figure 6) which includes the Cascade Range and Olympic Mountains only. This is due to limited avalanche-related spatial data available for other parts of the state, which is a data gap we hope to fill in the future to improve our avalanche hazard and vulnerability analysis.

The typical avalanche season begins in November, continuing into early summer for all mountainous areas. In the high alpine regions of the state – primarily in the Cascades and Olympics – avalanches are a year-round event. Table 6 below summarizes the location, extent, and previous occurrences of avalanches in Washington. Table 7 provides a summary of the probability of future avalanches and projected changes in location, extent, intensity, frequency, and/or duration based on the influence of climate change, population growth, and other external factors. Other key findings from the avalanche hazard analysis include:

- Estimated population within avalanche hazards zones: between 70,000 and 75,000
- Projected population within avalanche hazard zones by 2050: between 77,000 and 79,000
- Estimated socially vulnerable population within avalanche hazard zones: 21,000
- Estimated population exposed to the direct or indirect impacts of avalanches: 250,000
- Estimated State-owned or -leased facilities within avalanche hazard zones and dollar value: 540, $121 million
- Estimated miles of public roads in avalanche hazard zones: 2,400
- Critical intermodal transportation facilities in avalanche hazard zones: 0
- Number of licensed hospitals in avalanche hazard zones: 1
- Number of first responder facilities in avalanche hazard zones: 59
- Number of power plants and miles of electric power transmission lines in avalanche hazard zones: 23 power plants, 1,300 miles of transmission lines
- Number of public drinking water supplies in avalanche hazard zones: 1,240
- Number of publicly owned wastewater treatment plants in avalanche hazard zones: 0

Table 6. Overview of location and extent of previous avalanches.

Location	Possible Extent (Magnitude/Severity)	Previous Occurrences
Mountainous areas statewide	Category 5 (extreme) avalanches are possible in WA, based on likelihood, size, and distribution of avalanche activity	No recent declarations for avalanche, but avalanche activity is an annual event in the mountainous areas of the state

Table 7. Overview of the probability of future avalanches, projected changes in avalanche impacts, and the jurisdictions most at-risk to avalanches.

Probability	Projected Changes	Region Most At-Risk
< 1% chance of an avalanche-related disaster declaration each year	Regional research on climate impacts to avalanche activity is missing, though climate change is expected to result in decreased snowpack in WA – as much as a 70% decrease by 2080 compared to 2006. Year-to-year variability in precipitation makes it difficult to predict snowfall rates with accuracy. However, given the overall expectation of warmer winters, avalanches that put people and/or assets at risk may become rarer.	Puget Sound & Northwestern

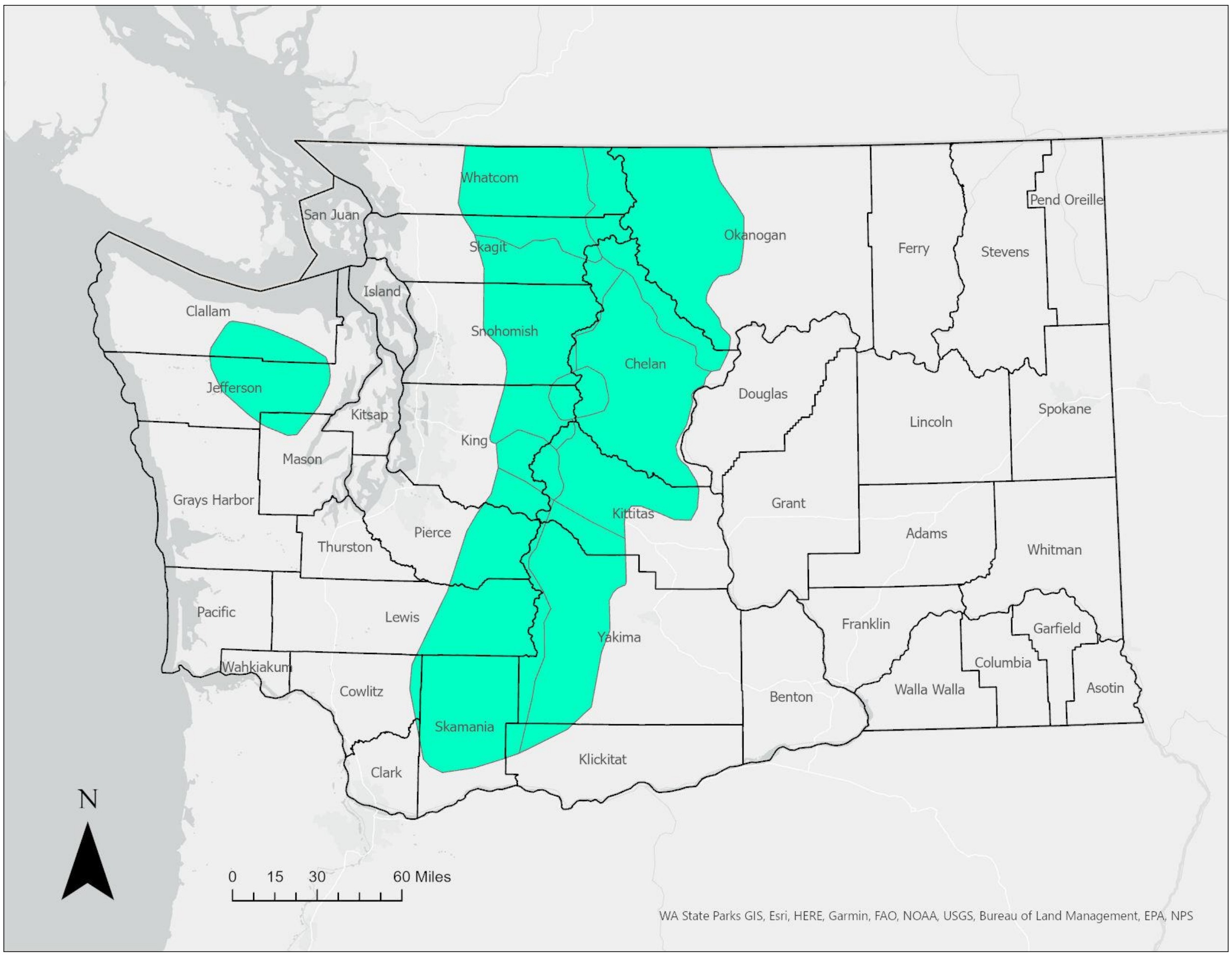

Figure 6. Avalanche hazard zones according to the Northwest Avalanche Center.

Avalanche hazard and vulnerability analysis

Avalanches around the world are tied to severe winter storms because precipitation and air temperatures during storms, as well as prior snow conditions, influence the frequency and types of avalanches. Because of this, climate change is expected to have an impact on avalanche activity though this has not been fully evaluated, especially in high alpine areas above the tree line. Research indicates that less snow because of climate change may not result in fewer avalanches (Ballestros-Canovas et al., 2018), but regional predictions are still needed. However, it is currently believed that avalanches will decrease at lower elevations because of the high rate of warming in lower elevation mountainous areas around the world (Hock et al., 2019). The avalanches that do occur are going to be more likely associated wet snow, even in winter.

Between 1960 and 2017, Washington experienced 129 avalanche events resulting in property losses worth $2.7 million. The counties of King, Pierce, Lewis, and Whatcom experience the most avalanches, largely due to the terrain in these counties, including multiple skiing destinations. In North America, avalanche accidents primarily involve winter sports enthusiasts, with at least 90% of avalanches that involve injury or death being triggered by recreational activity (Stapazzon et al., 2021). Even if climate change decreases avalanche hazards over time, the frequency of human-triggered avalanches might not decrease if winter sports remain popular in Washington.

State-owned or -leased facilities

There are approximately 540 State-owned or -leased facilities in the NWAC avalanche hazard zones, which is 4.6% of all State facilities. Use types for these properties include residential buildings, offices, and educational facilities (among other types). The counties with the most State facilities in avalanche hazard zones are Chelan (n=129, 24%), Kittitas (n=89, 16.5%), Okanogan (n=74, 13.7%), and Yakima (n=73, 13.5%). Total estimated dollar value of State facilities in avalanche hazards zones is $121 million.

Critical infrastructure

- **Transportation.** Although only about 3.5% of the state's public roads fall into the NWAC avalanche hazards zones (~2,400 miles), several are critical transportation routes, including heavily used mountain passes, such as Snoqualmie Pass (Interstate 90) and Stevens Pass (US Highway 2), that serve as vital east-west linkages for people and commerce. Many important railroads also pass through these areas, with 3% of the state's total railroad lines intersecting with avalanche hazard zones. Aside from the actual roads and railroads, there are no critical intermodal facilities located in avalanche hazard areas.

- **Health & safety.** There is one hospital located in the avalanche hazard zones: Cascade Medical Center in Leavenworth (Chelan County), although it is unclear how likely it is that an avalanche would directly impact this facility. There are 55 fire stations (4% of all fire stations in WA) and four police stations (1%) located in the NWAC avalanche hazard zones. However, like the Cascade Medical Center, it is unclear if these facilities are likely to be directly impacted by avalanches given their specific locations. Access routes to these facilities are sometimes located near steep slopes that could be prone to avalanches.

- **Energy.** There are more than 1,300 miles of power transmission lines in the NWAC avalanche hazard zones (~8% of state total). There are 23 power plants in the avalanche hazard zones (14.5% of state total). Most of those 23 power plants and/or their access roads are at the base of, or are adjacent to, steep slopes along the western side of the Cascade Range prone to avalanches, especially in King and Whatcom Counties.

- **Water & wastewater.** The total number of public drinking water supplies (groups A and B) within avalanche hazard zones is 1,240 (~7% of all drinking water supplies in the state). Most of these supplies are in Central Washington, especially in Chelan, Kittitas, and Okanogan Counties. There are no publicly owned wastewater treatment facilities in the avalanche hazard zones.

Population

Population estimates in the avalanche hazard zones are difficult to determine given that Census tract shapes do not always align with the actual distribution of people, especially in rural areas such as the avalanche hazard zones. The Census tracts that do overlap with the avalanche hazard zones have an approximate population of 250,000, but most of their total area is outside the avalanche hazard zones. As such, the actual number of residents in the avalanche hazard zones on a consistent basis is likely much lower. Using population projection data (Gao, 2017), we estimate the population of the avalanche hazard zones to currently be between 70,000-75,000, with expected increases to 77,000-79,000 by 2050.

The median social vulnerability ranking for these residents is 0.48, which is slightly below the state average (0.50). Of those 70,000-75,000 people, we estimate about 21,000 (or 28%) are considered socially vulnerable, with an SVI rank of 0.75 and above. Most of those socially vulnerable people reside in Central Washington, namely Chelan and Okanogan Counties. The primary drivers of their social vulnerabilities are socioeconomic, including higher rates of poverty and unemployment and lower rates of education. Many of these same residents are also exposed to various environmental health disparities, including diminished air quality and lower-than-average birth weights. However, avalanches are likely to exacerbate these social and environmental vulnerabilities only minimally.

The region most at-risk for avalanche hazards is Puget Sound & Northwestern Washington. The counties of King, Pierce, Lewis, and Whatcom experience the most avalanches, largely due to the terrain in these counties, including multiple skiing destinations that place more people at risk than in other parts of the state. Although Central Washington has more critical assets within the NWAC avalanche hazard zones, it is difficult to determine exactly to what extent those assets are exposed to avalanche hazards. An analysis of previous avalanches suggests Puget Sound & Northwestern Washington is most likely to be impacted directly by avalanches.

3.1.b. Drought

Situational overview

Drought, defined by state statue as below 75% of normal water supply for a given area, is a widespread natural hazard in Washington. Among the most significant impacts of drought in Washington are the affects it can have on agricultural activity, fisheries health, and drinking water supply. The most significant drought exposures and extents are found east of the Cascade Range, which includes many counties that are predominantly agricultural.

Between 1980 and 2022 there were 10 official drought declarations in the state. This was used to establish the annual probability of a drought declaration in the table below, but it should be noted that such declarations are not entirely based on objective biophysical metrics. Declarations are the result of a hydrometeorological component as well as a consideration of potential hardship, the latter of which may be subjective in nature.

The most recent State-level drought emergency declaration was issued on July 24, 2021, and covered virtually the entire state (aside from parts of King, Pierce, and Snohomish Counties). Streamflows, groundwater levels, and recent precipitation (e.g., previous 90 days) were far enough below normal, with forecasts indicating little likelihood of improved conditions, to warrant a drought declaration.

Table 8 summarizes the location, extent, and previous occurrences of droughts in Washington. Table 9 provides a summary of the probability of future droughts and projected changes in location, extent, intensity, frequency, and/or duration based on the influence of climate change, population growth, and other external factors. Other key findings from the drought hazard and vulnerability analysis include:

- Estimated population exposed to severe drought: 2 million
- Estimated population exposed to severe drought by 2050: 2.4 million – 2.5 million
- Estimated socially vulnerable population impacted by severe drought: 1 million
- Estimated population exposed to the direct or indirect impacts of drought: 7.5 million
- Number of power plants exposed to severe drought: 89
- Number of public drinking water supplies exposed to severe drought: 7,000
- Number of publicly owned wastewater treatment facilities exposed to severe drought: 2

Table 8. Overview of location and extent of previous droughts

Location	Possible Extent (Magnitude/Severity)	Previous Occurrences
Statewide, with the most frequent droughts primarily in Eastern Washington	Hydrologic drought in WA is determined when a geographic area receives less than 75% of its normal (median) water supply; the 2015 drought declaration was statewide in scale	2022, 2019, 2015, 2006, 2005, 2001, 1994, 1992, 1988

Table 9. Overview of probability of future droughts, projected changes in drought impacts, and jurisdictions most at-risk to drought

Probability	Projected changes	Region most at-risk
24% chance of a drought-related disaster declaration each year	Drought (including "abnormally dry" classification) is expected to increase in extent, intensity, frequency, and duration in WA, driven primarily by climate change. The geographic distribution of drought hazards is expected to increase, with western WA becoming more drought prone as climate change continues. However, the primary area at-risk to the most severe droughts continues to be east of the Cascades. Drought intensity was an especially high in 2021, with 100% of the state classified as at least abnormally dry that September, including 45% classified as experiencing "extreme" drought.	Central

Drought hazard and vulnerability analysis

According to a 2015 report from the Department of Homeland Security (DHS, 2015), the most vulnerable sectors to drought include water/wastewater and energy. As such, our assessment will focus primarily on those sectors and less so on transportation, health, and safety. Additional discussion will focus on potential impacts to agricultural production.

Although much of the state has experienced some form of drought in recent memory, including abnormally dry conditions, the areas most affected by severe drought is east of the Cascade Range. For the purposes of this hazard and vulnerability analysis, we focused only on the U.S. Drought Monitor drought classifications of severe (D2), extreme (D3), and exceptional (D4) drought in Washington, which may differ from the definition of drought in state statute. For example, it is possible for the US Drought Monitor to identify an area as D2 without a drought declaration from the state because the state considers potential hardship before making a declaration. We used data from the U.S. Drought Monitor's most recent complete year (2021) to assess drought risks and vulnerabilities (U.S. Drought Monitor, 2022).

Based on monthly data from the U.S. Drought Monitor, more than half of the state experienced at least severe drought conditions at some point in 2021 (Figure 7), including every county east of the Cascades. West of the Cascades,

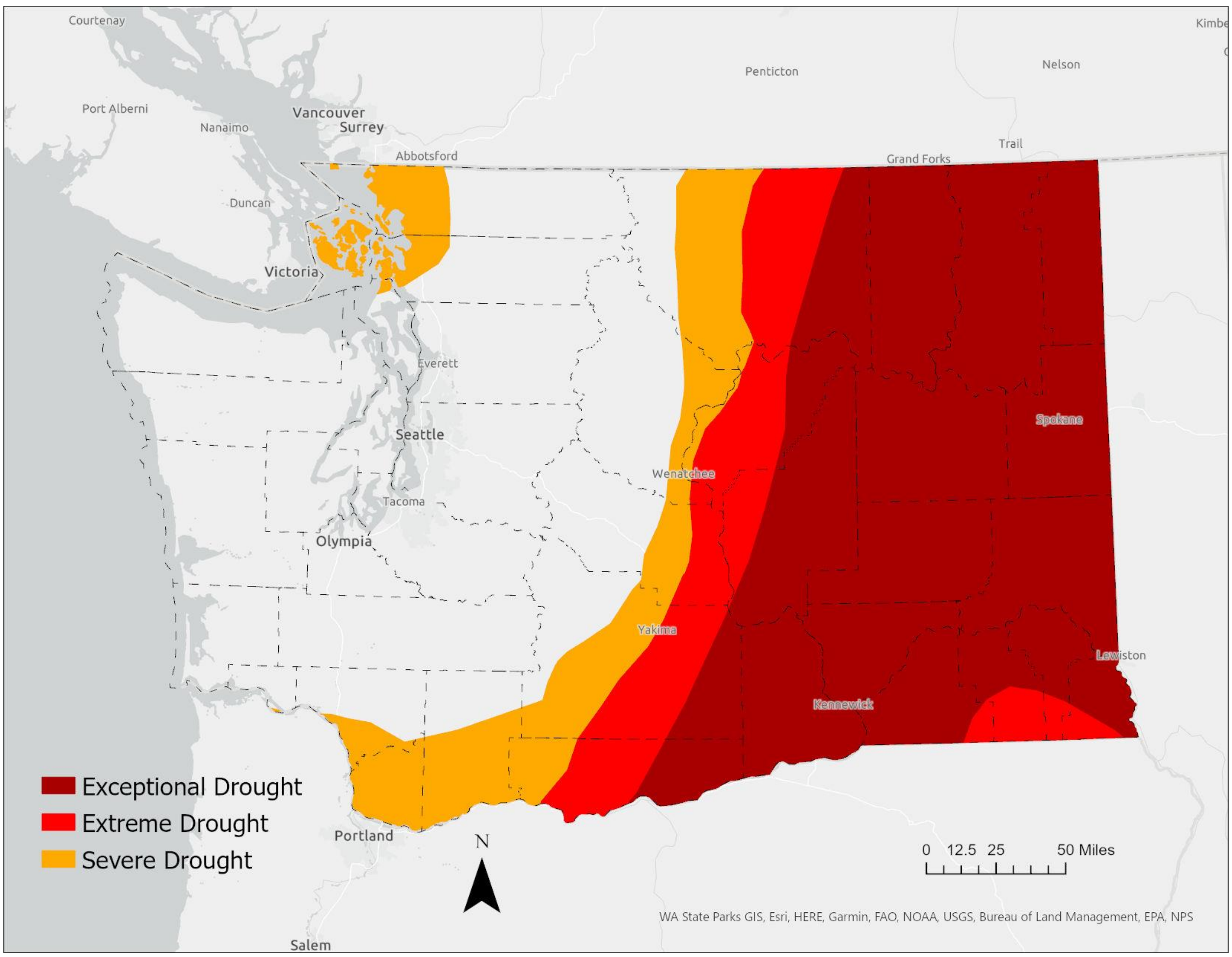

Figure 7. Shaded areas represent at least severe drought conditions (U.S. Drought Monitor class DM2 or above) during 2021. Not all areas experienced severe+ drought the entire year. Portions of Benton, Grant, Kittitas, Klickitat, and Yakima Counties did experience severe drought (or worse) throughout all of 2021. Although not mapped above, much of western Washington experience abnormally dry conditions and were included in the July 2021 drought emergency declaration.

virtually all of San Juan and Clark Counties experienced a minimum of severe drought, as well as portions of Cowlitz, Island, Skagit, Skamania, Wahkiakum, and Whatcom Counties. There are portions of Benton, Grant, Kittitas, Klickitat, and Yakima Counties that were under severe drought (or worse) conditions for all of 2021. There were about four months of exceptional drought in 2021, roughly from August through November. Drought conditions harmed agricultural production significantly in eastern Washington. In August, 93% of wheat and 66% of barley crops were reported by producers in Washington as being in very poor or poor condition (Tinker & Gutzmer, 2021). Drought also contributed to excessively dry vegetation and soil, which allowed for the potential for wildfires all over the western US (Tinker & Gutzmer, 2021).

Exceptional drought impacted 36% of the state in 2021, including every county in the Eastern region. Extreme drought impacted 45% of the state (again including every Eastern region county), while severe drought impacted 53% of the state and included numerous central and western Washington counties.

Although virtually all the state is exposed to some level of drought conditions, drought's direct near-term impact on the average Washington resident is relatively minor. However, long-term drought can lead to indirect public health concerns (e.g., drinking water shortage, diminished air quality) that can be difficult to monitor and assess, especially among the state's very small and potentially unmapped water systems. Due to drought's complex nature and multiple dimensions, as well as direct and indirect relationships with other natural hazards, drought risk is often reduced to its environmental impact (e.g., agricultural impacts) (Hagenlocher, et al., 2019). In this update, we attempt to draw connections between drought exposure and vulnerability while acknowledging that physical vulnerability of a given structure (e.g., a police station, power transmission line) to drought is unknown at this time and may in fact be minimal. Because drought has been tied to clear social and environmental impacts, we prioritized social vulnerability to drought in our analysis, including potential impacts on drinking water supplies.

State owned or leased facilities

Approximately 43% of all state owned or leased facilities (n=4,378) are within the areas that were exposed to a minimum of severe drought in 2021. Over 2,000 of these facilities are classified as educational. Other common use types in the severe drought area are recreational, agricultural, and non-commercial forests. Total estimated value of state facilities exposed to severe drought in 2021 is $46 billion.

Total estimated value of all properties, including privately-owned real estate, located in the 2021 severe drought-impacted areas is $262 billion. It should be noted, however, that drought is less likely to directly impact State facilities. This figure does not account for estimated value of agricultural products.

Critical infrastructure

- **Transportation:** The potential impact of drought on roads is indirect, with primary drought-related road impacts being associated with extreme heat that can accompany drought conditions (DHS, 2015). Although there are many miles of roads located in drought-impacted parts of Washington, the drought-specific impacts are minimal. As such, it can be assumed that roads and transportation facilities are less vulnerable to drought.

- **Health & safety:** Like transportation infrastructure, the vulnerability of police, fire, and healthcare facilities to drought-specific impacts is assumed to be minimal and was not assessed in this update.

- **Energy:** More than half (56%, n=89) of the state's power plants are in the areas impacted by severe (or worse) drought in 2021. Of those, 42 are conventional hydroelectric power plants whose energy production capacity is vulnerable to drought. Most of these conventional hydroelectric power plants are in the Central region (62%) followed by the Eastern region (33%). Grant and Yakima Counties have the most hydroelectric power plants in the drought impact areas of any single county, with 5 in each. Drought is less likely to impact the functionality of power transmission lines, though drought-associated impacts (e.g., extreme heat) could have some effect (Harto, et al., 2012).

- **Water & wastewater:** There are approximately 7,000 public drinking water supplies (groups A and B combined) in the areas impacted by severe (or worse) drought in 2021, which is about 41% of all drinking water supplies in the state. Of those 7,000, almost half (47%, n=3,300) are in the Central region, particularly in the Yakima Basin, while 18% (n=1,236) are in the Eastern region. The remaining 35% of the drinking water supplies in drought-impacted areas are spilt between the Puget Sound & Northwestern region and the Olympic Peninsula & Southwestern region. The counties with the most public drinking water supplies within the 2021 severe (or worse) drought zones are Yakima, Benton, and Spokane. There are two publicly owned wastewater treatment facilities in the 2021 drought zones, both in Yakima County.

Population

Estimated total population within the severe (or worse) drought zones in 2021 is 2 million. By 2050, this number could increase to 2.4 – 2.5 million. These residents have an above average social vulnerability ranking of 0.56 (state average is 0.50). The most influential factor driving the above average social vulnerability is lower per capita income levels. Also contributing are higher rates of poverty and lower average education levels. There are a few clusters of socially vulnerable populations that are also exposed to several environmental and health disparities in addition to drought impacts. Clusters are in Vancouver (Clark County), Yakima (Yakima County), Kennewick (Benton County), Pasco (Franklin County), and Spokane (Spokane County). These environmental health disparities include the potential environmental effects of lead in housing, proximity to Superfund sites, and diminished air quality (e.g., higher particulate matter and ozone concentrations).

The region most vulnerable to the impacts of drought is the Central Washington region. This determination is based on the number of critical assets (e.g., drinking water supplies and power plants) exposed to severe, extreme, and exceptional drought in recent years. Additionally, there is a significant population of socially vulnerable residents in the Central Washington region whose vulnerabilities could be easily exacerbated by drought impacts, particularly regarding drought-driven declines in drinking water availability or quality. For example, water shortages are expected to occur more frequently in the Yakima Basin soon, so much so that demand may eventually become greater than available supply (Washington Department of Ecology, 2022). Many of these same residents in Central Washington also live in areas with already diminished air quality, which has been shown to further decline under drought conditions (Wang, et al., 2017). However, many of these same issues can be found in Spokane County, in the Eastern Washington region, elevating that county's risk for drought impacts. It is also known that drought impacts on Washington agriculture are prevalent in both the Central and Eastern regions, though those impacts have not been quantified in this plan update.

Harto et al. (2012) analyzed the impacts of drought on electricity production in the Pacific Northwest and found that power production could decrease as much as 22% during droughts. As climate change continues to increase competition for water supplies, it is possible that our capacity for hydropower will decrease, as much as 11% during the 2020s, while demand continues to increase (Washington Department of Ecology, 2022). The state's hydropower resources provide most of our electricity (approx. 66%), making much of our energy production in Washington directly vulnerable to drought conditions.

3.1.c. Earthquake

Situational overview

Washington remains as the number two state in the country for assets exposed to earthquake impacts (with California number one). Given the geological nature and location of Washington, earthquakes are recorded here daily, but almost all earthquakes are too small to be felt without instrumentation. Since 1870, there have been 27 earthquakes of moderate size or larger (M5 or greater) in Washington, with the most recent events in 2001 (M6.8 in Feb. 2001 and a M5 in June 2001).

Although strong earthquakes capable of causing significant damage in Washington can occur from multiple faults located throughout the state, the fault with the potential for generating the most catastrophic earthquake possible in Washington is the Cascadia Subduction Zone (CSZ). Over the last 10,000 years, there have been 41 large-scale events along the CSZ, with 19 of those thought to be full-scale ruptures of the CSZ generating a M9.0 earthquake (Goldfinger, et al., 2012). The most recent full-scale rupture of the CSZ was in the year 1700. Because of its statewide implications, use in emergency planning at the State and local levels, and use as a reference against which earthquake hazard mitigation activity is conducted, the bulk of our hazard and vulnerability analysis below uses a CSZ event to assess seismic risk and vulnerability. We acknowledge that other types of earthquakes exist in Washington, including deep and crustal earthquakes, which happen more frequently than CSZ earthquakes. More detailed information on earthquake characterization can be found in materials developed by the Washington Department of Natural Resources.

Table 10 below provides an overview of the location and extent of previous earthquakes (since 1980), while Table 11 summarizes the probability of an earthquake-related disaster declaration each year, project changes to earthquake impacts, and the region most at-risk. Other key findings from the earthquake hazard and vulnerability analysis include:

- Estimated population within high hazard seismic zones: 5.7 million
- Projected population within high hazard seismic zones by 2050: 6.4 million – 6.6 million
- Estimated socially vulnerable population within high hazard seismic zones: 2.6 million
- Estimated population exposed to the direct or indirect impacts of earthquakes: 7.5 million
- Estimated State-owned or -leased facilities within high hazard seismic zones and dollar value: 7,300, $108 billion
- Estimated miles of public roads located in high hazard seismic zones: 32,000
- Critical intermodal transportation facilities located high hazard seismic zones: 21
- Number of licensed hospitals in high hazard seismic zones: 71
- Number of first responder facilities in high hazard seismic zones: 1,071
- Number of power plants and miles of electric power transmission lines high hazard seismic zones: 73 power plants, 7,300 miles of transmission lines
- Number of public drinking water supplies in high hazard seismic zones: 11,000
- Number of publicly owned wastewater treatment plants in high hazard seismic zones: 4

Table 10. Overview of location and extent of previous earthquakes

Location	Possible extent (magnitude/severity)	Previous occurrences
Statewide, with the most pronounced impacts felt in western WA	2001 event was M6.8; there is potential for a M9.0 event from the Cascadia Subduction Zone (CSZ)	2001 (DR-1361)

Table 11. Overview of probability of future earthquakes, projected changes in earthquake impacts, and jurisdictions most at-risk to earthquakes

Annual probability	Projected changes	Region most at-risk
2.5% chance of an earthquake-related disaster declaration each year	Exposed population and property will increase as earthquake-prone areas see continued population growth and development (e.g., Seattle-Tacoma region). Projected population growth in the state suggests 6.5 million people will reside in high hazard seismic zones by 2050, an increase of 14% compared to 2020.	Puget Sound & Northwestern

Earthquake hazard and vulnerability analysis

According to a dataset provided by Washington Geological Survey (WGS, 2019A) of earthquake damage from the three most recent damage-causing earthquakes in Washington (April 1949, April 1965, and February 2001), such damage was largely restricted to west of the Cascade Range except for one known incident of damage in Roslyn (Kittitas County) in the 1965 quake. We analyzed the locations of previous earthquake damage to determine where significant clusters of damage have occurred and found three such clusters – one each in Seattle (King County), Tacoma (Pierce County), and Olympia (Thurston County) (Figure 8). Based on previous damage and density of development (and expected continued development), these areas remain among those across Washington with a high likelihood of experiencing damage from an earthquake in the future.

Based on seismic hazard maps from the U.S. Geological Survey (current as of 2022), the areas of Washington most susceptible to the impacts of seismic activity are still west of the Cascade Range. Although seismic risks do exist east of the Cascades, our analysis focused on western Washington given the level of exposure there and potential for catastrophic earthquakes. However, it should be noted that damaging earthquakes have occurred in eastern Washington (as recently as 1936) and that earthquake risk can be high for some eastern Washington localities.

We used data on peak ground acceleration (PGA), which is a way to measure the likely intensity of an earthquake (Figure 9). The areas shaded in the darkest shades in Figure 9 reflect high PGA values with a 2% chance of being exceeded within the next 50 years (USGS, 2018). This area is also referred to in this Plan as the "high hazard seismic zone." According to this data, every county west of the Cascades is exposed to high seismic hazards (approx. 40% of the state). Many of these same places are also susceptible to liquefaction (DNR, 2010) (Figure 10), which can increase the amount of damage caused during intense shaking.

Earthquake prediction and probability

Earthquakes happen at random time intervals with few, if any, scientifically-well tested early warning signs to indicate when one is likely to occur. Determining the probability of a future earthquake in Washington is difficult because of their infrequency and our lack of a long enough record of them to be able to establish reliable recurrence intervals. As a result, we are left to analyze their occurrence data to help identify patterns that may be helpful for planning and decision-making. However, pattern detection can be misleading (e.g., pattern recognition bias) and we need to be careful when basing decisions on them. Even with sophisticated analyses, earthquakes remain notoriously unpredictable.

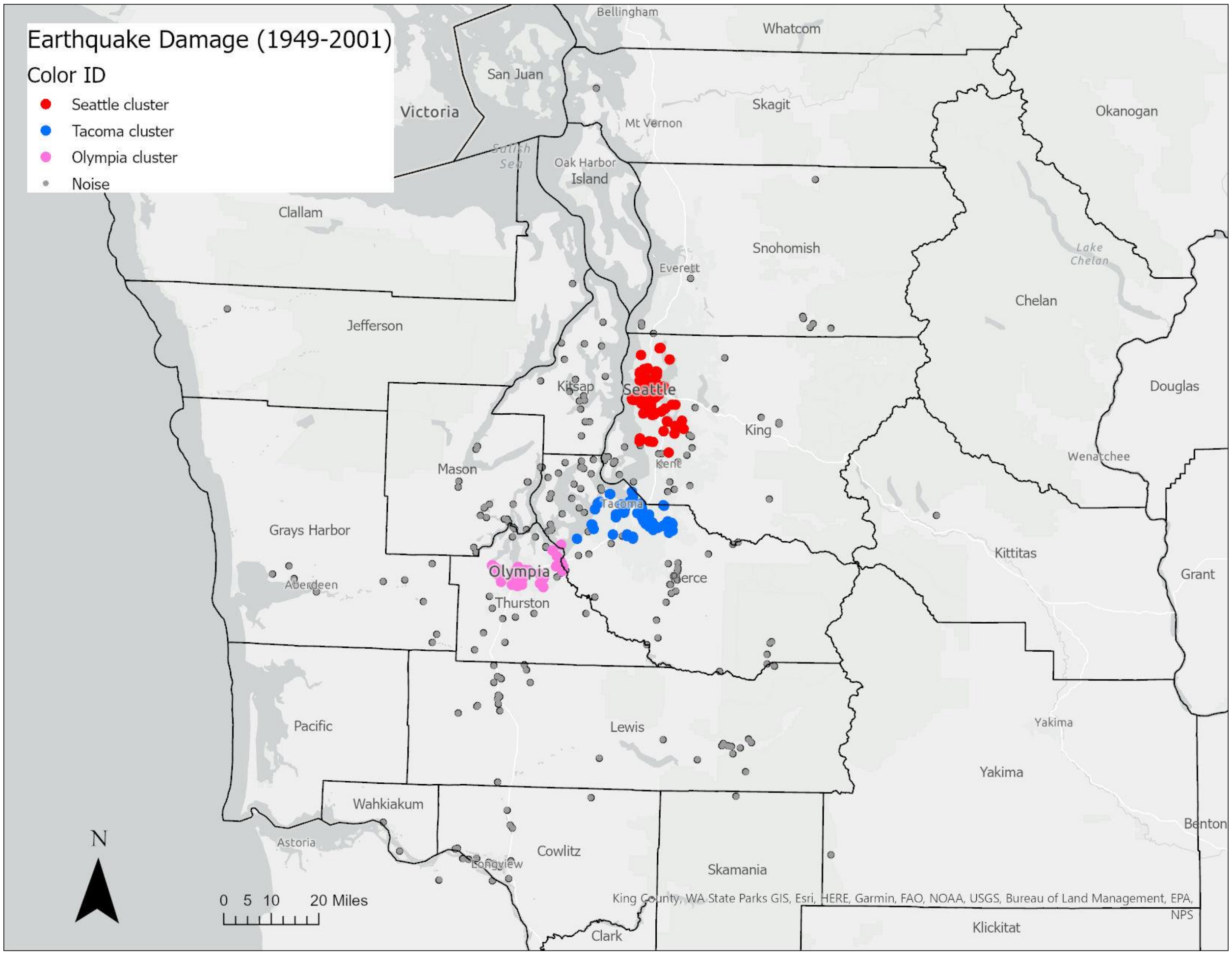

Figure 8. Locations of recorded earthquake damage from 1949 to 2001. Significant clusters of damage are represented by colored points (red, blue, pink) (WGS, 2019A).

For example, there is an often-cited recurrence interval for CSZ earthquakes that one occurs, on average, every 247 years. This is based on calculating the average duration between the 41 CSZ events (also called interevent periods), most of them not full-scale ruptures, discovered by Goldfinger et al. (2012). However, it should be noted that there is variation of interevent period durations (Figure 11) that makes the 247-year recurrence interval an unreliable planning metric. In other words, some interevent periods were much longer than 247 years and some were much shorter, meaning no discernible regularity in interevent period length can be determined. Additionally, Goldfinger et al (2012) found that there is no apparent relationship between interevent period length and earthquake strength.

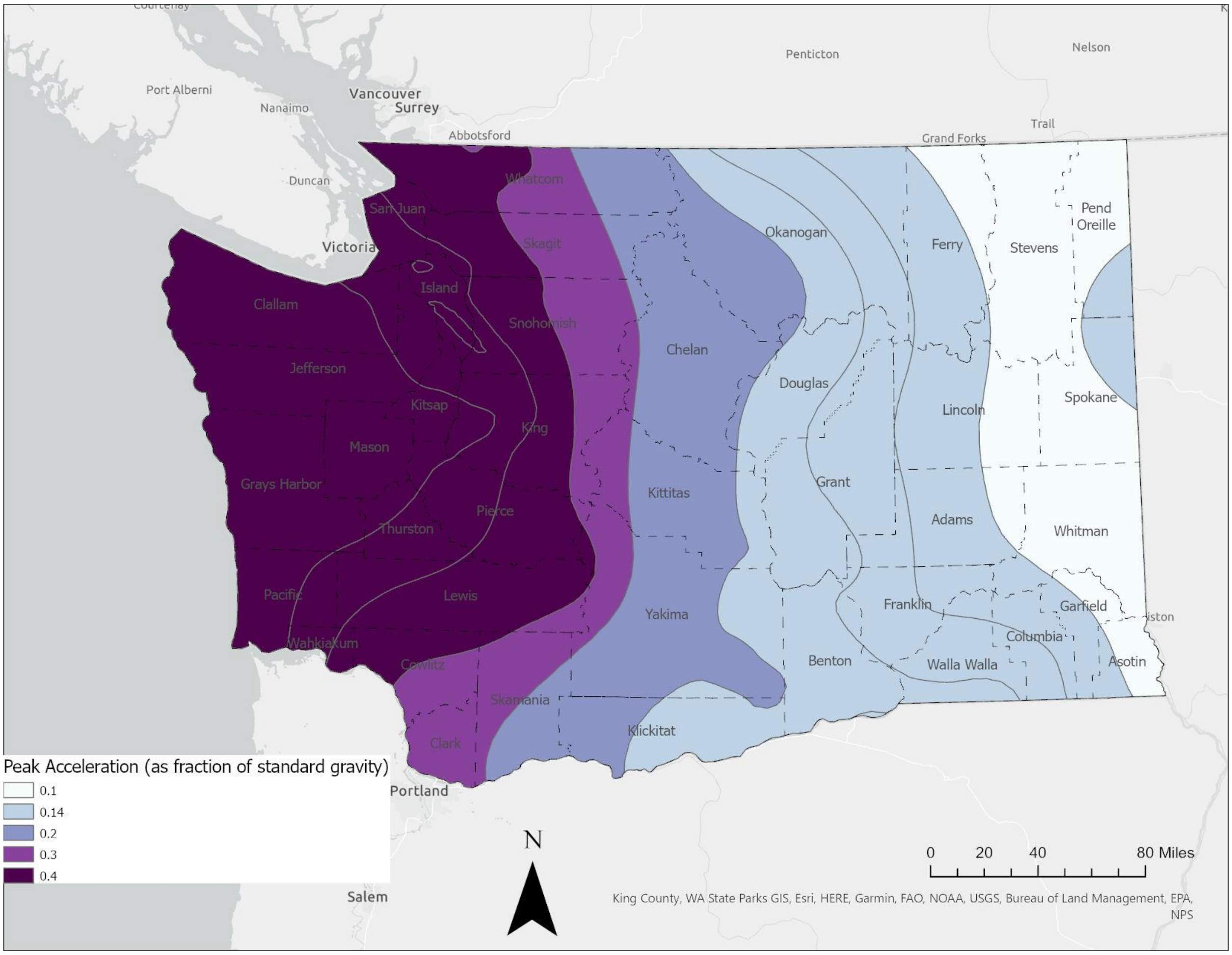

Figure 9. Peak ground acceleration (PGA) values for Washington. These PGA values are estimated as having a 2% chance of being exceeded in the next 50 years (USGS, 2018).

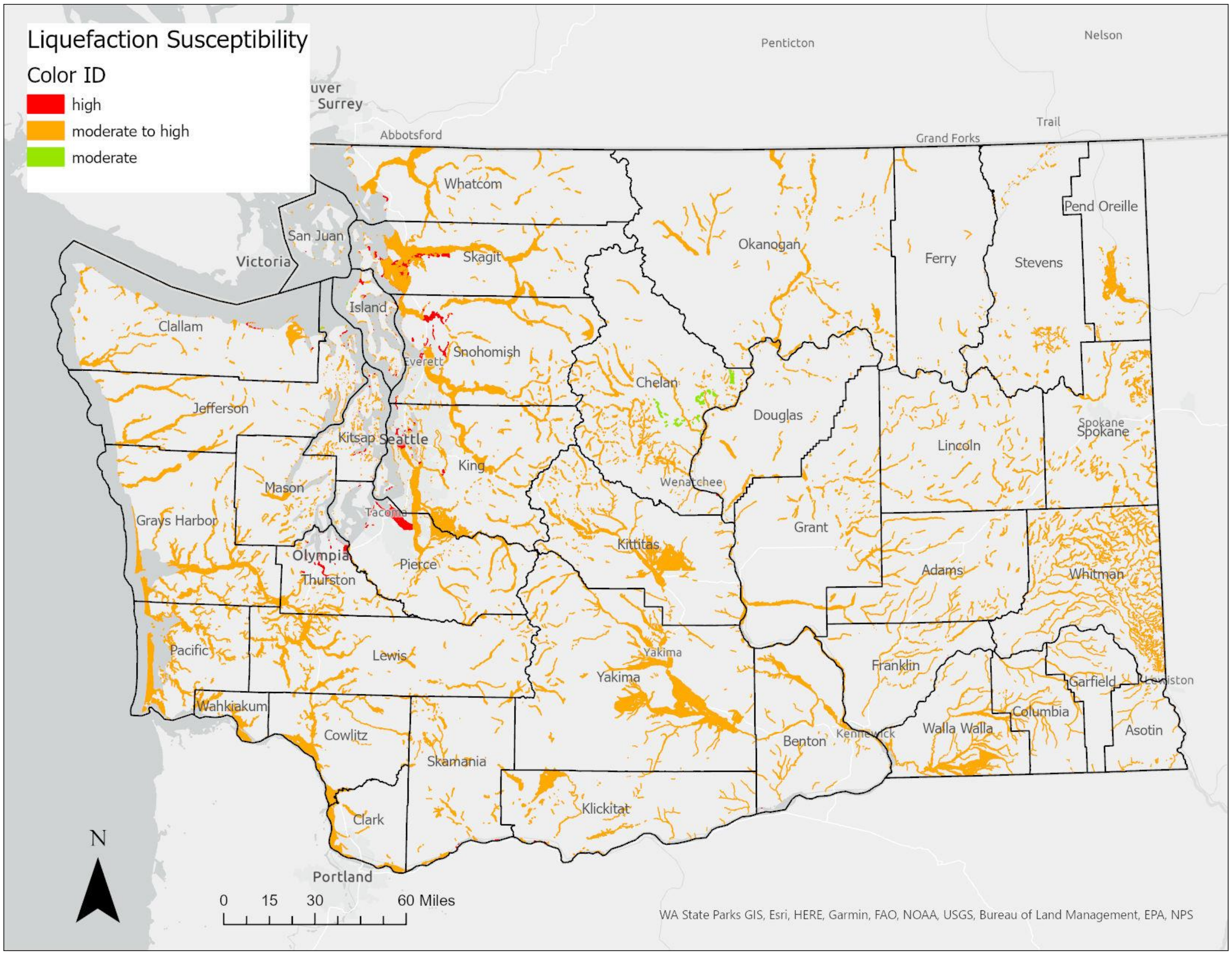

Figure 10. Areas susceptible to liquefaction across Washington (DNR, 2010).

<u>*State-owned and -leased facilities*</u>

Approximately 65% (n= 7,300) of all State-owned and -leased facilities are in areas exposed to high seismic hazards. Total estimated value of these facilities is $108 billion. A sub-set of about 1,500 of these facilities are also located in liquefaction zones and may be at the highest risk of damage. Use types for these facilities vary widely and include educational, residential, office, healthcare, recreational, and laboratory uses.

<u>*Critical infrastructure*</u>

- **Transportation:** There are more than 32,000 miles of public roads in western Washington, where exposure to seismic impacts is highest. These include multiple critical transportation routes, including large portions of Interstates 5 and 90 and their feeder roads. More than 5,000 miles of those roads are also in areas with high susceptibility to liquefaction, including 190 miles of I-5 and 70 miles of I-90. There are 21 intermodal transportation assets in the western Washington high hazard area. These include major rail, airport (including Sea-Tac International Airport and Boeing Field), and port facilities (e.g., Port of Seattle, Port of Tacoma, and Port of Port Angeles). All but four are also in liquefaction zones.

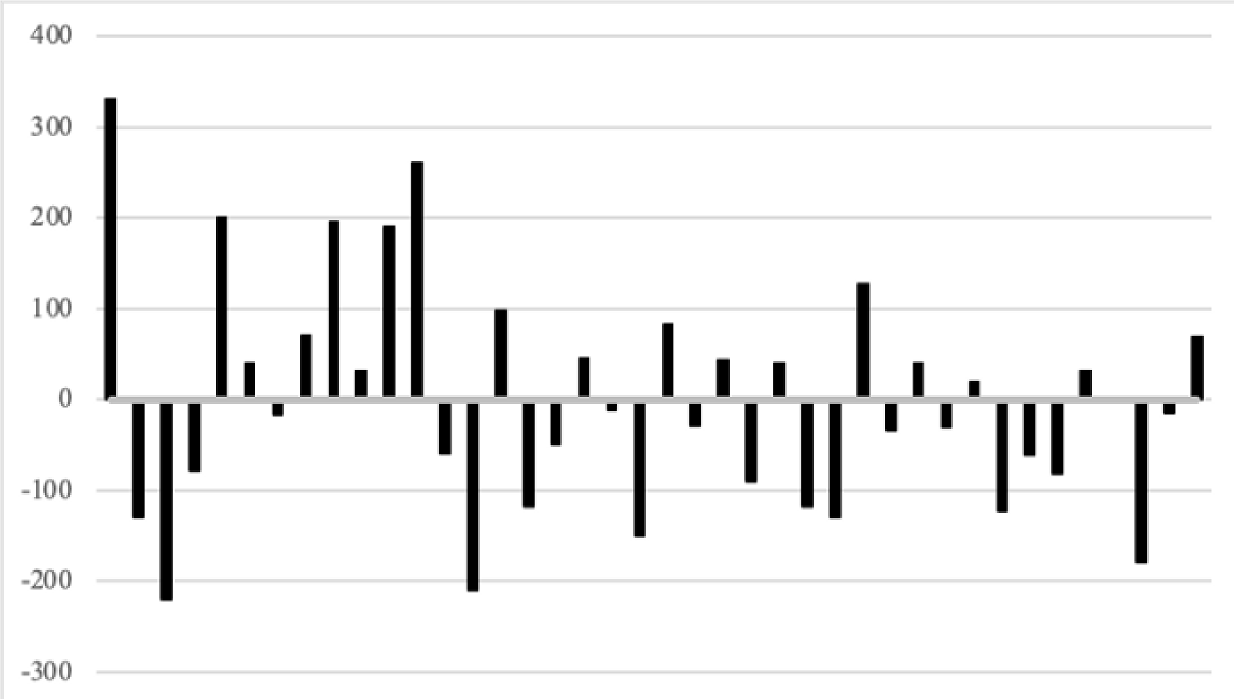

Figure 11. Relative durations between observed interevent periods and the 247-year expectation (shown here as the zero line). Interevent periods longer or shorter than 247 years are reflected here as positive or negative bars, with the earliest event going back 10,000 years on the left side and the most recent event in 1700 on the right.

- **Health & safety:** Most of the state's licensed hospitals (n=71, 60%) are in the seismic hazard area covering western Washington, including nearly 13,000 beds. Of those 71 hospitals, eight are also in areas with high susceptibility to liquefaction – two of which are in southern King County (St. Elizabeth in Enumclaw and Auburn Medical Center in Auburn). There are 231 police stations (66% of all police stations in the state) located in the western Washington seismic hazard area. Of those 231, 75 (32%) are also in liquefaction zones. Almost a quarter of those police stations in the liquefaction zones (n=18) are in King County alone. There are 840 fire stations in the western Washington seismic hazard area. Of those, 162 are also in liquefaction zones. The counties with the most at-risk fire stations are King (n=33), Skagit (n=18), Pierce (n=15), and Snohomish (n=14).

- **Energy:** There are about 7,300 miles of power transmission lines in the western Washington seismic hazard area, or about 45% of all power transmission lines in the state. More than 16% (approx. 1,200 miles) of those transmission lines are also in liquefaction zones, including long, nearly continuous sections of line in southern King County/northern Pierce County, southern Snohomish County, and in Skagit County along SR-20. Approximately 46% (n=73) of power plants in Washington are in the western Washington seismic hazard area. Of those 73, 25 are also in liquefaction zones and are at the highest risk of being impacted by an earthquake. Multiple western Washington counties have at least three power plants in liquefaction zones: Cowlitz, Grays Harbor, King, Pierce, Snohomish, and Whatcom.

- **Water & wastewater:** More than 11,000 public drinking water supplies (groups A and B combined) are in the western Washington seismic hazard area. About 14% of these supplies are also in liquefaction zones, with the most significant cluster of at-risk drinking water supplies in King and Pierce Counties. There are four publicly owned wastewater treatment facilities in the high seismic hazard area of western Washington –

two in Pierce County, and one each in King and Snohomish Counties. Only one of these facilities in also in a liquefaction zone: the City of Puyallup (Pierce County) Water Pollution Control Plant.

Population

Western Washington is the state's most populated region, with an estimated 5.7 million residents in the area most prone to damaging earthquakes, including an estimated 1.7 million in western Washington liquefaction zones. Most of these residents are in the Seattle-Tacoma metropolitan area, which is more than 4 million people. We estimate that this area will continue its current trend of population growth, with approximately 6.4 million – 6.6 million residents by 2050.

Although there are pockets of high social vulnerability throughout western Washington, the average social vulnerability ranking for the Census tracts that make up western Washington is below state average (0.46 versus 0.5 state average). This can be interpreted as an estimated 46% of residents in the western Washington seismic hazard area experience some level of social vulnerability to disasters. The most significant clusters of socially vulnerable residents are found in the Seattle-South King County, Tacoma-Lakewood (Pierce County), and Everett-Lynnwood (Snohomish County) areas. The main driver of high social vulnerability is primarily socioeconomics, especially Census tracts where most residents have below average per capita income. Also contributing is the higher number of crowded housing units across western Washington (e.g., residential units with more people than rooms).

The areas that are socially vulnerable within the seismic hazard zone are also exposed to above average environmental health disparities (average rank is 6.62 versus 5.5 for the whole state). Many of these environmental health disparities are common to densely populated urban environments, including diminished air quality from particulate matter, proximity to heavy traffic roadways, lead risk from housing, and proximity to Superfund sites. Many of the residents in these areas have other public health disparities, including higher rates of cardiovascular disease.

The region most at-risk to destructive earthquakes in the future is the Puget Sound & Northwestern region due to the number of critical assets and socially vulnerable population concentrated in that area. Virtually all earthquake-related damage since 1949 has occurred somewhere in western Washington, with the most significant clusters around the cities of Seattle (King County), Tacoma (Pierce County), and Olympia (Thurston County). King, Pierce, and Snohomish Counties have also seen rapid levels of population growth and urbanization over the past 20 years, and that trend is expected to continue – making the Puget Sound region more vulnerable to earthquakes over time. Although there has been great progress made toward seismic resilience in this part of the state, the catastrophic potential of a full-scale CSZ earthquake (although uncommon) cannot be overstated. Such an event would effectively shut down much western Washington's community lifelines, in addition to causing widespread damage to private property and deaths into the thousands (EMD, 2022).

3.1.d. Extreme Weather

Situational overview

Washington is exposed to many weather extremes. These include high winds, heat, cold, thunderstorms, rainfall, and snowfall. Some specific examples of extreme weather types in Washington are atmospheric rivers, tornadoes, heatwaves, and hailstorms, among others. Taken together, these weather extremes account for some of the most common natural hazard events we face in this state. They are often what trigger presidentially declared disasters, with more than 30 weather-related disaster declarations in Washington since 1980 (Table 12).

With continued climate change, we expect some extreme weather to become even more extreme. For example, we know that the Pacific Northwest can expect to see heatwaves, like the June 2021 "heat dome" event, to last longer and have higher temperatures (Philip et al., 2021) as well as atmospheric rivers that dump more rain over shorter periods of time (Gao et al., 2015). For these reasons, we have determined that every county is currently exposed to extreme weather (particularly atmospheric rivers and extreme heat), with likely future increases in frequency, magnitude, and severity driven by continued climate change.

Table 12 below provides an overview of the location and extent of previous weather events. Table 13 summarizes the probability of future weather disasters, as well as projected changes to weather impacts and the jurisdictions most at-risk. Other key findings from the extreme weather hazard and vulnerability analysis include:

- Estimated population within extreme weather hazard areas: 3.7 million
- Projected population within extreme weather hazard areas by 2050: 4.2 million – 4.3 million
- Estimated socially vulnerable population within extreme weather hazard areas: 820,000
- Estimated population exposed to the direct or indirect impacts of extreme weather: 7.5 million
- Estimated State-owned or -leased facilities within extreme weather hazard areas and dollar value: 4,800; $78 billion
- Estimated miles of public roads located in extreme weather hazard areas: 18,000
- Critical intermodal transportation facilities located in extreme weather hazard areas: 14
- Number of licensed hospitals in extreme weather hazard areas: 49
- Number of first responder facilities in extreme weather hazard areas: 674
- Number of power plants and miles of electric power transmission lines in extreme weather hazard areas: 46 power plants; 5,000 miles of transmission lines
- Number of public drinking water supplies in extreme weather hazard areas: 5,600
- Number of publicly owned wastewater treatments plants in extreme weather hazard areas: 2

Table 12. Overview of the location and extent of previous extreme weather events.

Location	Possible Extent (Magnitude/Severity)	Previous Occurrences
Statewide	Known weather extremes in WA include: • High winds (> 100 mph) • Heat (> 110°F) • Cold (< -40°F) • Thunderstorms (incl. lightning, hail, tornadoes) • Rainfall (+14" daily/185" annual) • Snowfall (+65" daily/+300" annual)	2022 (DR-4682, DR-4650); 2021 (DR-4593); 2020 (DR-4539); 2018 (DR-4418); 2017 (DR-4309); 2015 (DR-4253); 2015 (DR-4249); 2015 (DR-4242); 2012 (DR-4083); 2012 (DR-4056); 2011 (DR-1963); 2009 (DR-1825); 2009 (DR-1817); 2007 (DR-1734); 2006 (DR-1682); 2006 (DR-1671); 2006 (DR-1641); 2003 (DR-1499); 1997 (DR-1172); 1997 (DR-1159); 1996 (DR-1152); 1996 (DR-1100); 1995 (DR-1079); 1994 (DR-1037); 1993 (DR-981); 1990 (DR-896); 1990 (DR-833); 1990 (DR-852); 1989 (DR-822); 1986 (DR-784); 1986 (DR-769); 1986 (DR-762); 1983 (DR-676)

Table 13. Overview of future probability of extreme weather disasters, project changes to extreme weather impacts, and the jurisdictions most at-risk to extreme weather.

Annual Probability	Projected Changes	Region Most At-Risk
72% chance of an extreme weather-related disaster declaration each year	Extreme weather events currently average at approx. 1 event/year since 1980. Although no trend has been observed as of 2023, extreme weather is expected to increase in extent, intensity, and frequency, due primarily to climate change. The geographic distribution of extreme weather is also expected to increase (e.g., high-heat events in western WA). Population growth and continued development will put more people and property at risk to extreme weather. Projected population in these areas by 2050 is 4.2-4.3 million.	Puget Sound & Northwestern

Extreme weather hazard and vulnerability analysis

Because Washington is exposed to multiple types of extreme weather, our hazard and vulnerability analysis focused primarily on counties in the state that have experienced more weather-related disaster declarations than others since 1980. Figure 12 shows counties in the 75th percentile for number of weather-related disaster declarations since 1980, which we used as a proxy for understanding where extreme weather exposure is highest. These declarations include atmospheric river events and extreme snowfall. Extreme heat is not currently a natural hazard capable of triggering a presidential disaster declaration, and as such is not captured by this metric.

These counties are referred together throughout this analysis as "extreme weather hazard areas." We felt this was an appropriate framework for this analysis given the challenges driven by the variability of extreme weather incidents and the fact that disaster declarations, by definition, include damages to valuable assets. Most of these declarations were associated with severe storms, such as atmospheric rivers, and their secondary effects – such as flooding and landslides. There is no evidence to suggest that areas of Washington that already commonly experience extreme weather will see declines in extreme weather in the future, so locations where weather impacts have been high in the past will likely remain high in the future. The counties of Lewis, King, Snohomish, and Wahkiakum have all had 19 different weather disasters since 1980, with Grays Harbor having the second-most (17) and Clallam having the third-most (16). The counties with the fewest weather-related disasters are Asotin, Douglas, and Franklin Counties (each with two since 1980). It should be noted that Pierce, Island, and Kitsap Counties are not included because they each fell beneath the 75th percentile for number of weather-related disaster declarations; however, their exposure to extreme weather is assumed to be the same as the other counties nearby.

Given their prevalence and likely increase in the future, we also want to highlight two specific types of weather hazards: extreme heat and atmospheric rivers.

Extreme heat

Periods of high temperatures, including heatwaves, are projected to become more common in the Pacific Northwest (Figure 13). Central and Eastern regions commonly experience temperatures above 90°F each summer, however temperatures that high also occur west of the Cascade Range. Extreme heat is a hazard with a statewide extent, as shown in Figure 14 below illustrating the average temperatures statewide for June 2021. Temperatures well above average can be seen statewide, but especially in most of central and eastern Washington, as well as in urbanized areas in western Washington (e.g., Greater Seattle). The urbanized areas in western Washington are showing as much warmer than the rest of that region due primarily to the phenomenon known as urban heat-island effect. Buildings, roads, and other infrastructure absorb more heat than natural features, such as trees and water bodies. When they radiate that heat back, the effect can be an increase in ambient air temperature around that building, road, or other infrastructure. When such features are clustered, such as in cities, that effect can raise temperatures well above the surrounding non-urban areas, creating a "heat island".

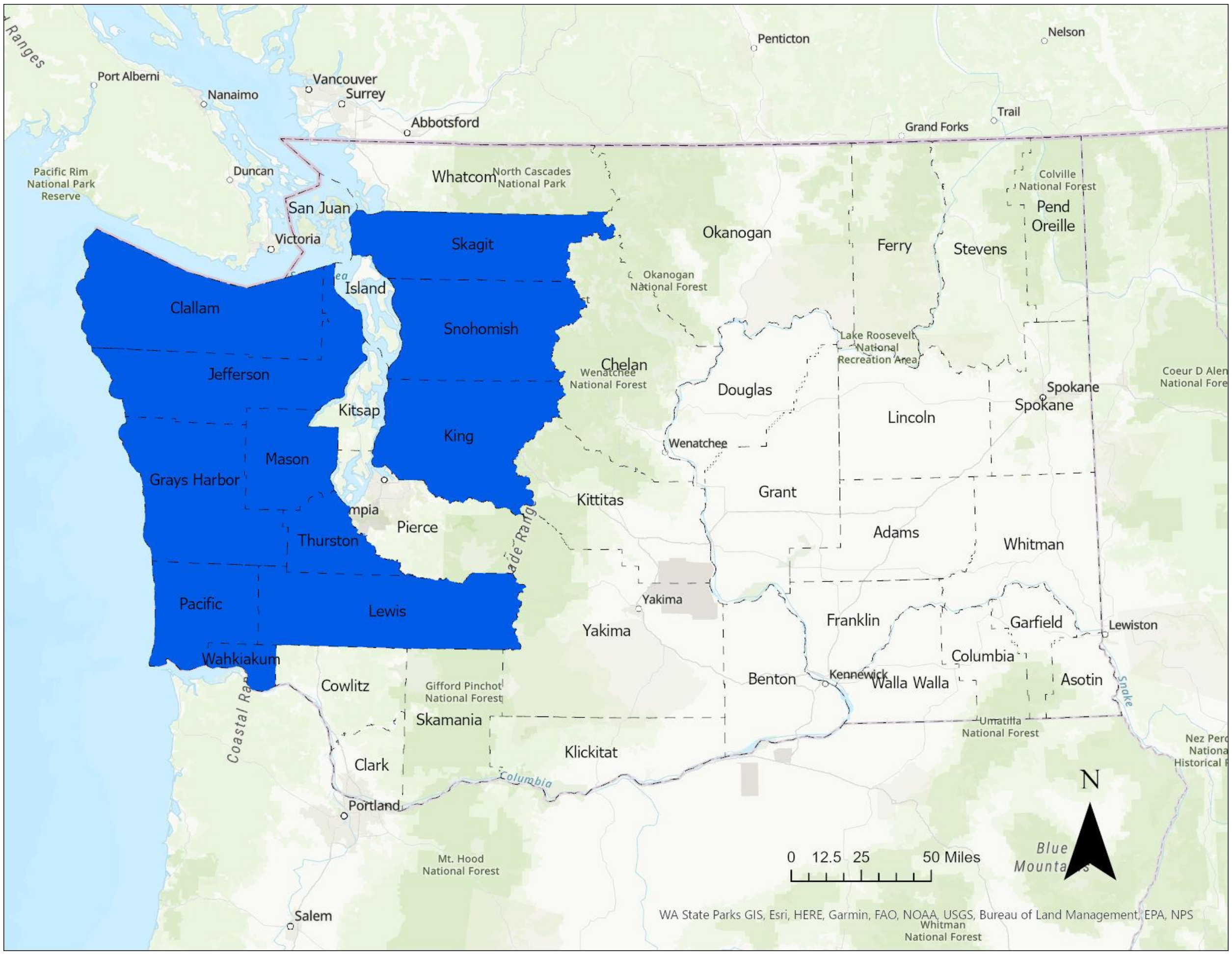

Figure 12. Areas in the 75th percentile for weather-related disasters since 1980. These areas are also referred to herein as extreme weather hazard areas.

Although the recent heat events in Washington had minor impacts on the built environment, the extreme heat in June 2021 revealed that even in historically cooler climates, such as the Pacific Northwest, temperatures can reach levels previously expected to be seen only in the hottest places on the planet (upwards of 110°F). Such heat can pose severe public health risks. Although heat has not been viewed as a traditional natural hazard or disaster incident, the event in 2021 led to the deaths of more than 150 people in Washington – making it the deadliest natural hazard event in our state's history.

Atmospheric rivers

Extreme wind and rainfall in Washington are often associated with atmospheric river events. Atmospheric rivers are long, narrow jets of air that can transport enormous volumes of water vapor from lower latitudes to the Pacific Northwest. When the moist air is forced up by Washington's mountain ranges, high rates of condensation result in heavy rain. In extreme cases, daily rainfall is well above average and can cause substantial flooding and trigger landslides.

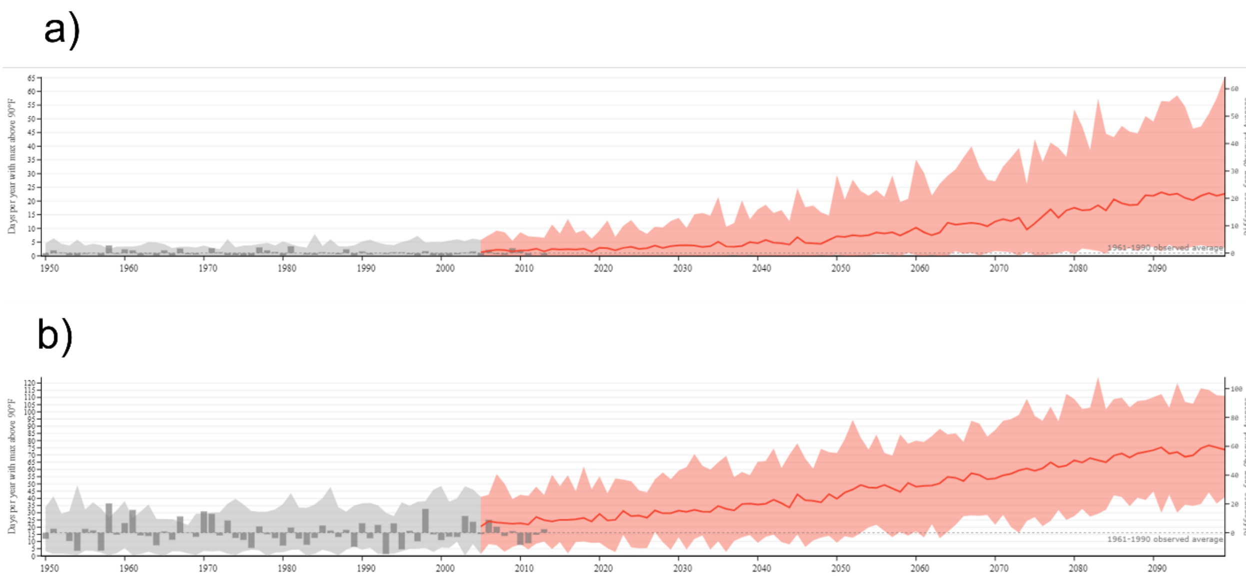

Figure 13. Observed and projected 90+ degree days (F) for King County (a) and Spokane County (b). These graphs show clear upward trends in the number of 90+ degree days each year for both western and eastern Washington areas (NOAA, 2022).

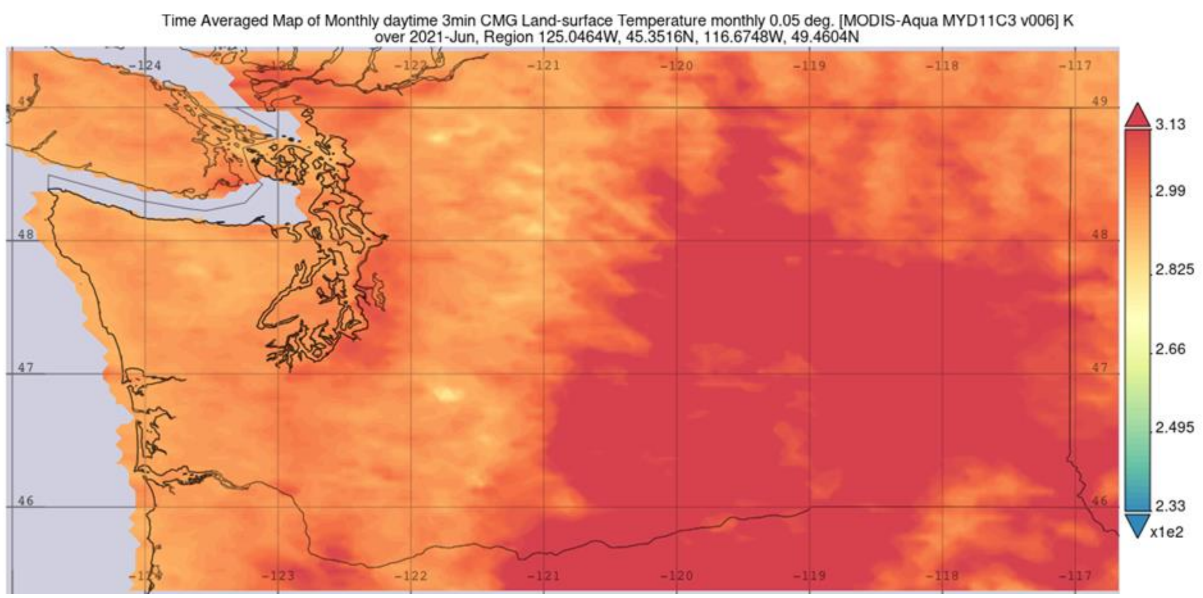

Figure 14. Average surface temperatures (in Kelvin) for Washington in June 2021. The highest temperature shown here is 313 K (107°F), located in the central and eastern portions of the state (Source: NASA/MODIS; visualization created with NASA Giovanni v. 4.35).

Atmospheric rivers also typically include high wind gusts, sometimes reaching hurricane strength. Of the most destructive windstorms globally over the last 20 years, atmospheric rivers were associated with half – totaling more than $25 billion in wind-related damages (Buis, 2017).

__State-owned or -leased facilities__

Our vulnerability analysis for state-owned buildings and critical infrastructure is focused primarily on places with previous weather-related damages (Figure 12). In those counties, there are more than 4,800 state-owned or -leased facilities with an estimated value of $78 billion. Just more than half of these facilities (53%, n=2,555) are in the Puget Sound & Northwestern region – namely in King, Snohomish, and Skagit counties. Their uses range widely, including residential, office, education, and health care. King County alone has more than 1,300 facilities worth an estimated $24 billion.

Critical infrastructure

- **Transportation.** More than 18,000 miles of public roads are in the counties with the most weather disasters, including more than 2,000 miles of national and state highways that serve as vital transportation routes. For example, more than 500 miles of Interstate 5 and about 400 miles of U.S. Highway 101 are in these counties. About 45% (n=14) of critical intermodal transportation facilities around the state are in the counties with the most weather disasters. These include multiple port facilities (Aberdeen, Anacortes, Everett, Olympia, Port Angeles, and Seattle) and multiple cargo airports (Boeing Field, Paine Field, and Sea-Tac International Airport).

- **Health & safety.** Of the state's licensed hospitals, 42% are in counties most impacted by weather disasters – totaling close to 8,000 beds in 49 hospitals. Out of those 49 hospitals, 36 are in the Puget Sound and Northwestern region (73%). About 41% (n=519) of fire stations in Washington are in the counties most impacted by weather disasters. Most of these fire stations are in the Puget Sound and Northwestern region (54%), with King County having the most of any single county (n=166). Approximately 44% of police stations in the state are in the counties most impacted by weather disasters (n=155). Like fire stations, most of those police stations are in the Puget Sound and Northwestern region (61%), with King County again having more than the other counties (n=62).

- **Energy.** More than 5,000 miles of power transmissions lines are in the counties impacted most by weather disasters, with 60% of those lines in King, Snohomish, and Skagit Counties. Of the 158 power plants in the state, 46 (29%) are in the counties most impacted by weather disasters, split evenly between the Olympic Peninsula and Southwestern region and the Puget Sound and Northwestern region.

- **Water & wastewater.** About 33% (n=5,600) of the state's public drinking water supply is in the counties impacted most by weather disasters (including groups A and B). Although these supplies are split evenly between the Puget Sound and Northwestern, and Olympic Peninsula and Southwestern regions, they are more concentrated in the Puget Sound area – particularly in King County. There are two publicly owned wastewater treatments plants in these weather-impacted counties – one each in King and Snohomish Counties.

Population

To assess the level of population exposure to extreme heat, we used the average maximum temperature for June 2021 (PRISM, 2022) – which is among the state's hottest months on record. Some parts of the state reached an average maximum temperature above 91°F that month (Figure 15). The estimated number of people living in the hottest 25% of the state that month is 4 million, or approximately 51% of Washington's population. About 52% of those 4 million people are considered socially vulnerable, which is just slightly above state average. The primary driver of this slightly higher social vulnerability ranking is the lower per capita income (on average) for the residents who live in the state's hottest areas.

When looking more broadly at the counties most impacted by weather disasters in the past, the population exposed to known weather extremes decreases slightly to 3.7 million. This is largely due to weather-related disaster declarations being limited to those events that significantly damage the built environment – which is driven primarily by extreme winds and has not included extreme heat events. Most of these exposed people live in the Puget Sound and

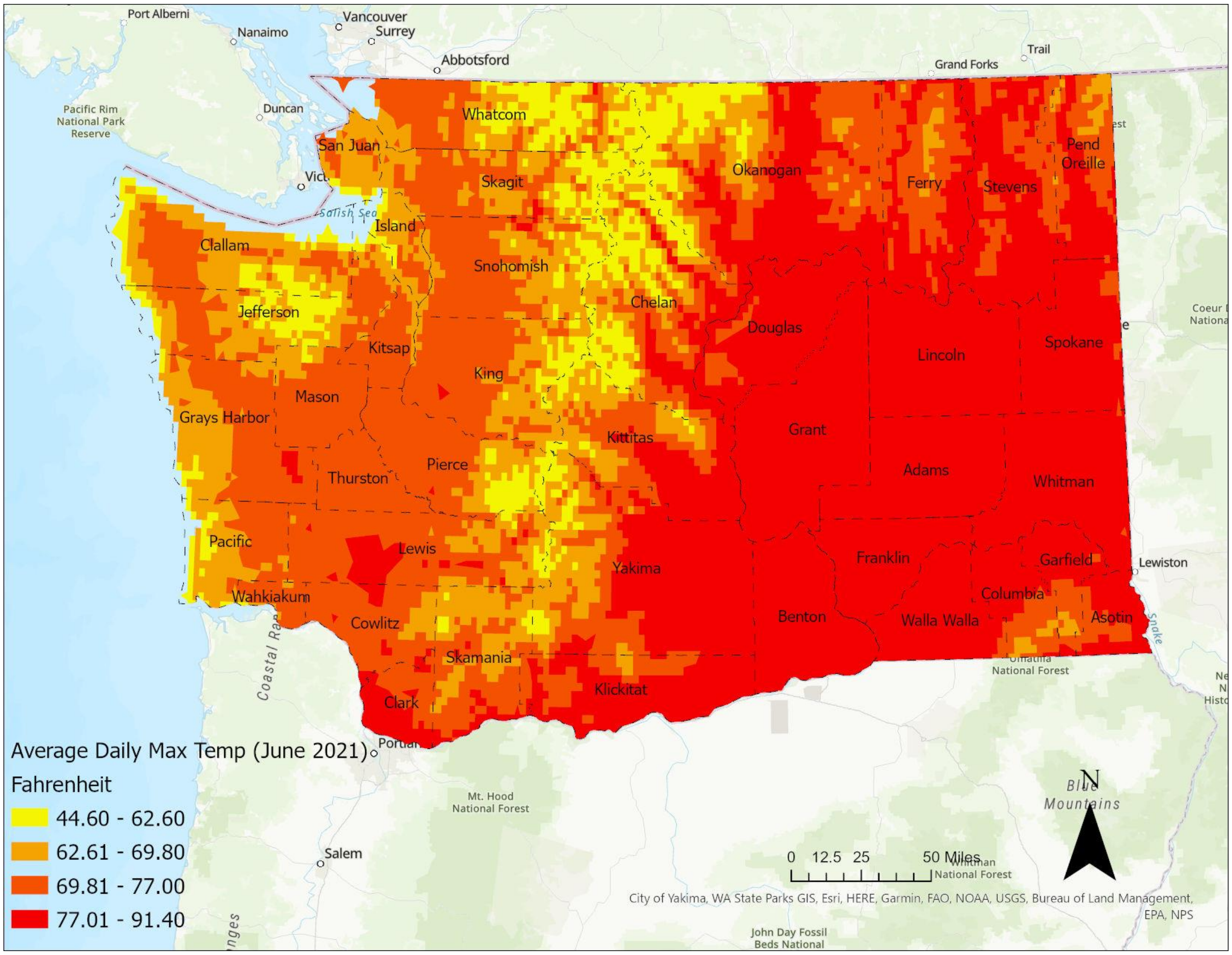

Figure 15. Average daily maximum temperature for Washington in June 2021. Some areas of central and eastern Washington reached average daily maximum temperatures above 90 degrees (F) that month. The "heat dome" event in late June 2021 would break multiple heat records across the Pacific Northwest.

Northwestern region, especially in King County (n=2.2 million). Although the average social vulnerability ranking in this area is below state average, some of the most socially vulnerable Census tracts in Washington are in these weather-impacted counties. This includes large sections of rural Clallam, Grays Harbor, Jefferson, and Pacific Counties as well as densely populated areas in King and Snohomish Counties. The most significant factors contributing to social vulnerability in these areas are poverty and per capita income as well as areas of crowded housing (i.e., residential units with more people than rooms).

Because of its inclusion of the Greater Seattle area, the population within the extreme weather hazard areas is expected to increase up to 16% by 2050, bringing the projected population to 4.2 million-4.3 million by 2050.

The region most at-risk to extreme weather is the Puget Sound and Northwestern region. Although previous weather disasters have covered a larger area of the Olympic Peninsula and Southwestern region, that area of the state is less populated and less developed – meaning fewer people and critical assets are in harm's way when compared to the Puget Sound and Northwestern part of the state. For example, although most of Jefferson County is classified as socially vulnerable, the actual estimated population there with a high social vulnerability rank is 2,100, while the estimated socially vulnerable population in King County is 425,000. This reflects the tendency of socially vulnerable residents to cluster in the state's urbanized regions, which have been shown to experience periods of extreme heat above the nearby non-urban areas in recent years as well as other weather impacts. Research in other parts of the

Pacific Northwest has shown that socially vulnerable groups, such as those living in poverty, tend to be at higher risk to heat exposure specifically (Voelkel et al., 2018), and that is the case in Washington as well.

However, the risk of extreme weather goes beyond heat and also includes the potential for damaging atmospheric rivers. Although atmospheric rivers impact the Olympic Peninsula and Southwestern region as often as the Puget Sound and Northwestern region, the potential for damage and asset loss is higher where there is more development. The Puget Sound area, in addition to more people, holds a significant number of critical infrastructure in the state – some of which has been shown to be susceptible to weather extremes. This includes power lines vulnerable to high winds and drinking water supplies vulnerable to heavy rains (e.g., stormwater runoff impacting water quality).

The 2021 Pacific Northwest Heat Dome

About 12,000 Americans die from heat-related causes each year (Shindell et al., 2020), making heat the deadliest of all extreme weather. Especially vulnerable are the elderly and people with comorbidities that heat can exacerbate (Sarofim et al, 2016). Also vulnerable are otherwise healthy people whose jobs require they work outside, as well as those dealing with homelessness.

Although the Pacific Northwest is not known for having a particularly warm climate, more people die from heat exposure here than in places that experience extreme heat more commonly, such as the Southwest and Southeast parts of the country (Shindell et al., 2020). A potential reason for this is precisely because the Pacific Northwest does not experience extreme heat very often, leaving residents unprepared when heatwaves do occur. The Seattle-Tacoma metropolitan area, for example, has the second lowest rate of air-conditioned homes of any major US city (Weinberger, 2022). This was the unfortunate reality in June 2021, when a rare atmospheric event called a “heat dome” brought extraordinary heat to the Pacific Northwest and broke numerous heat-related records, including for most consecutive days above 100°F (Gamillo, 2021). The public health impacts of the 2021 heat dome included more than 150 Washingtonians dying from heat exposure (DOH, 2021). That death toll easily makes the 2021 heat dome the deadliest natural hazard event in Washington’s history.

Although the Pacific Northwest is expected to remain a cooler place on average than the rest of the country, the unfortunate reality of continued climate change will be more high-heat days than what we are currently used to (Snover et al., 2013; Shindell et al., 2020). And if the number of additional high-heat days continues to outpace our ability to prepare for them, we can expect to also see additional heat-related illness and death.

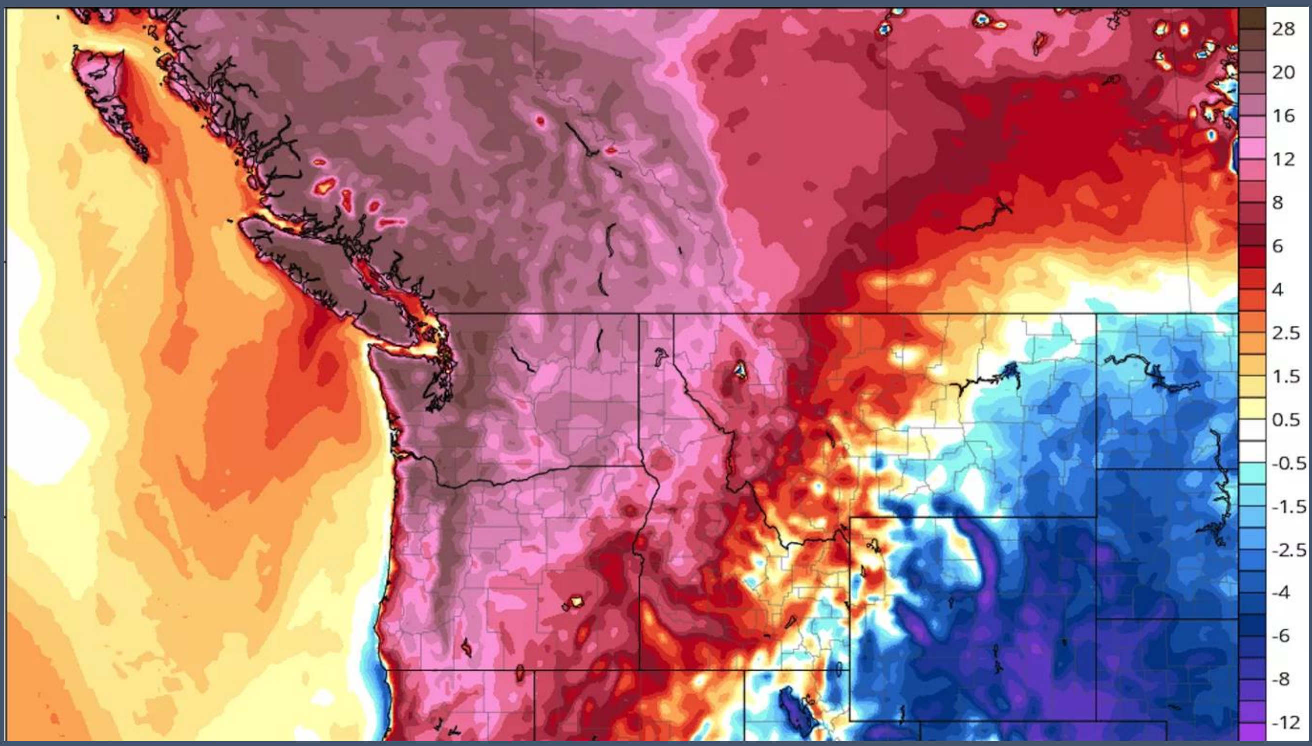

Figure 16. Temperature departures from average on June 28, 2021. This shows temperatures in Washington reaching 20°C (68°F) above normal in some places (Source: Freedman & Malcolm, 2021).

3.1.e. Flood

Situational overview

> **Flood Recurrence Intervals**
>
> Flooding is often described in terms of recurrence intervals. These intervals are expressed as percentages that indicate the likelihood that water levels will reach a certain magnitude during a given timeframe, normally a year. For example, 1% annual chance flood is a flood that has a 1-in-100 chance of occurring in any given year. It's also commonly referred to as a "100-year flood" for this reason.
>
> However, the "100-year flood" title can be misleading and cause some to believe such floods only happen once every hundred years. This is not true. Although unlikely, a flood with a 1% chance of occurring in any given year could happen *every* year. Recently, the frequency of extreme floods around the US, including in Washington, have shown that so-called "100-year floods" are occurring much more often than every hundred years. The reason is due to a combination of climate change (i.e., sea level rise and severe weather) and continued development in flood-prone areas. In essence, the influence of climate change and development on flooding events, whether coastal or riverine, is such that what was once considered a "100-year flood" may become more common – perhaps a 50-, 20-, or 10-year flood – because the chances of occurring in any given year are higher than 1% now.

Flooding is among the world's most common and damaging natural hazards, causing trillions in property losses and thousands of deaths in recent decades (Winsemius et al., 2016). In the United States, the risks associated with floods are expected to increase due to changes in exposure and vulnerabilities (Wing et al., 2018). In the Pacific Northwest, flood disasters are often tied to extreme rainfall events, such as atmospheric rivers (see section 3.1.e for more on extreme weather). Some research shows an estimated 5% increase in extreme rain events for parts of Washington, compared to the average from 1980-2010 (NASA, 2022). Sea level rise along portions of our coast is also contributing to more frequent nuisance and recurrent flooding (such as higher king tides) as well as permanent inundation in certain locations. This, combined with continued population growth and development in flood-prone areas means floods are likely to become "high frequency, high severity" events, where destructive floods are happening more often in Washington and risk is increasing. This differs slightly from the 2018 SEHMP, which characterized flooding to be a "medium" risk natural hazard.

Table 14 below summarizes the location, extent, and previous occurrences of floods in Washington. Table 15 provides a summary of the probability of future floods and projected changes in location, extent, intensity, frequency, and/or duration based on the influence of climate change, population growth, and other external factors. Other key findings from the flood hazard analysis include:

- Estimated population within the identified flood zones in WA: 2 million
- Projected population within the identified flood zones by 2050: 2.5 million – 2.6 million
- Estimated socially vulnerable population within the identified flood zones: 960,000
- Estimated population exposed to the direct or indirect impacts of wildfires in WA: 4 million
- Estimated State-owned or -leased facilities within the identified flood zones and dollar value: 482, $1.4 billion
- Estimated miles of public roads in the identified flood zones: 1,692
- Critical intermodal transportation facilities in the identified flood zones: 0
- Number of licensed hospitals in the identified flood zones: 0
- Number of first responder facilities in the identified flood zones: 67
- Number of power plants and miles of electric power transmission lines in the identified flood zones: 3 power plants, 585 miles of transmission lines
- Number of public drinking water supplies in the identified flood zones: 3,700
- Number of wastewater treatment plants in the identified flood zones: 2

Table 14. Overview of location and extent of previous floods in Washington.

Location	Possible Extent (Magnitude/Severity)	Previous Occurrences
Statewide	Coastal flooding during king tides have caused +15 ft of temporary sea level rise in some locations; determination of riverine flood magnitude/severity is dependent upon the stream itself, but all gaged streams in WA have the potential to exceed flood stage; a single rain-driven flood event in 1996 impacted 24 of 39 counties and +2,600 homes	2022 (DR-4682, DR-4650) 2021 (DR-4635, DR-4593) 2020 (DR-4539); 2018 (DR-4418); 2017 (DR-4309); 2015 (DR-4253); 2015 (DR-4249); 2014 (DR-4168); 2012 (DR-4083); 2012 (DR-4056); 2011 (DR-1963); 2009 (DR-1817); 2007 (DR-1734); 2006 (DR-1671); 2006 (DR-1641); 2003 (DR-1499); 1998 (DR-1252); 1997 (DR-1172); 1997 (DR-1159); 1996 (DR-1100); 1995 (DR-1079); 1990 (DR-883); 1990 (DR-852); 1989 (DR-822); 1986 (DR-784); 1986 (DR-769); 1986 (DR-762); 1983 (DR-676)

Table 15. Overview of probability of future floods, projected changes in flood impacts, and the jurisdictions most at-risk to flooding.

Annual probability	Projected changes	Region most at-risk
60% chance of a flood-related disaster declaration each year	WA averages approx. one major flood event/year since 1980. Although no trend has been observed as of 2023, climate change-driven increases in extreme precipitation is expected to increase the frequency, extent, intensity, and geographic distribution of floods in WA by 2100. Population growth and development in flood-prone areas is projected to continue, resulting in elevated risk over time. An estimated 2.5 million people will reside in flood hazard areas by 2050, an increase of 25% compared to 2020. Sea level rise will contribute to more frequent and severe coastal flooding, with the potential for some areas to see a +4 feet increase of average sea level by 2100.	Puget Sound & Northwestern

Flood hazard and vulnerability analysis

Flooding in Washington can come in different varieties and can occur in every county in the state. We discuss flooding in this section to include coastal flooding (related to coastal storms and sea level rise) and riverine flooding (which includes flash flooding). Also discussed are some of the secondary consequences of flooding, such as bluff erosion and stream channel migration.

Coastal flooding and sea level rise

Sea level rise is compounding existing hazards along Washington's coast, such as bluff erosion, storm surge, and groundwater intrusion (Miller et al., 2018). Coastal flooding, though, is the most studied and best characterized impact of sea level rise. Because Washington's coast is so varied (from rocky cliffs to sandy beaches to wetlands), coastal flooding can have different extents and impacts depending on the location. During severe storms, low-lying portions of the coastline can be flooded, and the depth, damage, and frequency of that flooding will increase as sea level rises.

Projections of future sea level rise in Washington can be tied to greenhouse gas emissions. The best-available sea level rise projections for our state indicate that between 1.4 and 2.8 feet of sea level rise is likely by 2100 under a high emissions scenario (Miller et al., 2018). It is important to note that magnitudes of sea level rise can vary at specific locations on the coastline and that other factors, including tectonic uplift of the land surface, contribute to the measured sea level rise (or fall) experienced for a given location. For example, tectonic uplift around Neah Bay is currently leading to sea level fall while subsidence around Puget Sound is expected to increase sea level rise (Miller et al, 2018). Table 16, adapted from Miller et al. (2018), provides an overview of relative sea level rise projections by 2100 for three locations: Tacoma (Pierce County), Neah Bay (Makah Tribe), and Taholah (Quinault Nation).

Table 16. Projected relative sea level change (in feet) for 2100, adapted from Miller et al. (2018). Likely ranges have 83 – 17% chance of occurring. "10% probability of exceedance" refers to the sea level rise magnitudes that are 10% likely to be exceeded by 2100 under a high (RCP 8.5) or low (RCP 4.5) emissions scenario.

Location	Emissions scenario	Likely range of sea level rise (feet)	10% probability of exceedance
Neah Bay	High	0.3–1.7	2.0
	Low	-0.1–1.2	1.5
Tacoma	High	1.9–3.3	3.6
	Low	1.5–2.7	3.0
Taholah	High	1.0–2.6	2.9
	Low	0.6–2.1	2.4

Riverine flooding

Apart from the relatively gradual flooding impacts related to climate-driven sea level rise along sections of Washington's coastline, the specific location and extent of a flood is often difficult to accurately predict given its relationship to a mix of factors including rainfall, topography, land cover, soil moisture, and others. Complex mathematical models can, in some cases, improve flood prediction but require large amounts of data and expertise (Mosavi et al., 2018). This makes riverine flooding a dynamic and difficult natural hazard to mitigate. For this reason, riverine flood hazard mitigation tends to rely on floodplain mapping to delineate possible flood extents at various annual probabilities (e.g., 1% annual probability) (Figure 17). While helpful, these flood maps require consistent updating, and they do not indicate the only areas capable of flooding and do not indicate overall flood risk.

FEMA's National Flood Hazard Layer (NFHL) is the most used geospatial dataset on potential flood extents in the country in support of the National Flood Insurance Program (NFIP). Unfortunately, many counties in Washington do not have digitized flood hazard data available on the NFHL, so it does not provide a full picture of potential flood extents in the state. Although the NFHL does show possible flood extents in the watersheds that have been mapped, these extents are based on modeling. The NFHL does not indicate where floods have occurred or what their actual extents may have been. The NFHL, therefore, does not provide a full characterization of flood risks in our state.

Additional research and analytical tools are available to help fill in the gaps found in the NFHL, particularly through improving the probabilistic estimates of flooding events at parcel scales as opposed to floodplain delineations. These kinds of products help to illustrate risk (i.e., the potential for impacts) more fully. Figure 19 provides an example of one such product, FloodFactor, which shows parcel-scale risk levels for the town of North Bend (King County). According to FloodFactor, there are more than 400,000 properties in Washington (13% of the state) with a greater than 26% chance of being impacted by floods in the next 30 years. Additionally, more than 580,000 properties are exposed to a 0.2% annual chance flood, which is a high magnitude flood.

Also, the Department of Ecology's Risk MAP program helps to fill in data gaps around flood risk. Subject matter experts there, in partnership with FEMA Region 10, provide technical assistance to local communities by providing tools and expertise to better understand their flood risks. Although Risk MAP is a federal program, Ecology coordinates Risk MAP in Washington with practical mapping tools, mitigation actions, and strategies across multiple agencies, including the state's Emergency Management Division and Department of Natural Resources.

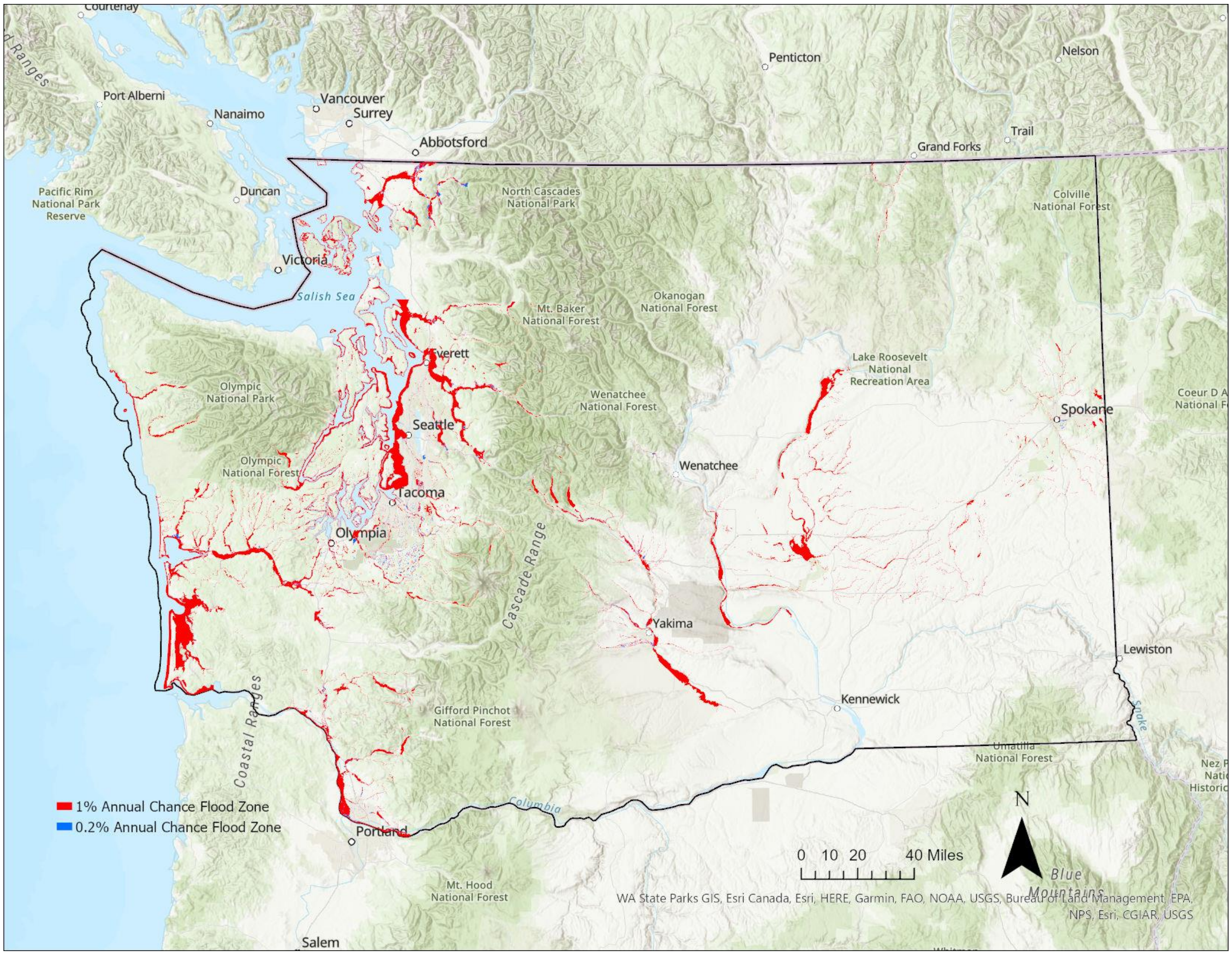

Figure 17. The 1% (in red) and 0.2% (blue) annual chance flood zones available for Washington (as of March 2022). Areas of the state without data shown above do not indicate no flood zones, but rather a lack of spatial data available in the National Flood Hazard Layer.

State-owned or leased facilities

There are 482 State facilities located in Washington's flood hazard areas (1% and 0.2% annual chance flood zones) available in the current NFHL. Estimated value of these facilities is $1.4 billion. This is likely to be an underestimation of State facilities at risk to flooding because of the gaps in the NFHL. When looking at proximity to streams and shorelines across the whole state, we found that approximately 700 facilities were within 500 feet of a stream or shoreline (Figure 20). This 500-foot buffer is somewhat arbitrary considering not all floodplains extend 500 feet from their waterbody (and some extend much farther). We examined the number of facilities within our 500-foot buffer that are also in counties with known NFHL flood zones and discovered the 500-foot buffer over-estimated the number of facilities in a flood zone by 70%. However, recent flood events in Washington have shown that a significant number of flood-damaged structures can be located outside the known flood zones in the NFHL. Although imperfect, we feel the 500-foot buffer is an adequate planning metric to supplement what is in the NFHL that we will work to refine in future updates.

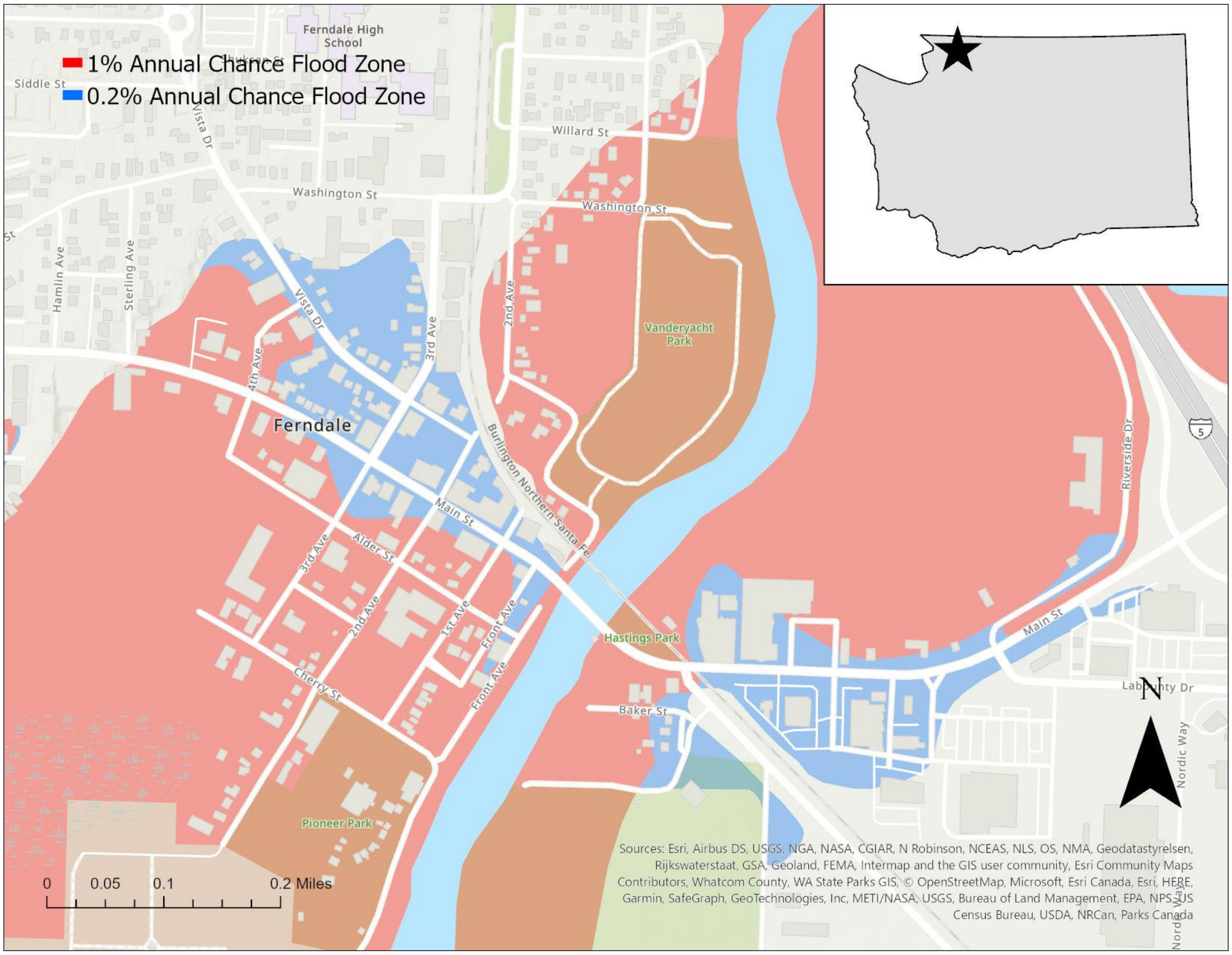

Figure 18. The 1% (red) and 0.2% (blue) annual chance flood zones for Ferndale, Whatcom County. This zoomed in version of Figure 17 illustrates the delineation of 1% and 0.2% flood zones. In Ferndale, these flood zones cover much of its downtown business district as well as important access routes to I-5.

Kittitas County has the largest proportion of State facilities within 500 feet of a stream or shoreline, with 93 (13% of total within 500 feet of a stream/shoreline), followed by King County with 72 buildings (10%) and Spokane County with 44 (6%). When looking at cities and towns, Ellensburg (in Kittitas County) holds the largest proportion of State facilities at 76 (11%). The cluster of facilities in Ellensburg are associated with Central Washington University and are located along the banks of Wilson Creek. To confirm this was indeed a statistically significant cluster in the Ellensburg area, we performed a density-based clustering analysis that revealed two primary clusters of facilities within potential flood zones – in the King/Pierce County area and the Kittitas/Yakima County area (including Ellensburg) (Figure 21).

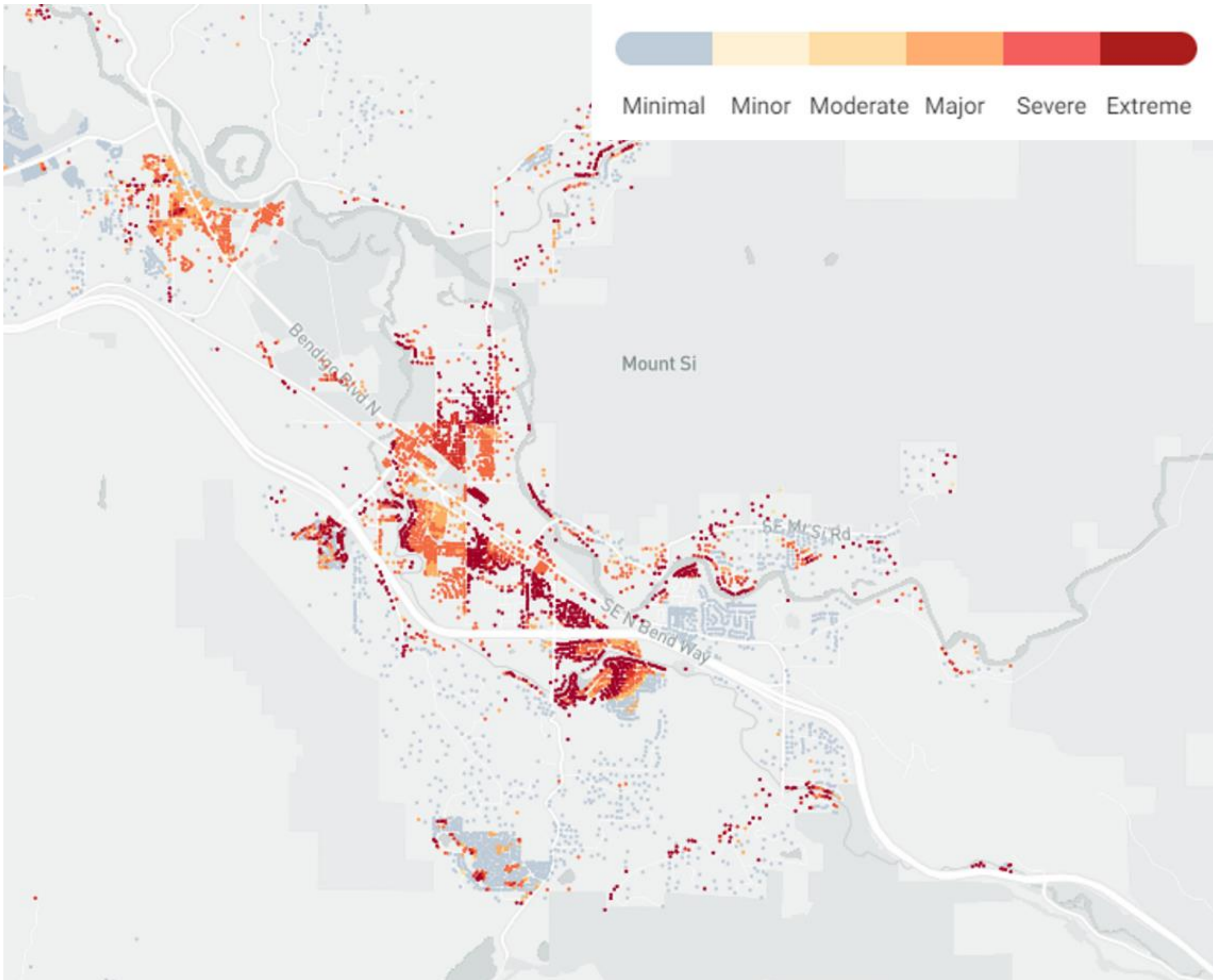

Figure 19. Overall parcel-scale flood risk for North Bend, WA (source: FloodFactor, www.floodfactor.com)

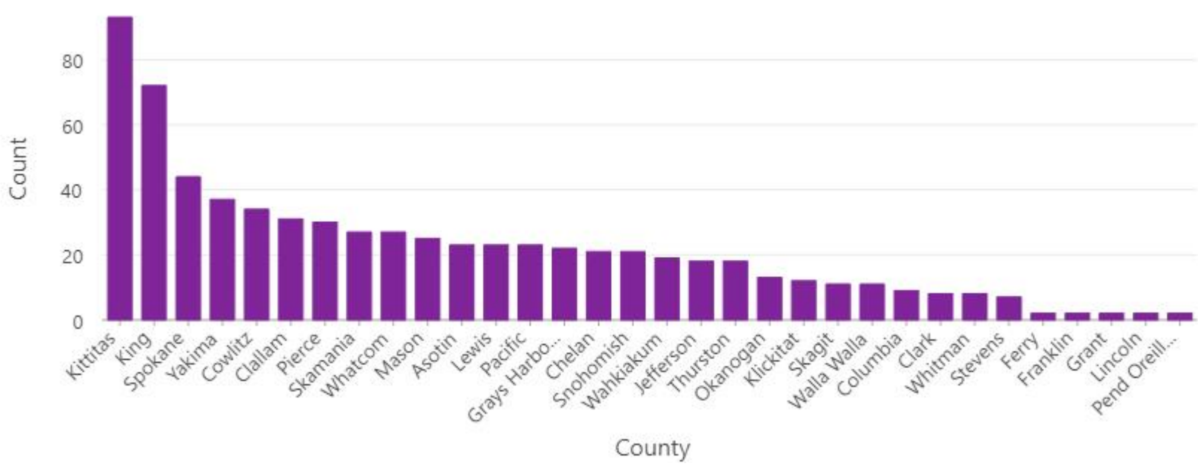

Figure 20. State facilities located within 500 feet of a stream or shoreline per county

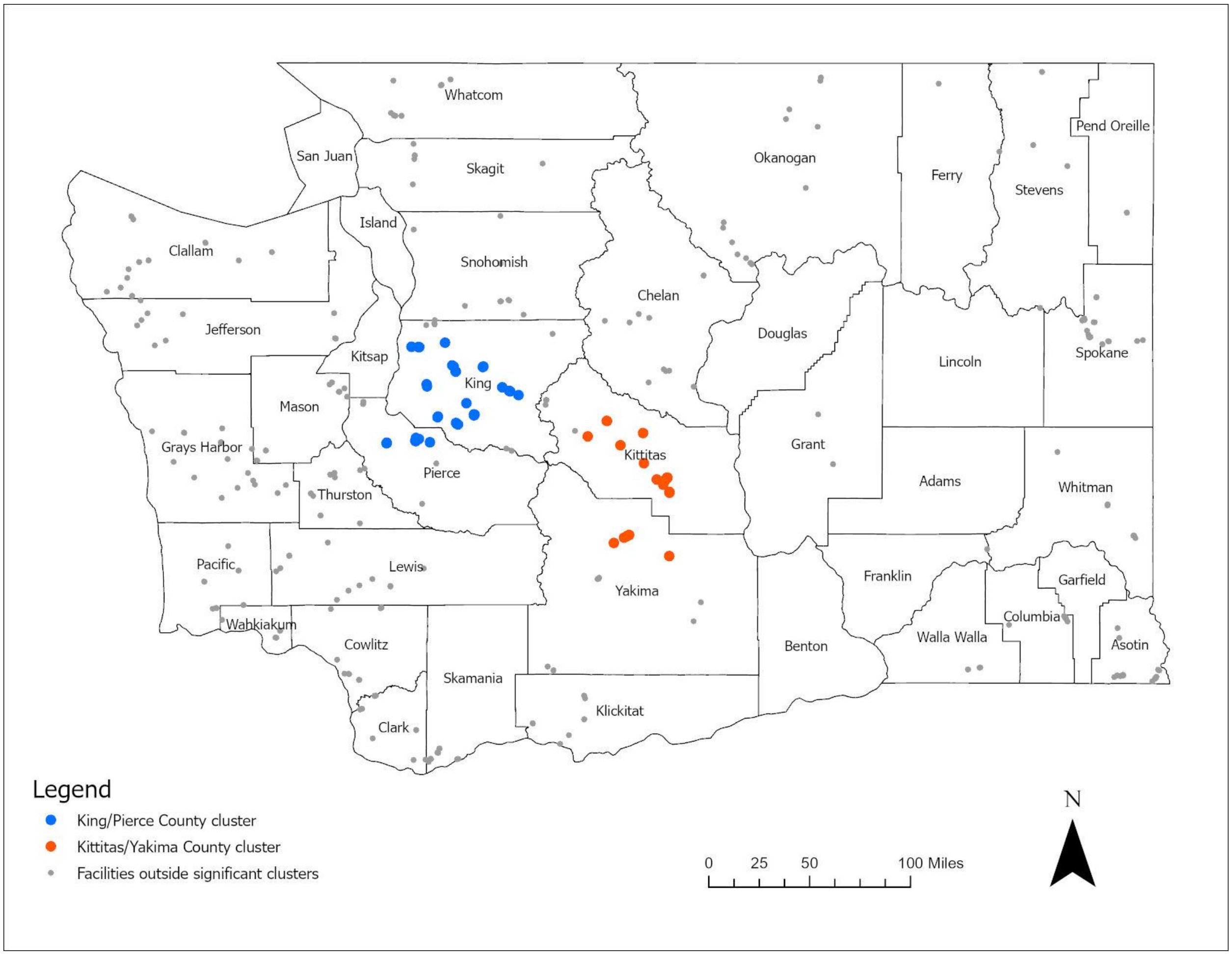

Figure 21. Significant clusters of State facilities within 500 feet of a stream or shoreline. This may provide an estimation of flooding exposure, but proximity to streams and shorelines is not enough to determine overall risk.

Critical infrastructure

- **Transportation.** Approximately 2.5% (1,692 miles) of the state's public roads are in the 1% or 0.2% annual chance flood hazard zones. Given the delineation of the flood hazard zones, most of these road miles are broken into small segments that intersect with flood-prone areas. For example, the average segment of high volume State Routes exposed to flood hazard zones is 0.6 miles. It is even smaller (0.2 miles) for non-highway public roads, such as minor collector and local access roads. Of those 1,692 miles exposed to known flood hazards, about 39% are in the Puget Sound and Northwestern region and about 24% are in the Olympic Peninsula and Southwestern region. The top three counties with the most roads in known flood hazard zones are Snohomish (219 miles, 13%), King (210 miles, 12%), and Grays Harbor (204 miles, 12%). The only intermodal transportation assets located in flood prone areas are the various ports, which is to be expected given their coastal locations.

- **Health and safety.** There are no licensed hospitals located in known flood zones nor any located within 500 feet of a stream, however the Olympic Medical Center (Clallam County) is located along the shore in Port Angeles. Of the 1,280 fire stations in Washington, 43 (~3%) are in either the 1% or 0.2% annual chance flood hazard areas based on the currently available NFHL. This number could increase as additional floodplains in the state are mapped. Seven of those 43 are in Whatcom County while six are in King County.

Snohomish and Grays Harbor Counties both have five fire stations in known flood hazard areas. Of the 350 police stations in the state, 24 (~7%) are in the currently available 1% or 0.2% annual chance flood hazard zones. Like fire stations, this number could increase as more floodplain data become available. King and Grant Counties are tied for having the most of any individual county, with four police stations in known flood hazard areas. Whatcom and Grays Harbor Counties both have three police stations in known flood hazard areas.

- **Energy.** Approximately 6% (585 miles) of electric power transmission lines in the state are in either the 1% or 0.2% annual chance flood hazard zones available in the current NFHL. More than half (55%) of those vulnerable power transmission lines is in the Puget Sound and Northwestern region of the state, while 46% are in the Olympic Peninsula and Southwestern region. Snohomish County has more flood-exposed power transmission lines than any other county with 106 miles, followed by King County (90 miles) and Pierce County (76 miles). Of the 158 power plants in the state, 16 are in known flood hazard areas; however, most of these are conventional hydroelectric plants whose vulnerability to flooding cannot easily be determined by proximity to streams alone. There are three non-hydroelectric plants located in flood hazard areas: two wood waste biomass plants in Grays Harbor County and a natural gas fired combined cycle plant in Whatcom County.

- **Water and wastewater.** There are more than 3,700 public drinking water supplies (groups A and B) in the known flood hazard areas in the currently available NFHL. It is possible that this is an underestimation given the data gaps in the NFHL. Approximately 55% of those of drinking water supplies are in the Puget Sound and Northwestern region, while about 33% are in the Olympic Peninsula and Southwestern region. There are two wastewater treatment facilities in the known flood hazard areas: one in the city of Puyallup (Pierce County) and another in the city of Toppenish (Yakima County). The site in Puyallup is along the Puyallup River, which tends to be flood-prone, with eight of its top 20 floods occurring since 1990.

Population

Based on population projection data (Gao, 2017), we estimate there to be about 2 million people residing in Washington's currently identified special flood hazard areas (1% and 0.2% annual chance flood zones). By 2050, this number could increase to between 2.5 million and 2.6 million based on expected population growth in the identified flood zones, however this is likely to be an underestimation given the areas of the state that currently do not have mapped flood zones available in the NFHL. Additionally, the geographical area of the flood zones may also change by 2050, with the potential to increase in extent and put more people and property at risk.

Based on the CDC's Social Vulnerability Index (CDC, 2018), we estimate about half (48%) of the population in the known flood hazard areas to be considered socially vulnerable. The primary drivers of social vulnerabilities in the flood hazard areas are related to household composition and disability, including an above average number of elderly residents (>65 years old), children under 17 years old, and disabled residents compared to the rest of the state. The average environmental health disparities (EHD) ranking for these residents is slightly below state average (5.47 vs. 5.52). However, there are socially vulnerable areas at risk to flooding and with high EHD rankings in the state, including two clusters in the South King County-North Pierce County area and another in the Yakima-Toppenish area of Yakima County (Figure 22). The high EHD rankings in these clusters are driven by diminished air quality (e.g., elevated diesel emissions and particulate matter), proximity to hazardous waste treatment facilities, and proximity to Superfund sites. Residents in some areas, such as Lakewood (Pierce County) and Union Gap (Yakima County), also experience higher rates of cardiovascular disease, below average birth weights, and elevated risk of lead poisoning from housing when compared to the rest of the state.

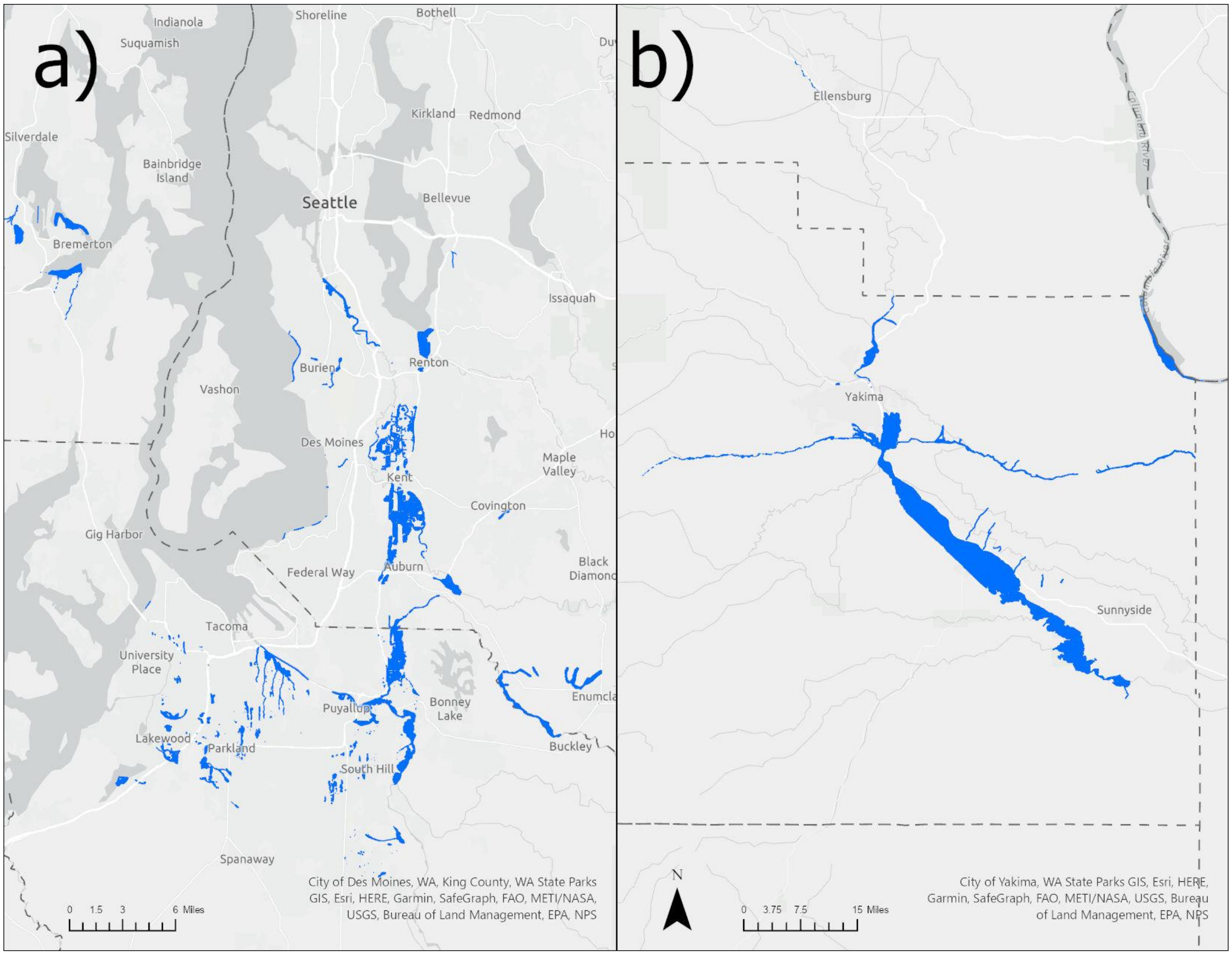

Figure 22. Areas shown in blue are portions of Census tracts where residents are highly socially vulnerable and experience high environmental health disparities while also being at-risk to flooding. Panel a) shows the South King County/North Pierce County area, including the cities of Kent, Federal Way, Tacoma, and Lakewood. Panel b) shows the Yakima County area, including the cities of Yakima and Toppenish.

The region determined most at-risk to flooding is the Puget Sound and Northwestern region, due to its frequency of flood disasters (both coastal and riverine) and the vulnerability of the communities and critical assets there. This includes a consideration of known repetitive loss or severe repetitive loss (RL/SRL) properties (n=1,592 statewide). Most of the state's unmitigated RL/SRL properties are in the Puget Sound and Northwestern region, namely King, Pierce, Snohomish, and Skagit Counties. Lewis County also holds a significant number of unmitigated RL/SRL properties, particularly in Centralia and Chehalis. Other towns with significant outliers of RL/SRL properties are Arlington (Snohomish County), Hamilton (Skagit County), and Issaquah (King County).

Although the probability of a flood-related disaster declaration is slightly higher in the Olympic Peninsula and Southwestern region, the number of critical assets and vulnerable people, including RL/SRL properties, exposed to riverine floods is larger in the Puget Sound and Northwestern region, particularly in Whatcom, Snohomish, King, and Pierce Counties. Flood data is mostly missing in Skagit County, but recent flood disasters there suggest an elevated flooding risk there. It was also identified in the 2018 SEHMP as having a high flood risk.

The potential direct impacts of flooding on Washington's critical assets include, primarily, the loss of or damage to property, roads, bridges, and other river-adjacent or coastal structures. For example, previous temporary inundation of coastal areas and floodplains in Washington has blocked roads (Clarridge & Kroman, 2022) and threatened bridges

(Mitchell, 2021). Additionally, the estimated value of all structures in the state's flood hazard areas (according to county assessors' data) is more than $86 billion, some of which are privately-owned residential properties. Given the location of these structures, they may be vulnerable to flash flooding or stream channel migration and other erosive events (e.g., bluff erosion in coastal areas). Most of that $86 billion valuation is in the Puget Sound and Northwestern region of the state ($54 billion, 63%), followed by the Olympic Peninsula and Southwestern region ($23 billion, 27%). Again, it is important to note that these are likely underestimations of total real estate value at risk to flooding given the lack of flood hazard data in some parts of the state.

A major concern is the areas of the state that are at risk to flooding while also showing high levels of social vulnerability and environmental health disparities. A major flood in one of these areas (e.g., in Figure 22 above) could expose residents who are already coping with various public health concerns to additional harm. For example, there exists the potential for floods to directly impact nearby Superfund sites (which are concentrated around Puget Sound) and trigger the release of toxic materials into floodwaters, other water ways, and groundwater (GAO, 2021). Another concern are the numerous drinking water supplies exposed to flood impacts. Floods can impact drinking water by contaminating supplies by transporting excess nutrients, sediment, and other potentially toxic material (DOH, 2019). An example of this is the 2007 flood that damaged several Lewis County water systems (DOH, 2019).

Given the lower level of exposure, flooding is less likely to directly impact hospitals and first responder facilities. However, the relatively low exposure belies the disproportionate impacts to communities if those facilities are flooded. It is also possible that temporary inundation or damage to roads during and after floods could diminish access to these facilities or the ability of first responders to provide service to people in need. Floods are also less likely to directly impact energy production and transmission across the state, with 94% of power transmission lines located outside of known flood-prone areas and only three power plant facilities with identifiable vulnerabilities to flooding.

November 2021 Floods: Erosion and Stream Channel Migration

On November 14, 2021, a series of atmospheric rivers began bombarding the Pacific Northwest and didn't let up until mid-December. They brought with them record-breaking rainfall and hurricane-force winds. In Bellingham (Whatcom County), 2.8 inches of rain fell in a 24-hour period (more than Bellingham typical receives in a month), a 300% increase above the previous 24-hour record. Schools were closed, and portions of Interstate 5 were closed due to a mudslide that trapped three cars. Just north of Bellingham, the Nooksack River crested at nearly 24 feet, the highest it had been in decades (Figure 23). In Sumas (Whatcom County), residents needed to be rescued after being stranded by rushing flood waters. In Skagit County, flooding from the Skagit River impacted parts of Sedro-Wooley, Burlington, and Mount Vernon. Gov. Jay Inslee declared a severe weather state of emergency in 14 counties and the State Emergency Operations Center was fully activated.

Soil moisture in the Pacific Northwest after this series of atmospheric rivers was higher than anywhere else in the country, which is why landslides and other erosive events can follow severe weather and floods. Stream channel migration is a form of erosion that can happen rapidly during floods and has been known to damage or threaten homes and infrastructure. In the November 2021 floods, multiple streams eroded their banks quickly and migrated, resulting in washed-out sections of roads, partial bridge collapses, and emergency evacuations of some homes. With climate change expected to intensify atmospheric rivers, these kinds of flooding and flood-related hazards may become more prevalent in our state.

Figure 23. Nooksack River flooding on November 16, 2021. Source: NASA Earth Observatory (2021).

3.1.f. Landslide

Situational overview

Washington remains one of the most landslide-prone states in the country. Landslides are often a component of or associated with flood disasters (Table 17), however they can happen on their own, such as the SR530 slide (also known as the Oso landslide) that occurred in 2014. However, most landslides that occur in Washington are not damaging and sometimes go undetected until much later.

Table 17 below provides an overview of the location and extent of previous landslides. Table 18 summarizes the probability of future landslides, as well as projected changes in landslide impacts and which jurisdictions are most at-risk. Other key results from the landslide hazard and vulnerability analysis below include:

- Estimated population in landslide hazard areas: 1.5 million
- Projected population in landslide hazard areas by 2050: 1.5 million
- Estimated socially vulnerable population in landslide hazard areas: 390,000
- Estimated population exposed to the direct or indirect impacts of landslides: 2.5 million
- Estimated State-owned or -leased facilities in landslide hazard areas and dollar value: 2,600, $41 billion
- Estimated miles of public roads in landslide hazard areas: 10,200
- Critical intermodal transportation facilities in landslide hazard areas: 3
- Number of licensed hospitals in landslide hazard areas: 23
- Number of first responder facilities in landslide hazard areas: 380
- Number of power plants and miles of electric power transmission lines in landslide hazard areas: 24 power plants; 3,100 miles of transmission lines
- Number of public drinking water supplies in landslide hazard areas: 3,600
- Number of publicly owned wastewater treatment plants in landslide hazard areas: 1

Table 17. Overview of the location and extent of previous landslides.

Location	Possible Extent (Magnitude/Severity)	Previous Occurrences
Mountainous and hilly areas statewide	Landslides have varied widely in magnitude and severity; SR530 slide in 2014 (a.k.a. Oso landslide) moved ~18 million tons of debris at an average speed of 40 mph, killing 43 people	2022 (DR-4682); 2021 (DR-4635, DR-4593); 2020 (DR-4539); 2018 (DR-4418); 2017 (DR-4309); 2015 (DR-4253); 2015 (DR-4249); 2015 (DR-4243); 2014 (DR-4168); 2012 (DR-4083); 2012 (DR-4056); 2011 (DR-1963); 2009 (DR-1817); 2007 (DR-1734); 2006 (DR-1682); 2006 (DR-1671); 2006 (DR-1641); 1998 (DR-1255); 1997 (DR-1172); 1989 (DR-822); 1986 (DR-762)

Table 18. Overview of the probability of future landslides, projected changes in landslide impacts, and the jurisdictions most at-risk.

Probability	Projected changes	Region most at-risk
44% chance of a landslide-related disaster declaration each year	Areas at-risk to landslides will continue to be at-risk and are expected to see more frequent landslides due to the impacts of extreme precipitation and wildfire (post-wildfire debris flows) resulting from climate change. Populations in landslide hazard areas are not expected to increase significantly by 2050.	Olympic Peninsula & Southwestern

Landslide hazard and vulnerability analysis

The best available data for landslide hazards in Washington comes from the Washington Geological Survey within the Department of Natural Resources. In 2018, WGS published a compilation of previous landslides within Washington (Figure 24). This landslide compilation includes minor and major landslides. It should be noted that the landslides shown in Figure 24 are from different data sources, each one focused on a specific area or areas within the state. As a result, this compilation covers the cumulative areas of these studies, not the entire state. As such, landslides may have occurred in areas that are unmapped in Figure 24.

We created a landslide hot spot map based on the 2018 landslide compilation data (Figure 25). Hot spots were determined by counting the number of landslides within and near each hexagon grid cell and then comparing that number to the average for the state to determine which hexagons had counts significantly higher than average. Based on this analysis, the areas with the most significant landslide activity are on the Olympic Peninsula, in southwestern Washington, and in northwestern Washington. However, because of the data gaps in the 2018 landslide compilation, it is possible that the hot spots shown in Figure 25 could change as new landslide data become available. We also recognize the coarseness of the analysis, including hexagon cells that may be too large and include areas that are not likely to experience landslides. Future SEHMP updates will incorporate updated landslide inventories from WGS as they become available.

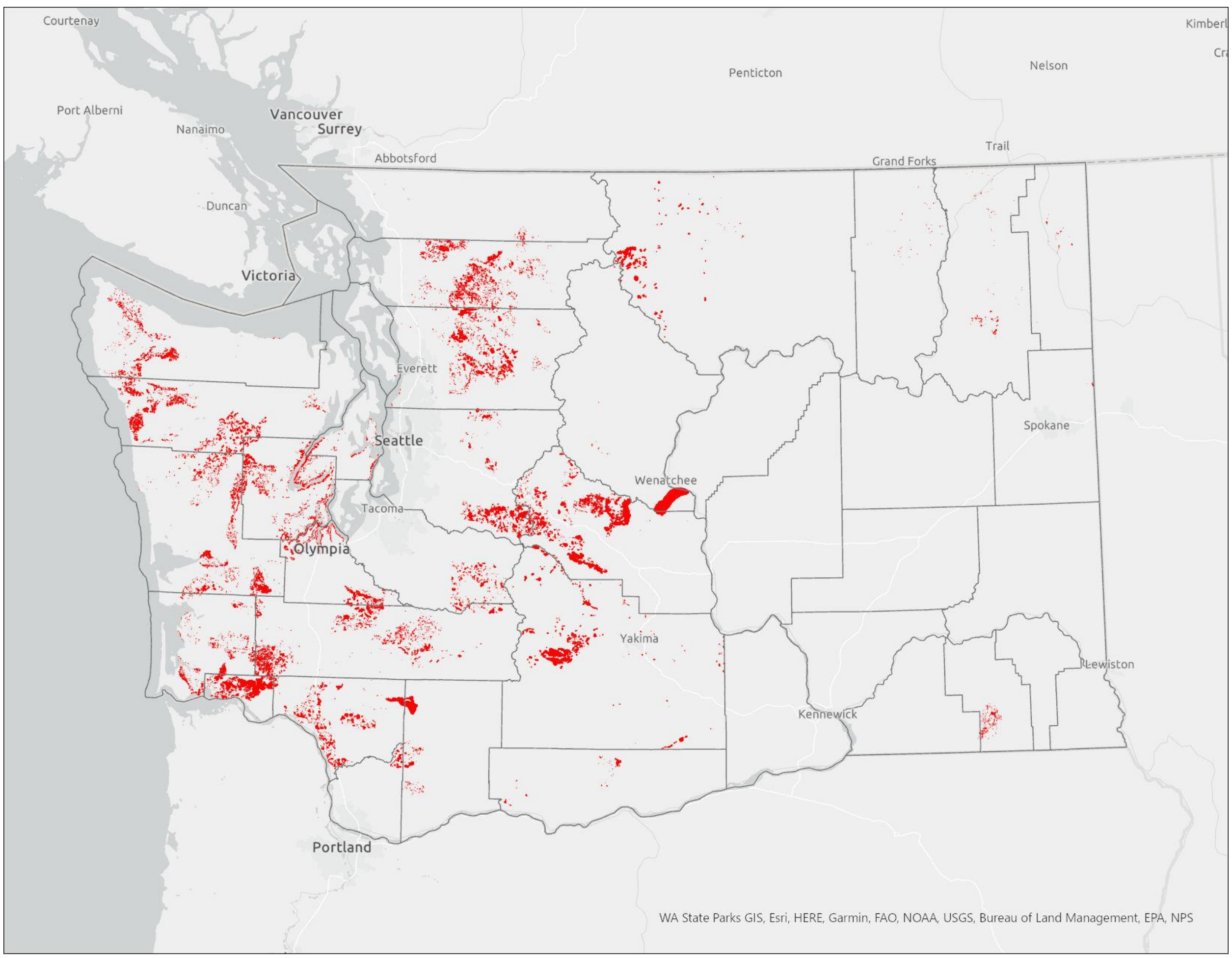

Figure 24. Compilation of previous landslide footprints (red polygons). Source: WGS, 2018.

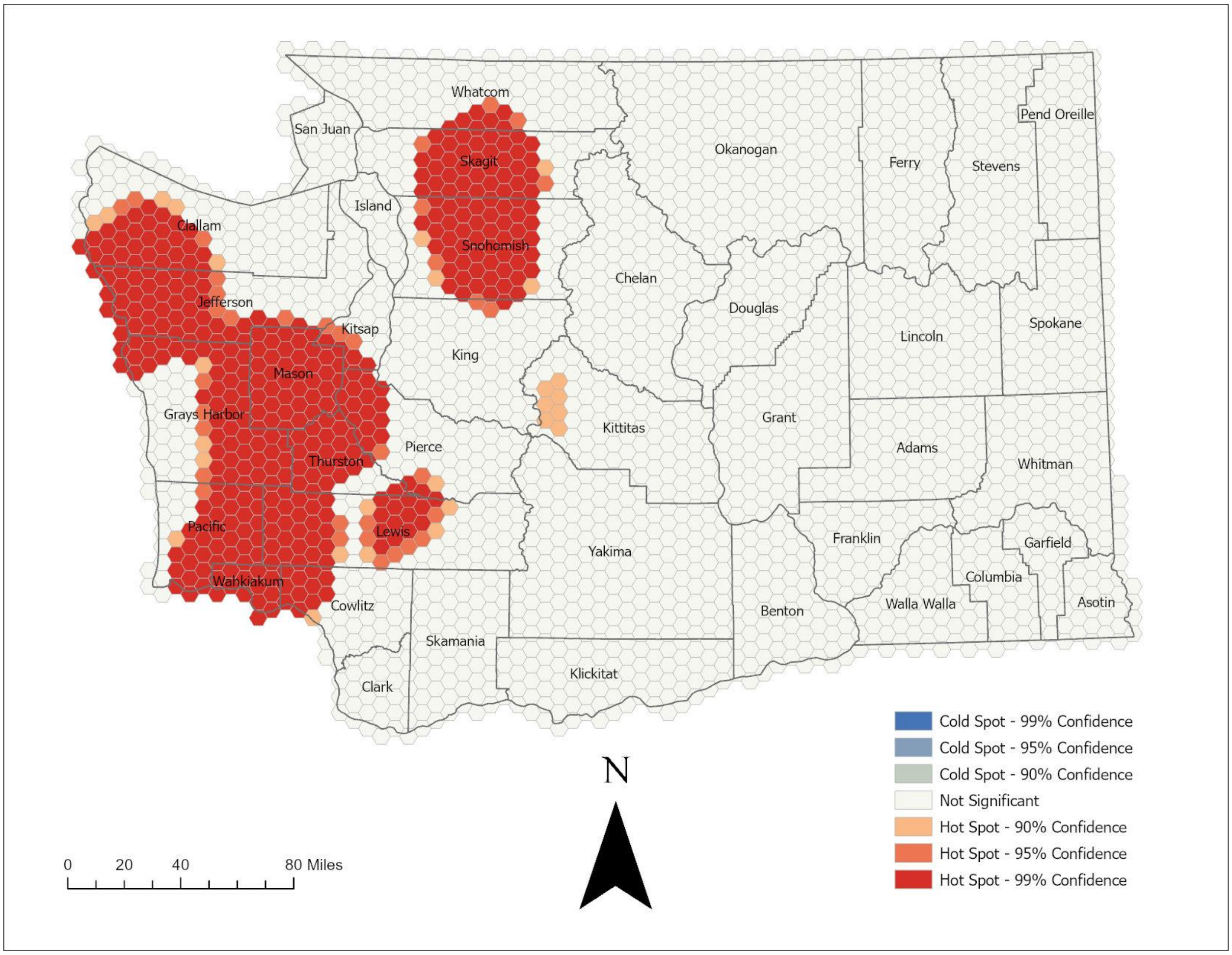

Figure 25.Landslide hot spot map based on the 2018 WGS landslide compilation data. Areas with counts we are 99% confident are higher than state average are shown in the darkest red shade and may be areas most prone to landslides in the future.

Landslides and extreme rainfall

Steeper slopes in areas with a greater possibility of extreme rain can lead to a higher likelihood of landslides in such places. Extreme rainfall and water-logged soils have been linked to numerous major landslides (USGS, 2020), including the SR530 landslide (Iverson et al., 2015; La Pointe & Godt, 2017). We used rainfall accumulation and soil moisture content to help determine the risk of soil oversaturation and landslide activity during periods of extreme rainfall and compared those measurements to the SR530 slide as a reference level. Archival earth observation data is available to show accumulated rainfall at the SR530 slide location over a pre-determined period (Figure 26). This capability allows for a potential baseline for rainfall accumulation rates capable of triggering major landslides.

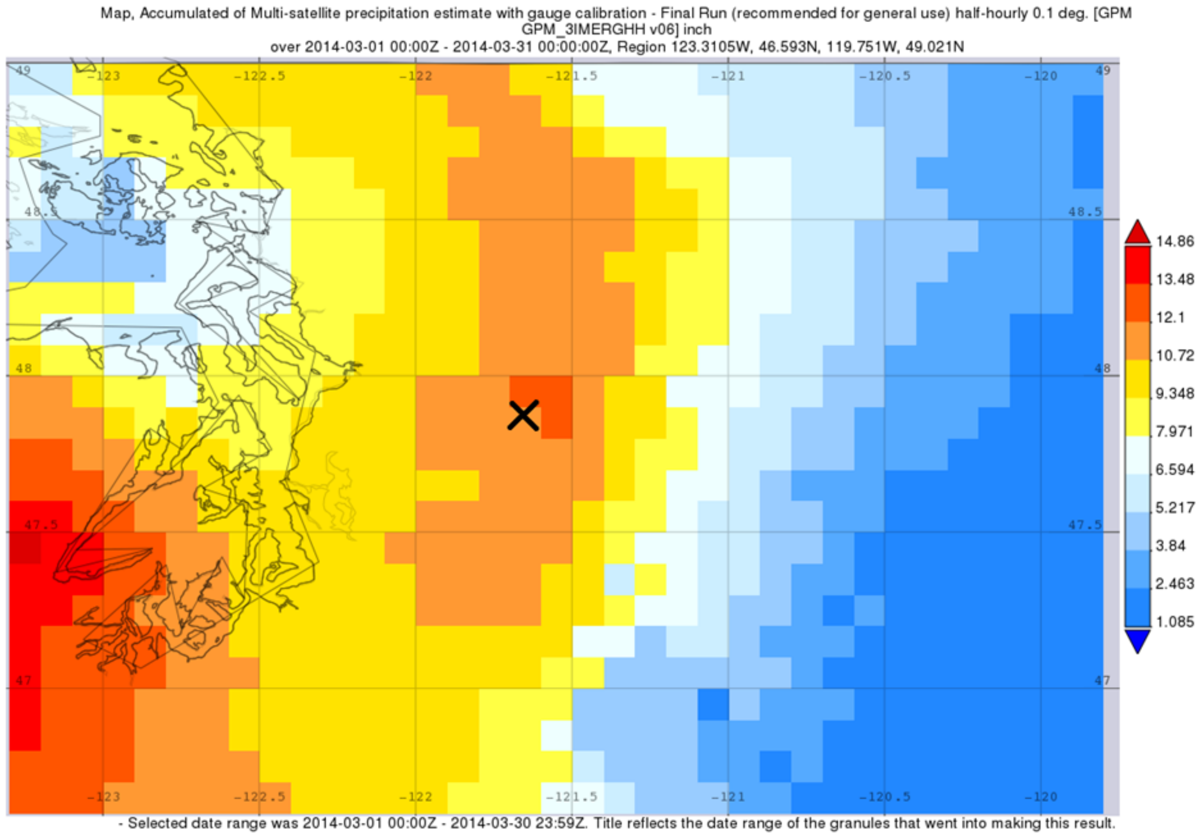

Figure 26. Rainfall accumulation using data from the Integrated Multi-Satellite Retrievals for GMP (IMERG) product. The "X" shows the approximate location of the 2014 SR530 slide near Oso, WA. Rainfall totals ranged from ~10 - 13 inches between March 1, 2014, to March 30, 2014, in that area. (Source: visualization produced NASA Giovanni).

Earth observations from satellites can also help analyze the SR530 landslide using other parameters that may indicate landslide risk or hazard potential. According to soil moisture rates calculated using NASA's Modern-era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) model (GMAO, 2022), average soil moisture content around the time of the SR530 landslide was approximately 0.39 m^3/m^3 (the volume of water that can be removed from a volume of soil). This means that a block of soil measuring approximately 13.8 feet on all sides would hold more than 100 gallons of water.

We compared soil moisture content during the December 2019 atmospheric river (AR) event with the March 2014 average to help determine landslide hazard potential given that severe ARs can carry enormous amounts of water vapor into western Washington. Average soil moisture content in Chehalis, WA during the December 2019 AR was found to be 0.32 m^3/m^3, near the levels seen near Oso in March 2014 – though it should be noted that prior to the AR event was an unusually dry November and early December, which likely influenced the lower average. It should also be noted that landslide hazards in Chehalis (a relatively flat topography) are not as severe as in the Oso area.

To supplement the monthly soil moisture averages, we used daily measurements of surface soil moisture content as measured by the Soil Moisture Active Passive (SMAP) satellite. We found that soil moisture rates increased significantly during the December 2019 AR event across virtually all western Washington (though more pronounced in southwestern Washington). SMAP data are only available from 2015 to present day, so no SMAP data exist for the 2014 SR530 landslide, but SMAP and MERRA-2 measurements are available in the name units (m^3/m^3), which allows for comparison.

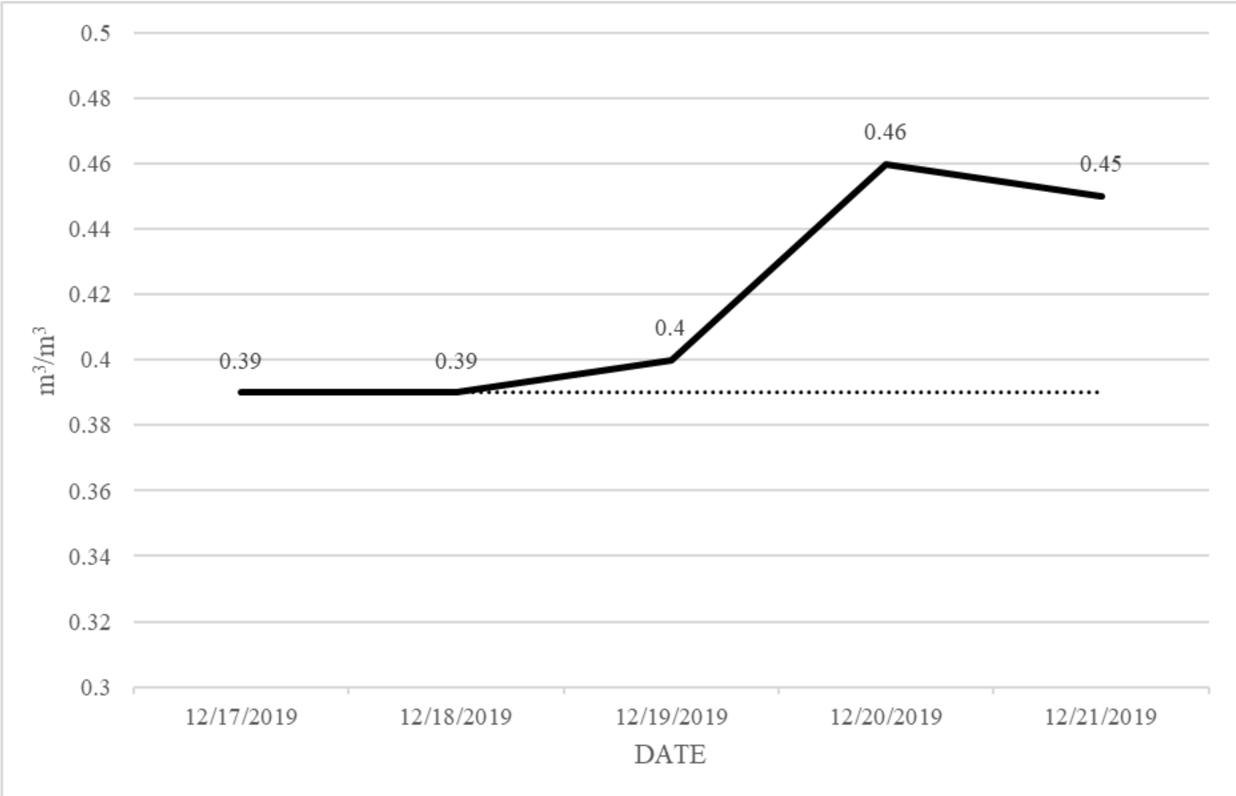

Figure 27. Soil moisture content at Chehalis, WA during the December 2019 atmospheric river. The dotted line indicates the monthly average soil moisture content near Oso, WA in March 2014 (0.39 m3/m3) according to MERRA-2. Levels at Chehalis during the December 2019 AR remained equal to or higher than average soil moisture content at Oso immediately preceding the 2014 landslide there, including at least two days of moisture content well above that average (12/20/2019 and 12/21/2019). (Source: Figure created from SMAP data (Entekhabi, et al., 2014), accessed February 2020).

The significant and rapid increase in soil moisture content during the December 2019 AR suggests that severe ARs could possibly trigger landslide activity, and that these weather systems should be considered when determining acute landslide hazard potential.

Post-fire debris flows

Landslides, in addition to their connection to floods and precipitation, are also connected to wildfires. Wildfires often leave large swaths of previously vegetated land exposed to precipitation, which can lead to the increased runoff of the recently burned topsoil creating a landslide known as a post-fire debris flow. These debris flows can be hazardous when located near populated areas or critical infrastructure because they can move rapidly, travel long distances, and can cause destruction in their path (DeGraff, 2018). Post-fire debris flows can be triggered by rain on a burn scar, as well by rapid snowmelt. The general rule is that the first two years after a wildfire is the most likely time for a post-fire debris flow, with an estimated 85% of post-fire debris flows occurring within the first 12 months following a fire (DeGraff et al., 2015).

Because climate change is increasing the likelihood of extreme rain as well as the size, severity, and intensity of wildfires in Washington, it is likely that landslides will also begin to increase over time.

State-owned or -leased facilities

Of the 11,000+ State owned and leased facilities, only 11 fall into the landslide footprints in the 2018 WGS compilation data. Seven of the 11 are in Yakima County and mostly related to a campground in Ahtanum State Forest, with the remaining facilities of various uses in Cowlitz, Kittitas, Klickitat, and Thurston Counties. When using the landslide hot spots we identified, the number of State owned or leased facilities within potential landslide hazard areas increases to approximately 2,600 worth about $41 billion. However, given the coarse nature of the landslide hazard hot spot analysis, this number is likely exaggerated and includes structures that are unlikely to be impacted directly by landslides. In future SEHMP updates, we will work to refine this analysis.

Critical infrastructure

- **Transportation**. There are approximately 10,200 miles of public roads in our identified landslide hazard hot spots, including more than 300 miles of Interstate 5 and 250 miles of Highway 101. Most of these roads are in the Olympic Peninsula and Southwestern region (6,100 miles, 60%). The only critical intermodal transportation facilities located in the landslide hot spots are port facilities in Olympia, Aberdeen, and Longview, where it is uncertain whether landslides pose direct risks to such facilities.

- **Health & safety.** There are 23 licensed hospitals in our landslide hazard hot spots (20% of state) totaling about 3,400 beds. There are about 300 fire stations in the landslide hazard hot spots as well as 80 police stations. Most of these resources are in the Olympic Peninsula and Southwestern region. We would like to note that many of these health & safety facilities are in urbanized areas (e.g., Olympia) and may be less likely to be directly impacted by landslides. Future landslide hazard analyses will refine these results.

- **Energy.** There are 3,100 miles of power transmission lines across the landslide hot spots, which is about 20% of all transmission lines in the state. In addition, there are 24 power plants in the landslide hot spots.

- **Water & wastewater.** Approximately 22% of the state's drinking water supplies (groups A and B combined) are within the landslide hot spots. There is one publicly-owned wastewater treatment plant in our identified landslide hot spots – the Chambers Creek facility in Pierce County.

Population

The estimated total population in all Census tracts within our identified landslide hot spots is 1.5 million – 800,000 of which reside in Census tracts with previous landslide activity. This is likely an underestimation given the potential for additional landslides that are not captured in the 2018 WGS compilation as well as continued population growth since the latest Census. Future SEHMP updates will incorporate best available landslide datasets from the WGS, including data that captures more of the state's population centers. Approximately 390,000 people live in Census tracts designated as socially vulnerable (i.e., a score of 0.75 or greater in CDC's 2018 Social Vulnerability Index). The counties with the largest number of socially vulnerable residents located near previous landslides are Yakima (approx. 48,000), Cowlitz (approx. 41,000), and Mason (approx. 41,000). This means approximately 31% of the socially vulnerable people who reside near previous known landslide activity live in Yakima, Cowlitz, or Mason Counties. The most common reasons they are considered socially vulnerable are because of socioeconomic factors, such as increased poverty and unemployment. In Yakima County, the higher rate of limited English proficiency among residents is also a contributing factor to social vulnerability there.

The average Environmental Health Disparities (EHD) ranking for the areas impacted by landslides in the 2018 WGS compilation is 3.4, which is below the average for the state. This suggests that the populations nearest those previous landslides are less likely to also be experiencing other environmental health disparities. However, there were some areas that did have high EHD rankings, including the highest ranking possible of 10 in the town of Kelso (Cowlitz County). In addition to landslide hazards, the population there is also exposed to various sources of air pollution (including ozone and diesel emissions), likely originating from the proximity of Interstate 5. The people there also experience poverty and unemployment rates above the state average and education levels below state average. These social vulnerabilities can exacerbate the impacts of landslides that may occur in the future. Other areas with high-ranking EHD scores include other portions of Cowlitz County, as well as portions of Yakima and Kitsap Counties.

Population growth is expected to stabilize in the landslide hazard areas, making our projection of people exposed to landslide hazards in 2050 to remain at 1.5 million.

The region most at-risk to future landslides is the Olympic Peninsula and Southwestern region, due primarily to the probability of future landslides in that area along with the above average number of socially vulnerable residents exposed to landslide hazards there. This largely follows the results of the 2018 SEHMP risk assessment, which identified Clallam, Jefferson, Lewis, and Skamania Counties as having high landslide risk. This is not to say that considerable landslide risks don't exist elsewhere. They most definitely do, including in portions of Central Washington (e.g., Yakima County) and the Puget Sound and Northwestern region (e.g., Snohomish and Skagit Counties). However, the bulk of potentially vulnerable people, roads, and health and safety assets are on the Olympic Peninsula and in the Southwestern region of the state. In parts of rural Grays Harbor, Jefferson, and Clallam Counties, for example, even small landslides along key roads have the potential to significantly impede travel and access to community lifelines, as well as evacuation routes. Most drinking water supplies exposed to landslide hazards are also in this same region, meaning there are potentially hundreds of drinking water supplies vulnerable to the impacts of sedimentation and other landslide-driven reductions in water quality and access.

3.1.g. Tsunami

Situational overview

Although tsunamis in Washington are often discussed as the after-effects of a local earthquake, our geological history indicates that most tsunamis that have impacted our coastline were generated elsewhere along the Pacific Rim. However, it is estimated that an earthquake (M8 or M9) in the Cascadia Subduction Zone will likely produce a significant tsunami with significant damaging and life-threatening impacts along our coastal shoreline communities. Because of the catastrophic nature of a CSZ-generated tsunami, our hazard and vulnerability analysis does primarily focus on that kind of event even though a lower-impact tsunami generated elsewhere is more probable. We should also note that an earthquake generated on a Puget Sound crustal fault (e.g., the Seattle Fault) could create a tsunami that would undoubtedly impact portions of the highly developed Puget Sound region. Inland tsunamis generated by landslides have also occurred in Washington, but these tsunamis are not considered in this update.

Table 19 provides an overview of the location and possible extent of previous or modeled tsunamis. Table 20 summarizes the probability of a future tsunami, projected changes in tsunami impacts, and which jurisdictions are most at-risk. Other key findings from the tsunami hazard and vulnerability analysis include:

- Estimated population within tsunami hazard areas: 260,000
- Projected population within tsunami hazard areas by 2050: 268,000
- Estimated socially vulnerable population within tsunami hazard areas: 50,000
- Estimated population exposed to the direct or indirect impacts of tsunamis: 5 million
- Estimated State-owned or -leased facilities within tsunami hazard areas and dollar value: 278; $318 million
- Estimated miles of public roads in tsunami hazard areas: 830
- Critical intermodal transportation facilities in tsunami hazard areas: 9
- Number of licensed hospitals in tsunami hazard areas: 0
- Number of first responder facilities in tsunami hazard areas: 43
- Number of power plants and miles of electric power transmission lines in tsunami inundation zones: 8 power plants; 174 miles of power transmission lines
- Number of public drinking water supplies in tsunami inundation zones: 340
- Number of publicly owned wastewater treatment plants in tsunami inundation zones: 0

Table 19. Overview of location and extent of previous and modeled tsunamis.

Location	Possible Extent (Magnitude/Severity)	Previous Occurrences
Statewide, but the most significant risk to life and property is on marine shorelines	Inland tsunamis (on lakes) can reach as high as 65 ft; a tsunami generated by a CSZ earthquake is expected to inundate all coastal areas with the likelihood of catastrophic consequences – including estimated deaths in the tens of thousands – along our coastline.	No recent seismic-driven tsunamis, but periodic inland tsunamis driven by landslides have occurred as recently as 2009

Table 20. Overview of the probability of future tsunamis, projected changes in tsunami impacts, and the jurisdictions most at-risk.

Annual Probability	Projected Changes	Region Most At-risk
< 1% chance of a tsunami-related disaster declaration each year	Exposed population and property, as well as social and structural vulnerability, will increase as tsunami-prone areas in the Puget Sound and Pacific Coast regions see continued population growth and development. Projected population growth in the state suggests 268,000 people will be residing in coastal tsunami inundation zones by 2050, an increase of 3% compared to 2020. This increase suggests increased vulnerability to tsunami impacts over time. Inland landslide-driven tsunamis in WA have largely been tied to human-made reservoirs and have seen declines in their frequency since the 1950s.	Olympic Peninsula & Southwestern

Tsunami hazard and vulnerability analysis

Figure 28 shows the tsunami inundation zones for coastal Washington (WGS, 2019), the most current dataset available when this analysis was performed. Future updates of this profile will include updated tsunami inundation zones.

It is clear the most significant inundation areas are along the Pacific Coast, particularly Pacific and Grays Harbor Counties, followed by Clallam County as well as the Puget Sound counties of Skagit and Whatcom. Although these mapped areas suggest some level of risk to tsunami impacts, it is important to note that tsunamis won't impact every part of the coastline in the same way. The shape of the seafloor and the shapes of bays and coastlines can cause tsunami waves to grow before they reach land. Similarly, the topography of the land onshore and the amount of vegetation on land can also affect the wave height and inland distance that the tsunami travels (DNR, 2022).

Tsunami waves that may impact mapped areas in Figure 28 will not behave like regular waves. Tsunamis typically involve multiple waves with the possibility of the largest wave not being the first one to arrive on shore nor the most destructive. The shape of tsunami waves is also distinct from wind-generated waves in that they are massive in width, length, and depth versus wind waves that may be taller than they are wide, allowing them to curl and "crash" on shore. Tsunamis typically arrive on shore like a wall of water, or storm surge, with a wave front followed by miles of water just as massive in severe events. As such, a tsunami event can last from hours to days.

Figure 28. Tsunami hazard areas (WGS, 2019)

State-owned or -leased facilities

Given the localized nature of tsunami hazards, only about 2% of all State facilities are exposed (n=278), worth an estimated $318 million. Most of those exposed facilities are in Pacific County (n=110) and Grays Harbor County (n=81). Many of these facilities are used for recreation, but other uses include office, transportation, and residential.

Critical infrastructure

- **Transportation**. About 830 miles, or 1% of all public roads in Washington, are exposed to tsunami hazards, with more than half of those exposed roads in either Grays Harbor or Pacific Counties. There are nine critical intermodal transportation facilities in the tsunami hazard areas, including numerous ports (e.g., Port of Aberdeen, Port of Tacoma) and rail facilities (e.g., Seattle International Gateway). Because of its more developed nature, most of these exposed intermodal transportation assets are along the Puget Sound coast.

- **Health & safety.** There are no licensed hospitals in the tsunami hazard areas. There are 32 fire stations exposed to tsunami hazards (2.5% of all fire stations in the state), with most of these in Grays Harbor or Pacific Counties. There are 11 police stations in the tsunami hazard areas (3% of the state), again with most of these in Grays Harbor or Pacific Counties.

- **Energy.** There are 174 miles of power transmission lines exposed to tsunami hazards, primarily in Aberdeen (Gray Harbor County) as well as in port areas of Tacoma (Pierce County), Seattle (King County), and Everett (Snohomish County). Approximately 5% of the state's power plants (n=8) are in the tsunami hazard areas totaling just over 300 megawatts of potential power generation. They are spread across the exposed areas, though Grays Harbor has the most of any single county (n=2).

- **Water & wastewater.** There are no publicly owned wastewater treatment plants in the tsunami hazard areas. It is possible that privately owned facilities are exposed to tsunami hazards and are not included in this analysis. However, about 2% of the state's public drinking water supply is exposed to tsunami hazards (n=340). As with other critical infrastructure sectors, the counties most exposed are Grays Harbor and Pacific.

Population

Estimated population in the tsunami hazard areas is 260,000 (not including visitors to beach areas). This number is expected to increase modestly by 2050 to 268,000. The average social vulnerability rank of the residents there is just under state average (0.47 vs. 0.50). There are areas with high social vulnerability ranks (≥0.75), particularly in cities such as Aberdeen and Westport (Grays Harbor County), Raymond (Pacific County), Tokeland (Pacific County), and Neah Bay (Makah Tribe). The primary drivers of social vulnerabilities in these and other high ranking areas are socioeconomic, particularly lower per capita incomes. High concentrations of elderly residents also contribute. The areas with the highest social vulnerability ranks show about average environmental and health disparities (EHD) relative to the state. Locations where EHD ranks are highest are often adjacent port facilities, where exposure to poor air quality and proximity to Superfund sites drive up the EHD ranking.

The region most at-risk to tsunami impacts is the Olympic Peninsula and Southwestern region. Although all the state's major ports are within tsunami inundation zones, there is a relatively low number of critical infrastructure facilities found within the tsunami hazard areas when compared to other more geographically extensive natural hazards (e.g., extreme weather, earthquake). This is likely due to the more rural nature of Washington's Pacific Ocean coastal area, which includes large sections of undeveloped land broken up by small coastal communities. However, the tsunami exposure for those small communities is significant. For example, although relatively few miles of public roads are exposed to tsunami hazards, those exposed include the entire towns of Ocean Shores and Westport, as well as significant portions of Hoquiam and Aberdeen (all of which are in Grays Harbor County). In Pacific County, the entire towns of Ocean Park, Tokeland, and Long Beach are exposed to tsunami hazards, as well as significant portions of South Bend and Raymond. Although a relatively small area of the state is exposed to tsunami hazards compared to other natural hazards (e.g., earthquake, wildfire), where exposure does exist is significant for those communities – particularly when considering that evacuation is a primary tsunami mitigation measure and virtually all their evacuation routes are in the tsunami hazard areas.

3.1.h. Volcano

Situational overview

The Cascade Mountains include multiple "high threat" volcanoes, stretching from northern California to British Columbia. Washington has five active volcanoes, four of which are considered high threat by the U.S. Geological Survey due to their proximity to developed areas (e.g., Seattle-Tacoma metropolitan area): Mount Baker, Glacier Peak, Mount Rainier, and Mount St. Helens. The fifth volcano, Mount Adams, is not considered high threat but is active.

The most recent volcanic event in Washington is the 1980 eruption of Mount St. Helens (Skamania County), which killed 57 people. That eruption led to large-scale and devasting lahars that destroyed more than 200 homes and caused long-term environmental degradation. Eruptions of similar scales are possible on all five of Washington's volcanoes, though such events are considered rare.

Table 21 below provides an overview of the location and extent of previous volcano disasters. Table 22 summarizes the probability of future volcano disasters, as well as the projected changes in volcano impacts and the jurisdictions most at-risk. Other key findings from the volcano hazard and vulnerability analysis include:

- Estimated population within volcano hazard areas: 300,000
- Projected population within volcano hazard areas by 2050: 300,000
- Estimated socially vulnerable population within volcano hazard areas: 69,000
- Estimated population exposed to the direct or indirect impacts of volcanoes: 7.5 million
- Estimated State-owned or -leased facilities within volcano hazard areas and dollar value: 350, $333 million
- Estimated miles of public roads in volcano hazard areas: 1,900
- Critical intermodal transportation facilities in volcano hazard areas: 1
- Number of licensed hospitals in volcano hazard areas: 1
- Number of first responder facilities in volcano hazard areas: 74
- Number of power plants and miles of electric power transmission lines in volcano hazard areas: 19 power plants; 489 miles of transmission lines
- Number of public drinking water supplies in volcano hazard areas: 603
- Number of publicly owned wastewater treatment facilities in the volcano hazard areas: 1

Table 21. Overview of location and extent of previous volcano disasters.

Location	Possible Extent (Magnitude/Severity)	Previous Occurrences
Primarily western Washington for lahar impacts; statewide for tephra/ash impacts	Explosive eruptions are possible on Mt. St. Helens, Rainier, Baker, and Glacier Peak, with ash/tephra capable of extending across the state; lahars from Mt. Rainier and Baker can reach Puget Sound.	1980 (DR-623)

Table 22. Overview of the probability of future volcano disasters, projected changes in volcanic impacts, and the jurisdictions most at-risk.

Annual Probability	Projected Changes	Region Most At-risk
2.5% chance of a volcano-related disaster declaration each year	Exposed population and property may increase if volcano-prone areas see continued population growth and development, particularly in lahar zones in western WA, although the number of people residing in lahar zones now is not expected to drastically increase by 2050. Given improvements in volcano awareness and eruption detection, it is possible that our vulnerability to volcanic impacts has decreased over time (though this has yet to be quantified).	Puget Sound & Northwest

Volcano hazard and vulnerability analysis

Figure 29. Volcano hazard areas for Washington. Red-shaded areas indicate near-volcano hazards (e.g., lava, rock falls, etc.) as well as far-traveling lahar zonesFigure 29 shows the volcano hazard areas for Washington, including near-volcano hazards (e.g., lava, pyroclastic flows, thick tephra, lahars, ballistic ejecta, and rock fall) as well as lahar zones (i.e., potentially far-travelled mixtures of rock and water in valleys draining a volcano). Because of the mostly remote nature of near-volcano hazards, the biggest risks associated with volcanoes in Washington come from the lahars that can travel along the more-developed river valleys in the Puget Sound lowlands (e.g., Puyallup River, Skagit River). It should be noted that although the most direct impacts of a volcanic eruption are expected only in western and central Washington, the impacts of volcanic ash can be far-reaching. The entire state is exposed to ash-related impacts. For this reason, our analysis here has focused only on near-volcano and lahar hazards with the assumption that the whole state has the same exposure to volcanic ash. However, the probability of severe ash-related impacts decreases with distance from the volcano itself.

State-owned or -leased facilities

There are about 350 State-owned or -leased facilities in the volcano hazard areas, worth an estimated $333 million. Their uses include recreation, office, residences, and education. Most of these facilities are in the Puget Sound & Northwestern region (81%, n=288), with many in Pierce and Skagit Counties.

Critical infrastructure

- **Transportation**. There are about 1,900 miles of public roads in the volcano hazard areas, including 87 miles of Interstate 5. Significant portions of Interstate 5 are in the lahar zones near Mount Vernon (Skagit County) and Tacoma (Pierce County). The only critical intermodal transportation facilities located in volcano hazard areas are associated with the Port of Tacoma, including the Port itself and multiple railroad facilities there.

- **Health & safety**. There is one licensed hospital in the volcano hazard areas – MultiCare Good Samaritan Hospital in Puyallup (Pierce County), which has 286 beds. Like most roads exposed to volcanic hazards, this hospital is in a lahar zone. There are 18 police stations in the volcano hazard areas (5% of all police stations in Washington). Most are in either Pierce or Skagit Counties, which both have five stations exposed to direct volcanic hazards. There are 56 fire stations in the volcano hazard areas (4% of the state), most of which are, again, in Pierce or Skagit Counties.

- **Energy.** There are 489 miles of power transmission lines exposed to volcanic hazards (3% of the state's power transmission lines). Most of these power lines are in the lahar areas near Tacoma/Puyallup (Pierce County) and Mount Vernon/Sedro-Wooley (Skagit County). There are 19 power plants exposed to volcanic hazards (12% of all power plants in Washington). Whatcom County has the most of any single county (n=5), followed by Pierce County (n=4) and Skagit County (n=3).

- **Water & wastewater**. About 3.5% of the state's public drinking water supply is exposed to direct volcanic hazards (n=603 supplies, groups A and B combined). An estimated 45% of those exposed supplies are in Pierce County alone. Pierce County also has the only publicly owned wastewater treatment facility exposed to volcanic hazards.

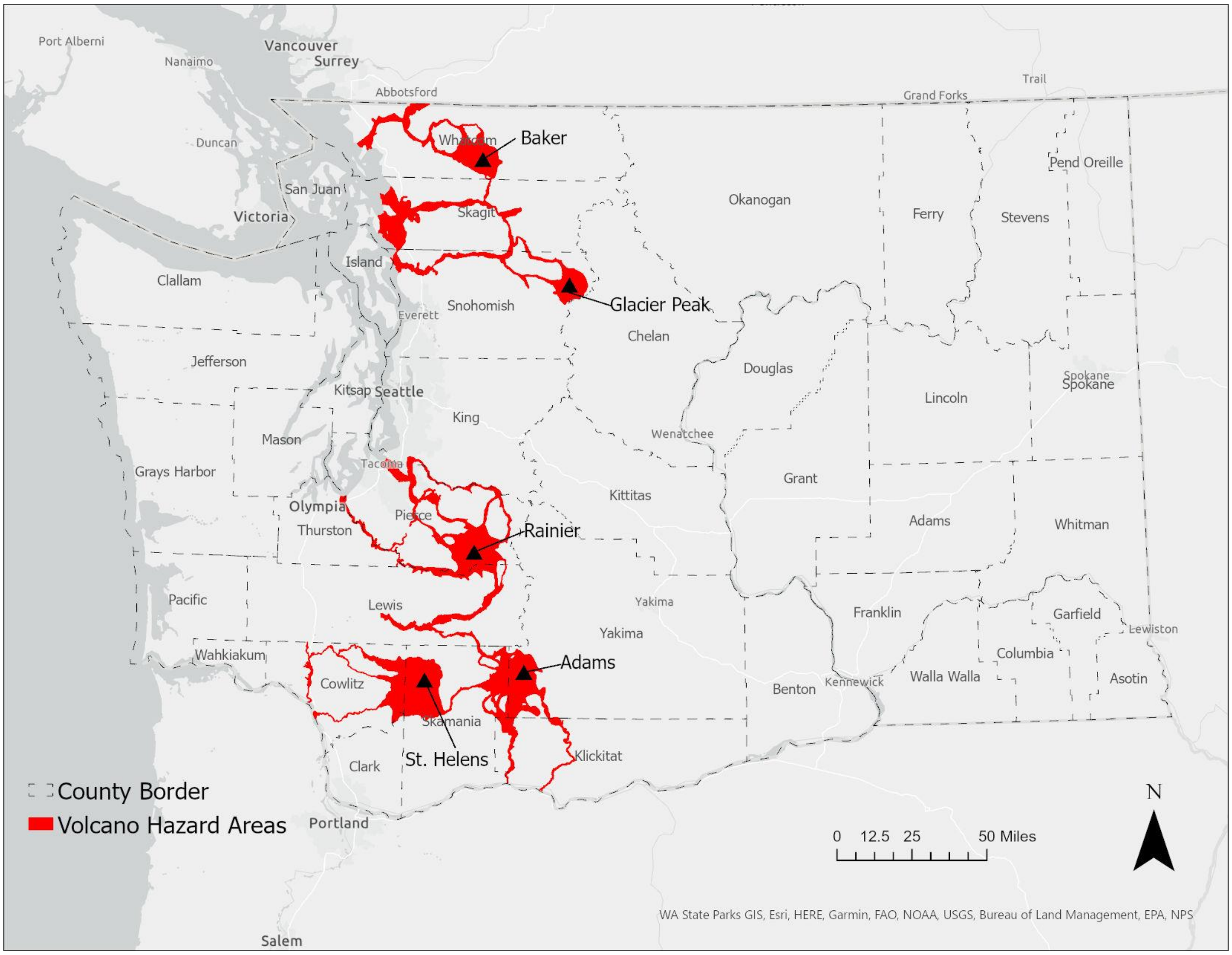

Figure 29. Volcano hazard areas for Washington. Red-shaded areas indicate near-volcano hazards (e.g., lava, rock falls, etc.) as well as far-traveling lahar zones associated with each of Washington's five active volcanoes.

Population

Total estimated population residing in the volcano hazard areas is 300,000, with about 23% considered socially vulnerable. The primary drivers of social vulnerability in those areas are socioeconomic, namely lower per capita incomes and higher rates of poverty than state average. The most significant cluster of socially vulnerable people is in the Mount Vernon and Sedro-Wooley area of Skagit County, which has an estimated socially vulnerable population of 32,000. The number of people living in volcanic hazard areas is expected to remain about the same by 2050.

The region most at-risk to future volcanic eruptions is the Puget Sound and Northwestern region, particularly Pierce and Skagit Counties – which have the highest level of exposed critical assets and population. These exposures include numerous drinking water supplies as well as power generation facilities located along waterways that are also the potential path of a lahar. Although the most direct impacts of a future volcanic eruption will be localized, thereby directly impacting a relatively small portion of the state, those local impacts could be severe and devastating – as shown in the 1980 eruption of Mount St. Helens. Lahars of similar scales in Pierce or Skagit Counties, where more people live and where more critical infrastructure is located, would likely have impacts beyond those during the 1980 St. Helens eruption. Finally, although we did not quantify the potential impacts of volcanic ash on the state, ash-related impacts could be significant in a full-scale eruption and have possible statewide consequences.

3.1.i. Wildfire

Situational overview

The increase in larger, more severe wildfires in the state of Washington over the past few decades (Wing & Long, 2015) follows what is generally happening in wildfire-prone regions around the world. More frequent large fires (Jolly, et al., 2015) are resulting in increases of annual average acres burned (Dennison, et al., 2014) and more extensive property damage (Rasker, 2015) in such regions. Wildfire smoke is diminishing air quality in the western US (McClure & Jaffe, 2018) with observable increases in mortality among some Washington residents (Doubleday, et al., 2020). It is important to remember, too, that wildfire smoke from fires in other states can impact Washingtonians, making wildfire smoke a regional (or arguably global) hazard (Figure 30). Wildfires can also trigger cascading impacts or multi-hazard events that can include flooding (Brogan, et al., 2017), and erosion and sedimentation (Sankey, et al., 2017).

Table 23 below summarizes the location, extent, and previous occurrences of wildfires in Washington. Table 24 provides a summary of the probability of future occurrence and projected changes in location, extent, intensity, frequency, and/or duration based on the influence of climate change, population growth, and other external factors. Other key findings from the wildfire hazard analysis include:

- Estimated population within the most wildfire-prone regions in WA: 900,000
- Projected population within the most wildfire-prone regions in WA by 2050: 1 million – 1.03 million
- Estimated socially vulnerable population within the most wildfire-prone regions in WA: 300,000
- Estimated population exposed to the direct or indirect impacts of wildfires in WA: 7.5 million
- Estimated State-owned or -leased facilities within the most wildfire-prone regions in WA and dollar value: 2,000, $13 billion
- Estimated miles of public roads located in the most wildfire-prone regions in WA: 20,000
- Critical intermodal transportation facilities located in the most wildfire-prone regions in WA: 4
- Number of licensed hospitals in the most wildfire-prone regions in WA: 21
- Number of first responder facilities in the most wildfire-prone regions in WA: 242
- Number of power plants and miles of electric power transmission lines in the most wildfire-prone regions in WA: 29 power plants, 3,000 miles of transmission lines
- Number of public drinking water supplies in the most wildfire-prone regions in WA: 2,378
- Number of wastewater treatment plants in the most wildfire-prone regions in WA: 1

Table 23. Overview of location and extent of previous wildfires.

Location	Possible extent (magnitude/severity)	Previous occurrences
Statewide, but most prevalent east of the Cascade Range	Wildfires in WA often reach class G (>5,000 acres); the Cold Springs Canyon-Pearl Hill fire complex in 2020 was the state's largest recorded and burned >410,000 acres	2021 (8 FMAGs); 2020 (DR-4584); 2018 (10 FMAGs); 2017 (3 FMAGs); 2016 (4 FMAGs); 2015 (DR-4243); 2014 (DR-4188); 2013 (3 FMAGs); 2012 (8 FMAGs); 2011 (1 FMAG); 2010 (2 FMAGs); 2009 (2 FMAGs); 2008 (2 FMAGs); 2007 (3 FMAGs); 2006 (3 FMAGs); 2005 (2 FMAGs); 2004 (5 FMAGs); 2003 (2 FMAGs); 2002 (2 FMAGs); 2001 (9 FMAGs); 2000 (3 FMAGs); 1998 (3 FMAGs); 1996 (1 FMAG); 1994 (4 FMAGs); 1992 (1 FMAG); 1991 (DR-922); 1988 (1 FMAG); 1985 (1 FMAG)

Table 24. Overview of probability of future wildfires, projected changes in wildfire activity, and jurisdictions most at-risk.

Annual probability	Projected changes	Region most at-risk
70% chance of a wildfire disaster declaration each year	The frequency of wildfires and number of acres burned has increased significantly in WA since 1970. Wildfires are expected to continue their increase in extent, intensity, and frequency for the entire state, with large fires becoming more likely in central and eastern WA. Western WA is expected to see more fire activity as well. Wildfire season is projected to increase in duration, putting more of the state at-risk for longer periods. These changes are driven by climate change and population growth and development in the wildland-urban interface (~85% of wildfires were human caused in 2020).	Central

Wildfire hazard and vulnerability analysis

When looking at the 50-year timespan between 1970 – 2020, Washington is shown to have multiple wildfire "hot spots" across large swaths of the state (Zerbe et al., 2022). These hot spots indicate areas where, when compared to the entire state, wildfires happened significantly more in the years between 1970 and 2020 (Figure 31). Based on these previous occurrences, these hot spots are areas most likely to see large fires (more than 100 acres) in the future, although additional modeling that incorporates climate change considerations should be done to pinpoint where future occurrences are expected with more accuracy. The number of large wildfires in Washington has significantly increased over time, with no indication of slowing down considering climate change and projected population growth.

Although the areas shaded red in Figure 31 are most likely to see large, and potentially destructive, wildfires in the future, large and destructive wildfires can occur elsewhere in the state – including some blue cold spots. The wildland-urban interface (WUI) is rapidly developing in Washington, which is likely putting more property and people in wildfire-prone places around the state than ever before. This includes many western Washington counties, such as King and Pierce, where a combination of WUI development and climate change (i.e., hotter, dryer summers) can result in a greater chance for a wildfire that puts people and property at risk (Dunagan, 2020). For now, however, the most at-risk counties for wildfires are still east of the Cascade Range.

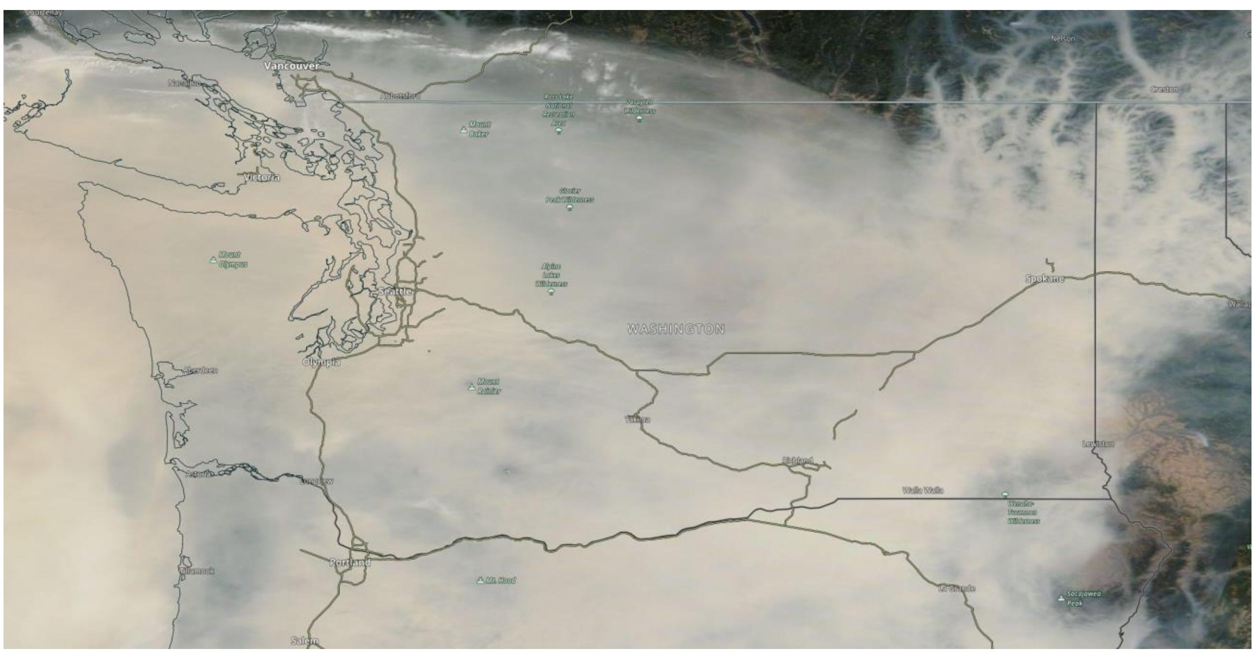

Figure 30. NASA MODIS satellite image from 9/12/2020. This image is showing wildfire smoke from fires within and outside WA covering the entire state. The public health implications from such widespread smoke events can be devastating. Source. NASA Worldview

To better understand why wildfire hot spots are located where they are, we explored the relationship between various socioeconomic, land use, and environmental factors and hot spot locations using a statistical model. We found that wildfire hot spot intensity tends to decrease as socioeconomic status (e.g., income, employment) increases, although this relationship was slight. This could be explained by the tendency for large fires to occur in rural areas where income and employment status may be below state average. We also found a slight relationship between crowded housing units (i.e., households with more people than rooms) and wildfire hot spot intensity, where a decrease in crowding comes a slight decrease in hot spot intensity. This again may point to the connection between rural areas and large wildfires. Our land use analysis had the same general results, reaffirming that land uses associated with undeveloped or minimally developed areas tend to associate with large wildfires. Of the environmental factors we studied, the average daily maximum temperature (between 1980-2019) was shown to have a significant relationship with wildfire hot spot intensity. As the average maximum daily temperature increases, so too does the hot spot's intensity, suggesting that environmental factors contribute significantly to large fires. This is supported by other research on this topic, which has long established the connection between heat and wildfire regime in western states since high heat tends to be followed by increased dryness or drought. As climate change increases the average temperature across Washington, the number of wildfire hot spots, or their intensity, is likely to increase as well.

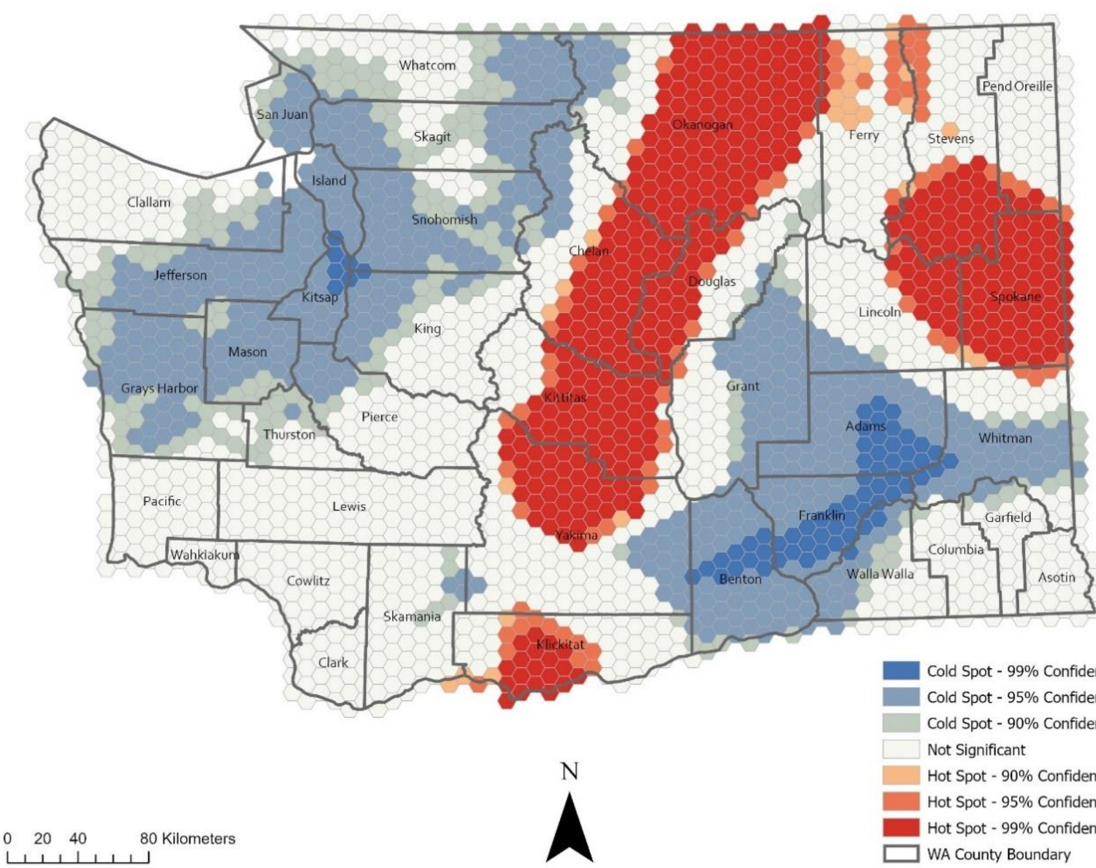

Figure 31. Wildfire hot spots and cold spots based on wildfire activity between 1970 and 2020. Hot spots were determined by counting the number of wildfire incidents within a 29-mile radius of each hexagon cell and comparing that number with the average for the state. Areas with counts we are 99% sure to be significantly higher than the state average are the deepest red color and are most prone to large fires in the future. Source: Zerbe et al., 2022.

Like temperature, precipitation was seen as having a significant impact on wildfire hot spot intensity, with more precipitation increasing wildfire hot spot intensities (potentially changing a minor hot spot into a significant one). This was a surprising result, but this relationship between precipitation and wildfire is supported by the fact that more spring precipitation in Washington leads to more grass and other vegetation (Weinberger, 2022).

To help fill in the gaps left in our modeling, we consulted local Community Wildfire Protection Plans (CWPPs) and the Washington Department of Natural Resources wildfire statistics data to better understand ignition sources of specific fires. According to the 2013 Okanogan County CWPP, most wildfires there between 1972-2012 were ignited by lightning strikes (58% of all fires during that time). Other common ignition sources were debris burning and sparks from various human activity (e.g., electric fencing, structure fires, power lines). Less common, but still significant, sources included recreation activity (e.g., campfires), cigarettes, fireworks, and arson. When looking at the DNR statistics data for the 2020 wildfire season (Washington's worst ever), many large fires around the state were started from the same or similar sources. Although many fires are still being investigated as of this writing, the fires with known ignition sources included electric power lines (n=4), lightning (n=3), passenger vehicles (n=3), debris burning (n=3), structure fire (n=1), firearm use (n=1), and arson (n=1).

Wildfire smoke as a natural hazard

Wildfire smoke is a mixture of gases and fine particles that poses a significant health risk to Washingtonians. People with pre-existing health conditions such as asthma or other chronic respiratory conditions and cardiovascular disease, people 18 and younger or older than 65, pregnant people, outdoor workers, people of color, tribal and indigenous people, and people with low income and/or are experiencing homelessness are particularly vulnerable to suffering adverse health effects from smoke exposure. The quantity and duration of smoke exposure, as well as a person's age and health status play a role in determining whether someone will experience smoke-related health problems. The potential health effects vary depending on the size of the particles. Particles larger than 10 micrometers usually irritate only the eyes, nose, and throat. Fine particulate matter (PM2.5), or particles smaller than 2.5 micrometers, can be inhaled deeply into the lungs, which increases the risk of cardiovascular and respiratory problems.

PM2.5 concentrations are the most useful measurement of smoke levels with respect to health and are commonly used as a proxy for the intensity of wildfire smoke exposure. To improve risk communication, the U.S. Environmental Protection Agency's (EPA) Air Quality Index groups PM2.5 concentrations into health hazard levels and six categories. Health precautions in each category are based on current conditions weighted to "24 hour-like" average concentrations. Hourly-updated levels of the AQI are publicly available to help inform decisions.

While the extent of wildfire seasons generally increasing in Washington and the surrounding region, the impacts of wildfire smoke vary year to year. Between 2012 and 2022 there were four years when most of Washington's population lived in areas where there was "Unhealthy" or worse air quality for at least one day according to the AQI. Often when a larger population is exposed, it is due to smoke from more distant wildfires that blankets Washington and beyond for multiple days. Depending on the meteorological conditions, smoke from more local wildfires can also impact large population centers.

Particulate matter in the atmosphere (dust, smoke, pollution) can block sunlight by absorbing or by scattering light. Aerosol optical depth (AOD) is a measure of the extinction of the solar beam by dust and haze and is a common indicator of air quality. An AOD of less than 0.1 indicates a clear sky with maximum visibility, and a value of 1 indicates extreme haze caused by dense particulate matter. The average AOD in the US ranges between 0.1 and 0.15 (NOAA, 2020).

The Moderate Resolution Imaging Spectroradiometer (MODIS) Combined Value-Added Aerosol Optical Depth layer (Levy & Hsu, 2015) can give a quick, synoptic view of the level of aerosols in the atmosphere. Using the EOSDIS Worldview tool, we found that monthly averages of daily AOD for Washington in August 2018 ranged from 0.31 to 0.9+, with the highest averages closest to the location of active wildfires (within approximately 40 miles of wildfires) (see Gelaro et al., 2017, for more about the monthly reanalysis of MODIS AOD measurements). The EOSDIS Worldview tool shows no part of the state was free from elevated AOD during this time, with the entire state showing above the US average range. Comparable AOD averages were found across the state in August 2015 (range: 0.13 - 0.9+) during similar levels of wildfire activity.

These August 2018 averages across the state are supported by *in situ* measurements of aerosols at two locations in Washington: The Pacific Northwest National Laboratory (PNNL) in Benton County and the Wind River Experimental Forest (WREF) in Skamania County. Figure 32 shows total AOD for a 10-day period in August 2018 as measured by ground-based radiometers.

Given the likelihood of more frequent and severe wildfires, as well as longer wildfire seasons, due to climate change (Snover et al., 2013; May et al., 2018), it is possible that aerosol readings comparable to August 2018 conditions could be repeated and should be considered when determining the overall impact of wildfires to the public.

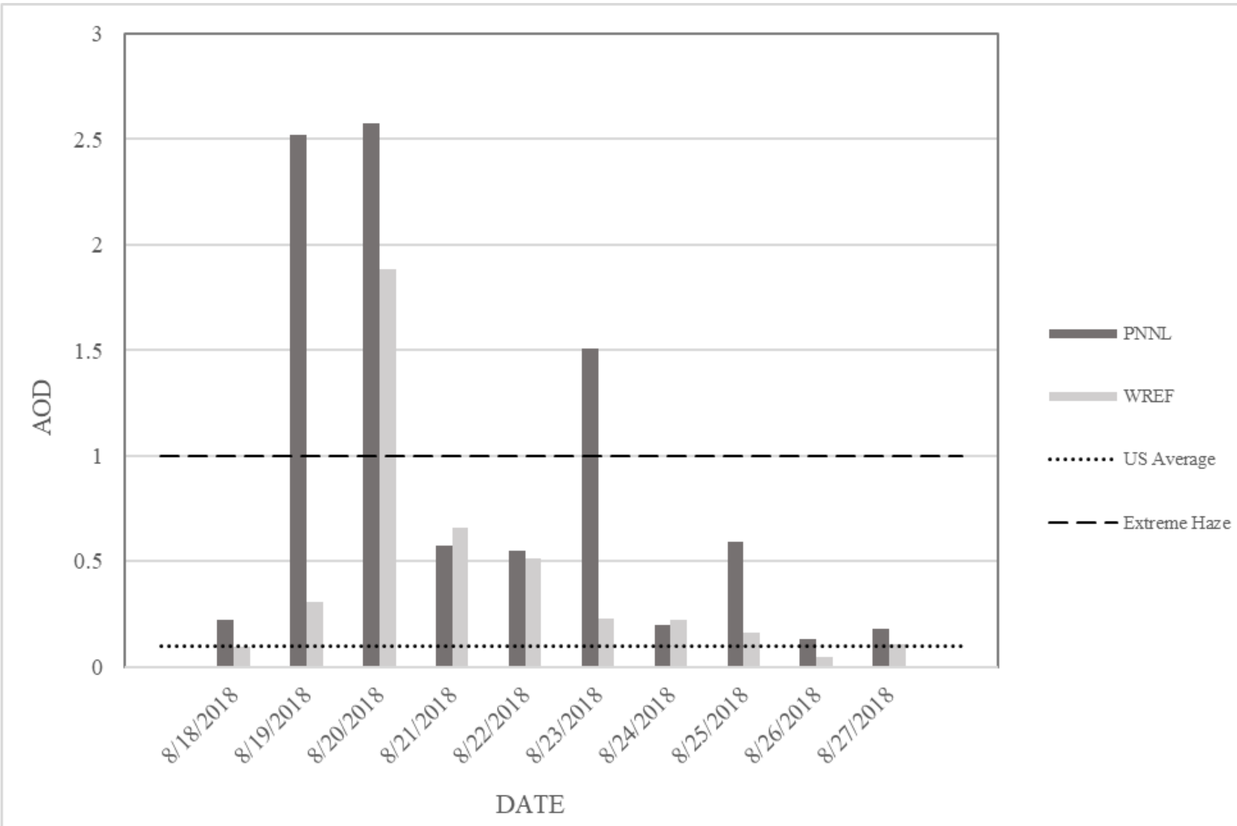

Figure 32. Total AOD measurements at the Pacific Northwest National Laboratory (PNNL) (Benton County, WA) and Wind River Experimental Forest (WREF) (Skamania County, WA) over a ten-day period of elevated AOD in August 2018 resulting extreme wildfire smoke. Figure created from Aerosol Robotic Network (AERONET) data (2018).

<u>*State-owned and -leased facilities*</u>

Using the hot spot map in Figure 31 above, we determined there are approximately 2,000 state-owned or leased facilities located in the most wildfire-prone areas of the state (Figure 33), the majority of which are in the central part of the state in Chelan (n=193), Douglas (n=91), Kittitas (n=297), Klickitat (n=83), Okanogan (n=289), and Yakima (n=326) Counties. Spokane County has the most state-owned or leased properties in wildfire-prone areas for any individual county (n=717). Use types for these structures vary widely and include educational (n=123), healthcare (n=10), laboratory (n=41), office (n=202), and residential (n=381) structures. Total estimated dollar value of State facilities in the identified wildfire hot spots is $13 billion, $11 billion of which is also in the WUI and considered at the highest risk for direct wildfire impacts.

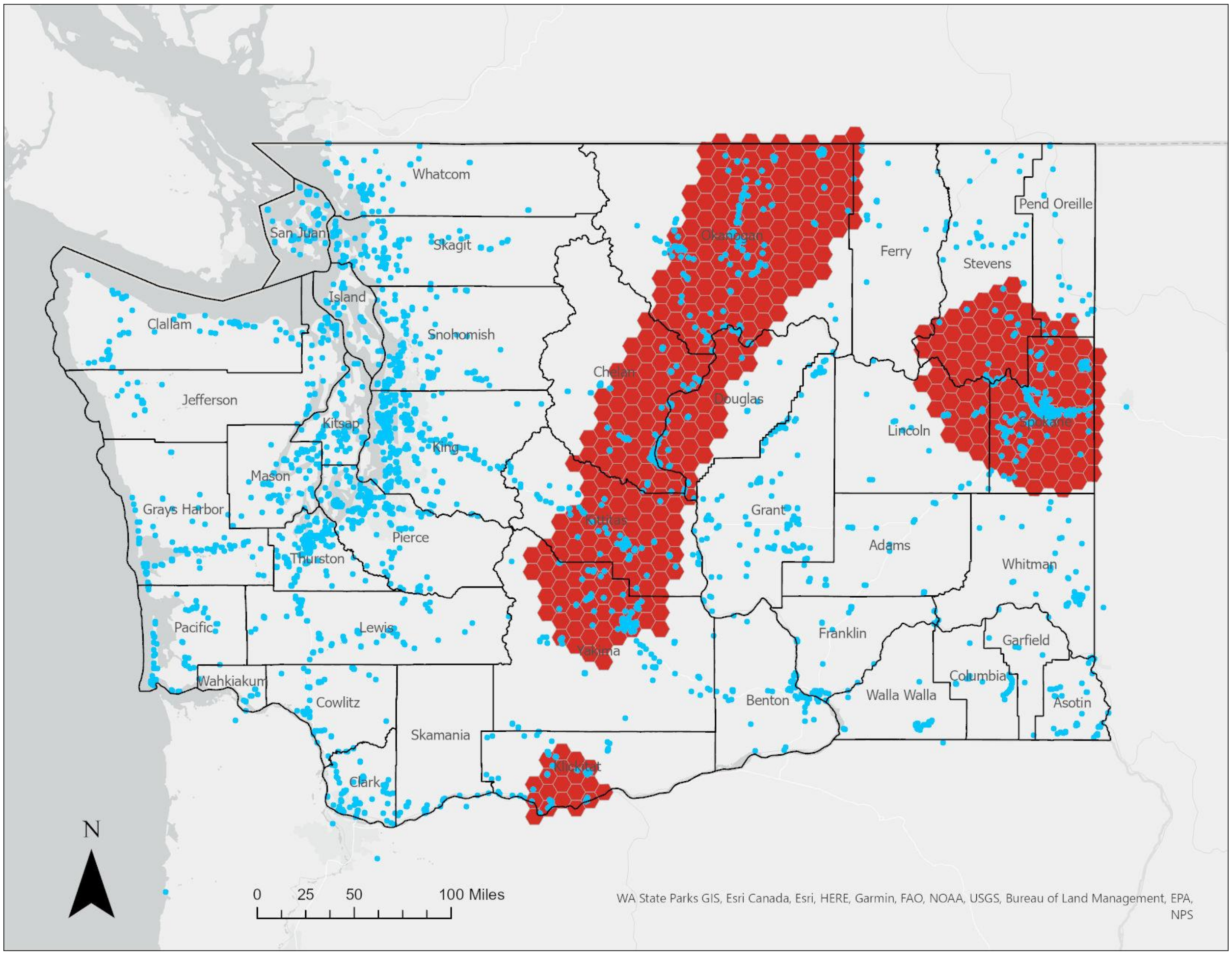

Figure 33. State-owned facilities (blue points) within and outside the most wildfire-prone areas, or hot spots, of the state (red hexagons).

<u>*Critical infrastructure*</u>

- **Transportation**. There are four intermodal facilities located in the wildfire hot spots identified in Figure 31. All four are in Spokane County, including the Spokane International Airport. However, the other three facilities, including the Spokane Intermodal Center (a bus and train station) are located within the urbanized areas of the city of Spokane and are less likely to be impacted directly by wildfire. There are approximately 20,000 miles of public roads in the most wildfire prone areas of the state, including sections of numerous major highways. There are 247 miles of Interstate 90 located in our wildfire hot spots in Kittitas and Spokane Counties, as well as 98 miles of Interstate 82/U.S. Highway 12 (in Kittitas and Yakima Counties), 204 miles of U.S Highway 2 (in Chelan, Douglas, Lincoln, and Spokane Counties), and 73 miles of U.S. Highway 395 (in Stevens and Spokane Counties).

- **Health and safety**. There are 38 hospitals located in the wildland-urban interface, however many of these are in the less wildfire-prone areas of western Washington. A total of 21 licensed hospitals are in the most wildfire-prone areas of the state, which is approximately 18% of all hospitals in Washington. This equates to more than 2,600 hospital beds. Nine of the 21 hospitals are in Spokane County, however all of them are in urbanized areas less likely to be impacted directly by wildfires. The number of hospitals in known wildfire hot spots and in the wildland-urban interface is 11 statewide, most of which are in central Washington in the counties of Chelan, Kittitas, Klickitat, and Okanogan. Given their location in both the WUI and a known wildfire hot spot, these 11 hospitals are likely the most at-risk to the direct impacts of wildfire, threatening 735 beds. Of the 1,280 fire stations in Washington, 195 are in known wildfire hot spots with 87 of those also located in the WUI and at the highest risk of direct impacts from wildfires. Spokane County has the largest proportion of fire stations in both the WUI and known wildfire hot spots for a single county, at 36.7% (32 stations). Regionally, central Washington has the most fire stations in both the WUI and a hot spot at 52% (45 stations), followed by eastern Washington at 48% (42 stations). Of the 350 local law enforcement stations in Washington, 47 are in wildfire hot spots with 28 of those also in the WUI and at the highest risk of direct impacts from wildfires. Okanogan, Spokane, and Yakima Counties are each tied for having the largest proportion of police stations in both the WUI and a hot spot at 21.4% (6 stations each). Similar to fire stations, the Central Washington region has the most police stations in both the WUI and a hot spot at 71% (20 stations), followed by Eastern Washington with 29% (eight stations).

- **Energy.** There just more than 3,000 miles of electric power transmission lines in the wildfire hot spots we identified, with approximately 280 miles of those lines (about 9%) also falling within the WUI – indicating the lines most at-risk to the direct impacts of wildfire. Most of these power transmission lines (67%) are in the Central Washington region. Of the 158 power plants in Washington, 29 (18%) are in wildfire hot spots. Of those 29, five are also within the WUI and are at the highest risk of direct impacts from wildfire (however, each is located on or near a body of water). Most of these power plants (66%) are in the Central Washington region.

- **Water and wastewater.** There are 2,378 public drinking water supplies (groups A and B) in the state's wildfire hot spots. Approximately 32% of those supplies are also in the WUI and are considered at the highest risk to direct wildfire impacts. Most of those high-risk drinking water supplies are in Eastern Washington, namely in Spokane County (88%). Wildfires have well-documented impacts on surface water, including contaminating freshwater bodies with heavy metals, sediment, and excess nutrients, but more research is needed to determine the treatability of wildfire-contaminated drinking water supplies (Bladon, et al., 2014). The only publicly owned wastewater treatment plant in the wildfire hot spots is in the city of Yakima. The specific location of this facility is also in the WUI, so it is considered at a higher risk to direct wildfire impacts.

Population

Total population within the most wildfire prone areas in Figure 31 is estimated at 900,000. We calculated this based on Census tract data used in the CDC's Social Vulnerability Index, which may not provide a fully accurate picture of where people live given the sometimes-odd shape of Census tracts and may not reflect the actual distribution of people, particularly in rural areas. Of the estimated 900,000 residents, approximately 300,000 are considered socially vulnerable. Of the counties with socially vulnerable residents residing in wildfire prone areas, Yakima has the largest portion at 28%, followed by Spokane (27%) and Chelan (15%). This means that an estimated 70% of the state's socially vulnerable people who also live in wildfire prone regions reside in Yakima, Spokane, and Chelan Counties.

Using global population projections (Gao 2017), we estimate the number of people residing in Washington's most wildfire-prone areas to increase between now and 2050, from 900,000 to between 1 – 1.03 million. This projection does not consider the potential for areas that are not currently wildfire hot spots to become wildfire hot spots by 2050. As such, the projection could be an underestimation.

The region determined most at-risk to destructive wildfires in the future is Central Washington, due to the combination of State facilities, critical infrastructure, and socially vulnerable populations co-located in the most wildfire-prone areas. This area includes the counties of Chelan, Douglas, Kittitas, Klickitat, Okanogan, and Yakima. Although not located in central Washington, it should be noted that Spokane County is also at significant risk to wildfires given the population and critical assets located in wildfire-prone areas there. This determination of the most at-risk counties in Washington differs slightly from the 2018 SEHMP, which also included Island and San Juan Counties as "high risk" but failed to identify Chelan, Douglas, and Yakima as high risk.

The potential direct impacts of wildfire on Washington's critical assets would include loss of residences, access to healthcare or other medical facilities, the closing of schools and other educational facilities, loss of recreational facilities such as campgrounds, and much more. Based on county assessors' data, the estimated value of all parcels in our wildfire hot spots is approximately $99 billion. There are also numerous potential impacts to public health. The most common characteristics causing social vulnerability in our state's most wildfire-prone areas are lower per capita income, higher rates of unemployment, and more people living in poverty relative to the rest of the state. Many of these same residents are exposed to various environmental health disparities as well. Using the Washington Department of Health's Environmental Health Disparities (EHD) data, we found the average EHD ranking of Census tracts in wildfire prone regions of the state is 5.84, which is slightly above the state's average EHD rank of 5.52. There are two predominant clusters of Census tracts with the highest possible EHD rankings of 8, 9, or 10 located in the cities of Yakima and Spokane. The environmental health concerns in those cities include diminished air quality from elevated levels of ozone and particulate matter as well as proximity to hazardous waste facilities and Superfund sites. This indicates residents in the state's most wildfire-prone areas also face an above average level of potential public health concerns that could be exacerbated during a wildfire or make it more difficult to withstand or recover from wildfire impacts.

Lastly, although not currently considered as significantly at-risk relative to the rest of the state, we want to highlight that western Washington is expected to see more frequent and severe wildfires in its future, like those seen in parts of Pierce County in September 2020. Such fires will have the potential to be highly destructive and dangerous for the communities west of the Cascade Range. Population growth is likely to continue in western Washington, particularly in the greater Seattle area (King, Pierce, and Snohomish Counties), with the potential for more people, property, and critical infrastructure in areas exposed to wildfire hazards.

Climate change and wildfires: Labor Day, 2020

On September 7, 2020, wildfires burned in every part of the state – eastern, central, and western Washington alike. Smoke diminished air quality virtually everywhere for days, with some places reaching unhealthy levels of particulate matter – endangering the health of everyone but putting anyone with respiratory issues at significant risk. Interstates 90 and 82 were shut down temporarily due to a combination of smoke and dust kicked up by hurricane-force winds that dropped visibility to dangerous levels and contributed to multiple car crashes (Tri-City Herald Staff, 2020). The road closures stymied evacuation efforts in Okanogan, Spokane, and Whitman Counties, and power outages were experienced across the state (Epperly, et al., 2020). West of the Cascades, where the impacts of wildfire are much less common, wildfires threatened several homes and temporarily closed SR-410 and SR-167 near Sumner (in Pierce County), forcing school closures for the following day (Glenn, 2020). By the morning of September 8, approximately 300,000 acres burned across Washington in fewer than 24 hours. The state woke up to 57 active fires. And the town of Malden in Whitman County was wiped out (White et al., 2020) (Figure 34). Local authorities there reported the fire was too hot and too quick to save much of the town's buildings (White et al., 2020).

By the end of that week, more than 120 homes across the state – including many in western Washington – were destroyed, and the life of a 1-year-old had been claimed (Green, et al., 2020). In just a few days' time, roughly 500,000 acres burned, which is more than most seasons entirely (Green, et al., 2020).

Those of us in the American West know that wildfire is a normal part of summer. Smoky days from nearby fires is a part of life here. While it's true that wildfire is a natural part of forest ecosystem health, days like we experienced in early September 2020 are not natural. While that was happening in Washington, the same – or worse – conditions were seen in Oregon, California, and other western states too. In Washington, every fire that was started that Labor Day weekend was human caused (KING 5 Staff, 2020). This could mean campfires, fireworks, arson, a downed power line, or simply a cigarette from a passing car. And in every case, a small ignition grew to severe and dangerous levels because of the extremely dry, hot, and windy conditions across the Pacific Northwest. Those conditions, without a doubt, were driven by hotter temperatures and less precipitation resulting from climate change. Does this mean that climate change caused those fires? No. But did climate change create the conditions needed for *extreme* wildfires? 100%.

It is well-established that climate change is contributing to more frequent, larger, and more severe wildfires across the western US (Wehner, et al., 2017). Wildfire risk is associated with many factors, including temperature, vegetation (i.e., fuels), and soil moisture. The increase in summer temperatures and longer dry spells observed in Washington are the result of climate change (Snover, et al., 2013), and together they create dry fuels that help fires spread and make them more difficult to put out. Climate change is also shown to be the cause of increased wind speeds since at least 2010 (Zeng, et al., 2019; Harvey, 2019), which together with high heat and drought make for extremely dangerous fire conditions. Research shows that this scenario of more frequent dangerous fire weather is likely to get worse overtime (Wehner, et al., 2017), with profound changes in western forests and increasing risks for the communities near them. In Washington, that means wildfire risk is expected to increase on both sides of the Cascades (Dunagan, 2020).

Figure 34. Devastation in Malden, WA on 9/8/2020. Source: Whitman County Sheriff's Office.

3.2. Human-Caused Hazards

The following sections provide overviews of human-caused (also called technological) hazards present in Washington. Because the focus of this Plan is on natural hazards, these sections on human-caused hazards are not intended to provide detailed risk analyses but rather serve as high-level summaries of risk to the people of Washington and our critical assets.

3.2.a. Dam Failure

A dam is defined as an artificial barrier that can impound 10 acre-feet or more of water or water-like substances such as mine tailings, sewage, and manure. A dam failure can result in the uncontrolled release of impounded water resulting in downstream flooding, which can affect life, property, and the environment. The dam failure could also result in loss of essential services provided by the impounded water such as drinking water supply, irrigation water, and water for hydropower generation.

Failures can involve the dam itself, or its appurtenant structures such as spillways and piped outlets. Dam failures can be caused by heavy periods of rain, flooding, earthquakes, blockages, landslides, lack of maintenance, improper operation, poor design and construction, vandalism, or terrorism.

Overall dam safety in Washington is managed by the Department of Ecology's Dam Safety Office (DSO). The DSO's September 2017 Inventory of Dams identifies 1,197 dams of 10 acre-feet or more. A breakdown of dams by county is provided in Figure 35.

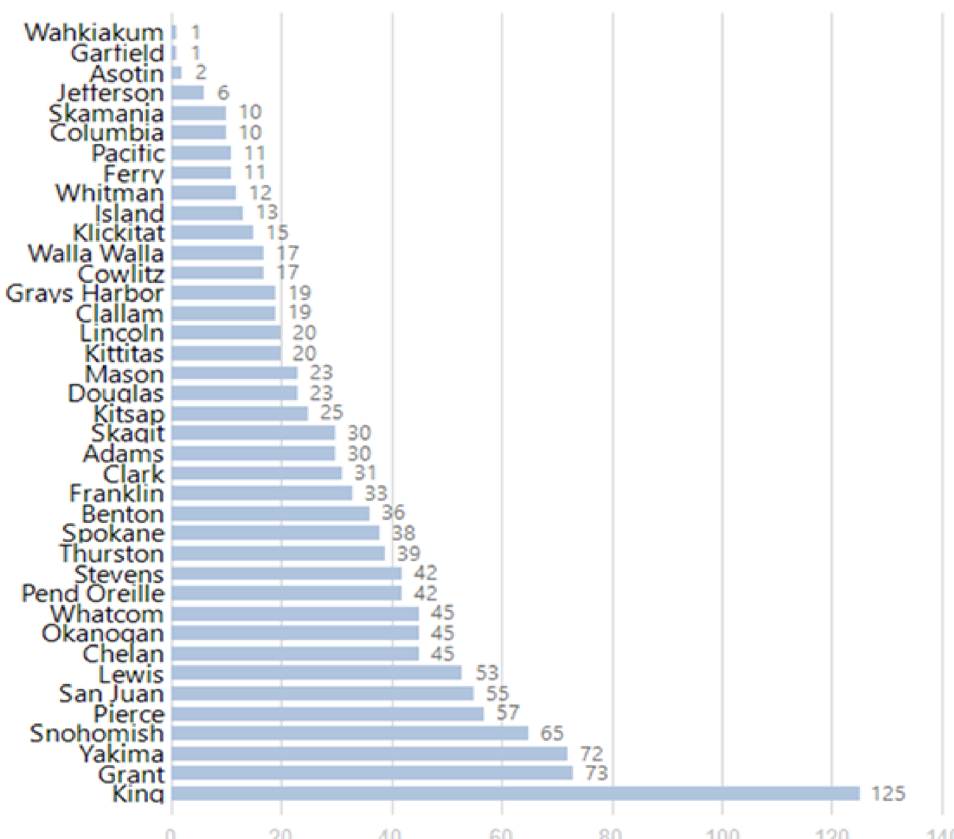

Figure 35. Number of dams per county in 2017.

The average life expectancy of a dam is about 50 years and more than half of Washington's dams are at or beyond that age (Figure 35). The age of a dam may be a factor in its stability because some materials may deteriorate under continued load and environmental conditions. In addition, as with any technology, there have been enhancements in dam materials, design, and construction techniques over the years which earlier projects could not take advantage of. Seismic design for the earthquake potential in the Pacific Northwest has advanced greatly and some older dams may not fare well under the dynamic conditions posed by an earthquake. Therefore, age can be a consideration in determining dam failure vulnerability.

Hazard classification of Washington dams

All dams are assigned a high, significant, or low hazard classification (Table 25) as part of the permitting process for new dams or modifications to existing dams, following the procedure defined by WAC 173-175-130. This classification is initially determined using the purely quantitative "Population at Risk." In some cases, based upon qualitative evaluations of other factors, including the severity of each deficiency at an individual dam, potential economic and environmental losses, age of the dam, the adequacy of warning systems, and the best professional judgement of the DSO engineer assigned to the dam, the DSO may increase the hazard class for dams. Hazard classifications are re-assessed during DSO periodic inspections.

Application of this basic methodology to each dam ensures the calculated population at risk (PAR) and other elements of assessment are applied in a similar and equitable manner. Development and assessment of PAR, risk factors, modeling assumptions and inundation areas are typically done under consultation between multiple dam safety engineers to achieve consistent application to each dam.

The distribution of dams by county with any people at risk and/or with significant economic or environmental impacts is depicted in Figure 38. As of May 2023, there are 247 dams that meet this classification. Hazard potential is defined by the number of people likely impacted by dam failure, so counties with more high and significant hazard potential dams may have larger proportions of their populations at risk to the impacts of dam failure. Because of the classification system used by the Department of Ecology's Dam Safety Office, the counties with more high/significant hazard potential dams are inherently more vulnerable to this hazard.

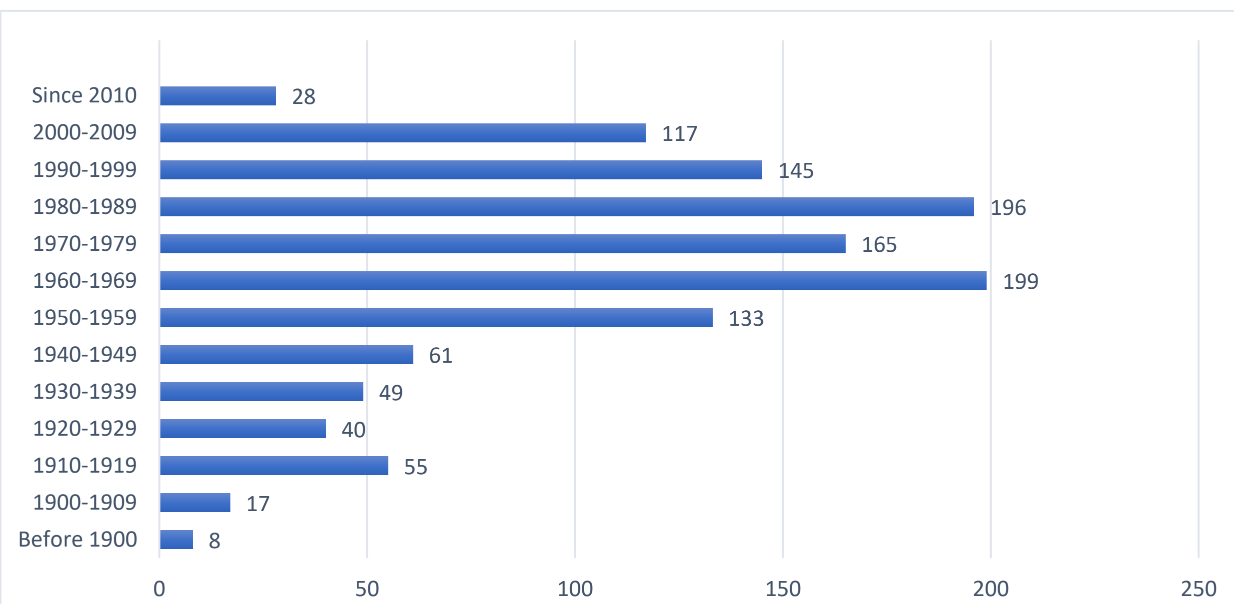

Figure 36. Washington dams by completion date (i.e., age).

Table 25. Downstream dam failure hazard classifications

Downstream hazard potential	Downstream hazard class	Population at risk (PAR)	Critical assets impacted	Environmental damage
Low	3	0	Minimal	Minimal
Significant	2E (no PAR) 2D (PAR)	1-6	Appreciable: 1-2 inhabited structures; agricultural activity; secondary highway/rail lines	Short-term, limited water quality degradation
High	1C	7-30	Major: 3-10 inhabited structures; low density suburbs; primary highway/rail lines	Severe water quality degradation; long-term impacts on aquatic and human life
	1B	31-300	Extreme: 11-100 inhabited structures; medium density suburban or urban area with associated industry, property, and transportation	
	1A	>300	Extreme: >100 inhabited structures; highly developed, densely populated suburban or urban area with associated industry, property, transportation, and other community lifelines	

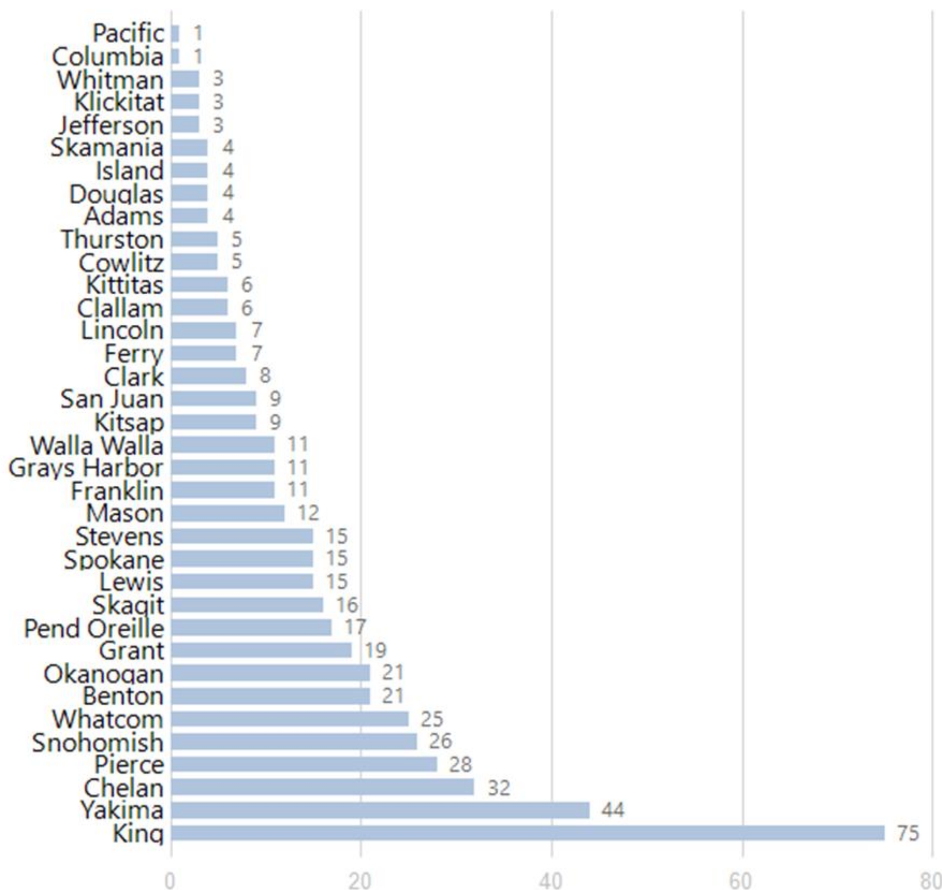

Figure 37. High hazard potential dams (1C, 1B, and 1A) by county.

King and Pierce Counties have the most dams with the 1A classification (highest risk) at eight each. They are followed by Grant and Whatcom Counties (n=6), and Kittitas and Yakima Counties (n=4). Local mitigation of dam failure risk can be a challenge in Washington when HHPDs may be in one jurisdiction but downstream impacts cross jurisdictional boundaries. This situation requires levels of regional partnership that do not always exist and may also place an additional burden on the State to facilitate such partnerships. The development of such multi-jurisdictional partnerships is a primary way Washington intends to address this deficiency at the State and through local capabilities. Ownership can also present challenges, including whether and how privately owned HHPDs can be mitigated. For example, many local governments do not own the HHPDs that put their communities at risk and are therefore ineligible applicants to the HHPD Grant Program. Further exploration of the HHPD Grant Program and what is fundable, led by the Department of Ecology's Dam Safety Office, is key for addressing that deficiency. Additionally, continued partnership between the State and multi-jurisdictional partnerships with HHPD owners and communities at-risk should increase the opportunities for local governments to mitigate the risk of dam failure.

A full list of high hazard potential dams, including a map of their locations, can be found in Appendix A.

3.2.b. Disease Outbreak, Epidemic, and Pandemic

Communicable disease

Communicable disease outbreaks can be caused by many agents and transmitted in several ways. While public health measures have controlled many diseases in this country, there remains a risk from new agents such as new COVID-19 variants, novel strains of influenza, or severe acute respiratory syndrome (SARS) that emerge with the potential to cause outbreaks. Emerging conditions or novel diseases that have limited or no medical countermeasure (therapeutic or vaccine) pose as a high risk/low frequency event that have the potential to broadly impact health and medical capacity as well as disrupt critical resources and support infrastructure.

Periodic outbreaks, including COVID-19 and novel strains of influenza, are a likely hazard in Washington. The state's connection to the global economy and the ease of national and international travel increases the potential for a new disease being introduced here. Additionally, natural disasters could result in displaced populations and mass sheltering, which increase the potential for communicable disease outbreaks. This occurred in 2020 during the height of the COVID-19 pandemic protections, when wildfire responses required wildland firefighters to adjust their typical basecamp procedures to account for physical distancing mandates. Operations at the State Emergency Operations Center also had to be amended while other emergencies overlapped with COVID-19, including moving to remote operations for some personnel.

All jurisdictions are at risk for outbreaks, though that risk may be influenced by other factors such as population density, contact with animals, international travel and commerce, and access to health care. Additionally, the COVID-19 pandemic has shown that disease risk can be amplified by other external factors, such as supply chain shortages that impact the availability of medical devices and equipment as well as a decrease in available outside help. Hospital capacity also became an issue, especially in smaller, more rural Washington towns, however this was also experienced in larger population centers. The COVID-19 response demonstrated that while masking and physical distancing were effective in slowing the spread of a novel respiratory pathogen, some groups did not tolerate extended public health orders, which likely contributed to continued increases in case rates.

Agricultural disease

Agriculture is one of our state's largest industries. An animal disease, crop disease, pest infestation or food safety outbreak can occur at any time. Animal and crop diseases are endemic in many parts of the world. These diseases can cause widespread devastation of animal populations and crops. Given rapid movement of trade products nationally and internationally, even with strict biosecurity measures, disease outbreaks can still occur. Crops are grown year-round, processed throughout the state, imported from around the world, and sold nationally and internationally. With many manufacturers distributing their products on a national and sometimes international scale, food and feed safety continues to be an important component to Washington agriculture. In many cases, diseases may take several days to weeks to manifest, resulting in a widespread outbreak.

While the risk posed to human health is low, these animal, crop, and plant diseases and infestation outbreaks do pose a risk to our economy. They could result in immediate national and international embargos of Washington state agricultural products.

Animal and crop disease outbreaks occur frequently. The severity of each outbreak varies depending on virulence. For example, in 2016, the Washington State Department of Agriculture (WSDA) sprayed an organic pesticide on 10,500 acres to prevent further spread of the Asian Gypsy Moth from infecting our state and national forests. And in 2015 and 2016, WSDA euthanized hundreds of backyard poultry to prevent the spread of highly pathogenic avian influenza that was introduced via wild birds. The 2003 bovine spongiform encephalopathy (a.k.a. mad cow) outbreak in eastern Washington caused immediate international embargos from more than 109 countries and an estimated loss to the U.S. beef industry of more than $3.5 billion. Because Washington is a national and international leader in many agricultural areas, there is continued potential for future outbreaks to impact our economy and agricultural communities. More recently, an ongoing outbreak of H5N1 HPAI that began in early 2022 has been the longest and deadliest outbreak of HPAI among birds in the U.S. This outbreak has impacted both backyard and commercial flocks within Washington, with over a million birds euthanized in the state to-date.

3.2.c. Hazardous Materials

Hazardous materials are defined as such because of their chemical, physical or biological nature, which can pose a potential risk to human health, property, or the environment when released. A release may occur by spilling, leaking, emitting toxic vapors or any other process that enables the material to escape its container, enter the environment and create a potential hazard. Potential sources of hazardous material releases include superfund sites, storage facilities, residences, manufacturers, transportation carriers, hospitals/medical facilities, veterinary hospitals/clinics, and brownfield sites. The hazard can be explosive, flammable, combustible, corrosive, reactive, poisonous, toxic, or radioactive, and can exhibit qualities of a biological agent. There are also naturally occurring hazardous materials releases that may produce the same potential risk to human health as the manufactured chemicals or agents.

In Washington, more than 20 billion gallons of oil and hazardous chemicals are transported by ship, barge, pipeline, rail, and road each year. Equipment failure and human error in these situations can lead to oil and chemical spills that threaten public health and wildlife, contaminate the environment, and ultimately damage the state's economy and quality of life. Superfund sites in Washington also pose a hazard to communities and the environment, especially when other hazards (e.g., floods) trigger release or spread of potentially toxic substances. Such sites tend to be clustered in the Puget Sound area, due to its long history as a site for naval and maritime activities.

The exact location and severity of future hazardous materials incidents are difficult to predict because so many factors can contribute and there are so many different types of incidents. Nonetheless, hazardous materials incidents have impacted every county in the state and every jurisdiction is at some level of risk from future incidents. Western Washington counties are more at risk due to dense industrial and populated areas and major transportation routes surrounding Puget Sound and coastal waterways.

3.2.d. Radiological Incident

The Washington Fixed Nuclear Facility Protection Plan maintained by the state's Emergency Management Division provides guidance to State agencies in the event of a radiological material incident. This plan covers incidents that may occur at the U.S. Department of Energy's Hanford Site, Energy Northwest's Columbia Generating Station nuclear power plant, the U.S. Navy bases located in the Puget Sound region, and operations at Framatome Richland

Engineering and Manufacturing Facility (EMF). Of these four risk sources, the Hanford Site and Columbia Generating Station present the greatest risk to Washington.

Though radiological releases can adversely affect people, the likelihood that a release would cause significant injury or death for large numbers of people is low. The primary impact of a radiological incident is more likely to be a permanent relocation of people in the communities directly impacted, which would greatly disrupt their local economies and potentially the state's. Other economic disruptions would include the impacts to agriculture resulting from potential embargoes. Public perceptions could lead to consumers no longer buying agricultural products from Washington, leading to long-term declines in the agricultural economy.

Hanford site

The Hanford Site was built in 1943 for the Manhattan Project, the wartime effort to build the atomic bomb. The 560-square mile site bordering 51 miles of the Columbia River near the cities of Richland, Pasco, and Kennewick, is the most contaminated site in North America, holding more than 60 percent of the nation's highly radioactive and chemically hazardous wastes. This waste is stored in tanks that pose a serious threat to the land, the nearby Columbia River, human health, and the region's economy. As of 2018, more than one million gallons of highly toxic contaminants have leached into the ground and are moving through groundwater toward the Columbia River.

Approximately one million people live in the 42 cities and towns downstream from the Hanford site. About 8,000 farms worth an estimated $6.4 billion are in and around these communities and contribute significantly to the economies of Washington and Oregon.

The most recent significant release of radioactive hazardous waste at the Hanford Site was in 2007. Future incidents are difficult to predict, especially as measures and plans are put in place and exercised to mitigate risk, though future releases are likely.

Columbia Generating Station

The Columbia Generating Station (CGS) is located on the Hanford site about 10 miles north of Richland and two miles west of the Columbia River. Energy Northwest's CGS is Washington's only operating commercial nuclear power plant. There have been no incidents of radiological release at CGS, though minor incidents do occur. However, like the rest of the Hanford site, the primary concern at CGS is a potential release of radiological material. To ensure the likelihood that impact to people and agricultural products is minimized, emergency plans are in place and exercises conducted in accordance with Federal regulations. In addition, safety inspections are performed at the plant to ensure proper operation and safety procedures are followed.

Two Emergency Planning Zones have been established to protect the public in the event of an incident at CGS. A 10-mile emergency planning zone (EPZ) is designed to protect residents from direct exposure to radiation in the event of a release of radioactive material. The 50-mile emergency planning zone is designed to keep people from consuming potentially contaminated fresh food and milk products by keeping those products out of the marketplace. Examples of fresh food products that can become contaminated with radiation are milk, fresh fruits, vegetables, processed products, and grains as well as open water sources.

3.2.e. Terrorist Attack

With terrorist and violent extremist attacks and plots becoming more prevalent, Washington has encountered more than 40 attempted or successful attacks in the decade between 2008 and 2018 – an average of four per year. Although a large-scale attack in a densely populated place could have significant, statewide impacts on public safety and the economy, a more likely scenario would be an active shooter or vehicle attack, where few people would be impacted directly, and economic disruptions would be less severe. The total impact of a terrorist or violent extremist event is dependent upon the actor's motivation or desired outcome, tactic used, specific location, weapon type, and success of the attack. However, the psychosocial impacts, also known as the "fear factor" of an attack, would likely be a major economic factor. This can include the declined perception of local stability, hesitation of going to public places, mistrust in law enforcement and government to deter such events, and a general uneasiness in certain areas where an attack has occurred.

The prediction of future terrorist or violent extremist events is beyond the scope of this plan. on recent, successful terrorist and violent extremist events, the most likely tactics include active shooter(s), vehicle attacks, stabbing/cutting, bombings and cyberattacks. The least likely tactics include chemical, biological, radiological, and nuclear (CBRN) bombing, hijacking/skyjacking, and maritime attacks. The most likely targets include human targets (particularly military, government and law enforcement personnel), government facilities, commercial facilities (including public assembly, retail, and entertainment and sports venues) and transportation. The least likely targets include amusement parks, bridges, museums, national monuments or icons, and vessels.

Generally, terrorists target densely populated or high-profile areas. Therefore, any of Washington's major urban areas could be considered at risk, as well as any of the state's higher profile critical infrastructure. King, Pierce, Snohomish, Clark, and Spokane counties have the highest populations and critical infrastructure densities in the state. However, the specific motivations of terrorist and violent extremists dictate target selection, thus any location in Washington has the potential to become a target.

3.3. Regional Vulnerability Assessments

The below sections provide a summary of the vulnerabilities commonly found in each of the four regions we used for this plan update. Vulnerabilities are different from impacts and risk, although the concepts are related. For the purposes of this plan, vulnerability refers to the characteristics of a community and/or its critical assets that make them more susceptible to the impacts of a disaster. Vulnerabilities, therefore, can amplify the impacts of a disaster. Also, because vulnerability is tied to communities and assets, the level or type of vulnerability can change over time or under new circumstances.

The sections below provide examples of common vulnerabilities found in each region as well as information on how vulnerabilities may have changed since the last SEHMP update in 2018 and how they may change in the future.

3.3.a. Olympic Peninsula and Southwestern Washington

The Olympic Peninsula and Southwestern Washington region (OPSW) is prone to multiple natural hazards, including climate-related hazards (e.g., flooding, extreme weather, and wildfire) as well as geological hazards (e.g., earthquakes, tsunamis). According to the 2023 HIVA (see section 3.1), the OPSW region is the most at-risk region in the state for landslides and tsunamis.

Some common vulnerabilities in the OPSW region:

- Geographically isolated communities
- Critical transportation routes located in landslide hazard areas or near eroding bluffs
- Significant elderly population
- Few redundancies for power distribution and supply
- Lower-than-state-average per-capita income

Landslide vulnerabilities in the OPSW region

A large portion of vulnerable people, roads, and health & safety assets (e.g., hospitals, police stations) in the OPSW region are exposed to landslide impact. The most common landslide-related impact in the OPSW region is damage to or blocking of important transportation routes. This is largely due to the often isolated nature of the communities in this part of the state. U.S. Highway 101 is a critical lifeline transportation route for virtually the entire region that also has few alternate routes when it becomes compromised by a landslide.

The consequences of a landslide-damaged road become even more amplified for the extremely isolated communities along the far western edge of the OPSW region, such as Neah Bay (Makah Tribe) and La Push (Quileute Tribe), both of which have one road in/out of town. State Route 112, the road connecting Neah Bay with Highway 101, has chronic issues with landslides and coastal erosion that cause damage to the road and sometimes restrict its use (Figure 39). Such landslides can cause massive impacts on vulnerable communities in the OPSW, including delays in the delivery of important resources (e.g., food, fuel) and restricted access for first responders during emergencies.

Tsunami vulnerabilities in the OPSW region

Though tsunamis are among the rarest type of natural hazard event in Washington, the level of tsunami exposure in the OPSW region is significant. Nearly all its coastline has some level of tsunami exposure, which puts multiple types of critical infrastructure and assets at potential risk, including roads, hospitals, ports, business districts, and residential areas.

Since mitigation efforts cannot reduce the number of tsunamis Washington can expect, they instead focus on ensuring people in tsunami hazard areas can get out of harm's way. However, residents or visitors to coastal areas in the OPSW region will have limited options to find safe high ground, especially in towns where high ground is located miles away, such as Ocean Shores (Grays Harbor County) and Westport (Pacific County).

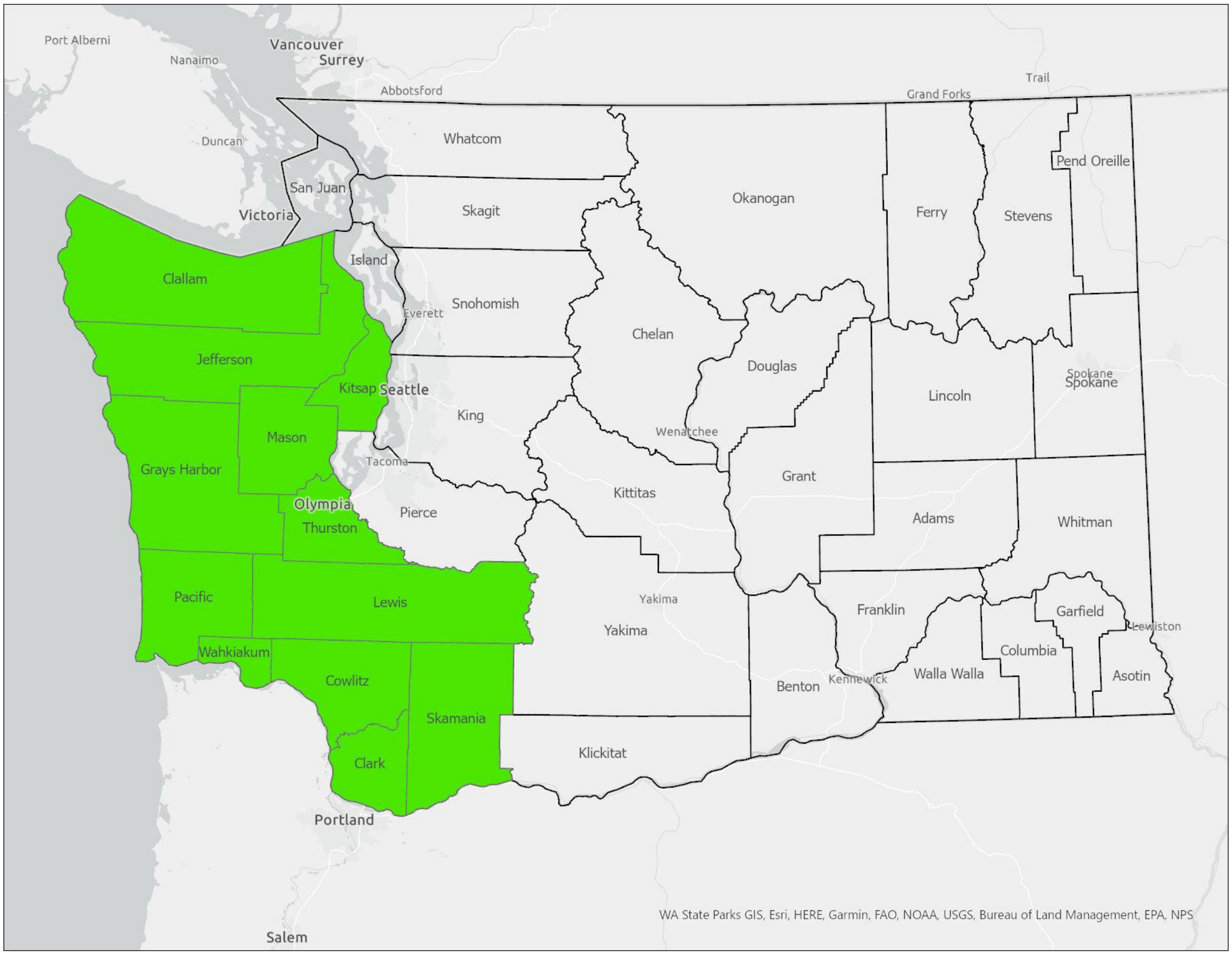

Figure 38. Olympic Peninsula & Southwestern Washington region (green shade)

Strategically placed vertical evacuation structures can help in this regard, but there are not currently enough of them to reduce this vulnerability completely. Also, because these towns are remote and isolated with few roads connecting them to other parts of the state, critical evacuation routes are more likely to be clogged or damaged.

Other vulnerabilities

Although the OPSW region is not at the highest risk for other natural hazards, its vulnerability to hazards such as wildfire and extreme heat are increasing as climate change worsens. There have been significant wildfires in parts of this region that have impacted roads and threatened structures, including a 2020 fire in the Lake Crescent area of Olympic National Park that shutdown an important access road, threatened nearby cabins and other structures, and caused long-term slope instability issues (which has increased the risk of landslides in that area).

Extreme heat events are also impacting the OPSW region. The isolation of OPSW communities results in a lack of access to potential cooling centers for heat-vulnerable residents, such as the significant elderly population that lives in this region. This region also sees an influx of visitors when extreme heat affects other parts of western Washington because of its reputation as being cooler as well as its many lakes and beaches. These influxes can clog the few state routes and highways that connect the region and cause other temporary strains on the limited resources these communities possess.

3.3.b. Puget Sound and Northwestern Washington

The Puget Sound and Northwestern region of Washington (PSNW) is the most populated area in the state as well as home to numerous critical assets and infrastructure facilities with regional, national, and international significance. The PSNW, like the OPSW, is also directly exposed to every natural hazard found in Washington. According to section 3.1 of this Plan, the PSNW has the state's highest risk of impacts associated with avalanches, earthquakes, extreme weather, flooding, and volcanic eruptions. There is little evidence to suggest that hazard events such as extreme weather and flooding occur more frequently in the PSNW region than other parts of the state. However, because of its densely populated nature, and continued urbanization and population growth, more presidentially declared disasters occur in this region than any other in Washington.

Some common vulnerabilities in the PSNW region include:

- Densely populated communities
- Concentrations of old structures (e.g., unreinforced masonry buildings)
- Concentrations of socially vulnerable residents, including SVI ranks of 0.8+
- Significant transportation and commerce assets with few regional redundancies (e.g., Port of Seattle)
- Structural densities contributing to urban heat-islands
- Urbanized areas with diminished air quality and other environmental disparities

Earthquake vulnerabilities in the PSNW region

Although all of western Washington is exposed to potentially catastrophic earthquakes (e.g., CSZ ruptures), the level of possible damage – including number of injuries and deaths – is highest in the PSNW region. In cities such as

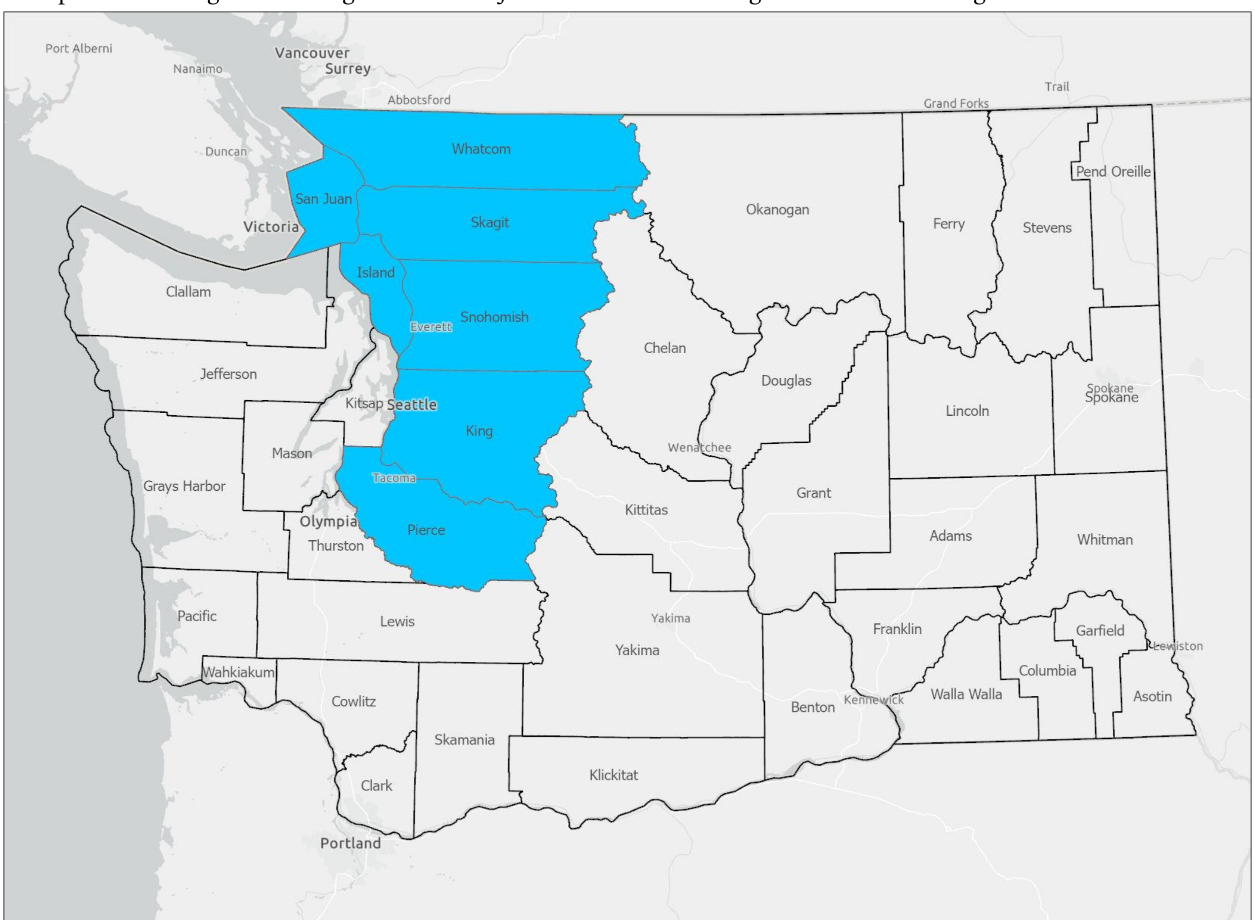

Figure 39. Puget Sound & Northwestern region

Seattle, Tacoma, and Everett there are concentrations of historic structures and unreinforced masonry buildings that are especially susceptible to intense shaking from earthquakes. These structures include residential, educational, and office uses. Roads and bridges are vulnerable to earthquakes as well, with most of the bridges along the I-5 corridor expected to have some level of damage in a full rupture of the CSZ. Transportation, evacuation, commerce, and emergency services would be impacted severely by such damages. Other critical assets in the PSNW region, including hospitals and energy production, are vulnerable as well, with far-reaching indirect consequences on the state if brought offline by an earthquake.

Extreme weather vulnerabilities in the PSNW region

As determined in section 3.1, Washington is prone to myriad weather extremes that include atmospheric rivers and heatwaves. The PSNW region was determined to be the region most at-risk to such weather extremes largely because of its densely populated nature. A single atmospheric river or heatwave can impact the entire state, but the pockets of social vulnerability, co-location of critical assets, and urbanization tend to amplify the impacts of such events in the PSNW region. For example, the 2021 heat dome event was exacerbated by the structural density of the Seattle-Tacoma metropolitan area, which created an urban heat-island there that caused temperatures to be higher than nearby areas.

Flooding vulnerabilities in the PSNW region

After extreme weather events, the most common natural hazard occurrence in the PSNW region is flooding. However, it should be noted that extreme weather events in the PSNW often include flooding. For example, in 2021, more than 500 people were displaced by extreme flooding in the Nooksack River watershed in Whatcom County after an atmospheric river brought significant rainfall to the area. Sumas (Whatcom County) proved especially vulnerable to this event, as roads leading in and out of the town were washed out and effectively isolated the community, prompting multiple search-and-rescue missions there. Other small, river-side communities throughout the PSNW region are likely to have similar geographical vulnerabilities to floods. Such towns may include Index (Snohomish County), Hamilton (Skagit County), and North Bend (King County).

Other vulnerabilities in the PSNW region

Although other regions are more vulnerable to hazards such as wildfire and drought, the PSNW is not without these hazards as well. Recent wildfires in western Washington (e.g., Sumner Grade, Bolt Creek) indicate that damage-causing fires are becoming more frequent over time and are most likely driven by climate change, population growth, and continued urban development. The dense vegetation in the PSNW region's wildland areas can become significant fuel loads after prolonged droughts and dry periods, which can contribute to larger and more frequent, severe, and intense wildfires west of Cascades and in the Puget Sound lowlands.

3.3.c. Central Washington

The Central Washington region, although capable of experiencing multiple natural hazard types, is most impacted by wildfire, extreme weather, and flooding (often accompanied by landslide activity). According to section 3.1.j. of this Plan, Central Washington is more at-risk to destructive wildfires than any other region of the state. Some of the most extreme wildfire events, such as the Carleton Complex (2014), Okanogan Complex (2015), and Cold Springs Canyon-Pearl Hill Complex (2020), occurred in Central Washington. The location of numerous critical infrastructure assets in this region, as well as a growing population, increase hazard vulnerability there.

Some common vulnerabilities in the Central region include:

- Above average elderly population
- Below average per capita incomes
- Numerous low-capacity jurisdictions that do not have a FEMA-approved hazard mitigation plan
- Popular recreation assets that see increased visitation during wildfire season
- Numerous jurisdictions that rely on agricultural assets at risk to wildfire, heat, and drought

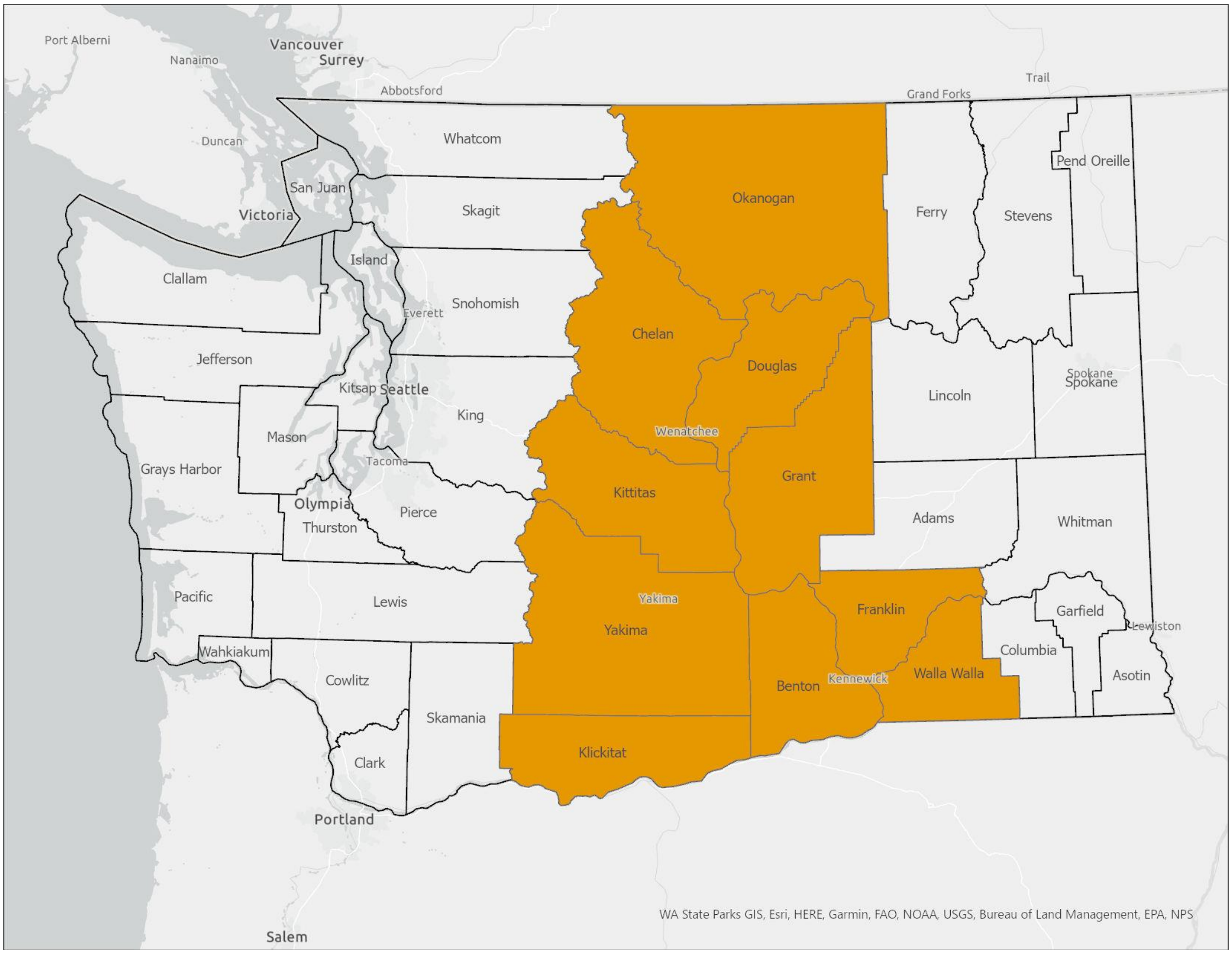

Figure 40. Central Washington region

Wildfire vulnerabilities in the Central region

As mentioned above, the Central region has the state's highest risk of wildfire impacts. This high risk level is driven mostly by the likelihood of large wildfires occurring there in the future. Although much of the Central region is sparsely populated, the potential for extremely large wildfires there means an increased chance for such fires to directly impact communities and the built environment. In some cases, however, entire towns are located within wildfire hot spots as well as the wildland-urban interface, such as the city of Leavenworth (Chelan County), where even smaller fires can have outsized impacts. Also, important to note is that air quality impacts from wildfire smoke tend to be more severe closest to the wildfire itself. This means that this region is also likely to see regular impacts associated with wildfire smoke. The above average elderly population there could be vulnerable to poor air quality, even for short durations, as could non-elderly residents with other respiratory issues (e.g., asthma).

Other vulnerabilities in the Central region

Extreme heat vulnerabilities in the Central region are also worrisome, though it appears more residential buildings have air conditioning compared to western Washington. Geographic isolation can be a concern in some areas too. For example, previous landslides and other debris flows have temporarily blocked or damaged important transportation routes in this region and many towns have few redundancies if the route blocked happens to be a U.S. highway or state route.

3.3.d. Eastern Washington

Although the rural and less developed nature of the Eastern region (compared to other regions in the state) means the potential for disaster impacts is lower, this region does experience extreme weather, drought, and wildfire frequently. From a statewide perspective, the risk of these hazards is lower than in other regions, however, the impacts they cause on the residents of Eastern Washington are significant. Additionally, at the county-scale, Spokane County was found to have similar levels of risk from wildfire and drought as the Central region and extreme weather as the PSNW regions. This is likely due to our risk analysis focusing on the built environment and social vulnerabilities, both of which are in high concentrations in Spokane County.

Some common vulnerabilities in Eastern Washington include:

- Geographically isolated communities with limited transportation routes and options
- Agricultural communities with economies at risk from extreme heat and cold, wildfire, and drought
- Clustered populations of socially vulnerable residents (in Spokane County)
- Above average elderly populations
- Below average per capita income
- Numerous low capacity jurisdictions without a FEMA-approved hazard mitigation plan

Drought vulnerabilities in Eastern Washington

In the most recent drought event (2021), the Eastern region experienced at least "severe" drought conditions for almost an entire year, comparable to the intensities found in the Central region. Eastern Washington's water supply is subject to the some of the same risks as central Washington's, including the potential for water shortages to create a demand that is above supply in the future. In addition to the agricultural communities in eastern Washington, residents and industry based in remote areas or anyone relying on small reservoirs or individual water systems are vulnerable to such shortages. Drought has also been shown to exacerbate existing air quality issues, which makes residents with pre-existing respiratory conditions (e.g., asthma) especially vulnerable.

Wildfire vulnerabilities in Eastern Washington

Eastern Washington is second to central Washington in terms of number of people and critical assets exposed to wildfire impacts, but this does not diminish the high level of risk wildfire poses to Eastern communities. The Babb Road fire in 2020 highlighted many of the vulnerabilities found in eastern Washington, especially in rural areas with fewer resources available to mobilize quickly. The towns of Malden and Pine City (Whitman County) lost 85% of their structures in that fire, including important town government buildings along with residences. Fires in other areas of the state meant that few firefighters and trucks were readily available to deploy to the remote towns, meaning the fast-moving Babb Road fire spread unabated. Amplifying the losses for many residents is the lack of fire insurance to help with recovery in the towns themselves or to establish themselves in new places. It can be assumed that many small, remote communities throughout eastern Washington have similar vulnerabilities.

Other vulnerabilities in Eastern Washington

Eastern region residents are also exposed to extreme heat and cold, both of which pose risks to agricultural activity and people with social and/or environmental health disparities (e.g., the elderly). Extreme cold weather, including ice and snowstorms, have caused massive disruptions to transportation through eastern Washington before, such as temporarily shutting down important roadways. Dust storms have also had this effect, including in 2020 when

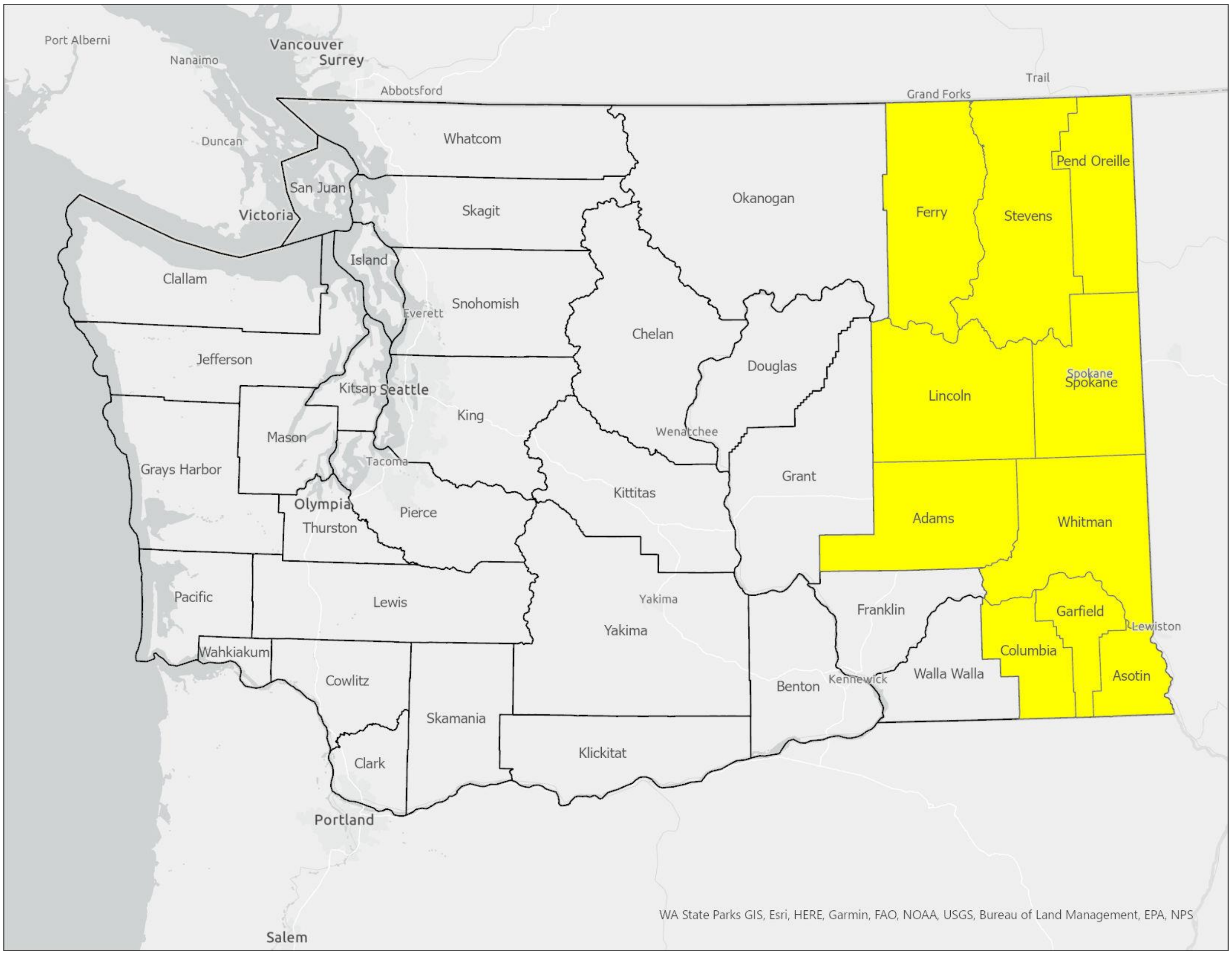

Figure 41. Eastern Washington region.

Interstate 90 was temporarily closed due to reduced visibility from dust and wildfire smoke, significantly impacting ongoing wildfire evacuations.

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Chapter 4: Mitigation Strategy

Chapter 4: Mitigation Strategy

4.1. Hazard Mitigation Goals and Objectives

The mitigation goals and objectives outlined in this section represent what the State seeks to accomplish through this Plan's implementation and are informed by the risks and vulnerabilities identified in the HIVA (see Chapter 3). Among other outcomes, the accomplishment of these goals will result in reduced vulnerabilities at state- and local-levels. As much as possible, these goals are designed to reduce risk to State facilities as well as the vulnerabilities of local jurisdictions. Section 4.2 provides a crosswalk between these goals and the specific mitigation actions the State plans to take and shows how these goals were used to guide the development of those actions.

The Hazard Mitigation Working Group and SEHMP Editors reviewed, refined, and approved the below list of goals and objectives.

Goal 1. Reduce the impacts of natural hazards on Washington residents and our community lifelines, including State-owned or operated facilities

We understand that the primary goal of any hazard mitigation plan is to ensure its implementation results in the reduction of risk and vulnerability experienced by the community it serves. As a statewide plan, our focus is on reducing risk to State-owned and operated facilities as well as other critical infrastructure across Washington. This includes non-State-owned facilities, such as ports, dams, transportation assets, and energy production, among others. We feel the following goals and objectives are each in service to this overarching goal of risk reduction.

Goal 2. Prioritize effective and long-term partnerships across State, Federal, Tribal, and local stakeholders

Disaster risk and hazard mitigation are interdisciplinary and complex. To be more resilient requires us to develop partnerships that integrate a diversity of thought and experience. The leveraging of knowledge across disciplines and sectors, as well as lived experiences, is key to addressing the hazard vulnerabilities that impact us all one way or another. Interdisciplinary stakeholder engagement also helps to improve "buy-in" for our mitigation goals, thereby increasing the likelihood that mitigation actions will be sustainable and a better use of resources (Twigg, 2015).

- *Objective 2.a.*: Continue to engage the Hazard Mitigation Working Group as the State's leading stakeholder group for statewide mitigation work but invite State agencies that are traditionally less represented to join and provide input, especially when those agencies interact or work closely with vulnerable and underserved populations.
- *Objective 2.b.*: EMD-funded projects will provide the time and resources required to build partnerships, including virtual communication and teleworking tools. Applicants for EMD funding will be required to consider who might be missing from such partnerships and how they could be engaged through the proposed project.

Goal 3. Let the vulnerability assessments drive our mitigation strategy and prioritization of mitigation actions

For maximum impact, our mitigation strategy needs to be tied directly to the vulnerabilities identified in our HIVA. This means that we will devote our mitigation strategy to being informed by stakeholder needs and an understanding of local contexts. Letting vulnerability drive our mitigation strategy ensures that the actions we implement will more confidently reduce our hazard risks across the state. A mitigation strategy that is not driven by a comprehensive vulnerability assessment is less likely to reduce vulnerabilities and more likely to waste limited public resources.

- *Objective 3.a.*: Tie each mitigation action to a specific finding in a vulnerability assessment.
- *Objective 3.b.*: Broaden the available partners for implementing mitigation actions to NGOs and national institutions who have a long-term presence in the state and may serve as additional stakeholders.

Goal 4: Improve our understanding of multi-hazard environments

Among the first priorities of international and national frameworks for mitigating natural hazards is the need to understand hazard characteristics and the natural processes driving hazard events. We know that hazard events do not always occur independently (Kappes et al., 2012). In many cases, the relationships between hazards can create chains or networks of hazards, leading to multi-hazard events (Duncan et al., 2016). To ensure we are approaching mitigation as holistically as possible, the State will pursue a comprehensive and systematic understanding of hazard types, multi-hazard relationships, and hazard scales that can occur in Washington. Understanding this multi-hazard landscape will help inform mitigation actions and priorities, as well as help ensure our actions taken to reduce vulnerability to one hazard do not inadvertently increase vulnerabilities to other hazards.

- *Objective 4.a.*: Improve data collection for hazard events of all magnitudes, including small but frequent hazards (a.k.a. extensive hazards), to provide a fuller understanding of hazard characteristics affecting the state and improve spatial analyses and vulnerability assessments.
- *Objective 4.b.*: Digitize and update statewide disaster response, recovery, and mitigation databases to reflect multi-hazard dynamics.
- *Objective 4.c.*: Reduce our reliance of single-hazard modeling and analysis, and instead incorporate analyses of multi-hazard dynamics in real-world contexts.

Goal 5. Embed cultural understanding into our mitigation work

Regardless of efforts to avoid it, we are all part of and effected by culture as mitigation researchers, administrators, and program managers for the State. Our belief systems, values, and livelihood choices can shape the way we approach ideas and partnerships. Culture can also influence (e.g., increase or decrease) vulnerabilities to hazards for individuals or entire communities, shaping the norms by which vulnerability is defined (O'Connell et al., 2017). As such, understanding culture is integral for reducing our hazard vulnerabilities. Doing so will enrich the data we have available to us, improve contextual understanding, and improve dissemination of important information to help create a mitigation-minded state.

- *Objective 5.a.*: Work with cultural experts and behavioral scientists to improve our understanding of how culture relates to disaster risk and vulnerability and develop culturally competent ways of reducing vulnerabilities.
- *Objective 5.b.*: Require applicants for EMD-funded projects to outline the proposed project's impact on society and how information will be disseminated to stakeholders, recognizing that the appropriate means of communicating information may change based on who is expected to consume it.

Goal 6. Ensure improved and equitable access to hazards information

Although our work tends to stop at the successful implementation of a mitigation project, our hope is the information within this SEHMP or similar documents with State-generated research reach a much wider audience than only those looking to do a mitigation project. Hazard information needs to reach everyone who needs it, be understood, and acted on if vulnerabilities are going to be reduced (Mohadjer et al., 2016). This includes the public as much as local and State partners actively pursuing their own mitigation work.

- *Objective 6.a.*: Leverage partnerships and diverse stakeholder groups to create useful, culturally contextualized hazard information.
- *Objective 6.b.*: Draw on good communication practices proven successful in their ability to make important information more accessible to groups outside of government. Consideration should always be given to the audience and their needs.
- *Objective 6.c.*: The Hazard Mitigation Working Group will work collaboratively to develop hazard information products with their intended audience, creating a two-way communication method and co-production of information.

- *Objective 6.d.*: The publication of EMD-led or funded research and planning documents should be open-access and free to all, either via publication on a public website (e.g., mil.wa.gov or a county website) or in an open-access journal.

Goal 7. Champion and prioritize people-centered mitigation actions

The UN's Sustainable Development Goals and other international frameworks for hazard mitigation emphasize a "no-one left behind" sentiment (Gill et al., 2020). The most vulnerable in our state should have access to the resources, information, and support required to effectively reduce vulnerabilities and encourage sustainable development. The ability for any given person or community to mitigate hazards is shaped by an array of social, cultural, economic, and political factors (Wisner et al., 2012). This means a systematic acknowledgement that hazard mitigation is not only about the hazard itself, but also about the people impacted by the event and who they partnered with to prepare, recover, and mitigate.

- *Objective 7.a.*: Use regional stakeholder groups with diverse representation of local and traditional knowledges when assessing vulnerabilities and developing mitigation actions.
- *Objective 7.b.*: Increase meaningful participation of persons with lived experience in underrepresented, vulnerable, and underserved groups in the hazard mitigation process.
- *Objective 7*.c.: Conduct research to assess the degree to which current mitigation strategies perpetuate historic biases that may adversely impact underrepresented, vulnerable, and underserved groups to inform future planning efforts.

Goal 8. Emphasize the role of sustainable development and climate adaptation in hazard mitigation

Vulnerability reduction, building resilience, early warning, and climate change adaptation all incorporate or intersect with poverty and hunger alleviation, public health, education, water resource management, infrastructure, land use, and environmental management (UN, 2015). Addressing inequalities, access to resources, and better urban planning can increase individual, community, and institutional resilience to hazards. Leveraging the results of our hazard analyses into tools that support sustainable development practices and policies, including climate adaptation, requires sustained and effective partnerships and communication.

- *Objective 8.a.*: Share success stories and advocate for State-led mitigation projects that provide multiple benefits (e.g., flood risk reduction and improved water quality simultaneously).
- *Objective 8.b.*: Require local mitigation project proposals to address how the project may accomplish sustainable development goals with multiple benefits and prioritize projects that do so effectively.
- *Objective 8.c.*: Require the meaningful incorporation of climate change and variability information in all EMD-funded hazard mitigation plans, including mitigation actions that address climate-change-driven hazards and improve climate resilience.
- *Objective 8.d.*: Continue participation by EMD Mitigation staff on interagency workgroups with climate change focuses, such as the Interagency Climate Adaptation Network and the Governor's Climate Resilience Task Force.

Goal 9: Strategically reduce the number of repetitive loss and severe repetitive loss properties in Washington

According to Chapter 3 of this plan, flooding continues to be one of Washington's most common natural hazards. Although the number of repetitive loss and severe repetitive loss (RL/SRL) properties has declined over time, there are still significant clusters of RL/SRL properties in the state.

- *Objective 9.a.*: Use RL/SRL data to identify areas for targeted outreach about the FMA program.
- *Objective 9.b.*: Increase the number of FMA grant applications Washington submits each year until all RL/SRL properties are mitigated.

Goal 10: Ensure all counties and sub-county jurisdictions understand their hazard risks and are eligible for mitigation funding opportunities

As of 2020, each of the 39 counties in Washington was actively involved in hazard mitigation planning, with many having an approved plan already and significantly increasing the number of jurisdictions eligible for HMA funding in this state. However, there are still numerous jurisdictions that are not actively engaged in the mitigation planning process, even if their counties are. These jurisdictions include cities, towns, and special purpose districts.

- *Objective 10.a.*: Improve the level of technical support to counties and sub-county jurisdictions engaged in hazard mitigation planning.
- *Objective 10.b.*: Improve the State hazard mitigation plan review process, including providing meaningful comments and suggestions for improvement.
- *Objective 10.c.*: Encourage counties to engage more of their sub-county jurisdictions during their planning processes and to assist with the development of jurisdictional annexes in county mitigation plans.

4.2. Mitigation Actions

Our mitigation actions are based on the risk and vulnerability assessment detailed in Chapter 3 of this plan as well as input from the subject matter experts on the Hazard Mitigation Working Group. These actions are how the State intends to reduce our hazard risks and vulnerabilities long-term and achieve the goals listed in section 4.1. We used the STAPLEE method (FEMA 2003) to evaluate and prioritize actions according to likely cost-effectiveness, environmental benefits, and technically feasibility. The full list of actions can be found in Appendix A.

The actions that met at least 90% of our evaluation criteria are listed below (Table 26) from highest score to lowest. The hazards addressed below include all our highest-risk hazards except for any wildfire-specific actions. Wildfire actions are included in the full list in Appendix A but are met with more technical and administrative challenges and thus scored lower. Wildfire risk could also be addressed in the actions that address all hazards.

The most common challenges facing the implementation of the actions below are administrative (e.g., lack of staffing or funding).

Table 26. Highest ranking mitigation actions

Action	Hazard(s) Addressed	Lead Agency	Score (out of 23)
Update ShakeMaps using best available science	Earthquake	Natural Resources	23
Secure year-to-year drought contingency funding from the state legislature	Drought	Ecology	23
Support the construction of the North Shore Levee and West Segment in Aberdeen and Hoquiam	Flood	Ecology	22
Use geologic hazard modeling to update building codes as appropriate	Earthquake, tsunami, volcano, landslide	Natural Resources	22
Further flood safety through integrated management of floodplain areas throughout the state	Flood	Ecology	22
Develop guidance for local governments to include climate-related natural hazard considerations in their comprehensive plans	All except earthquake, tsunami, and volcano	Commerce	22
Improve integration of hazard mitigation into local comprehensive plans	All	Commerce	22
Develop and evaluate a comprehensive local action plan to reduce flood damage in the Chehalis Basin	Flood	Ecology	22

Improve drought contingency planning and response capabilities	Drought	Ecology	21
Continue efforts to support locally scaled climate vulnerability assessments and provide technical assistance and expertise for adaptation efforts	All except earthquake, tsunami, and volcano	Ecology	21
Enable communities to do flood risk reduction planning and projects, including home elevations, buyouts, levee work, and ecosystem improvement	Flood	Ecology	21

Appendices

Appendix A: Reviewers' Appendix

The purpose of this appendix is to provide a consolidation of information pertinent to the plan requirements under 44 CFR Part 201. This appendix should help FEMA reviewers quickly find and assess whether the 2023 SEHMP is meeting the requirements needed for "enhanced" status. These requirements and responses are based on the 2015 *State Mitigation Plan Review Guide*.

Standard State Plan Requirements

S1. Description of the process used to develop the 2023 SEHMP

The first step in our process getting to the 2023 State Enhanced Hazard Mitigation Plan (SEHMP) was a comprehensive review and evaluation of the 2018 SEHMP. Beginning in Fall 2019 through Summer 2020, we combed the 2018 plan for inaccuracies, weaknesses, and strengths so we could be sure the 2023 plan built on the successes of 2018 while improving it wherever possible. During this evaluation, we updated the Dam Failure Hazard Profile and received approval from FEMA in July 2020, making the State eligible for funding under the High Hazard Potential Dam Grant Program. However, the primary result from our evaluation was that the SEHMP could be greatly improved through more rigorous hazard analysis methods that can address some of the weaknesses in the 2018 Hazard Inventory and Vulnerability Analysis (HIVA).

We based the 2023 update on a scientific and data-driven HIVA using mainly quantitative geospatial methods – such as statistical modeling of hazard risks – to show changes in risk over time and space. We also used statistical models to determine the environmental, social, and land use attributes that are most likely contributing to hazard occurrences. Data collection for the modeling work began in early 2020 after it became apparent the HIVA would be strengthened with a new approach. We used wildfire as a case study to hone and validate our methods, with initial results by late 2020. To further validate our methods, we developed and submitted a paper based on our wildfire analysis to the peer-reviewed *International Journal of Disaster Risk Science* where other experts in the field of hazard mitigation could review and offer feedback on our approach. Much of this data collection and validation process was aided greatly by the Washington Geospatial Open Data portal managed by WaTech (www.geo.wa.gov) and other open data portals. Other hazard analyses were conducted from September 2020 through September 2022, with updated risk assessments for every natural hazard.

A full standard methodology for our approach to risk analysis was developed by the SEHMP Editors after the full evaluation of the 2018 SEHMP and presented to the Hazard Mitigation Working Group (HMWG) for its input in the September 2020 meeting. This methodology was followed as closely as possible with deviations driven by data availability. Many hazard profiles required full re-writes since 2018 to build a spatial data foundation for us to use to run more rigorous analyses at a later date. As such, many hazards received a traditional, exposure-based risk assessment in the 2023 HIVA and are slated for further analysis prior to the next comprehensive update.

The evaluation of the 2018 SEHMP also revealed the many strengths of the 2018 Mitigation Strategy, including its statewide and comprehensive nature. At a basic level, we updated the 2018 mitigation actions and designed new actions to address the specific vulnerabilities and drivers of risk in Washington revealed by the updated risk assessment, thereby increasing our confidence of their risk reduction potential. We did not see the need to drastically alter the Mitigation Strategy other than general updates to the actions listed with input from the HMWG members to make them current and aligned with the new risk assessment. We also updated the format we chose to present those mitigation actions, based on STAPLEE, which we feel will allow us to monitor progress and document changes more easily for use in the next comprehensive update as well as our EMAP accreditation.

Table 27 presents the schedule used to guide the development of the 2023 SEHMP.

Table 27. SEHMP timeframe with milestones, beginning in Jan. 2021 when the SEHMP update grant application was submitted to the State under HMGP DR-4539.

Title	2023 Washington State Enhanced Hazard Mitigation Plan
Editors	Kevin Zerbe, Stacey McClain, Tim Cook

Submit to FEMA

2021				2022				2023		
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Jan Feb Mar	Apr May Jun	Jul Aug Sept	Oct Nov Dec	Jan Feb Mar	Apr May Jun	Jul Aug Sept	Oct Nov Dec	Jan Feb Mar	Apr May Jun	Jul Aug Sept

	Requirement	Milestones	Owner	Start Date	Est Finish Date
Plan Development	S1.0	Develop plan development process	Kevin	10/15/2019	1/27/2021
EC: 3/31/23	S2.0	Ensure and mantain coordination with other State agencies	Kevin	10/15/2019	3/31/2023
Risk & Vulnerability Analysis	S3.0	Create summary of natural hazards (location, extent, and previous occurences)	Kevin	6/1/2022	6/30/2022
EC: 9/30/22	S4.0	Determine probability of future hazard events (projected changes in location, extent, intensity, frequency, and/or duration)	Kevin	8/1/2020	5/31/2022
	S5.0	Determine potential impacts to and vulnerability of State assets, including potential dollar losses	Kevin	7/1/2021	5/31/2022
	S6.0	Determine jurisdiction-level (i.e. counties) vulnerability and identify potential losses to structures	Kevin	6/1/2022	9/30/2022
	S7.0	Identify changes in development and revise the risk assessment accordingly	Kevin	8/1/2020	7/31/2021
Mitigation Strategy	S8.0	Develop State-level mitigation goals to reduce vulnerability to the State and local jurisdictions	Kevin	10/15/2019	7/31/2021
EC: 12/31/22	S9.0	Prioritize mitigation actions according to cost-effectiveness, feasibility, risk reduction potential, and connection to local HMPs	Kevin	8/1/2021	12/31/2022
	S10.0	Identify funding sources for mitigation action implementation	Kevin	8/1/2022	9/30/2022
	S11.0	Update 2018 mitigation actions to refelct current status and current risk assessment	Kevin	8/1/2022	10/31/2022
	S12.0	Evaluate State policies, programs, capabilities, and funding sources for mitigation	Kevin	8/1/2022	10/31/2022
	S.13.0	Describe and analyze the effectivenss of local and tribal mitigation policies programs and capabilities	Kevin	10/1/2022	10/31/2022
	S14.0	Develop process for local HMP support and approval	Kevin	12/1/2022	12/31/2022
	S15.0	Develop criteria for prioritizing jurisdictions to receive grant funding	Tim	12/1/2022	12/31/2022
	S16.0	Develop process for local HMP review and submission to FEMA	Kevin	12/1/2022	12/31/2022
Plan Review & Evaluation	S17.0	Develop process to monitor, track, and update the plan in order to keep it current	Kevin	1/1/2023	1/31/2023
EC: 1/31/23	S18.0	Develop systems for monitoring plan implementation and reviewing progress	Kevin	1/1/2023	1/31/2023
Plan Adoption & Submission	S19.0	Request documention for formal adoption by designee prior to final review and approval	Stacey	5/1/2023	5/31/2023
EC: 5/31/23	S20.0	Provide State assurances	Stacey	2/1/2023	2/28/2023
Enhanced Plan Requirements	E1.0	Check all standard requirements	Kevin	3/31/2023	5/31/2023
EC: 5/31/23	E2.0	Demonstrate integration with othe State plans	Kevin	8/1/2022	3/31/2023
	E3.0	Demonstration commitment to comprehensive mitigation program	Kevin	8/1/2022	3/31/2023
	E4.0	Document capability to implement mitigation actions	Kevin	8/1/2022	3/31/2023
	E5.0	Document use of HMA funding to demonstrate effective use of mitigation programs to achieve mitigation goals	Tim	12/1/2022	12/31/2022
	E6.0	Document capbility to prepare and submit accurate environmental reviews and BCAs	Tim	12/1/2022	12/31/2022
	E7.0	Document ability in HMA to prepare and submit environmental reviews and BCAs to demonstrate state capability	Tim	12/1/2022	12/31/2022
	E8.0	Document capability to submit complete and accurate quarterly and financial reports	Tim	12/1/2022	12/31/2022
	E9.0	Document capability to complete HMA projects within POP, including financial reconciliation	Tim	12/1/2022	12/31/2022
	FEMA Review			3/31/2023	9/30/2023

The complete 2023 SEHMP was prepared using a stakeholder-driven planning process from start to finish. The State's official planning team is the interagency HMWG made up of State agency representatives (full list can be found in Chapter 2). The HMWG met multiple times throughout the update process between 2020 and 2023, with SEHMP-specific meetings beginning in the September 2020 meeting. We continued meeting quarterly throughout the planning process. Between September 2020 and submission of this plan to FEMA in March 2023, all HMWG meetings were geared toward specific sections or requirements of the 2023 SEHMP update, such as risk analysis methodology development, presenting new data or hazard information for use in the plan, development of a comprehensive range of mitigation actions for the mitigation strategy, and more. Aside from meeting attendance and participation, members' responsibilities included reviewing and writing plan content, providing data and information for use in the risk analyses and mitigation strategy, and ensuring their home agencies' plans informed the 2023 SEHMP and vice-versa.

Lastly, we regularly engaged with our state-level counterparts in Oregon's Office of Emergency Management and Department of Land Conservation & Development to share best practices and information on mitigation planning and program management. We also shared drafts of the 2023 HIVA methodology for their review, feedback, and advice.

Table 28. Summary of planning team (i.e., HMWG) meetings

Date	SEHMP Topic(s) Discussed
9/30/2020	Review of state plan requirements, including enhanced requirements; Presentation on the new risk assessment approach
12/16/2020	Plan development process; Overview of the SEHMP grant applications materials
3/18/2021	Regional vulnerability assessments; Local stakeholder engagement approach
6/23/2021	SEHMP timeframe and integration with other State planning efforts
10/8/2021	Update on current accomplishments (e.g., project charter finalized) and next steps, including HMWG roles in 2022 and 2023
3/29/2022	Update to the hazard profiles and HIVA timeline
8/4/2022	Example HIVA results (Combined meeting with FEMA Consultation)
9/14/2022	Detailed HIVA results; shifting toward updated the Mitigation Strategy (Combined meeting with Interagency Climate Adaptation Network)
Quarter 4 2022	No meeting. Members spent this quarter reviewing the 2018 Mitigation Strategy and providing updates to their respective sections
Quarter 1 2023	No meeting while this plan was being drafted and prepared for FEMA review

Table 29. Summary of interstate meetings with State of Oregon

Date	Attendees	Topic(s) Discussed
2/23/2021	Stacey McClain (EMD), Tim Cook (EMD), Kevin Zerbe (EMD), Stephen Richardson (OEM), Joseph Murray (OEM)	Enhanced status requirements; Statewide comprehensive mitigation program management
5/20/2021	Kevin Zerbe (EMD), Stephen Richardson (OEM), Joseph Murray (OEM), Amie Bashant (OEM)	Annual validation and consultation results from WA and OR; WA plan update approach
5/25/2021	Kevin Zerbe (EMD), Stephen Richardson (OEM), Joseph Murray (OEM)	State-level mitigation planning best practices
7/9/2021	Kevin Zerbe (EMD), Jason Gately (OEM)	Risk and vulnerability assessment methods; Use of contractors for plan development

8/24/2021	Kevin Zerbe (EMD), Marian Lahav (DLCD)	Risk assessment methods
9/16/2021	Kevin Zerbe (EMD), Tim Cook (EMD), Stephen Richardson (OEM), Joseph Murray (OEM), Amie Bashant (OEM) Anna Feguim (OEM), Jason Gately (OEM)	Approach to ensuring local technical assistance and local mitigation plan review and approval
5/31/2022	Kevin Zerbe (EMD), Tim Cook (EMD), Stephen Richardson (OEM), Joseph Murray (OEM), Anna Feguim (OEM), Jason Gately (OEM)	The incorporation of human-caused hazards into state-level HMPs
7/21/2022	Kevin Zerbe (EMD), Tim Cook (EMD), Stephen Richardson (OEM), Joseph Murray (OEM), Jason Gately (OEM)	State plan progress, schedule, and timelines
11/17/2022	Kevin Zerbe (EMD), Tim Cook (EMD), Stephen Richardson (OEM), Anna Feguim (OEM), Jason Gately (OEM), Joseph Murray (OEM)	Preparation for BRIC 2022; status of the WA SEHMP development

S2. Coordination with other agencies and stakeholders

As mentioned above, we coordinated extensively with State and non-State agencies to craft each section of the plan. S1 above describes how the coordination process via the HMWG (web conferences and working group assignments) and Chapter 2 includes the names and affiliations of the HMWG members.

HMWG members represent the following sectors: emergency management (EMD), economic development (Dept. of Commerce), land use (Dept. of Commerce), public health (Dept. of Health), infrastructure (Dept. of Ecology), cultural resources (Dept. of Archaeology and Historic Preservation), and natural resources (Dept. of Ecology and Dept. of Natural Resources), among others. We currently do not have any active members representing the housing sector, though the State Department of Social and Health Services provides housing assistance and may have staff available to participate in the HMWG before the next comprehensive update.

S3. Overview of the type and location of natural hazards that can affect Washington

The table below presents a summary of hazard type, location, extent, and previous occurrences based on state- and federal-level natural disaster declarations or other documented occurrences since 1980. A list of high hazard potential dams (HHPDs) as of May 2023 (Table 31) and a map of their location (Figure 42) is also included. Other human-caused hazards are not included here, though information on human-caused hazards can be found in Chapter 3. Additional detail, including maps of exposure areas, can be found on each of these hazards in Chapter 3.

Table 30. Overview of type and location of all the natural hazards in Washington

Type	Location	Possible Extent (Magnitude/Severity)	Previous Occurrences (disasters since 1980)
Avalanche	Mountainous areas statewide	Category 5 (extreme) avalanches are possible in WA, based on likelihood, size, and distribution of avalanche activity	No recent declaration for avalanche, but avalanche activity is an annual event in the mountainous areas of the state
Drought	Statewide, with the most frequent droughts primarily in Eastern Washington	Hydrologic drought in WA is determined when a geographic area receives less than 75% of its normal (median) water supply	2022, 2019, 2015, 2006, 2005, 2001, 1994, 1992, 1988
Earthquake	Statewide	2001 event was 6.8M; there is potential for a >9.0M event from the Cascadia Subduction Zone (CSZ)	2001 (DR-1361)
Extreme weather	Statewide	Known weather extremes in WA include: • High winds (> 100 mph) • Heat (> 110°F) • Cold (< -40°F) • Thunderstorms (incl. lightning, hail, tornadoes) • Rainfall (>14” daily/185” annual) • Snowfall (>65” daily/300” annual)	2022 (DR-4682, DR-4650); 2021 (DR-4593); 2020 (DR-4539); 2018 (DR-4418); 2017 (DR-4309); 2015 (DR-4253); 2015 (DR-4249); 2015 (DR-4242); 2012 (DR-4083); 2012 (DR-4056); 2011 (DR-1963); 2009 (DR-1825); 2009 (DR-1817); 2007 (DR-1734); 2006 (DR-1682); 2006 (DR-1671); 2006 (DR-1641); 2003 (DR-1499); 1997 (DR-1172); 1997 (DR-1159); 1996 (DR-1152); 1996 (DR-1100); 1995 (DR-1079); 1994 (DR-1037); 1993 (DR-981); 1990 (DR-896); 1990 (DR-833); 1990 (DR-852); 1989 (DR-822); 1986 (DR-784); 1986 (DR-769); 1986 (DR-762); 1983 (DR-676)
Flood	Coasts and floodplains statewide	Coastal flooding during king tides can reach >15 ft in some locations; determination of riverine flood magnitude/severity is dependent upon the stream itself, but all gaged streams in WA have the potential to exceed flood stage; a single rain-driven flood event in 1996 impacted 24/39 counties and >2,600 homes	2022 (DR-4682, DR-4650); 2021 (DR-4635, DR-4593); 2020 (DR-4539); 2018 (DR-4418); 2017 (DR-4309); 2015 (DR-4253); 2015 (DR-4249); 2014 (DR-4168); 2012 (DR-4083); 2012 (DR-4056); 2011 (DR-1963); 2009 (DR-1817); 2007 (DR-1734); 2006 (DR-1671); 2006 (DR-1641); 2003 (DR-1499); 1998 (DR-1252); 1997 (DR-1172); 1997 (DR-1159); 1996 (DR-1100); 1995 (DR-1079); 1990 (DR-883); 1990 (DR-852); 1989 (DR-822); 1986 (DR-784); 1986 (DR-769); 1986 (DR-762); 1983 (DR-676)
Landslide	Mountainous and hilly areas statewide	Landslides vary widely in magnitude and severity; SR530 slide in 2014 (a.k.a. Oso landslide) moved 18 million tons of debris at an average speed of 40 mph	2022 (DR-4682); 2021 (DR-4635, DR-4593); 2020 (DR-4539); 2018 (DR-4418); 2017 (DR-4309); 2015 (DR-4253); 2015 (DR-4249); 2015 (DR-4243); 2014 (DR-4168); 2012 (DR-4083); 2012 (DR-4056); 2011 (DR-1963); 2009 (DR-1817); 2007 (DR-1734); 2006 (DR-1682); 2006 (DR-1671); 2006 (DR-1641); 1998 (DR-1255); 1997 (DR-1172); 1989 (DR-822); 1986 (DR-762)
Tsunami	Coasts and lakes statewide	Inland tsunamis (on lakes) can reach as high as 65 ft; a tsunami generated by a CSZ earthquake is expected to inundate all coastal areas	No recent seismic-driven tsunamis, but periodic inland tsunamis driven by landslides have occurred as recently as 2009
Volcano	Primarily western Washington for lahar impacts; statewide for	Explosive eruptions are possible on Mt. St. Helens, Rainier, Baker, and Glacier Peak with ash/tephra capable of extending across the state; lahars from Mt. Rainier and Baker can reach Puget Sound	1980 (DR-623)

	tephra/ash impacts		
Wildfire	Vegetated areas statewide	Wildfires in WA often reach class G (>5,000 acres); the Cold Springs Canyon-Pearl Hill fire complex in 2020 was the state's largest recorded and burned >410,000 acres	2022 (3 FMAGs); 2021 (9 FMAGs); 2020 (DR-4584); 2018 (10 FMAGs); 2017 (3 FMAGs); 2016 (4 FMAGs); 2015 (DR-4243); 2014 (DR-4188); 2013 (3 FMAGs); 2012 (8 FMAGs); 2011 (1 FMAG); 2010 (2 FMAGs); 2009 (2 FMAGs); 2008 (2 FMAGs); 2007 (3 FMAGs); 2006 (3 FMAGs); 2005 (2 FMAGs); 2004 (5 FMAGs); 2003 (2 FMAGs); 2002 (2 FMAGs); 2001 (9 FMAGs); 2000 (3 FMAGs); 1998 (3 FMAGs); 1996 (1 FMAG); 1994 (4 FMAGs); 1992 (1 FMAG); 1991 (DR-922); 1988 (1 FMAG); 1985 (1 FMAG)

Table 31. List of high hazard potential dams in Washington, as of May 2023. Total population at risk statewide is 33,797.

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
3 Amigos Reservoir	Chelan	WA00685	1C	18
Aberdeen Lake Dam	Grays Harbor	WA00112	1C	18
Anderson Lake Dam	Mason	WA00114	1B	66
Antilon Lake Dam	Chelan	WA00081	1B	45
Asamera Cannon Mine Tailings Dam	Chelan	WA00499	1A	303
Baby Gap Ranch Reservoir	Benton	WA02057	1B	45
Badger Mountain Irr Dist Reservoir Expan	Benton	WA01488	1B	36
Beacon Hill Reservoir	Grays Harbor	WA01790	1B	306
Bear Mountain Dam	Chelan	WA01960	1C	30
Beehive Dam	Chelan	WA00055	1B	150
Beehive Saddle Dam	Chelan	WA00361	1C	30
Belfair WWTP Treated Water Storage Pond	Mason	WA00728	1B	45
Bellingham Airport SW Detention Pond 3	Whatcom	WA02040	1B	66
Berger Dam	Thurston	WA00220	1C	18
Beryl Baker Dam	Stevens	WA01324	1C	24
Bitter Lake Reservoir	King	WA00213	1A	500
Black Rock Orchards Dam	Yakima	WA00506	1B	51

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
Blair Reservoir Dam	Benton	WA00059	1B	189
Boeing Creek M1 Detention Dam	King	WA00483	1C	9
Boeing Creek Park North Pond Dam	King	WA01782	1C	9
Bonney Lake WSU Infiltration Pond	Pierce	WA02010	1C	12
Boyd Lower Reservoir Dam	San Juan	WA01384	1C	18
Bremerton Reservoir No 4	Kitsap	WA01207	1B	141
Camano Island Cattle Co Dam	Adams	WA00689	1C	9
Camp Kwoneesum Dam	Skamania	WA00131	1C	12
Carlisle Lake Dam	Lewis	WA00222	1B	60
Casad Dam	Kitsap	WA00171	1A	500
Cedar Heights Dam	Skagit	WA01900	1C	15
Cedar Way Stormwater Detention Dam	Snohomish	WA01404	1B	75
Chaplain Lake North Dam	Snohomish	WA00196	1B	40
Chaplain Lake South Dam	Snohomish	WA00197	1A	360
Chase Lake Stormwater Detention Dam	Snohomish	WA00603	1C	9
Chiawana Gleed Ranch Dam	Yakima	WA01975	1B	36
Clear Lake Dam	Chelan	WA00230	1C	27
Clear Lake Saddle Dam	Chelan	WA00411	1C	27
Colchuck Lake Dam	Chelan	WA00227	1B	42
College Hill Reservoir	Grays Harbor	WA00663	1A	900
Columbia River Orchard Reservoir 2	Douglas	WA01931	1C	9
Cranberry Lake Dam	Skagit	WA00282	1B	87
Cranberry Lake Stormwater Detention Dam	Mason	WA00594	1C	66
Crystal Lake Dam	King	WA00195	1B	72
Dad's Lake Dam	Stevens	WA00373	1C	15
Davenport Sewage Lagoon No 1	Lincoln	WA01727	1C	30
Davenport Sewage Lagoon No 2	Lincoln	WA01602	1C	30
Davenport Sewage Lagoon No 3	Lincoln	WA01603	1C	30

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
Davenport Sewage Lagoon No 4	Lincoln	WA00560	1C	30
Dawn Lake Dam	Clallam	WA01064	1B	39
Deer Park Sewage Treatment Lagoon	Spokane	WA01467	1C	30
Deer Park Waste Water Storage Lagoon	Spokane	WA01468	1A	303
Deer Park Wastewater Storage Lagoon No	Spokane	WA00655	1A	303
Del Monte Foods Inc	Yakima	WA01950	1C	30
Den Hoed Dam No 1	Yakima	WA01948	1B	42
Diamond Lake Aeration Lagoon No 2	Pend Oreille	WA00568	1C	27
Diamond Lake Aeration Lagoon No 3	Pend Oreille	WA00567	1C	27
Diamond Lake Sewage Lagoon No 1	Pend Oreille	WA01632	1C	27
Eaglemont Storm Pond	Snohomish	WA02053	1B	54
Edaleen Dairy Waste Storage Pond No 3	Whatcom	WA01914	1A	301
Edaleen Dairy Waste Storage Pond No. 2	Whatcom	WA01694	1A	301
Eightmile Lake Outlet Dam	Chelan	WA00228	1B	150
Erickson Dam	Clark	WA00102	1B	39
Evans Far West Pond Dam	Yakima	WA01919	1B	42
Evans Flavorland Reservoir No 1	Yakima	WA00715	1B	50
Evans Flavorland Reservoir No 2	Yakima	WA00716	1B	50
Evans Tieton Pond Dam	Yakima	WA00717	1B	45
Everett Reservoir No 3	Snohomish	WA00283	1B	30
Fairview Reservoir No 1	Grays Harbor	WA00548	1B	126
Fairview Reservoir No 2	Grays Harbor	WA01728	1B	45
Fanchers Dam	Okanogan	WA00040	1C	21
Farmland Ranch 19 Dam	Yakima	WA00719	1B	36
Finley Ranch Reservoir	Benton	WA02048	1C	18
Fire Mountain Boy Scout Camp Dam A	Skagit	WA00382	1C	15
Gamache Dam	Yakima	WA01947	1C	15
Gap Road Reservoir	Benton	WA01874	1B	48

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
Garrison Creek 98th Avenue Detention D	King	WA00650	1C	27
Great Depression Dam	Chelan	WA01781	1B	135
Haight Reservoir Dam	Clark	WA01039	1C	27
Hannegan Road Detention Basin	Whatcom	WA00610	1B	90
Happy Valley Stormwater Detention Basin	Whatcom	WA01347	1C	30
Harbor Hill North Pond	Pierce	WA00729	1B	15
High Point Redevelopment Stormwater Dam	King	WA01869	1B	45
Hilltop Waterski Pond	Snohomish	WA00616	1C	12
Hog Lake Dam	Spokane	WA00056	1C	30
Holmes Harbor Reclaimed Water Ponds	Island	WA01952	1C	30
Honeymoon Lake Dam	Island	WA00203	1C	9
Icon Materials	King	WA00683	1C	10
Iman Lake Dam	Skamania	WA01770	1C	18
Interfor Pacific Stormwater Pond	Clallam	WA02003	1C	30
Islewood Dam	Skagit	WA01506	1C	15
Issaquah Highlands Detention Pond	King	WA00707	1A	100
Issaquah Highlands NP2 Pond Dam	King	WA01858	1C	15
Issaquah Highlands NPE Pond	King	WA01867	1C	9
Issaquah Highlands Reid Pond Dam	King	WA00680	1B	50
Issaquah Highlands South Pond Dam	King	WA00688	1B	18
Johnson Pond Dam	King	WA01999	1B	66
Judy Reservoir Dam A	Skagit	WA00183	1B	90
Judy Reservoir Dam B	Skagit	WA00181	1B	270
Kayak Lake Dam	Snohomish	WA00199	1C	12
Kinross Gold Kettle River Tailings Dam	Ferry	WA00592	1B	44
Klahanie Stormwater Detention Dam No 13	King	WA00602	1B	36
Klonaqua Lake Dam	Chelan	WA00225	1A	6
Koppert Pond	Lewis	WA00500	1C	18

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
Koura Dam	Kitsap	WA01336	1C	30
Lake Forest Park Reservoir	King	WA00217	1A	3000
Lake Kittyprince Dam	King	WA00201	1B	54
Lakemont Stormwater Pond	King	WA01651	1B	297
Latitude 47 Commerce Center Stormwater Pond	Pierce	WA02072	1B	31
Leach Creek Stormwater Detention Dam	Pierce	WA00611	1B	102
Leader Lake Dam	Okanogan	WA00223	1B	180
Leader Lake Saddle Dam	Okanogan	WA00358	1B	180
Lily Lake Dam	Chelan	WA00231	1B	39
Limerick Lake Dam	Mason	WA00130	1C	113
Locke Dam	Pend Oreille	WA00019	1C	9
Loon Lake Aeration Lagoon	Stevens	WA01495	1C	24
Loon Lake Polishing Lagoon	Stevens	WA00519	1C	24
Loon Lake Waste Storage Lagoon	Stevens	WA00518	1C	24
Lords Lake East Dam	Jefferson	WA00357	1A	432
Lords Lake North Dam	Jefferson	WA00243	1A	432
Madsen Creek West Basin Dam	King	WA01862	1A	540
Marcel Lake Dam	King	WA00200	1C	15
Margaret Lake Dam	King	WA00236	1C	21
Marshall Lake Dam	Pend Oreille	WA00353	1C	15
Masonry Dam	King	WA00255	1A	1000
May Lake Dam	Stevens	WA01533	1C	9
McCain Foods Process Water Storage Facil	Adams	WA00657	1C	18
McCormick North Phase I East Pond	Kitsap	WA01891	1B	72
McCormick Woods Pond RC-8	Kitsap	WA01920	1B	24
Meadow Lake Dam	Chelan	WA00072	1C	15
Mill Creek Canyon Stormwater Detention D	King	WA01443	1B	100
Mill Creek Dam Cosmopolis	Grays Harbor	WA01730	1B	240

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
Mill Pond Stormwater Detention Dam	King	WA01716	1C	10
Milles Lake Dam	Okanogan	WA01788	1B	45
Minckler Dam A	Island	WA01884	1C	30
Minckler Dam B	Island	WA00691	1C	30
Moccasin Lake Dam	Okanogan	WA00053	1C	9
Mountain View East Storm Pond	Snohomish	WA02077	1B	15
N Marysville Regional Stormwater Pond	Snohomish	WA01875	1B	135
N Marysville Regional Stormwater Pond No. 2	Snohomish	WA00735	1B	135
Newcastle Railroad Embankment Dam	King	WA00648	1C	24
Newcastle Vista Pond 3	King	WA01908	1A	301
Newman Lake Flood Control Dam	Spokane	WA00396	1C	66
Nielsen Dam B	Snohomish	WA01521	1C	9
Nielsen Dam C	Snohomish	WA01522	1C	9
North Fork Clover Creek E1 Det Basin	Pierce	WA01776	1A	1500
North Fork Clover Creek W1 Det Facil	Pierce	WA01831	1B	300
Olympic Orchards Dam 1	Yakima	WA01936	1B	39
Olympic Orchards Dam 2	Yakima	WA01937	1B	39
Olympic Orchards Dam 3	Yakima	WA01938	1B	39
Olympic Orchards Dam 4	Yakima	WA01939	1B	39
Olympic Orchards Dam 5	Yakima	WA01940	1B	39
Orchards Block 96 Reservoir Dam	Walla Walla	WA01839	1C	20
Padden Lake Dam	Whatcom	WA00364	1A	849
Panther Lake Ballfield Dam	King	WA01737	1B	33
Panther Lake Detention Dam	King	WA01733	1B	33
Panther Lk First Avenue Bas Detent Pond	King	WA01747	1B	33
Parker Reservoir Dam	Yakima	WA00287	1B	60
Pasco Process Water Reuse Storage Lagoon	Franklin	WA00661	1C	24
Patterson Lake Dam	Okanogan	WA00073	1C	24

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
Peabody Heights Reservoir	Clallam	WA01210	1B	210
Peterson Stormwater Detention Dam	King	WA01337	1C	16
Port of Sunnyside Anaerobic Pretreatment System	Yakima	WA02052	1B	30
Power Lake Dam	Pend Oreille	WA00010	1C	15
Radar Lake Dam	King	WA00186	1B	42
Rainbow Springs Dam	Snohomish	WA00205	1C	27
Reardan Sewage Lagoon	Lincoln	WA01880	1C	12
REC Silicon Wastewater Pond	Grant	WA00723	1B	150
Redmond Ridge Cedar Dam	King	WA01802	1C	30
Redmond Ridge Drive EC 4N Roadway Dam	King	WA01837	1B	39
Redmond Ridge East Pond SRN 2 No 1	King	WA01892	1C	15
Redmond Ridge East SRS 1 Pond No 1	King	WA01922	1C	12
Reflection Lake South Dam	Spokane	WA00050	1C	9
Roche Harbor Lake Dam	San Juan	WA00444	1C	14
Roche Pomona Dam	Yakima	WA01918	1C	27
Roosevelt Reservoir	King	WA00212	1A	3300
Roza WW5 Reregulation Reservoir	Yakima	WA00740	1A	301
Sacheen Lake WWTP Lagoons	Pend Oreille	WA00738	1B	78
Schweitzer Dam and Reservoir	Okanogan	WA02026	1C	9
SeaTac Airport Pond M	King	WA02038	1C	10
Seattle City Volunteer Park Reservoir	King	WA00210	1A	870
Seattle Port Lagoon NO 3 Expansion	King	WA00671	1C	10
Selah Aerated Lagoon	Yakima	WA01478	1C	12
Selah Home Ranch Reservoir	Yakima	WA01954	1C	18
Selah Naches Ranch Reservoir	Yakima	WA01964	1C	15
Silver Firs Detention Pond No 3	Snohomish	WA01792	1C	18
Sinlahekin Dam No 1	Okanogan	WA00007	1C	15
Sinlahekin Dam No 3	Okanogan	WA00005	1C	15

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
Snoqualmie Ridge Osprey Ct Pond D1	King	WA01804	1C	21
Solmar Lake Dam	Clallam	WA00410	1B	93
South 336th Street Stormwater Dam No 1	King	WA01754	1C	10
South 336th Street Stormwater Dam No 2	King	WA01767	1C	10
South Fork McCorkle Creek Detention Dam	Cowlitz	WA00585	1B	100
South Ridge Stormwater Detention Dam	King	WA01820	1C	27
Southwest Genesee Street Detention Dam	King	WA00380	1C	9
Spokane Hutterian Brethren Dam	Spokane	WA00720	1C	27
Sprague Wastewater Treatment Lagoons	Lincoln	WA00635	1C	27
Spring Hill Dam	Chelan	WA00234	1C	30
Spring Hill Saddle Dam	Chelan	WA00360	1C	21
Springwood Stormwater Detention Dam	King	WA01668	1C	10
SPSCC Stormwater Pond F	Thurston	WA01886	1C	12
St Clair Stormwater Detention Dam	Whatcom	WA01566	1A	525
Steilacoom Lake Dam	Pierce	WA00139	1B	180
Stemilt Equalizing Reservoir	Chelan	WA01476	1C	21
Stemilt Main Dam	Chelan	WA00014	1B	36
Stemilt Saddle Dam	Chelan	WA00363	1C	36
Stevenson Dam	Yakima	WA01010	1C	12
Sunnyside MP 23.7 Reservoir	Yakima	WA00709	1A	301
Sunnyside MP 37.1 Reservoir	Yakima	WA00725	1B	100
Sunnyside MP 59.29 Reservoir	Benton	WA00690	1B	45
Swano Lake Dam	Grays Harbor	WA00547	1A	570
Tahuyeh Lake Dam	Kitsap	WA00188	1B	90
Talus P5 Stormwater Detention Dam	King	WA01844	1C	9
Tapps Lake Backflow Prevention Structure	Pierce	WA00703	1C	30
Tapps Lake Dike No 1	Pierce	WA00418	1A	420
Tapps Lake Dike No 11	Pierce	WA00427	1A	1000

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
Tapps Lake Dike No 12	Pierce	WA00428	1C	30
Tapps Lake Dike No 2A	Pierce	WA00419	1C	30
Tapps Lake Dike No 2B	Pierce	WA00420	1C	30
Tapps Lake Dike No 3	Pierce	WA00421	1B	100
Tapps Lake Dike No 4	Pierce	WA00296	1A	1000
Tapps Lake Dike No 5	Pierce	WA00422	1A	1000
Tapps Lake Dike No 6	Pierce	WA00423	1A	1000
Tapps Lake Dike No10	Pierce	WA00426	1C	7
Tesoro Water Storage Reservoir	Skagit	WA01968	1C	9
Tri Mountain Estates Dam	Clark	WA00103	1C	15
Trossachs Detention Pond PC-2	King	WA01833	1C	30
Trout Lake Storage Dam	San Juan	WA00202	1C	12
Tuck Lake Dam	King	WA00180	1C	18
Tyson Fresh Meats Storage Pond 4	Walla Walla	WA00633	1C	9
Upper Loop Reservoir	Chelan	WA00743	1C	21
Upper Mill Creek Stormwater Detention Da	King	WA00582	1B	300
Upper Sunlight Lake Dam	Kittitas	WA00666	1C	12
Upper Wheeler Dam	Chelan	WA00079	1B	60
Upper Wheeler Saddle Dam	Chelan	WA00629	1B	60
Van Stone Pit Lake Dam	Stevens	WA02033	1C	9
Wapato Lake Dam	Chelan	WA00321	1C	21
Welcome Lake Dam	King	WA00194	1B	300
Wenas Dam	Yakima	WA00002	1B	180
West Bank Project Reservoir	Franklin	WA00684	1C	30
Weyerhaeuser Enumclaw Flood Control Dam	King	WA00636	1C	27
Whatcom Lake Dam	Whatcom	WA00158	1B	50
Whistle Lake Dam	Skagit	WA00705	1C	12
William Symington Dam	Kitsap	WA00190	1B	42

Name	Location	National Inventory ID	Hazard Classification	Population At Risk
Windsor Waterski Pond	Thurston	WA01711	1C	18
Wood Reservoir Dam No 1	Chelan	WA00015	1C	12
Yellow Lake Outlet Dike	King	WA00559	1B	36
Youngs Lake New Inlet Dam	King	WA00415	1C	15
Youngs Lake Outlet Dam	King	WA00254	1A	301
Zintel Canyon Dam	Benton	WA00617	1A	900

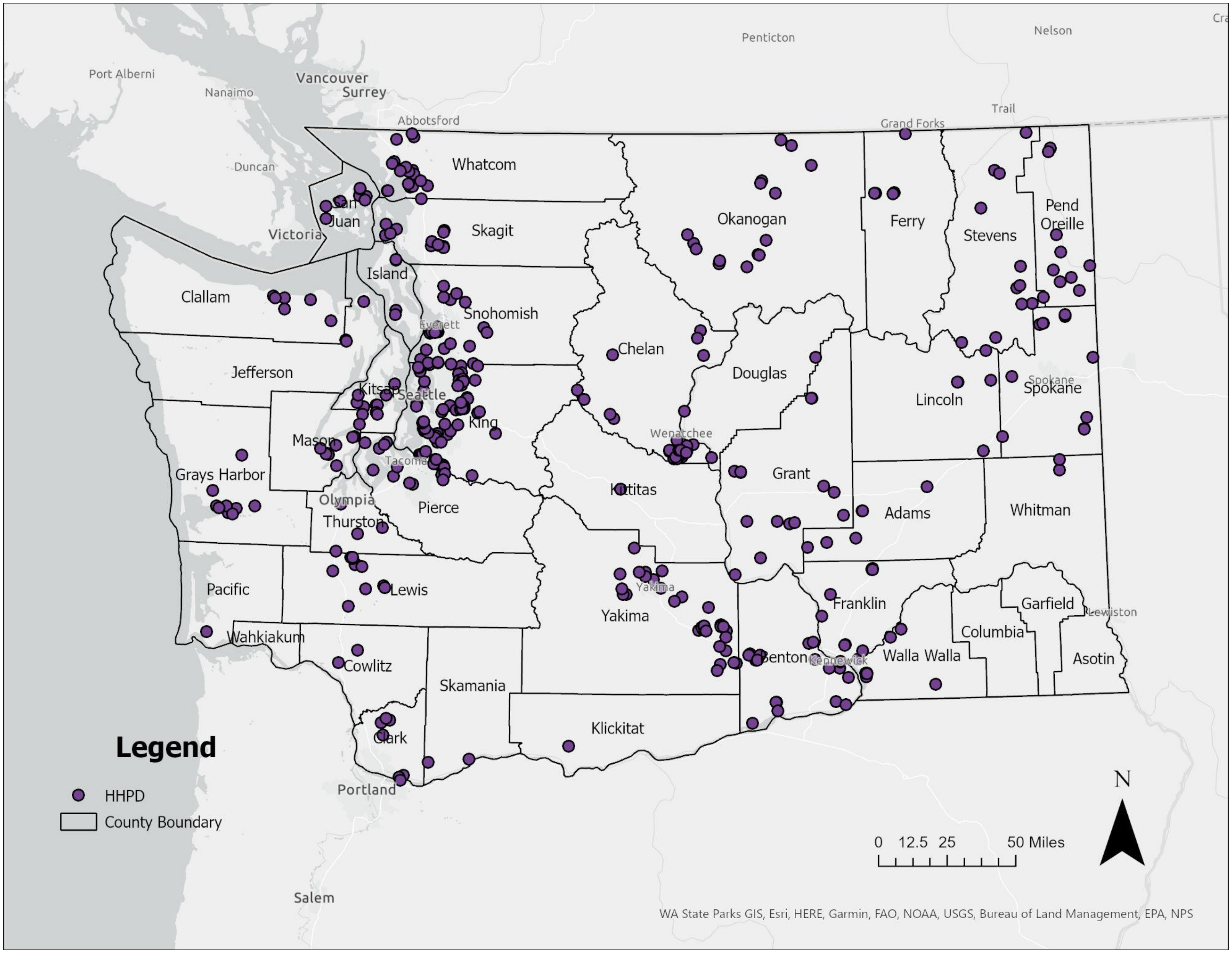

Figure 42. Location of high hazard potential dams statewide

S4. Overview of the probabilities of future hazard events

The table below provides an overview of the future probability of each natural hazard present in the state, including considerations of future conditions such as population growth and climate change.

Probabilities are based on the percent annual chance of at least one major event occurring (i.e., a state- or federal-level disaster declaration). These probabilities are based on historical data between 1980 and 2022. We chose this method because disaster declarations indicate a high degree of impact caused by a natural hazard, and our goal for this risk assessment is to understand the potential for impact. Although this does not fully characterize the influence of climate change or population growth on hazard probability, their contributions to declared disasters in Washington are inherent in the data but could be further explored later. Both climate change and population growth are discussed in the Projected Changes column. Additionally, many natural hazards occur very frequently without noticeable impacts on life, property, or the environment (e.g., minor earthquakes happen nearly daily). These minor, relatively unnoticed events are not considered in our annual probabilities even though data may be available.

The Projected Changes column discusses the influence of climate change, population growth, and other external factors on hazard location, extent, intensity, frequency, and/or duration. Population growth statistics presented in this table were derived from the Shared Socioeconomic Pathways Scenario 2 (Jones & O'Neil, 2016) which is a global population projection that assumes much of the world continues its current path of social, economic, and technological advancement and rate of population growth (a.k.a. a "business as usual" scenario).

Regions most at-risk were determined by the potential for damage or loss to critical assets (e.g., population, critical infrastructure, etc.) based on the likelihood of a destructive event (one that causes damage to property and environment and/or places people at physical risk). For most of the natural hazards, we used historical disaster declaration data since 1980 for this determination. We chose this method because disaster declarations are based on damage caused and clearly illustrate the potential for future damage. Consult Chapter 3 for a breakdown of which counties fall into each of the regions below.

Table 32. Overview of the probabilities of future hazard events

Hazard	Probability	Projected Changes	Region Most At-Risk
Avalanche	< 1%	Regional research on climate impacts to avalanche activity is missing, though climate change is expected to result in decreased snowpack in WA – as much as a 70% decrease by 2080 compared to 2006. Year-to-year variability in precipitation makes it difficult to predict snowfall rates with accuracy. However, given the overall expectation of warmer winters, avalanches that put people and/or assets at risk may become rarer.	Puget Sound & Northwestern
Drought	24%	Drought (including "abnormally dry" classification) is expected to increase in extent, intensity, frequency, and duration in WA, driven primarily by climate change. The geographic distribution of drought hazards is expected to increase, with western WA becoming more drought prone as climate change continues. However, the primary area at-risk to the most severe droughts continues to be Eastern Washington. Drought intensity was an especially high in 2021, with 100% of the state classified as abnormally dry that September, including 45% classified as experiencing "extreme" drought.	Central
Earthquake	2.5%	Exposed population and property will increase as earthquake-prone areas see continued population growth and development (e.g., Seattle-Tacoma region). Projected population growth in the state suggests 6.5 million people will reside in seismic zones by 2050, an increase of 14% compared to 2020.	Puget Sound & Northwestern
Extreme weather	72%	Extreme weather events currently average at approx. 1 event/year since 1980. Although no trend has been observed as of 2023, extreme weather is expected to increase in extent, intensity, and frequency, due primarily to climate change. The geographic distribution of extreme weather is also expected to increase (e.g., high-heat events in western WA). Population growth and continued development	Puget Sound & Northwestern

		will put more people and property at risk to extreme weather. Projected population in these areas by 2050 is 4.2-4.3 million.	
Flood	60%	WA averages approx. 1 major flood event/year since 1980. Although no trend has been observed as of 2023, climate change-driven increases in extreme precipitation is expected to increase the frequency, extent, intensity, and geographic distribution of floods in WA by 2100. Population growth and development in flood-prone areas is projected to continue, resulting in elevated risk over time. An estimated 2.5 million people will reside in flood hazard areas by 2050, an increase of 25% compared to 2020. Sea level rise will contribute to more frequent and severe coastal flooding, with the potential for some areas to see 4 feet of sea level rise by 2100.	Puget Sound & Northwestern
Landslide	44%	There is some indication that landslide activity may be increasing in WA since 1980. Areas at-risk to landslides will continue to be at-risk and are expected to see more frequent landslides due to the impacts of extreme precipitation and wildfire (post-wildfire debris flows) resulting from climate change. Population growth in landslide risk areas is expected through 2100, particularly in western WA, contributing to elevated risk to people and property.	Olympic Peninsula & Southwestern
Tsunami	< 1%	Exposed population and property, as well as social and structural vulnerability, will increase as tsunami-prone areas in the Puget Sound and Pacific Coast regions see continued population growth and development. Projected population growth in the state suggests 268,000 people will be residing in coastal tsunami inundation zones by 2050, an increase of 3% compared to 2020. This increase suggests increased vulnerability to tsunami impacts over time. Inland landslide-driven tsunamis in WA have largely been tied to human-made reservoirs and have seen declines in their frequency since the 1950s.	Olympic Peninsula & Southwestern
Volcano	2.5%	Exposed population and property may increase if volcano-prone areas see continued population growth and development, particularly in lahar zones in western WA, although the number of people residing in lahar zones now is not expected to drastically increase by 2050. Given improvements in volcano awareness and eruption detection, it is possible that our vulnerability to volcanic impacts has decreased over time (though this has yet to be quantified).	Puget Sound & Northwestern
Wildfire	70%	The frequency of wildfires and number of acres burned has increased significantly in WA since 1980. Wildfires are expected to continue their increase in extent, intensity, and frequency for the entire state, with large fires becoming more likely in central WA. Western WA is expected to see more fire activity as well. Wildfire season is projected to increase in duration, putting more of the state at-risk for longer periods. These changes are driven by climate change and population growth and development in the wildland-urban interface (~85% of wildfires were human caused in 2020).	Central

S5. Vulnerability of State assets and potential dollar losses

Whether the State's critical assets are vulnerable to the hazard(s) they are exposed to depends on the characteristics of the assets themselves. For example, a bridge in a seismic zone built before the standard seismic code is considered more vulnerable to earthquakes than a bridge in the same area that has been retrofitted, even though the exposure to seismic hazards and probability of an earthquake event is identical for both. Therefore, we would consider the older bridge more at-risk than the retrofitted bridge due to its higher vulnerability. This example illustrates the way in which we incorporate vulnerability as one of many factors contributing to overall risk from an asset perspective. A reminder that risk, in our plan, is defined according to FEMA's definition of "potential for damage" (FEMA, 2011). In such cases as our example, vulnerability can be a determining factor of risk when all else is equal. It is also important to note that vulnerability in our analysis is relative to other assets exposed to a given hazard.

Such characteristics of critical assets are not always available in geospatial form. When this is the case, we modified our geospatial approach to a non-spatial approach, which may include secondary review of pertinent studies, reports, plans, or non-spatial data on the asset in question to make educated assumptions about asset vulnerability.

In addition to State-owned property and critical infrastructure, we considered population as a critical asset, and used the 2020 Census data and the Washington Department of Health's Environmental Health Disparities map to define population characteristics that may contribute to natural hazard vulnerability. A summary of how social and environmental vulnerabilities relates to natural hazard risk can be found in each of the hazard profiles in Chapter 3.

An analysis of potential impacts of hazard events to state assets (e.g., state-owned/operated buildings, critical infrastructure) can be found in each of the hazard profiles. These analyses also include a summary of the types of State facilities vulnerable to the identified hazards (e.g., educational, recreational, medical, etc.). The regional vulnerability assessments also describe potential outcomes of disaster losses on those regions.

The following is a list of estimated potential dollar losses for State-owned or leased facilities for each of the natural hazards:

- Avalanche: $121 million
- Drought: $262 billion*
- Earthquake: $108 billion
- Extreme weather: $78 billion
- Flood: $1.4 billion
- Landslide: $41 billion
- Tsunami: $318 million
- Volcano: $333 million
- Wildfire: $13 billion
  **Denotes total assets within drought declared regions, but losses directly associated with drought are unlikely.*

Given the above, the top five natural hazards with the most potential for damage to State facilities are earthquakes, extreme weather, landslides, wildfires, and floods. Extreme weather, landslides, wildfires, and floods are also the state's most common natural hazard events each year.

S6. Overview and analysis of vulnerability to jurisdictions and potential losses to structures

The regional vulnerability assessments in Chapter 3 provide an overview of the vulnerabilities experienced in each region (four total across the state). Jurisdictions (i.e., counties) most threatened are summarized in these regional vulnerability assessments, as well as in each of the hazard profiles. The summary of total potential losses is represented by the real estate value of both residential and State-owned/operated facilities in the hazard profiles. Because we have no way to accurately calculate what proportion of the total exposed real estate value would be lost in a given hazard event, the inherent assumption is that it is non-zero while complete loss of the total potential dollar value is unrealistic.

We determined which jurisdictions may be most susceptible to damage or loss from hazard events related to population and assets by using the CDC's Social Vulnerability Index and the Washington Department of Health's Environmental Health Disparities rankings. These metrics allowed us to understand where the impact of disaster losses may be amplified by pre-disaster vulnerabilities. Descriptions of social and environmental health vulnerabilities can be found in each of the hazard profiles.

S7. Risk assessment revisions to reflect changes in development

The "Projected Changes" column in the table found in S4 above provides information on how population, urban development, and climate change are expected to influence natural hazard vulnerability in the future.

Washington has seen continued population growth and urban development since the 2018 SEHMP was approved. There is also increased evidence that climate change is worsening throughout the Pacific Northwest, resulting in elevated risk from some climate-related hazards. A good example of this trend is the steady increase in wildfire-related disaster declarations in the state. Our analysis also suggests that, without extensive wildfire mitigation, the number of wildfire-related declarations will continue to increase, reaching a projected average of eight per year by 2030. Although we couldn't fully quantify the relationship between wildfire disasters and development, we do know that the wildland-urban interface is the most rapidly developing land use designation in Washington, suggesting there may be a relationship there. Similarly, floodplains and coastal areas continue to develop aside from some key exceptions of managed retreat in the state (e.g., various acquisition projects). Overall, these changes in development increase the state's risk and vulnerability to natural hazards, including to State-owned or leased facilities.

To help us capture the influence of population growth and the built environment on hazard risk, we used the most current and available datasets on the built environment and population distribution in our geospatial analyses and statistical models. These included a dataset of statewide building and road locations retrieved from OpenStreetMap as well as the 2020 Census. These datasets were available in GIS formats, which allowed us to use them as variables in our spatial analyses to test the influence of population and the built environment on natural hazard risk (e.g., the relationship between population clusters and wildfire occurrences). As such, population and the built environment are inherent and "baked in" components of our risk assessments results. We also used population growth projections to assess the number of potential people in harm's way by 2050 (these results can be seen in each hazard profile). Our regional vulnerability assessments also considered changes in social vulnerability. By using the CDC's Social Vulnerability Index and the WA Department of Health's Environmental Health Disparities Index, we were able to identify which communities may see amplified disaster impacts when events occur there.

Earth and environmental systems variables were used similarly to population and the built environment in our analyses, allowing us to assess the relationship between climatological/meteorological attributes and natural hazard occurrences. Therefore, climate considerations are also inherent components of the risk assessment results, though specific quantification of the climate-hazard relationship was not performed.

Vulnerability of State facilities exposed to the various natural hazards is tied to asset type and age. Older structures are assumed to be more vulnerable to natural hazards, although we recognize that assumption may be incorrect at times (i.e., ecological fallacy). We will work in the future to improve upon this assumption, including identifying structures that have had some level of mitigation activity (e.g., retrofitted URMs). Asset type was used as a vulnerability characteristic by hazard. For example, recreational assets such as remote campgrounds are considered more vulnerable to direct wildfire damages than educational facilities located within urbanized areas, even when both are in an identified wildfire hotspot.

S8. Goals for reducing long-term vulnerabilities from the identified hazards

1. Reduce the impacts of natural hazards on our community lifeline infrastructure and other critical assets
2. Prioritize effective long-term partnerships across all levels of government
3. Allow the risk and vulnerability assessments to drive the State's Mitigation Strategy and prioritization of mitigation actions
4. Improve our understanding of multi-hazard environments
5. Embed cultural understanding into our mitigation work
6. Ensure improved and equitable access to hazards information
7. Champion and prioritize people-centered mitigation actions in addition to property-centered ones
8. Emphasize the role of sustainable development and climate adaptation in hazard mitigation
9. Strategically reduce the number of repetitive loss and severe repetitive loss properties
10. Ensure all counties and sub-county jurisdictions in Washington understand their hazard risks and are eligible for mitigation funding opportunities

S9. Prioritization process for mitigation actions

The mitigation actions in section 4.2 are based on the risk and vulnerability assessment detailed in Chapter 3 of this plan as well as input from the subject matter experts on the HMWG. These actions are how the State intends to reduce our hazard risks and vulnerabilities long-term and achieve the goals listed in S8 above. Some actions are carried over from the 2018 plan if they are still valid and ongoing and are noted as such within the table below. Each action is listed under a specific goal to reflect how that individual action contributes to the goals listed.

We used the STAPLEE method (FEMA 2003) to evaluate and prioritize actions that we feel are cost-effective, environmentally sound, and technically feasible. Actions received a +1 if it had a positive (or no) impact on a given evaluation criterion and +0 if it had a negative impact. Scores were summed and actions were sorted from highest to lowest under each mitigation goal.

Among the most significant changes from the 2018 Mitigation Strategy is the simplification of the list of actions that comprise this strategy. For 2023, we focused specifically on the implementation aspects of the State's various hazard mitigation-related programs as opposed to providing overviews of the programs themselves. However, like 2018, the actions listed are implemented via the various programs that exist across State agencies and departments. Lead agencies for each action are noted within the table.

The link between this Mitigation Strategy and local hazard mitigation efforts is summarized in the "Requires Local Participation" column. When marked "Yes," this indicates the State agency responsible for that action will have to engage local partners during its implementation. We also use an established and direct link to a local FEMA-approved HMP as a metric for prioritizing grant sub-applications.

Table 33. 2023 SEHMP mitigation actions. Sc = STAPLEE (Social, Technical, Administrative, Political, Legal, Economic, Environmental) score. Haz = hazard(s) addressed. 2018 = inclusion in 2018 SEHMP. LA = lead agency. Loc = local participation required. Fun = potential funding sources.

Goals and Actions	S		T			A			P			L			Econ.				Env.					Sc	Haz	2018	LA	Loc	Fun
	Community Acceptance	Effect on Segment of Population	Technical Feasibility	Long-term Solution	Secondary Benefits	Staffing Available	Funding Available	Maintenance/Operations	Political Support	Local Champion	Public Support	State Authority	Local Authority	Potential Legal Challenges	Benefit of Action	Cost of Action	Contributes to Economic Goals	Outside Funding Required	Effects on Natural Resources	Effects on Endangered Species	Effects on HAZMAT/Waste Sites	Consistent with Environmental Goals	Consistent with Federal Law						
1. Reduce the impacts of natural hazards on our community lifeline infrastructure and other critical assets																													
Pass legislation to authorize the Washington State Building Code Council to develop a mandatory seismic retrofit code.	1	1	1	1	1	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	17	Earthquake	Y	DES	N	State
Improve the resilience of affordable housing stock through building performance standards and reduced development in hazard zones	1	1	1	1	1	0	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	18	All	Y	COM	Y	State
Complete emergency action plans for 100% of high and significant hazard potential dams	1	1	1	0	1	0	0	0	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	17	Dam failure	Y	ECY	Y	HHPD; BRIC; HMGP

Develop guidance for mitigating geological hazards through the use of land use and zoning	1	1	1	1	1	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	18	Earthquake, tsunami, volcano	Y	DNR	Y	State; HMGP
Require seismic evaluations to be completed during real estate transactions	1	1	1	0	1	1	0	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	19	Earthquake	Y	DNR	N	NA
Identify mitigation needs for the Capitol Campus	1	1	1	0	1	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	16	All	Y	DES	N	State; HMGP
Conduct a hospital and healthcare system resilience assessment	1	1	1	0	1	0	0	0	NA	1	1	1	1	1	0	1	0	0	1	1	1	1	1	15	All	Y	DOH	Y	State; HMGP
Support the construction of the North Shore Levee and West Segment in Aberdeen and Hoquiam	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	22	Flood	N	ECY	Y	BRIC
Provide pass-through funding to local governments for projects that protect public infrastructure from flood damage	1	1	1	1	1	1	0	1	1	0	1	1	1	0	1	0	1	0	1	1	1	1	1	18	Flood	N	ECY	Y	State; BRIC; HMGP
Manage the vulnerability of drinking water systems, especially weather-sensitive vulnerabilities exacerbated by climate change, through systematic planning and technical assistance.	1	1	1	1	0	1	1	1	1	0	1	1	0	1	1	0	0	0	1	1	1	1	1	17	All	Y	DOH	Y	State; HMGP
Use geologic hazard modeling to update building codes as appropriate	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	22	Earthquake, tsunami, volcano	N	DNR	N	State
Lead a close regional network of partners and area experts that work to operate, maintain, and manage dams	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	17	Dam failure	N	ECY	Y	State
Maintain data and documentation on all 1,300+ dams in WA for use in planning, hazard mitigation, and disaster response	1	1	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	16	Dam failure	Y	ECY	N	State
Complete dam inspections for each site every five years and ensure that each	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	18	Dam failure	Y	ECY	Y	State

emergency action plan reflects actual risk																												
Secure year-to-year drought contingency funding from the state legislature	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	23	Drought	Y	ECY	N	State
Explore avenues to be more resilient to drought in addition to responding when drought conditions occur	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	20	Drought	N	ECY	N	State; HMGP
Reduce damage to structures and infrastructure from channel migration and support ecosystem function and salmon recovery goals	1	1	1	1	1	0	0	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	18	Flood	N	ECY	Y	BRIC; HMGP
Replace all fish barrier culverts statewide and reduce the impact of undersized culverts on riverine flooding	1	1	1	1	1	0	0	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	18	Flood	Y	DOT	Y	BRIC; HMGP
Identify areas along state highways that are chronically deficient and require repetitive repairs or maintenance, often exacerbating floods and impacts to aquatic habitat	1	1	1	1	1	0	0	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	18	Flood	Y	DOT	N	State; BRIC; HMGP
Reduce the impacts of unstable slopes on transportation facilities through design, proactive mitigation, and improved emergency response	1	1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	17	Landslide	Y	DOT	Y	State; BRIC; HMGP
Prioritize and strengthen the elements of transportation system most critical to emergency response after a seismic event	1	1	0	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	18	Earthquake, tsunami	N	DOT	N	BRIC; HMGP
Retrofit seismically vulnerable bridges in western WA to prevent collapse	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	19	Earthquake	Y	DOT	Y	BRIC; HMGP
Build stormwater flow control facilities to address existing pavement that does not have flow control	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	18	Flood	Y	DOT	N	BRIC; HMGP

Address the risk of bridge foundation undermining due to scour during floods	1	1	1	1	1	0	0	0	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1	16	Flood	Y	DOT	N	HMGP
Develop and implement risk-based asset management plans for the National Highway System components in WA	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	All	Y	DOT	N	State
2. Prioritize effective long-term partnerships across all levels of government																													
Improve multi-agency participation in Risk MAP	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	20	Flood	Y	ECY	Y	State
Coordinate across agencies and levels of government to provide resources to reduce flood risks	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Flood	N	ECY	Y	State
Manage action groups for Floodplains By Design project proponents to come together to work through issues and address policy questions	1	1	1	0	1	0	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	18	Flood	N	ECY	Y	State
Establish a stakeholder business continuity workgroup of relevant entities	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	16	All	Y	OIC	Y	State
3. Let the risk and vulnerability assessments drive the State's Mitigation Strategy and prioritization of mitigation actions																													
Consult the 2023 SEHMP's HIVA when reviewing sub-applications for HMA funding	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	All	N	EMD	N	State
4. Improve our understanding of multi-hazard environments																													
Use LiDAR to identify landslide deposits and map landslide susceptibility statewide	1	1	1	0	1	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	16	Landslide	Y	DNR	N	BRIC; HMGP
Provide hands-on technical assistance to local governments, landowners, and residents to design and implement projects that reduce flood risk consistent with ecosystem protection	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	20	Flood	N	ECY	Y	State
Conduct scientific research and analysis to help communities	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	16	Flood	N	ECY	Y	State; HMGP

understand and evaluate flooding risks.																													
Use spatial statistical approaches to understand hazard relationships and drivers of hazard risks	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	16	All	N	EMD	N	State; HMGP
Continually update and amend tsunami modeling as new science becomes available and provide updated data to communities	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Tsunami	Y	DNR	N	State
Publish tsunami inundation models as modeling is completed for each area	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Tsunami	Y	DNR	N	State
Continue to develop new and updated geologic hazard maps as technology and techniques improve	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Earthquake, tsunami, volcano	Y	DNR	N	State
Update seismic hazard maps statewide (i.e., liquefaction, site class, seismic scenarios) and prioritize areas for detailed mapping	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Earthquake, landslide	N	DNR	N	State
Update ShakeMaps using best available science	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	23	Earthquake	N	DNR	N	State
Maintain an online subsurface database for the state, combining data from geotechnical work, surveys, and deep-well studies	1	1	1	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	15	Earthquake	N	DNR	N	State
Update the seismic scenario catalog	1	1	1	0	0	1	1	0	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	18	Earthquake	Y	DNR	N	State
Update liquefaction and site class maps to identify earthquake hazards for critical area ordinances	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	20	Earthquake	Y	DNR	N	State
Complete storm surge, wave runup, and flood inundation modeling along coasts	1	1	1	0	1	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	16	Flood	N	ECY	N	State; HMGP
Develop a strategic program plan for the Coastal Monitoring and Analysis Program	1	1	1	0	0	1	1	0	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	18	Flood	N	ECY	N	State

Better assess and understand dam failure hazards and hazard-potential creep driven by development occurring beneath dams	1	1	1	0	1	0	0	0	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	17	Dam failure	N	ECY	N	State; BRIC; HMGP
Inventory and catalog existing channel migration zone maps statewide	1	1	1	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	15	Flood	N	ECY	N	State
Identify priority routes and research liquefaction hazards under bridges	1	1	1	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	15	Earthquake, landslide	Y	DOT	N	State; HMGP
Research the effects of a Cascadia Subduction Zone event on bridges, tunnels, and other state transportation assets	1	1	1	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	15	Earthquake	Y	DOT	N	State; HMGP
5. Embed cultural understanding into our mitigation efforts																													
Provide tailored planning assistance and guidance to support locally relevant flood-related policies and plans	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	18	Flood	N	ECY	Y	State
Honor Tribal treaty-rights and incentivize improved used of nature-based solutions in mitigation grants	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	20	All	N	EMD	N	NA
Integrate an equity and environmental justice lens into how actions and services to address coastal hazards are deployed	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	20	Flood, tsunami, landslide	N	ECY	Y	NA
6. Ensure improved and equitable access to hazard information																													
Develop a website for the 2023 SEHMP that includes interactive features, such as maps and figures found within the plan	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	18	All	N	EMD	N	HMGP
Ensure State-led natural hazard research is published in free and publicly-accessible forums, such as open-access journals and State-owned websites	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	18	All	N	Multi	N	NA
7. Champion and prioritize people-centered mitigation actions in addition to property-centered ones																													

Describe, plan for, track, and begin adapting to the public health impacts of climate change.	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	17	All except earthquake, tsunami, and volcano	Y	DOH	N	State; BRIC; HMGP
Track the impacts of wildfire smoke on public health and communicate the risks of smoke to the public	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	20	Wildfire	N	DOH	N	State
Work with communities to refine tsunami evacuation routes	1	1	1	1	0	0	0	0	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1	15	Tsunami	Y	DNR	Y	State
Continue push to build vertical evacuation structures in tsunami hazard areas	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	19	Tsunami	N	EMD	Y	BRIC
Develop lahar evacuation routes with local jurisdictions near Mt. Rainier	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	16	Volcano	N	DNR	Y	State
Use social vulnerability as a metric for scoring hazard mitigation grant applications	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	20	All	N	EMD	N	NA
8. Emphasize the role of sustainable development and climate adaptation in hazard mitigation																													
Avoid or minimize the existing and future impacts of coastal hazards on communities and natural resources	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	19	Flood	Y	ECY	Y	State; BRIC; HMGP
Further flood safety through integrated management of floodplain areas throughout the state	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	22	Flood	Y	ECY	Y	State; BRIC; HMGP; FMA
Improve drought contingency planning and response capabilities	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	21	Drought	Y	ECY	N	State
Develop guidance for local governments to include climate-related natural hazard considerations in their comprehensive plans	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	22	All except earthquake, tsunami, and volcano	N	COM	Y	State
Provide assistance to local jurisdictions in updating the Frequently Flooded Areas section of their Critical Areas Ordinances	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Flood	Y	ECY	Y	State

Continue efforts to support locally scaled climate vulnerability assessments and provide technical assistance and expertise for adaptation efforts	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	21	All except earthquake, tsunami, and volcano	N	ECY	Y	State
Use the water supplier annual survey to determine if water systems experience supply shortages the previous year	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	20	Drought	N	DOH	Y	State
Complete natural hazard and climate threat profiles for consideration in transportation asset management plans	1	1	1	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	15	All	N	DOT	N	State; HMGP
9. Strategically reduce the number of repetive loss and severe repetitive loss properties																												
Enable communities to do flood risk reduction planning and projects, including home elevations, buyouts, levee work, and ecosystem improvement	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	21	Flood	Y	ECY	Y	State; BRIC; HMGP; FMA
Use RL/SRL data to identify repetitive loss "hotspots" and provide targeted outreach and technical assistance to these communities focusing on FMA opportunities	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	20	Flood	N	EMD	Y	State; FMA
10. Ensure all counties and sub-county jurisdictions understand their hazard risks and are eligible for mitigation funding opportunities																												
Improve integration of hazard mitigation into local comprehensive plans	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	22	All	Y	COM	Y	State
Develop and disseminate a template for cities, counties and tribes to adopt that articulate and detail strategies, tasks, and tools for cultural resource resilience	1	1	1	1	1	0	0	0	1	1	1	1	1	0	0	1	1	0	1	1	1	1	1	17	All	Y	DAHP	Y	State; HMGP
Develop and evaluate a comprehensive local action plan to reduce flood damage in the Chehalis Basin	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	22	Flood	N	ECY	Y	State; HMGP

Conduct NFIP training, community assistance visits, communities assistance contacts, and ordinance assistance for local jurisdictions	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	20	Flood	Y	ECY	Y	State
Provide comprehensive flood hazard management plan guidance	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	20	Flood	Y	ECY	Y	State
Improve the use of RiskMAP data in local hazard mitigation plans	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Flood	N	ECY	Y	State
Work with communities to educate on landslide hazards	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Landslide	Y	DNR	Y	State
Work with planners, emergency managers, and other officials on implementing landslide hazard mapping into Critical Areas Ordinances, emergency planning, and community education	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Landslide	Y	DNR	Y	State
Establish a consistent means of communicating seismic maps to local jurisdictions for use as best available science under the Growth Management Act	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	19	Earthquake	Y	DNR	Y	State
Provide coastal communities and tribes with the tools they need to undertake project planning and access federal funding to address coastal hazards and climate impacts	1	1	0	1	1	0	0	0	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	17	Flood, tsunami, landslide	N	ECY	N	State; BRIC; HMGP
Expand state funding and technical assistance for local government drought contingency planning, especially for rural and remote users of water	1	1	1	0	0	1	0	0	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	17	Drought	Y	ECY	Y	State
Issue "Drought Advisories" to alert water users of potential drought conditions and support mobilization of resources	1	1	1	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	16	Drought	N	ECY	Y	State

S10. Current and potential sources of funding to implement mitigation actions and activities

The primary source of funding Washington uses to implement mitigation actions is FEMA's Hazard Mitigation Assistance (HMA) grant programs, such as the Hazard Mitigation Grant Program (HMGP) and Building Resilient Infrastructure and Communities (BRIC). Washington has seen an increase in annual HMA funding made available in the state due to large-scale disasters, including $100 million from the COVID-19 pandemic declaration (DR-4481), as well as success in the national BRIC competition in 2020 and 2021. Washington has ranked in the top five states in the country in terms of BRIC funding selected both years. Mitigation actions funded recently through these opportunities include various planning initiatives (e.g., local hazard mitigation plan updates), as well as construction-based projects to reduce the risk of disasters on the state's critical infrastructure. The Annual Reports in Appendix D provide summaries of specific mitigation projects.

Also vital in implementing mitigation actions and accomplishing our mitigation goals is the strategic use of Public Assistance (PA) Categories C-G funding. Although PA dollars are meant to help public assets recover from direct disaster damages, Washington is committed to ensuring damaged assets are rebuilt stronger than they were before, thereby mitigating future risk.

The Flood Mitigation Assistance program (FMA) is available to Washington as a potential funding source but has been historically underused in our state – in part due to data gaps where repetitive loss or severe repetitive loss structures are located. Through a data-sharing agreement with FEMA Region 10, EMD was able to gain access to that data in late 2022 and will be using it to develop strategic flood risk reduction efforts that could be funded, in part, using the FMA program.

S11. Reflect progress in statewide mitigation efforts and changes in priorities

Uncompleted actions from the 2018 SEHMP that are still relevant are listed in S9. These actions include ongoing activities (e.g., planning activities that require periodic updates, like the SEHMP), as well as activities that require long durations to complete or have yet to secure funding. A list of completed 2018 actions can be found in the table below. Actions that were included in 2018 but are not found in either the table below or in S8 were removed because they were deemed irrelevant, mostly due to not having a hazard mitigation focus (e.g., response-oriented actions, general capital improvement actions, etc.).

Other hazard mitigation activities have occurred throughout the state since 2018 but are not listed in the table below because these activities were not explicitly called out in the 2018 SEHMP. Many of these activities are described in the Annual Reports found in Appendix D.

Table 34. Completed 2018 SEHMP mitigation actions

Completed 2018 Actions	Lead Agency
Landslide hazard maps for Thurston and Clark County	DNR
Entire state modeled for tsunami inundation from distant-sourced Alaska earthquake	DNR
Tsunami Mapping Program gap analysis	DNR
Include seismic risk in DNR's LIDAR acquisition program	DNR
Reference the updated liquefaction hazard maps in building codes	DNR
Publish databases necessary to implement seismic provisions of building codes and accurately interpret seismic recordings in real time to allow for quicker response to events	DNR
Develop a database that enables the Pacific Northwest Seismic Network to calibrate their seismic records leading to improved seismic hazard analysis	DNR
Identify a method to provide information to water systems on threats and risks and begin sharing this information with water systems	DOH

Complete the Washington Coastal Resilience Project	ECY
Update the SEHMP to comply with HHPD requirements	ECY
Develop long-term water rights leases	ECY
Amend the State Drought Statute	ECY
Determine the feasibility of the North Shore Levee in Grays Harbor County	ECY
Determine the feasibility of a natural approach for flood damage reduction in the upper Chehalis Basin	ECY
Release RFPs and accept applications for the 2019-2021 Floodplains by Design program as well as RFPs for 2021-2023	ECY
Update the 5-year business plan for Floodplains by Design	ECY
Add chronic environmental deficiencies to the risk-based Transportation Asset Management Plan	WSDOT
Prioritize current chronic environmental deficiencies for permanent fixes	WSDOT
Complete flow control retrofits on active construction projects in the 2017-2019 biennium	WSDOT
Complete statewide evaluation of National Highway System by 11/23/2018 and all other state highways by 11/23/2020	WSDOT

S12. Evaluation of the State's hazard management policies, programs, capabilities, and funding sources

Section 2.3 provides an evaluation of the State's various policies, programs, and capabilities pertaining to hazard mitigation, including NFIP, CRS, and Risk MAP.

Washington funds most of its mitigation activity at the local level via HMA grants before a declared disaster and PA Categories C-G after a declared disaster. Active HMA grants in Washington include those funded under HMGP, BRIC, and FMA. There are also legacy PDM-funded projects still being implemented. As of February 2023, the State is administering approximately $200 million in active mitigation grants. The total amount received includes HMGP rounds for notable disasters, such as COVID-19 and the 2020 wildfires. Due to our "enhanced" status, Washington receives an additional 5% in funding for all HMGP rounds. Specific examples of projects and other mitigation activity funded since 2018 can be found in the Annual Reports in Appendix D.

Washington also provides its own funding mechanisms for hazard mitigation unrelated to federal grant dollars. This includes funds appropriated by the State Legislature to help sub-applicants meet the cost share requirements of HMGP grants (12.5% of cost share requirement). Since 2018, the State has also allocated $50.9 million for Floodplains by Design projects for 2021-2023. In 2021, the Governor's Office allocated funds to the Office of the Chief Information Officer to develop a natural hazards data portal for use by State agency staff involved in hazard mitigation efforts (expected completion in 2023). Also in 2021, the Office of Financial Management coordinated a task force of State agency representatives to provide the Legislature with future climate resilience funding recommendations, worth approximately $50 million, though funds have not yet been allocated.

S13. The effectiveness of local mitigation policies, programs, and capabilities

As of June 2023, all 39 counties in Washington are actively engaged in hazard mitigation planning. All counties except one (Adams) have completed at least one county-wide hazard mitigation plan (HMP), with many having gone through multiple comprehensive updates. As such, as of June 2023, 32 out of 39 counties (covering 92% of the state's population) have assessed their natural hazard risk, developed a mitigation strategy, and are currently eligible for hazard mitigation grants. Adams County has a plan in development but has not yet received FEMA approval (as of June 2023), which means 100% of the state's population resides in a county that has assessed its natural hazard risk at least once. Most of these county HMPs are multijurisdictional and include numerous adopting jurisdictions. At the time of this writing, there are 357 total jurisdictions (including counties, cities, and special purpose districts) that are HMA eligible in Washington. Many more are in the process of adopting an approved HMP or developing an annex or stand-alone plan. Prior to the next comprehensive update, we intend to do a deeper dive into the number of sub-county jurisdictions covered by an approved HMP (either stand-alone or in a multijurisdictional HMP) since we expect this number to grow over time.

The increased participation in mitigation planning statewide indicates an overall increase in local jurisdictions' capability to accomplish hazard mitigation. This is also reflected in the number of pre-applications EMD receives for hazard mitigation grants, which has also increased in recent years. For example, we received more than 200 pre-applications from local jurisdictions for the 2021 BRIC round and the DR-4481 HMGP round. The total estimated value of projects submitted for our review for the DR-4481 round was more than $1.4 billion.

It is clear from the above descriptions of increased participation in hazard mitigation that local mitigation-related plans, programs, and policies are generally effective in allowing local jurisdictions to secure grant funding for mitigation projects. Although Washington has been successful in acquiring mitigation funds, obstacles and challenges remain. Among the most well-known is the inherent difficulty our local partners face in applying for HMA grants, which can take extensive amounts of time that is not always available (especially in lower capacity jurisdictions). Additionally, the BCA requirements are often too arduous for many jurisdictions to meet and take specialized skills and training to complete fully, which can result in jurisdictions choosing not to proceed with the application process or projects having a BCA that is inaccurate despite a potentially cost-effective project. Jurisdictions with the means to do so have resorted to hiring contractors to assist with developing BCAs, but not all jurisdictions have the funds available to hire contractors pre-award. We feel this problem contributes to the inequitable distribution of HMA funds.

For jurisdictions that do have projects selected for award, the time it takes to receive the award and begin work can cause major delays and jeopardize overall project success. This is true for construction-based projects as well as planning grants.

Also, the structure of Washington's state law regarding sensitive information (i.e., PII) makes it difficult to share detailed RL/SRL data with state and local authorities. This makes it difficult to grasp the full scale of the state's RL/SRL problem as well as how best to target it. EMD has committed to securing the most up-to-date RL/SRL data and using it to identity target areas for outreach on the FMA program and development of FMA-appropriate projects.

Washington shares the results of its Risk MAP work with local communities during planning grant kick off meetings when sources of best available information are shared with the county or jurisdiction working to update their HMP. Partnerships with local communities are built during the mapping and assessment process, as led by FEMA engineers that oversee those analyses. Areas for restudy are determined by FEMA engineers as well, although considerations of HMP update timelines are made via a FEMA-EMD partnership through the monthly Risk MAP coordination calls. Results are also shared with the general public during public meetings once the assessments are completed.

Based on our review of county-level HMPs, local jurisdictions generally exhibit the following capabilities and challenges associated with implementing their HMPs, specifically regarding addressing climate impacts and their underserved communities, although exceptions do exist. Generally speaking, counties are eligible entities for HMA funding to implement their mitigation strategies, but can also apply for CDBG, NOAA, or state-sponsored grants (when available). Counties also have the ability to levy taxes for specific purposes and issue bonds that could go toward funding mitigation projects. Counties also tend to have staff with subject matter expertise needed to develop, apply for, and implement mitigation grants, such as public works, city planning, and economic development departments with the authority to manage such projects. However, flood risk reduction projects may be more difficult for some counties that do not have certified floodplain managers on staff (which is not uncommon, though most counties do). Counties are also able to develop robust public outreach capabilities, including often having a Public Information Officer on staff.

Some counties have taken additional steps in their HMPs to discuss adaptive capacity regarding climate resilience. Many of the authorities and expertise described above provide counties with a good foundation for addressing climate impacts, even when the county itself feels it does not have a high level of understanding of climate-related natural hazards risk. In these cases, capacity exists to adapt to climate impacts but may not be fully used. The reason for that varies but includes lack of identified climate adaptation goals and/or projects, lack of champions at local scales for climate resilience, lower political and/or public support for climate resilience, and unclear financial mechanisms for funding climate resilience.

There are numerous State initiatives that tie into local capabilities to mitigate climate-related natural hazard risk and implement their HMPs. The Department of Commerce, as directed by the State Legislature and in partnership with EMD and other agencies, is developing guidance for local comprehensive plans to include climate resilience considerations. This guidance specifically calls out how to use an HMP for this purpose, developing a route for meaningful integration of HMPs and local comprehensive plans. This could result in more climate-related goals and projects in future HMPs. EMD has also been required to develop a State Resilience Office, which will, in part, help to coordinate resilience-related funding across State agencies with the potential for funding local-level resilience projects. This new office, once created, could help locals identify financial mechanisms for funding climate resilience projects. Lastly, the State will be updating the State Climate Response Strategy for the first time since 2012, through a multi-agency panel led by the Department of Ecology that includes EMD staff. The Strategy will serve as the basis for Washington's overall response to climate impacts and will likely pull from the SEHMP in numerous areas. The panel developing this update will submit to the Legislature their list of recommendations, which will likely include improve local-level resilience to climate change via funding, partnerships, and technical assistance.

S14. Process to support the development of approvable local mitigation plans

The State supports the development and update of local HMPs primarily through funding HMP activity in our state set-aside under BRIC and HMGP rounds and providing direct technical assistance to local jurisdictions during their planning process and review of completed HMPs prior to FEMA review. Technical assistance is jurisdiction-led and initiated, most often coming in the form of *ad hoc* assistance on specific sections of their draft HMPs. In some cases, EMD Mitigation staff attend local planning meetings to provide direct advice and answer questions. However, due to limited capacity within EMD Mitigation, this can currently only be done when time and availability permits. Lastly, the State supports HMP development through training, including hosting or providing instruction for FEMA's G318 Local Hazard Mitigation Planning course.

The figure below shows the status of county hazard mitigation plans statewide as of February 2023. All 39 counties in Washington are actively involved in hazard mitigation planning, with a majority having FEMA-approved plans (as of

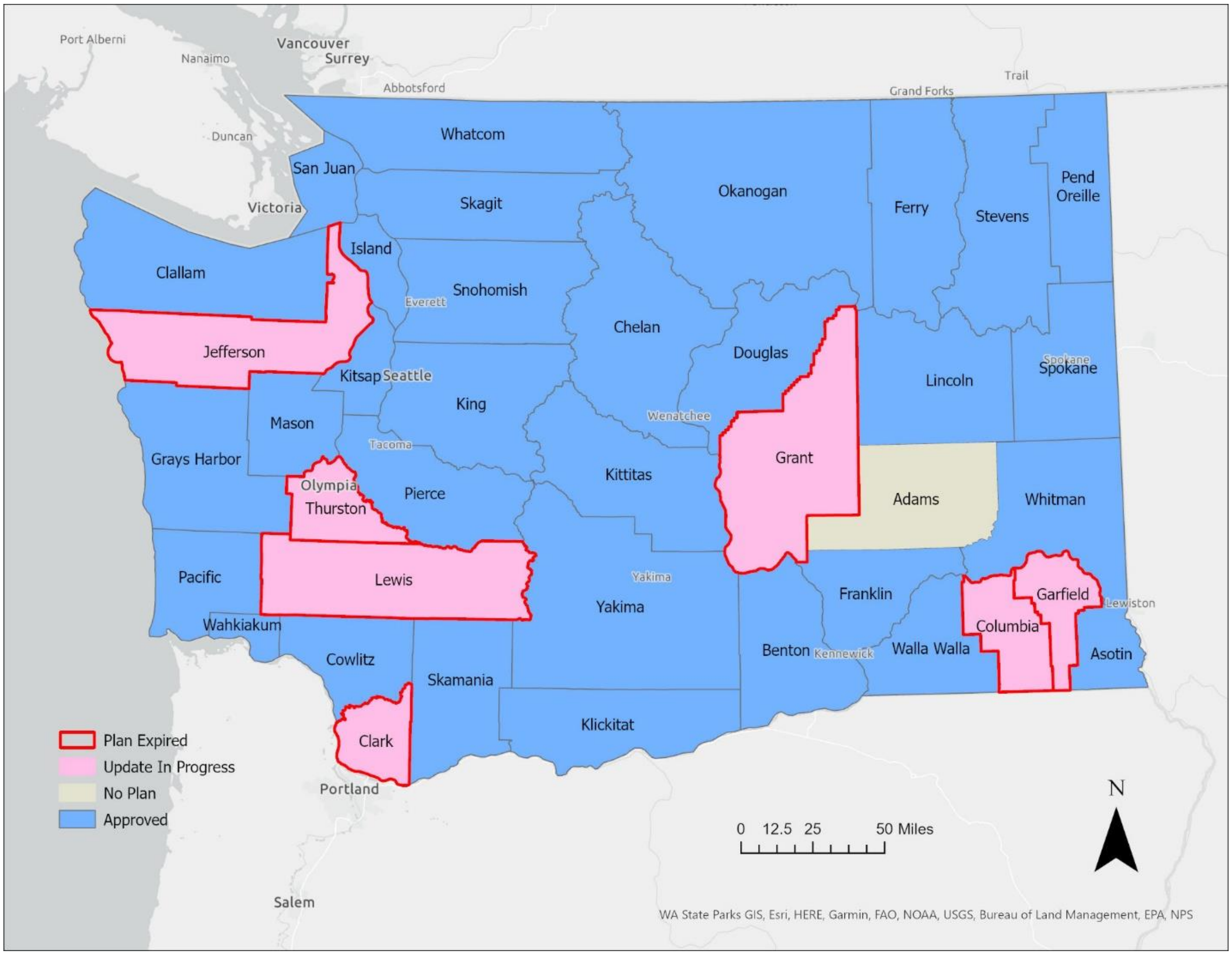

Figure 43. County-level hazard mitigation plan statuses (Mar. 2023). Adams County is currently developing their first HMP.

February 2023). This means most people in Washington reside in a county with an approved HMP and the number of sub-county jurisdictions with annexes to county HMPs continues to increase. Additional analysis will have to be done to understand what proportion of the state's critical assets are eligible for HMA funding, considering not only location but ownership as well. This will require near-constant update as plans migrate in and out of approval status.

Although Washington counties have vastly increased their efforts in mitigation planning, barriers remain. Cost and the HMA grant application process are significant barriers for some counties, especially counties with lower capacity to dedicate to a plan update or to meet cost-share requirements. However, aside from the mechanics of applying for a planning grant and performing an update, we find that some county-level HMPs suffer from vague risk assessments and vague mitigation strategies. Risk assessments that lack specificity and rigor can lead to mitigation strategies with less power to reduce long-term risk.

Our approach to removing some of the barriers local jurisdictions face is to create a SEHMP that can serve as a "head start" for local planners. Ideally, a main use of the SEHMP will be as a starting point for local HMP updates and as a reference. Also, the State is working to make natural hazards spatial data publicly available for use in risk and vulnerability analyses. These include traditional hazard datasets (e.g., wildfire location data from DNR) as well as spatial data pertaining to social vulnerabilities (e.g., environmental health disparities from DOH). Finally, EMD has pursued funding from the State to build out its capabilities to provide local technical assistance and outreach around hazard mitigation planning, research, and tool development. As of February 2023, this funding has not yet been secured.

S15. Criteria for prioritizing funding

Jurisdictions identified as having been directly impacted in a presidential disaster declaration are given priority in the following HMGP round, should they submit a sub-application. This is true for planning and project sub-applications. Planning sub-applications are generally prioritized in any grant round – HMGP or BRIC – and most often funded through state set aside. Planning sub-applications that are multijurisdictional are typically prioritized over single jurisdiction plans.

Quantitatively, we use FEMA's BCA metrics to screen projects for eligibility, effectiveness, and competitiveness prior to submitting our state application package to Region 10. The qualitative criteria we use to rank and prioritize project sub-applications during every open HMA grant round are:

- The proposed project anticipates impacts on disadvantaged communities (e.g., socially vulnerable populations), especially regarding the Justice40 Initiative, equitable risk reduction outcomes, and whole community approaches
- The proposed project addresses community lifelines and critical infrastructure vulnerability
- The proposed project has multiple benefits beyond hazard risk reduction, including climate change resilience, sustainable development, and environmental restoration
- The proposed project is collaborative and promotes shared responsibility, partnerships, and is supported by multiple jurisdictions or agencies
- The proposed project includes innovative solutions to mitigate natural hazards, such as nature-based solutions when feasible
- The proposed project has a clear and direct link to a FEMA-approved hazard mitigation plan

Projects are rated using the above criteria on a scale of 0-4 by multiple members of the EMD Mitigation team during the prioritization process. No weighting is currently applied to any criterion.

Projects targeting RL/SRL properties, whether applying for FMA funds or not, are prioritized. Acquisition projects that include floodplain restoration elements tend to rank higher than elevations using our criteria.

S16. Process and timeframe to review, coordinate, and link local HMPs with the State's plan

Local HMPs (including multi-jurisdictional HMPs that may include tribal partners) are submitted to EMD's Mitigation Strategist for official state review and approval, given the authority to do so by the State Hazard Mitigation Officer. Standalone tribal HMPs in Washington are typically funded independently of the State, so it is uncommon for them to be submitted to EMD for review and approval. The majority of tribal HMPs EMD reviews and approves are annexes in county-level multi-jurisdictional HMPs, in which case they follow the same review and approval process as any other jurisdiction in the HMP (but using the Tribal HMP Policy as a guide as opposed to the Local Policy). EMD's internal goal for an HMP review period is 30 days. The Strategist's review is to ensure local HMPs are meeting federal requirements according to FEMA's most current and official interpretations of 44 CFR 201. When HMPs pass state review, the Strategist submits the draft to FEMA Region 10 for their first official review. If the HMP does not pass state review, the Strategist sends the submitter either a plan review tool with suggested revisions, an email describing the changes that should be made, or both. The Strategist also facilitates dialogue between the local jurisdiction and FEMA Region 10 throughout the review and approval process, including assisting with interpreting FEMA's required revisions when necessary and offering technical assistance to make revisions.

Local HMPs are linked with this SEHMP in two ways: 1) their risk and vulnerability assessments were consulted during the development of the 2023 HIVA as a means of validating our results (e.g., ensuring no major discrepancies in overall assessments of risk and vulnerability), and 2) local mitigation strategies are reviewed during the prioritization of sub-applications for every HMA grant round EMD administers to assess for direct links between the project in the sub-application and the jurisdiction's HMP. This is to help ensure alignment between State and local mitigation priorities and determinations of risk.

EMD will share its state-level risk assessment data with local jurisdictions during the planning grant award kick-off phase to ensure our information is available to use while the local HMP is being updated. This data will be available in the form of this SEHMP, available publicly immediately after FEMA R10 approval, as well as digitally in the form of spatial datasets available for public use on OCIO's www.geo.wa.gov prior to the end of our grant's period of performance. Ad hoc data needs will be met on a case-by-case basis, with the Mitigation Strategist being the primary point of contact for locals needing data.

S17. Describe the method and schedule for keeping the plan current

The Mitigation Strategist within EMD will be responsible for monitoring the relevance and implementation of the 2023 SEHMP via quarterly HMWG meetings. Intermittent updates to the 2023 SEHMP will keep the plan current and may be spurred by feedback from HMWG members, local jurisdictions, newly available hazard data and information, state and/or federal policy changes, disaster events, and so on. Updates will be reflected on an "Updates" page near the front of this plan.

Progress toward implementing the 2023 SEHMP's goals will be summarized in an annual report written by the Mitigation Strategist with input from state, local, tribal, and federal partners on their mitigation activity occurring throughout the state. This report will inform our assessment of the Plan's effectiveness at achieving its goals and objectives. Additionally, formal plan evaluation will be a standing agenda item for a minimum of one HMWG meeting each year.

S18. System for monitoring implementation and reviewing progress

Implementation of the 2023 Plan's goals will be monitored by the Mitigation Strategist at EMD through quarterly HMWG meetings and annually via a report that highlights mitigation activity occurring around the state.

HMWG members will be responsible for reporting progress on the specific mitigation actions in the 2023 Strategy that fall within their agency's purview during HMWG meetings, with at least one meeting each year dedicated to this effort.

The annual report will also provide a qualitative assessment of the progress made toward achieving the Plan's overarching mitigation goals. This will include listing which goals the projects that are summarized in an annual report pertain to. HMWG members will also be asked, at least once per year, to list agency-specific actions that contribute to the 2023 goals. Those briefings will be used in the next comprehensive update to the Mitigation Strategy.

S19. Formal adoption

A copy of the signed adoption resolution is attached as Appendix E.

S20. Assurances

The State of Washington will comply with all applicable Federal statutes and regulations in effect with respect to the periods for which it receives grant funding, including 2 CFR parts 200 and 3002. The State will amend its plan whenever necessary to reflect changes in State or Federal statutes and regulations.

RL. Repetitive loss strategy

The flood hazard profile in Chapter 3 addresses RL/SRL properties (S6).

Among our overarching goals for long-term natural hazard risk reduction (S8) is the goal to reduce the number of RL/SRL properties around the state. Included in our list of mitigation actions (S9) is our intent to use the most recent (as of February 2023) version of the RL/SRL list acquired from FEMA Region 10 to identify RL/SRL clusters and perform targeted outreach to local jurisdictions to spur interest in the FMA program (S10). However, as mentioned in S13, the structure of Washington's state law regarding sensitive information (i.e., PII) makes it difficult to share detailed RL/SRL data with other State and local authorities. This makes it difficult to grasp the full scale of the state's RL/SRL problem as well as how best to target it since it will largely be a State-led effort rather than a local one.

Regardless, project sub-applications targeting RL/SRL properties are prioritized for funding under our administration of the FMA program (S15). Acquisition projects that also include floodplain restoration elements tend to score better than elevation projects.

Enhanced State Plan Requirements

E1. Meet all the standard requirements

See the section above titled Standard State Plan Requirements**.**

E2. Capability to meet application time frames and submitting complete applications

Since 2018, EMD's Mitigation team has consistently submitted its HMA applications to FEMA within the established deadlines and entered them into the proper electronic data systems (eGrants for PDM, FEMA GO for BRIC and FMA, and NEMIS for HMGP and HMGP Post-Fire). Its BRIC applications are submitted well ahead of the established deadlines to avoid potential technical issues during the final submission week. Washington's 2022 BRIC application was submitted a full week ahead of the FEMA deadline. Recent COVID-impacted HMGP rounds have required EMD to secure application period extensions, in part due to challenges with implementing new Federal cost-share requirements for disasters with incident periods occurring in CY2020. But our application submissions for those rounds met (or will meet) FEMA's newly established deadlines.

All EMD's HMA grant applications include an eligibility & completeness checklist. For HMGP, an Application Review Tool (ART) is also completed and submitted for each sub-application. During the 2020 BRIC round, FEMA GO challenged EMD's efforts to submit these checklists: they were attached to the "Review" section, but apparently FEMA reviewers were unable to view that section. Adjustments were made in the following years to ensure these checklists are attached to sections FEMA can access.

HMA grant application completeness was a topic EMD and FEMA discussed in detail during its 2022 SEHMP Validation meetings. In the past few years, EMD took the following actions to ensure its continued capability to meet the requirements of element E6:

- EMD doubled the size of its Mitigation Team since January 01, 2021 from six to 13, including the creation of a new EMPS-3 position: Mitigation Program Monitoring and Closeout Specialist. This increased capacity, and along with an overhauled training standard for new hires, has greatly improved our bandwidth to address FEMA RFIs in a timely manner. This also signals EMD's strong commitment to enhanced administration of our HMA programs.
- EMD secured an on-call BCA contractor that's available to assist our staff (and sub-applicants as needed) with any BCA-related RFIs. Without professional assistance, these RFIs can prove especially challenging to address quickly.
- EMD developed a more robust RFI tracking process using SharePoint and other "non-siloed" information tools. This will help ensure that staff turnover does not lead to RFIs getting lost or otherwise missed during transition.

E3. Capability to prepare and submit accurate environmental reviews and benefit cost analyses

Over the past five years, EMD's Mitigation team has increased its efforts to conduct advance EHP coordination and preliminary reviews of complex HMA grant project proposals with FEMA's EHP staff. While staff turnover and low-capacity issues, particularly during the 2020-2022 COVID-19 pandemic, have challenged those efforts as EHP reviews remain among the most time-consuming elements of an HMA project review process, EMD remains committed to submitting high-value, quality mitigation projects even when they are EHP-complex. Our HMGP sub-applications include a comprehensive EHP Q&A section that is reviewed by EMD staff prior to FEMA submission, and phasing project proposals likely to need extensive EHP work has become common practice in recent years.

Regarding EMD's commitment to providing complete and accurate cost-effectiveness determinations, it has retained the services of a BCA contractor to assist with all our BCA related work since 2021. Since then, all BCA-related portions of Washington's application packages are reviewed, vetted, and revised as needed prior to FEMA submission. BCA contractors are also used to help WA's sub-applicants address FEMA RFIs related to BCAs, which have become increasingly detailed and complex in recent years, coinciding with the addition of FEMA's own BCA contractor. We have made significant investments in BCA support services since 2021, which has resulted in vastly improved BCA submissions compared to those from previous years. As FEMA's scrutiny of submitted BCAs continues to increase, so will EMD's BCA support costs. As long as BCAs remain among the most significant technical barrier to entry for Washington's disadvantaged communities, EMD will remain committed to providing expanded BCA support, despite the additional costs and administrative burden.

E4. Capability to submit complete and accurate quarterly progress and financial reports on time

EMD's Mitigation team consistently submits all required HMA grant quarterly progress and financial reports in accordance with 2 CFR 200.300-309. The details of its reporting processes are described in the 2023 WA State Administrative Plan for Mitigation. For FMA, PDM and BRIC grants, SF-PPRs are completed and submitted (directly into FEMA GO for BRIC). For all HMGP and HMGP Post-Fire grants, a FEMA-provided Excel spreadsheet is completed and submitted. While the COVID-19 disruptions between 2020-2022 impacted the accuracy of a small number of FFRs, those issues have been addressed and resolved, and EMD's overall HMA reporting track record is strong. In 2022 the Mitigation team added a Mitigation Program Monitoring and Closeout Specialist to help ensure its capabilities in this area remain high—and to ensure added programmatic resilience to future disruptions.

E5. Capability to complete HMA projects within the established performance periods, including financial reconciliation

EMD's HMA grants are routinely completed within their established periods of performance (POPs). Between 2020 to 2023, time extensions for several active grants were needed due primarily to COVID-19 delays, which also disrupted EMD's typical POP monitoring capabilities. But as of February 2023, the extended POP end dates have provided sufficient time to complete the remaining grant-funded work and the broader trend over the past five years has been positive. The same is also true for HMA grant closeouts and financial reconciliations during liquidation: 2020-2022 brought about disruptions to EMD's long track record of consistency, but the post-COVID recovery shows an overall increase in capabilities and a return to the broader, positive trend. The following measures helped EMD address the COVID-19 disruptions and significantly increase its capacity to meet the requirements of E9:

- EMD filled several staff vacancies and created/filled new grant coordinator positions, more than doubling the size of our Mitigation Team. This increase in capacity helped address the significant workload.
- EMD created and filled a new Mitigation Program Monitoring and Closeout Specialist position to oversee our financial reconciliation work with Washington Military Departments (MIL) Finance Department and FEMA's GPD staff to conduct QA/QC reviews for our outgoing closeout packages, and track our closeout deadlines and liquidation period requirements.
- EMD created and tested new financial drawdown procedures and processes with MIL's Finance department to ensure federal funds are drawn quarterly during active POPs and financial reports are reconciled in a timely manner during or before a grant's Liquidation Period.
- EMD's Finance Department filled key vacancies and added support staff to ensure HMA grant financials are properly monitored and tracked.

Since 2021, WA EMD's Mitigation team established (and re-established in some cases) effective financial reporting and reconciliation processes, and it actively supported them by creating and filling new positions—both in the Mitigation

Team office and the Finance Department office. These and other items listed under requirement E9 were discussed during FEMA's 2022 SEHMP Validation meetings with EMD.

E6. Integration with other state planning initiatives and FEMA mitigation programs and initiatives

The 2023 SEHMP draws from multiple State planning initiatives. Appendix B provides specific references to State plans, data, reports, and studies used in this update. Among them include the Department of Health's Environmental Health Disparities Rankings, which provides detailed spatial data on various environmental and public health conditions around the state. These data were used extensively in our risk and vulnerability analyses (Chapter 3). Multiple sources from the Department of Natural Resources were used in this update, including wildfire location data, tsunami inundation zones, and locations of previous earthquake damage. We also included the results of the Washington Sea Grant-led study into relative sea level rise around the state, as well as the University of Washington Climate Impacts Group's state of knowledge report.

Aside from ensuring other State-developed plans were used to inform this update, the State of Washington has a long history of embedding mitigation into programs across State government through a coordinating structure of agency representatives called the Hazard Mitigation Working Group (HMWG). The HMWG meets quarterly to share information, develop the SEHMP, and track progress on its implementation. Additionally, EMD Mitigation staff are engaged members of multiple other hazard mitigation-related groups. These include the Washington Silver Jackets, Infrastructure Assistance Coordinating Council, Risk MAP Coordination, Interagency Climate Adaptation Network, and the Wildland Fire Mitigation & Management Commission.

Sector-specific examples of integrated planning efforts since 2018 include:

1. Emergency management: Continued partnership between EMD's Mitigation Strategist and the THIRA/SPR Program, including using the SEHMP to develop THIRA scenarios and, conversely, using THIRA impact analysis results for use in hazard analyses conducted for the purposes of mitigation; alignment of SEHMP planning processes with the EMAP standard; incorporating SEHMP HIVA results into the State CEMP
2. Economic development: Participation of EMD's Mitigation section on the Disaster Resiliency Working Group led by the Office of the Insurance Commissioner (OIC), including providing input on a final recommendation for establishing a statewide resilience office that would, in part, address economic concerns associated with disasters
3. Land use: Partnership between EMD's Mitigation Strategist and the Department of Commerce on creating climate resilience sub-elements in local comprehensive plans, including the use of local HMPs for this purpose
4. Housing: Partnership between EMD's Mitigation section and OIC on developing/adopting a wildfire building standard for residential structures; Use of property values (developed by the Office of Financial Management) in the 2023 SEHMP HIVA; Use of drinking water location data (developed by Dept. of Health) in the 2023 SEHMP HIVA
5. Health and social services: Integration of Department of Health's Environmental Disparities Rankings into the 2023 SEHMP HIVA; use of hospital location data in the 2023 SEHMP HIVA
6. Infrastructure: Integration of high-priority transportation, dam, energy production, water, wastewater, and health and safety assets in the 2023 SEHMP HIVA (with many of these datasets coming from the federal Dept. of Homeland Security)
7. Natural and cultural resources: Completion of a coastal erosion risk assessment conducted by the Department of Ecology but funded by EMD; participation of EMD's Mitigation section on an interagency panel working to update the state's URM database (includes Dept. of Archaeology and Historic Preservation, EMD, and DNR staff)

The State has continued to integrate its mitigation-related programs with FEMA's. This includes a significant expansion of Washington's state-run Public Assistance program (including 406 Mitigation activities). This also includes increases in the use of HMGP and HMGP Post-Fire programs since 2018. Washington has been a national leader in terms of projects funded by the BRIC program since its inception in 2020, and the State is also actively pursuing HHPD compliance with this SEHMP and applying for HHPD grants through the Department of Ecology's Dam Safety Office. Section E8 below has additional detail pertaining to many of these programs.

Although the State feels the above examples indicate our continued commitment to integrating the SEHMP and other State-led planning initiatives and programs, there are of course areas for improvement. As a large governmental entity, it is virtually impossible to ensure the SEHMP is meaningfully integrated with every applicable program, policy, or plan that Washington creates. Continued communication with non-EMD partners, led by the SHMO and Strategist, is vital in ensuring this plan is known and valued and that other initiatives are used in EMD Mitigation's work as well. E7 below illustrates many of the mechanisms the SHMO and Strategist use to accomplish that kind of communication and partnership.

E7. Commitment to a comprehensive mitigation program

As mentioned in E6, Washington has a long history of cross-agency engagement around hazard mitigation and a broad range of State-supported initiatives. Section 4.2 provides a comprehensive list of mitigation actions and the lead agency responsible for each. These include targeted risk reduction of flooding via Department of Ecology's floodplain management and coastal resilience programs. Such programs include management of NFIP and Risk MAP. They also include targeted risk reduction of wildfire, tsunami, earthquake, and volcano impacts across the Department of Natural Resources programs, such as the Washington Geological Survey. The Department of Commerce also includes multiple programs with a hazard mitigation focus, including leading the development of guidance for locals to better incorporate climate resilience into long-range plans. Other examples include the Office of Insurance Commissioner leading the statewide Disaster Resiliency Working Group in 2020 and the Office of the Chief Information Officer developing a natural hazard data portal (expected completion in 2023). More examples of Washington's comprehensive mitigation program can be found in the Annual Reports in Appendix D.

Our program also includes support for local HMP development to ensure continued HMA eligibility by the most jurisdictions possible. As of June 2023, 32 out of 39 counties (or 82% of all counties, which covers 92% of the state's population) have assessed their natural hazard risk, developed a mitigation strategy, and are currently eligible for hazard mitigation grants. Adams County has a plan in development but has not yet received FEMA approval (as of June 2023), which means 100% of counties and the entire state's population resides in a county that has assessed its natural hazard risk at least once. Most of these county HMPs are multijurisdictional and include numerous adopting jurisdictions. At the time of this writing, there are 357 total jurisdictions (including counties, cities, and special purpose districts) that are HMA eligible in Washington. Many more are in the process of adopting an approved HMP or developing an annex or stand-alone plan.

E8. Effective use of mitigation programs to achieve mitigation goals

As of January 2023, EMD's Mitigation team was actively managing and making use of 32 ongoing Hazard Mitigation Assistance (HMA) grant rounds worth more than $350 million in federal, state, and local mitigation dollars. Of those active grant rounds, 20 of them were announced within the last five years: three new PDM rounds, two new FMA rounds, three new BRIC rounds, four new HMGP- Post Fire rounds, and eight new HMGP (DR-) rounds. EMD doubled its mitigation team staff to ensure the State can effectively manage and make use of its large HMA grant portfolio.

For HMGP rounds, our state applications consistently include sub-applications worth at least the overall available amount. To help minimize unclaimed grant funds, EMD includes in its HMGP applications several alternate sub-applications. These alternates are available for FEMA funding in the event a primary sub-application drops out or if additional funds otherwise become available.

Washington has been especially successful in securing FEMA selections under the new BRIC grant program. For BRIC's national project competition selections, Washington's results ranked in the top-three (by dollar value) for all states in both 2020 and 2021 rounds, with the 2022 results still pending. We continue to ramp up our efforts to maximize our use of BRIC, including the recent addition of a year-round sub-application development strategy that will better prepare us for the compressed BRIC application periods in Oct-Jan.

For Washington's HMGP Post-Fire rounds, EMD has submitted full packages for FEMA funding in all available years. The available HMGP Post-Fire funds have been challenging to use for wildfire-specific mitigation activities, as there remain several eligibility and EHP-related constraints for wildfire mitigation projects in general. So, while these rounds are essentially all-hazard funding rounds for Washington, we have been able to secure subawards for defensible space, fuels reduction, and wildfire education/outreach activities in high-hazard WUI communities.

EMD's HMA grants mitigation programs have a longstanding track record of helping local and tribal jurisdictions leverage its funding opportunities. Between 2018-2023, Washington's Legislature maintained its cost-share support for all HMGP sub-recipients, covering half of their non-federal match requirements. In recent years this support was extended to include BRIC sub-recipients as well, marking a significant state-level investment in cost-effective mitigation actions—and an important step toward providing equitable access to these funding opportunities for smaller, disadvantaged communities.

In 2020-2022, during the most significant months of COVID-19 pandemic disruptions, EMD navigated its HMA programs through unprecedented challenges to make use of its HMA programs to accomplish a great deal of important work toward its goals. During this timeframe, EMD submitted to FEMA 95 grant sub-applications and 44 grant closeout packages, passed two FEMA monitoring visits with excellent marks, and doubled its Mitigation Team staff from six to 13 personnel. These accomplishments represent an enormous workload to make the most of multiple, overlapping disaster and non-disaster grant rounds during COVID-19 and staffing disruptions.

Coming out of the 2020-2022 COVID-related challenges, EMD's current performance trends, investments in staffing and training, and work output show measurable and tangible increases in its capability to manage and make full use of HMA programs at an enhanced level.

WA has also leveraged other State programs beyond EMD's Mitigation team to help achieve the state's mitigation goals. The Floodplains by Design grant program, for example, is a state-funded grant opportunity administered by Washington's Department of Ecology, and its focus on holistic flood mitigation and integrated floodplain management measures compliments other risk-reduction efforts, such EMD's HMA grant programs. The Department of Commerce administers several grant programs aimed at increasing community resilience, especially for the energy sector. Washington's School Seismic Safety funding includes new state funding opportunities for earthquake and tsunami risk-reduction as well as all-hazard mitigation planning efforts for school districts. The State's Disaster Resilience Work Group and Hazard Mitigation Working Group are other examples of state-level efforts that directly address the state's mitigation goals.

Moving forward, EMD's Mitigation team, and the State's comprehensive mitigation program as a whole, is well positioned to effectively take full advantage of new and upcoming grant opportunities, provide enhanced assistance and coordination with its local, state, and tribal mitigation partners, and reduce the risk of natural hazards in this state.

Washington also accomplishes hazard mitigation through non-HMA means, and these include:

- PA Mitigation: Although the Public Assistance Program is primarily used for disaster recovery via funds for permanent work under Categories C-G, additional funds (i.e., 406 Mitigation) are made available to jurisdictions in declared areas to support rebuilding damaged infrastructure to a higher standard for the express purpose of mitigating future risk. Recent examples include installing regulators into a public utility district's distribution system to reduce the chance of structure fires, replacing a washed-out log-built stream crossing with a concrete culvert, and applying fire retardant paint to utility poles. Total funds awarded under

PA Mitigation for recent DRs include $15.6 million for DR-4635, $9.1 million for DR-4650, and $2.2 million for DR-4682.

- Community Assistance Program -State Support Services Element (CAP-SSSE): CAP-SSSE in Washington is used to fund the State's NFIP work via the agreement between Region 10 and the Department of Ecology (the State's NFIP coordinating office). Goals of this work include improving local capacity for floodplain management, building partnerships and collaboration around floodplain management across State agencies, and promoting the resilience benefits of strong floodplain management and insurance.
- High Hazard Potential Dam Grant Program: The Washington State Department of Ecology's Dam Safety Office (DSO) successfully applied for funds from FEMA's HHPD Grant for fiscal years (FY) 2019, 2020, 2021, and 2022, receiving a total of $1,508,794. Ecology has passed through all the grant awards to fund 14 dam projects. With the required match of 35% ($528,078) from the subrecipients, $2,036,872 will be spent to fulfill FEMA's program objectives for this grant to reduce or eliminate risk of dams of highest consequence and increase the understanding and management of risks posed by these high-risk dams in Washington State. Thus far Ecology has funded non-construction projects focused on risk analysis studies and planning. In the future Ecology will apply for and pass through FEMAs construction funding awards.
- NEHRP: NEHRP funding in Washington is used towards earthquake mitigation and preparedness efforts throughout the state. Through NEHRP, EMD hired a coordinator to work with State agency partners toward improving the inventory of unreinforced masonry buildings in Washington, and to help identify priority seismic retrofit projects. In addition, NEHRP funding each year goes towards EMD's largest annual outreach campaign: the Great Washington ShakeOut earthquake drill. Advertising for this drill promotes and improves awareness of Washington's earthquake hazards, earthquake protective actions, and encourages individuals, families, and businesses/organizations in Washington to take preparedness and mitigation actions for the earthquakes we will experience some day.
- Integrated Climate Response Strategy: The 2012 Integrated Climate Response Strategy offered recommendations on how existing programs and policies could help Washington prepare for anticipated climate change impacts. Although still considered helpful, it is considered out-of-date and was not viewed as current or best available information for this SEHMP update. In 2023, the State Legislature passed a bill requiring the Department of Ecology to oversee the update to the Climate Response Strategy before the 2023-2025 biennium. EMD is a named agency in the legislation and will actively participate in the update. The SEHMP will be a guiding document for the update and the new Climate Response Strategy will be integrated into future SEHMP updates.
- State Resilience Office: In 2023, the State Legislature passed a bill requiring EMD to create a State Resilience Office within the agency. At the time of this writing, this Office has not been created but it will have an influence on future mitigation planning and funding once it has been developed.
- CDBG-DR: The Department of Commerce oversees the administration of HUD funds via the CDBG-DR program. Commerce plans to spend $4.6 million on planning initiatives to inform future mitigation measures to be tackled under this program.
- US Army Corps of Engineers: Multiple Washington State agencies participate in the USACE-led Silver Jackets group, which identifies potential flood-related mitigation projects as part of its work (in addition to information sharing and collaboration). This group also discusses post-fire debris flow issues in the state.
- Community Wildfire Defense Grant Program: Washington was awarded $25 million in wildfire grants from the US Department of Agriculture's Community Wildfire Defense Grant Program in 2023. These funds are for more than 10 wildfire risk reduction projects across the state. The Department of Natural Resources is the administering agency for this funding.
- NGO relationships: Flood risk reduction in Washington is achieved through a public-private partnership between the Department of Ecology and American Rivers, a private nonprofit focused on stream restoration and flood management. Together, these organizations oversee the administration of the Floodplains by Design program, which is focused on integrated floodplain management that incorporates flood risk

reduction in their floodplain restoration work. Outside of flood-specific mitigation, multiple nonprofit organizations use PA Mitigation funds, including nonprofit public utility districts.

E9. Capability to implement mitigation actions

For 2023, we simplified the presentation of specific mitigation actions taken by State agencies and departments but our system to rank the mitigation measures continued to be robust by using the STAPLEE method to determine general feasibility and effectiveness of each measure. We also listed potential funding programs for each measure. The order of the funding programs listed indicates which funding program is prioritized for that measure. Washington's capabilities to implement funded actions can be found in Section 2.3.

We also rank and assess effectiveness during each grant round administered by EMD Mitigation. We use FEMA's benefit-cost metrics to quantify cost effectiveness as well as a list of internally developed qualitative criteria to rank and prioritize project sub-applications (see S15 above). These qualitative criteria include whether the project considers underserved communities. It is also assumed that a cost-effective project, according to FEMA's metrics, will result in tangible risk reduction benefits once completed. As such, this is an additional way that the State measures the effectiveness of its mitigation investments prior to project completion and without conducting loss avoidance studies. However, to build on the STAPLEE and BCA metrics we currently use, EMD Mitigation has begun a data collection process that will create a dataset of HMA projects statewide that can be used for spatial analysis of mitigation investments. This dataset will be used to determine where HMA funds are most needed based on identified risks and vulnerabilities in the HIVA and any potential geographical gaps in mitigation projects that are found as a result of using this dataset. This dataset will also be used to determine whether Washington's HMA funds are equitably distributed and, if not, help the State identify strategies for improving the equitable distribution of mitigation grants. The result of this work will be a data-driven risk-based needs assessment that will meaningfully incorporate equity considerations into our mitigation investments that the State can use when deciding where and how to apply federal mitigation funds.

Finally, beginning in 2022, EMD partnered with other State agencies to develop large-scale infrastructure project applications for submission under BRIC. This initiative was named "Pathfinder" and included project development sub-initiatives with Departments of Ecology, Fish & Wildlife, Natural Resources, and Transportation as well as the Office of the Superintendent of Public Instruction. The Pathfinder initiative is seen as a way of pooling resources and capabilities across State agencies that further develops our comprehensive approach to reducing losses of life and property. This initiative also leverages potential HMA dollars for the greatest number of Washington residents possible. Other State agencies are expected to be included in future Pathfinder initiatives.

Appendix B: References

Aerosol Robotic Network (AERONET). (2018). Retrieved from https://aeronet.gsfc.nasa.gov/new_web/data.html

Al-Ahmadi, K., Al-Amri, A., & See, L. (2014). A spatial statistical analysis of the occurrence of earthquakes along the Red Sea floor spreading: clusters of seismicity. *Arabian Journal of Geosciences, 7*, 2893–2904.

Balk, G. (2018, July 23). Seattle is least air-conditioned metro area in the US. So how do locals keep cool? *The Seattle Times*. Retrieved March 18, 2022, from https://www.seattletimes.com/seattle-news/data/seattle-is-least-air-conditioned-metro-area-in-the-u-s-census-data-show-so-how-do-locals-keep-cool/

Ballestros-Canovas, J., Trappmann, D., Madrigal-Gonzalez, J., Eckert, N., & Stoffel, M. (2018). Climate warming enhanced snow avalanche risk in the Western Himalayas. *PNAS, 115*, 3410-3415. doi:10.1073/pnas.1716913115

Bladon, K. D., Emelko, M. B., Silins, U., & Stone, M. (2014). Wildfire and the future water supply. *Environmental Science & Technology, 48*(16), 8936-8943.

Buis, A. (2017). *In Atmospheric River Storms, Wind Is a Risk, Too*. Retrieved from www.nasa.gov: https://www.nasa.gov/feature/jpl/in-atmospheric-river-storms-wind-is-a-risk-too

Caldas de Castro, M., & Singer, B. (2006). Controlling the False Discovery Rate: A New Application to Account for Multiple and Dependent Tests in Local Statistics of Spatial Association. *Geographical Analysis, 38*(2), 180-208.

Centers for Disease Control and Prevention (CDC), Agency for Toxic Substances and Disease Registry. (2018). *CDC/ATSDR Social Vulnerability Index (SVI)*. Retrieved from astdr.cdc.gov: https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html

Chleboard, A. F., & Schuster, R. L. (1990). *Ground failure associated with the Puget Sound earthquakes of April 13, 1949 and April 29, 1965*. U.S. Geological Survey.

Clarridge, C., & Kroman, D. (2022, January 7). I-5 reopens after flooding closed 20-mile stretch in Chehalis for several hours. *The Seattle Times*. Retrieved from https://www.seattletimes.com/seattle-news/weather/20-mile-stretch-of-i-5-closed-in-chehalis-due-to-flooding/

De Graff, J. (2018). A rationale for effective post-fire debris flow mitigation within forested terrain. *Geoenvironmental Disasters, 5*. doi:10.1186/s40677-018-0099-z

DeGraff, J., Cannon, S. H., & Gartner, J. E. (2015). The timing of susceptibility to post-fire debris flows in the western United States. *Environmental & Engineering Geoscience, 21*(4), 277-292.

Department of Homeland Security (DHS), Operational Analysis Division. (2016). *Drought Impacts to Critical Infrastructure.* Office of Cyber and Infrastructure Analysis, Department of Homeland Security.

Duncan, M., Edwards, S., Kilburn, C., Twigg, J., & Crowley, K. (2016). An interrelated hazards approach to anticipating evolving risk. In *The Making of a Riskier Future: How Our Decisions Are Shaping Future Disaster Risk* (pp. 114-121). Washington, DC: Global Facility for Disaster Risk Reduction.

Entekhabi, D., Yueh, S., O'Neill, P. E., Kellogg, K. H., Allen, A., Bindlish, R., . . . West, R. (2014). *SMAP Handbook–Soil Moisture Active Passive: Mapping Soil Moisture and Freeze/Thaw from Space.* Pasadena, CA: JPL Publication.

Federal Emergency Management Agency (FEMA). (2003). *State and Local Mitigation Planning How-To Guide: Developing the Mitigation Plan - Identifying Actions and Implementation Strategies*. Washington, DC: FEMA.

Federal Railroad Administration (FRA). (2017, May). *Railroads*. Retrieved from Homeland Infrastructure Foundation-Level Data (HIFLD): https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::railroads/about

Finch, A. (2022, March 1). Seattle deluged with more than a month's worth of rain in 3 days. *UPI*. Retrieved from https://www.upi.com/Top_News/US/2022/03/01/Seattle-rain-weather/5171646185438/

Frankson, R., Kunkel, K. E., Champion, S. M., Easterling, D. R., Stevens, L. E., Bumbaco, K., . . . Sweet, W. (2022). *Washington State Climate Summary 2022*. Silver Spring, MD: NOAA Technical Report NESDIS 150-WA, NOAA/NESDIS.

Freedman, A., & Malcolm, H. (2021, June 28). Pacific Northwest heat dome roasts more than 25M. *Axios*. Retrieved from https://www.axios.com/pacific-northwest-heat-dome-25-million-records-bd910518-97ab-4834-85cd-c2941a99827e.html

Fricko, O., Havlik, P., Rogelj, J., Klimont, Z., Gusti, M., Johnson, N., & Riahi, K. (2017). The marker quantification of the Shared Socioeconomic Pathway 2: middle-of-the-road scenario for the 21st Century. *Global Environmental Change, 42*, 251-267.

Gamillo, E. (2021, June 29). Heat dome scorches Pacific Northwest with record-breaking high temperatures. *Smithsonian Magazine*. Retrieved March 18, 2022, from https://www.smithsonianmag.com/smart-news/heat-dome-scorches-pacific-northwest-180978085/

Gao, J. (2017). *Downscaling Global Population Projections from 1/8-degree to 1-km Grid Cells*. NCAR Technical Note NCAR/TN-537+STR. doi:10.5065/D60Z721H

Gao, J., & Pesaresi, M. (2021). Downscaling SSP-consistent global spatial urban land projections from 1/8-degree to 1-km resolution 2000–2100. *Scientific Data, 8*.

Gao, Y., Lu, J., Leung, L. R., Yang, Q., Hagos, S., & Qian, Y. (2015). Dyanmical and thermodynamical modulations on future changes of landfalling atmospheric rivers over western North America. *Geophysical Research Letters, 42*(17), 7179-7186.

Getis, A., & Ord, J. K. (1992). The Analysis of Spatial Association by Use of Distance Statistics. *Geographical Analysis, 24*, 189-206.

Gill, J. C., Taylor, F. E., Duncan, M. J., Mohadjer, S., Budimir, M., Mdala, H., & Bukachi, V. (2020). Invited Perspective: Building sustainable and resilient communities - Recommended actions for natural hazard scientists. *Natural Hazards and Earth System Sciences (pre-publication version)*.

Global Modeling and Assimilation Office (GMAO). (2022). *Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2)*. Retrieved from gmao.gsfc.nasa.gov: https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

Government Accountability Office (GAO). (2021). *Superfund: EPA Should Take Additional Actions to Manage Risks from Climate Change Effects*. Washington, DC: U.S. Government Accountability Office.

Hagenlocher, M., Meza, I., Anderson, C. C., Min, A., Renaud, F. G., Walz, Y., . . . Sebesvari, Z. (2019). Drought vulnerability and risk assessments: state of the art, persistent gaps, and research agenda. *Environmental Research Letters, 14*(8).

Halbe, J., Pahl-Wostl, C., & Adamowski, J. (2018). A methodological framework to support the initiation, design and institutionalization of participatory modeling processes in water resources management. *Journal of Hydrology, 556*, 701-716.

Harto, C. B., Yan, Y. E., Demissie, Y. K., Elcock, D., Tidwell, V. C., Hallett, K., . . . Tefsa, T. K. (2012). *Analysis of drought impacts on electricity production in the Western and Texan interconnections of the United States.* Argonne, IL: U.S. Department of Energy, Argonne National Laboratory.

Hock, R., Rasul, G., Adler, C., Caceres, B., Gruber, S., & Hirabayashi, Y. (2019). High Mountain Areas. In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (pp. 131-202).

Jarque, C., & Bera, A. (1980). Efficiency tests for normality, homoscedasticity, and serial independence of regression residuals. *Economic Letters, 6*, 255-259.

Jones, B., & O'Neil, B. C. (2016). Spatially explicit global population scenarios consistent with the Shared Socioeconomic Pathways. *Environmental Research Letters, 11*. doi:10.1088/1748-9326/11/8/084003

Kappes, M. S., Keiler, M., von Elverfeldt, K., & Glade, T. (2012). Challenges of analyzing multi-hazard risk: a review. *Natural Hazards, 64*(2), 1925-1958.

Matheswaran, K., Alahacoon, N., Pandey, R., & Giriraj, A. (2019). Flood risk assessment in South Asia to prioritize flood index insurance applications in Bihar, India. *Geomatics, Natural Hazards and Risk, 10*(1), 26-48.

McPhillips, D. F., Herrick, J. A., Ahdi, S., Yong, A. K., & Haefner, S. (2020). *Updated Compilation of VS30 Data for the United States.* U.S. Geological Survey.

Miller, I. M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., . . . Grossman, E. (2018). *Projected Sea Level Rise for Washington State - A 2018 Assessment.* Washington Sea Grant, UW Climate Impacts Group, University of Oregon, and U.S. Geological Survey.

Mitchell, C. (2021, November 15). *Update: US 101 Elwha River Bridge closed in Clallam County due to flooding*. Retrieved from Washington State Department of Transportation: https://wsdot.wa.gov/about/news/2021/update-us-101-elwha-river-bridge-closed-clallam-county-due-flooding

Mohadjer, S., Ehlers, T. A., Bendick, R., Stubner, K., & Strube, T. (2016). A Quarternary fault database for central Asia. *Natural Hazards and Earth System Sciences, 16*(2), 529-542.

Mosavi, A., Ozturk, P., & Chau, K. (2018). Flood prediction using machine learning models: literature review. *Water, 10*(11).

National Aeronautics and Space Administration (NASA). (2021, November). *Severe Flooding in the Pacific Northwest*. Retrieved April 14, 2022, from NASA Earth Observatory: https://earthobservatory.nasa.gov/images/149100/severe-flooding-in-the-pacific-northwest

National Oceanic and Atmospheric Administration (NOAA). (2022). *Climate Resilience Toolkit Climate Explorer (v. 3.1)*. Retrieved from crt-climate-explorer.nemac.org: https://crt-climate-explorer.nemac.org/about/

Northwest Avalanche Center (NWAC). (2022). Retrieved from nwac.us: https://nwac.us/

Oak Ridge National Laboratory (ORNL). (2019). Local Law Enforcement Locations. Retrieved May 2022, from https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::local-law-enforcement-locations/about

Oak Ridge National Laboratory (ORNL). (2022). *Electric Power Transmission Lines*. Retrieved from Homeland Infrastructure Foundation-Level Data (HIFLD): https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::electric-power-transmission-lines/about

O'Connell, E., Abbott, R. P., & White, R. S. (2017). Emotions and beliefs after a disaster: a comparative analysis of Haiti and Indonesia. *Disasters, 41*(4), 803-827.

Philip, S. Y., Kew, S. K., van Oldenborgh, G. J., Anslow, F. S., Seneviratne, S. I., Vautard, R., . . . Otto, F. L. (2021). Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada, June 2021. *Earth System Dynamics, in review*.

Phillips, S., Anderson, R., & Schapire, R. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling, 190*, 231-259.

PRISM Climate Group. (n.d.). (O. S. University, Producer) Retrieved August 12, 2022, from https://www.prism.oregonstate.edu/

Qiang, Y. (2019). Disparities of population exposed to flood hazards in the United States. *Journal of Environmental Management, 232*, 295-304.

Sarofim, M. C., Saha, S., Hawkins, M. D., Mills, D. M., Hess, J., Horton, R., . . . St. Juliana, A. (2016). Temperature-related death and illness. In *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (pp. 43-68). US Global Change Research Program.

Seto, K., Guneralp, B., & Hutrya, L. R. (2016). *Global Grid of Probabilities of Urban Expansion to 2030*. Retrieved March 22, 2022, from Socioeconomic Data and Applications Center (SEDAC): https://doi.org/10.7927/H4Z899CG

Shindell, D., Zhang, Y., Scott, M., Ru, M., Stark, K., & Ebi, K. L. (2020). The effects of heat exposure on human mortality throughout the United States. *Geohealth, 4*(4).

Strapazzon, G., Schweizer, J., Chiambretti, I., Brodmann Maeder, M., Brugger, H., & Zafren, K. (2021). Effects of climate change on avalanche accidents and survival. *Frontiers in Physiology, 12*. doi:10.3389/fphys.2021.639433

Tinker, R., & Gutzmer, D. (2021). *National Drought Summary for August 10, 2021*. Retrieved from U.S. Drought Monitor: https://droughtmonitor.unl.edu/Summary.aspx

Tobler, W. (1970). A Computer Movie Simulating Urban Growth in the Detroit Region. *Economic Geography, Vol. 46, Supplement: Proceedings. International Geographical Union. Commission on Quantitative Methods*, 234-240.

Twigg, J. (2015). *Disaster Risk Reduction*. Retrieved from Humanitarian Practice Network (www.goodpracticereview.org): https://goodpracticereview.org/9/

U.S. Drought Monitor. (2022). GIS Data. National Drought Mitigation Center, U.S. Department of Agriculture, and National Oceanic and Atmospheric Administration. Retrieved from https://droughtmonitor.unl.edu/DmData/GISData.aspx

U.S. Geological Survey (USGS). (2018). *2018 United States (Lower 48) Seismic Hazard Long-Term Model.* U.S. Geological Survey, Earthquake Hazards Program. Retrieved from https://www.usgs.gov/programs/earthquake-hazards/science/2018-united-states-lower-48-seismic-hazard-long-term-model

U.S. Geological Survey (USGS), National Geospatial Technical Operations Center. (2020). Fire Stations. Retrieved May 2022, from https://hifld-geoplatform.opendata.arcgis.com/datasets/fire-stations-1/about

U.S. Global Change Research Program (USGCRP). (2022). *Climate Explorer*. Retrieved March 21, 2022, from U.S. Climate Resilience Toolkit: https://crt-climate-explorer.nemac.org/

United Nations (UN). (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development.* Geneva: United Nations.

Wang, Y., Xie, Y., Dong, W., Ming, Y., Wang, J., & Shen, L. (2017). Adverse effects of increasing drought on air quality via natural processes. *Atmospheric Chemistry and Physics, 17*, 12827-12843.

Washington Department of Ecology. (2022). *Water Supplies & Climate Change*. Retrieved from ecology.wa.gov: https://ecology.wa.gov/Air-Climate/Climate-change/Climate-change-the-environment/Water-supply-impacts

Washington Department of Health (DOH). (2019). *Flood advice for drinking water systems.* Washington Department of Health. Retrieved from https://doh.wa.gov/sites/default/files/legacy/Documents/Pubs//331-300.pdf

Washington Department of Health (DOH). (2021). *Heat Wave 2021*. Retrieved March 18, 2022, from https://doh.wa.gov/emergencies/be-prepared-be-safe/severe-weather-and-natural-disasters/hot-weather-safety/heat-wave-2021

Washington Department of Health (DOH). (2021). *Hospitals*. Retrieved from https://geo.wa.gov/datasets/WADOH::hospitals/about

Washington Department of Health (DOH). (2022a). *Washington Environmental Health Disparities Map*. Retrieved from Washington Tracking Network: https://doh.wa.gov/data-statistical-reports/washington-tracking-network-wtn/washington-environmental-health-disparities-map

Washington Department of Health (WA DOH). (2022b). *Wellhead Protection Areas*. Retrieved from Washington Geospatial Open Data Portal: https://geo.wa.gov/datasets/WADOH::wellhead-protection-areas-assigned/about

Washington Department of Natural Resources (DNR). (2010). Liquefaction Susceptibility. Retrieved from https://www.dnr.wa.gov/programs-and-services/geology/publications-and-data/gis-data-and-databases

Washington Department of Natural Resources (DNR). (2022). *Earthquakes and Faults*. Retrieved from dnr.wa.gov: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/earthquakes-and-faults

Washington Department of Natural Resources (DNR). (2022). *Tsunami Hazards in Washington State.* Retrieved from www.dnr.wa.gov: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/Tsunamis#tsunami-hazard-maps

Washington Emergency Management Division (EMD). (2022). Catastrophic Incident Annex. Retrieved from https://mil.wa.gov/asset/63112eb9dbdoc

Washington Geological Survey (WGS). (2019A). Historical Earthquake Damage. Olympia, WA: Washington Department of Natural Resources. Retrieved from https://www.dnr.wa.gov/programs-and-services/geology/publications-and-data/gis-data-and-databases

Washington Geological Survey (WGS). (2019B). Tsunami Hazard GIS Data. (Washington Geological Survey Digital Data Series 22, version 1.1). Retrieved from https://www.dnr.wa.gov/programs-and-services/geology/publications-and-data/gis-data-and-databases

Weinberger, H. (2022, December). Seattle is no longer the US's least air conditioned city. *Crosscut*. Retrieved from https://crosscut.com/environment/2022/12/seattle-no-longer-uss-least-air-conditioned-big-city#:~:text=The%20number%20of%20Seattle%20homes,426%2C400%20(31%25)%20in%202013.

Weinberger, H. (2022, June 27). What WA's cold, wet spring means for summer wildfires. *Crosscut*. Retrieved from https://crosscut.com/environment/2022/06/what-was-cold-wet-spring-means-summer-wildfires

Wing, O. E., Bates, P. D., Smith, A. M., Sampson, C. C., Johnson, K. A., Fargione, J., & Morefield, P. (2018). Estimates of present and future flood risk in the conterminous United States. *Environmental Research Letters, 13*(3).

Winsemius, H. C., Aerts, J., van Beek, L. H., Bierkens, M., Bouwman, A., Jongman, B., . . . Ward, P. J. (2016). Global drivers of future river flood risk. *Nature Climate Change, 6*, 381-385.

Wisener, B., Gaillard, J., & Kelman, I. (2012). *Handbook for Hazards and Disaster Risk Reduction.* London: Routledge.

Appendix C: Hazard Analysis Methodology

This document provides details for the proposed methodology that Washington Emergency Management Division employed for the 2023 State Enhanced Hazard Mitigation Plan (SEHMP) risk and vulnerability assessments and will continue to do so in future updates.

Part I is an overview of the quantitative methods proposed for natural hazard analysis. Part II is a detailed standard method for how the models and approaches outlined in Part I were employed in 2023 and will be in continued hazard analysis work at EMD. Part III is an explanation of how local stakeholders will be engaged in this process in the future.

I. Quantitative Natural Hazard Vulnerability Analysis Using Spatial Statistics

The overarching goal of the 2023 SEHMP's risk and vulnerability analyses was to use quantitative methods as much as possible to reduce assumptions and inaccuracies. In some cases, this involved the use of spatial statistics to determine exposure and probability of future hazard occurrences. This section explains EMD's quantitative approach to natural hazard risk and vulnerability assessment for the 2023 SEHMP.

Overview of spatial statistics

Spatial statistics is all about the application of Tobler's First Law of Geography: Everything is related, but near things are more related than distant things (Tobler, 1970). The other guiding principle for spatial statistics, as with all types of statistics, is randomness. In spatial statistics, the assumption is always that whatever is happening on the landscape is the result of random processes. Spatial statistical tests are designed to determine just how random a given event or phenomenon was to test our assumption of randomness (i.e., hypothesis testing). This is especially true with a distribution of events, such as multiple wildfires happening over a large area.

Spatial statistics will ultimately allow us to quantify and measure relatedness and randomness, thereby revealing highly important characteristics of our geographic data, such as distributions, patterns, processes, and relationships. This is because spatial statistical tests and models incorporate space and spatial relationships into their mathematics. This allows researchers to determine where a given phenomenon is likely to occur by identifying statistically significant relationships between hazard occurrences and other geographical information (e.g., temperature, population density, etc.). Although the methods we used are not able to definitively establish causation, they are able to tell us – with confidence – what other geographical variables explain the occurrences of natural hazards.

Spatial statistics used for the SEHMP can be broken down into four major types of analysis:

- Analyzing patterns
- Mapping clusters
- Measuring geographic distributions
- Modeling spatial relationships

Each of these types of analysis were tested during the development of the 2023 SEHMP, though not all were fully employed. As our hazard analyses progress beyond experimentation, results will be added to the SEHMP via intermittent updates.

II. Standard Method for Quantitative Natural Hazard Vulnerability Analysis

The steps outlined in this section are meant to guide the analysis of natural hazard vulnerability using quantitative methods within a geographic information system (GIS). While this methodology provides a framework for performing the analyses outlined below, the specific restraints of the available data may require adaptations or adjustments to achieve desired results. In such cases, the deviations from this standard method will be documented and explained to provide additional context to the results.

Quantitative natural hazard vulnerability analysis (QNHVA)

QNHVA methods rely on the use of numerical data to explain the occurrence of a natural hazard. These numerical data allow for improved statistical testing of observed natural hazard phenomena, providing one with the ability to describe the relationships more accurately between stochastic natural processes and the hazards they create. When these relationships are understood, the causes of and contributions to natural hazard occurrences become revealed, and one becomes equipped to predict future hazard occurrences with improved accuracy.

Quantitative methods also provide many opportunities to discover ways of preventing natural hazards from adversely impacting human communities through the mitigation of factors contributing to hazard events, including adapting human behavior whenever necessary.

This standard method for QNHVA relies heavily on spatial statistical analysis and modeling. Spatial statistical methods bring geography into the mathematics but rely on the same mathematical principles as non-spatial statistics. Proximity, orientation, connectivity, and other spatial attributes become applications of Tobler's Law (Tobler, 1970) to explore patterns and relationships quantitatively. The standard method for QNHVA includes the following steps:

1. Cluster analysis of previous hazard occurrences and the identification of hazard hot spots
2. Spatial regression modeling to identify explanatory variables for hazard hot spots
3. Prediction of locations of future hazard hot spots (e.g., forest-based classification, presence-only prediction)
4. Overlay present and predicted hot spots maps with population and structure data

The above four steps are meant to be completed sequentially, with the cumulative results showing 1) where natural hazards are most likely to occur; 2) why they seem to occur where they do; and 3) where one can expect to see natural hazards occur in the future. Steps 2 – 4 assume the presence of reliable spatial datasets for use in a GIS.

Data collection and preparation

Data collection and preparation for the QNHVA will follow the same basic process regardless of the natural hazard being studied. The time required to collect or find the appropriate data and ensure its proper formatting can make this a lengthy process.

Most data used for QNHVA will be collected secondarily. As such, it is imperative that all potential data is reviewed carefully and deemed reliable before being used in later modeling. Open-source and publicly available data should be used.

Many reliable sources offer open-source datasets. These include:

- Geoportal: Many spatial datasets are available in appropriate GIS formats on the Washington Geospatial Open Data portal (www.geo.wa.gov), also known as the Geoportal. Data collected from the Geoportal will be verified for appropriate use based on a review of the metadata. Questions arising from the metadata review will be referred to the owner of the dataset.

- Earthdata: Earthdata is a repository of satellite-derived earth systems data produced and managed by NASA (www.earthdata.nasa.gov). Datasets include many of the potential explanatory variables for climatic and meteorological hazards, such as temperature and precipitation. Additional processing may be required when using these data, as multidimensional formats (raster and netCDF) are common.
- Data.gov: Many important natural hazard and demographic data are owned or generated by government agencies and can be found at www.data.gov. These include data from the US Census Bureau, Forest Service, FEMA, and many other agencies. Non-spatial data can also be found at this location.
- Living Atlas of the World: Esri's Living Atlas of the World (https://livingatlas.arcgis.com/en/home/) includes numerous spatial datasets and analyses that are available to other Esri users. Open and free datasets will be prioritized over datasets that require credits to use. Additional precaution will be applied when using Living Atlas data to ensure appropriateness and reliability.

Primary data collection for use in QNHVA is possible, but less common than secondary data collection. Primary data collection could include the digitization of archival mitigation and recovery files, such as past mitigation projects and FMAG declarations. Primary collection may also include the real-time collection of natural hazard observations during a natural hazard event. This may include recording the remotely sensed raw climatological, meteorological, and hydrological data during a flood, wildfire, or landslide, for example. Common sources of such raw data include NASA, USGS, and NWS. Because of the infrequency of primary data collection for QNHVAs, no specific method of data collection is outlined here. In any case, data collected will be compiled in a format for use within a GIS.

All data collected regardless of method must be processed and prepared to ensure reliable modeling results later on.

- <u>Storage</u>: All spatial datasets will be stored in file geodatabases. File geodatabases are freely available to all ArcGIS Pro users and are designed to provide simple and scalable storage. File geodatabases are known for their strong performance and ability to hold extremely large data volumes without requiring additional storage services.
- <u>Projection</u>: All spatial datasets will be projected in the NAD 1983 HARN StatePlane Washington North or South spatial reference.
- <u>Display</u>: All spatial datasets will be displayed and explored throughout the preparation process. Visual inspection and experimentation will determine if additional cleanup is required. Required cleanup will take place either within the GIS or other software (e.g., Excel, Python).

The data collection and preparation process will result in numerous base datasets that can be used to inform nearly all modeling regardless of natural hazard. These will include combined Census and social vulnerability indices and land use/land cover. Additional base datasets may be created based on the required explanatory variables for the model as needed.

Cluster analysis and identification of hazard hot spots

Cluster analysis will be used as a first step to determine statistically significant clusters and begin the evaluation of whether the spatial distribution of natural hazard phenomena is the result of random processes.[1]

All the analyses described below should be performed using ArcGIS Pro 2.4 (or newer as updates become available). In some cases, additional cluster analyses may be performed when the data exhibit attributes appropriate for additional analyses or when the below methods do not fully answer a given study question. For example, directional distribution

[1] The operating assumption for all spatial analyses (i.e. the null hypothesis) is that the spatial patterns detected in the data are the result of random chance. The statistical tests detailed in this document are designed to evaluate the truth of that assumption and provide quantitative evidence for supporting or rejecting the assumption.

analysis may be performed as an initial step in investigating spatiotemporal changes in hazard occurrence. Additional analyses will be performed according to best practices outlined by Esri and those found in peer-reviewed literature.

Hot spot analysis

Hot spot analysis will identify statistically significant hot spots and cold spots given a set of weighted features. A minimum of 30 features are needed for reliable results. This analysis uses the Getis-Ord Gi* statistic to generate a z-score for statistical significance (See Getis & Ord, 1992 for the mathematics of the statistic).

The Optimized Hot Spot Analysis model available in ArcGIS Pro 2.4 will perform an initial data assessment to ensure there are sufficient features and adequate variation in the values to be analyzed (not binary data, for example). If records contain corrupt or missing geometry, or if an analysis field is specified and null values are present, the associated records will be listed as bad records and excluded from the analysis.

Data aggregation may be required depending on feature type. Polygon features can be run without additional aggregation when an analysis field is specified. Point features will be aggregated using a fishnet or hexagon polygon mesh (grid). Grid cell size will be the smallest possible while still providing the minimum number of features after aggregation (n = 30). This size will be determined by comparing the density of input features to the density of *N* random features based on the minimum bounding polygon to improve fidelity in the output. An appropriate bounding polygon will be used to delineate the fishnet/hexagon grid, most often based on the shape of the state, county, or region with ancillary features removed to ensure the most accurate polygon (e.g., removing open water when modeling wildfire). At times, it may be more appropriate to count incidents within aggregation polygons, such as Census tracts, when points are associated with administrative units. In such cases, the aggregation polygons will be used instead of a fishnet/hexagon grid.

Each feature will be used to create a neighborhood of features that will be compared to the entire study area to determine significant difference in values. Neighborhood boundaries will be based on a fixed distance band, usually. The appropriate distance band is not always immediately known, so experimentation may be required.

The model output is a new feature class with a z-score, p-value, and confidence level bin (Gi bin) for each feature in the input class. It also includes a field with the number of neighbors each feature included in its calculations. The Gi bin field identifies statistically significant hot and cold spots, corrected for multiple testing and spatial dependence using the False Discovery Rate correction method (Caldas de Castro & Singer, 2006). Levels of significance included in the output are 90%, 95%, and 99% and output features are colored using the standard symbology for their given z-score.

This method has been used to analyze the spatial patterns of seismic activity (Al-Ahmadi et al., 2014), inform flood risk assessments (Matheswaran et al., 2019), and identify clusters of vulnerable populations (Qiang, 2019).

Spatial regression modeling

The above section described methods for analyzing spatiotemporal patterns of natural hazard observations. Understanding where natural hazard conditions exist over time and space is helpful, but this alone does not examine and quantify relationships among natural hazards and their causes. Spatial regression modeling allows one to make predictions for unknown values or to better understand key factors influencing the variable being modeled. This capability can help answer the question of why natural hazards occur where they do.

The methods described in the following sections will be completed using ArcGIS Pro 2.4 (or newer as software updates become available).

Exploratory regression

Exploratory regression is a data mining technique that is a common first step in building a more robust regression model. This method evaluates all possible combinations of candidate explanatory variables to see which models pass all the necessary regression diagnostics for the next step, Ordinary Least Squares (OLS). The results of exploratory regression are not used for determining vulnerability.

Thresholds for adjusted R^2, coefficient p-values, variance inflation factors, Jarque-Bera p-values, and spatial autocorrelation p-values will be set before the run. The tool offers a default setting that will be used on initial runs and adjusted as needed in additional runs. A minimum and maximum number of explanatory variables can also be set. Depending on the thresholds chosen and the number of explanatory variables preferred, the exploratory regression may run hundreds or thousands of times. This number of runs can increase model error. Spatial autocorrelation is run automatically when the tool finds a model that exceeds the adjusted R^2 threshold. A passing model is one that meets all the default and/or specific threshold criteria and is considered a properly specified OLS model. Theory, common sense, previously published research, and subject matter expertise will be used to determine if the explanatory variables revealed as important by the exploratory regression exhibit logical relationships with the dependent variable.

It should be noted that exploratory regression is only used here as a data mining technique for hypothesis development. It is not used to find the "best" model or to find out what variables are the "best" predictors, but to provide information that will be used to understand the relationship between the variables and allow a specific hypothesis to be constructed and tested using other regression models. There is inherent risk in relying too heavily on exploratory regression when the output is an overfit model that may indeed meet all the OLS diagnostic criteria but does not actually capture the key processes attempting to be modeled. To help ensure this is not the case, candidate explanatory variables will be supported by other research and institutional knowledge, and thresholds for OLS diagnostics (e.g., adjusted R^2) will not be set unrealistically.

Ordinary least squares

Ordinary least squares (OLS) is a multivariate linear regression model used often to generate predictions or to model a dependent variable in terms of its relationships to a set of explanatory variables. OLS is a global model that creates a single regression equation to represent the process being modeled. As such, it is used here as an early step in our spatial analysis given the assumption that localization with the use of other models will improve our results. In these cases, OLS results will be used as diagnostics to determine improved performance of the following models (GWR and RF).

The null hypothesis for OLS and other regression models used for QNHVA is that the spatial data are randomly distributed over the Earth's surface. P-values will be used to assess whether the null hypothesis can be rejected. The alpha used for OLS is 0.05, so p-values < 0.05 allow for null hypothesis rejection.

Coefficients under the null hypothesis are 0 (i.e., the assumption that a given explanatory variable is not helping the model). When coefficient p-values are < 0.05 that assumption will be rejected. Statistically significant coefficients will be deemed important to the model if theory/common sense supports a valid relationship with the dependent variable, if the relationship being modeled is primarily linear, and if the variable is not redundant to any other explanatory variable in the model. Variables with variance inflation factors (VIF) higher than 7.5 will be considered redundant variables in the model due to collinearity. These variables will be removed one-by-one in future model runs until all remaining explanatory variables have a VIF < 7.5. Additional diagnostics for the OLS include a test for the normal distribution of residuals using the Jarque-Bera statistic (Jarque & Bera, 1980) and a test for spatial autocorrelation. If the Jarque-Bera p-value is < 0.05, the residuals are not normally distributed, and the model is likely mis-specified. Additional or improved explanatory variables will be found, and the model will be re-run. Spatial autocorrelation tests whether the spatial processes created the observed pattern of values are the result of random chance. If the results determine that there is autocorrelation present, this may not indicate a flawed model. The results of spatial autocorrelation should be weighed against theory/common sense.

The Koenker BP statistic will be used to determine whether the OLS's global regression equation should be rejected, meaning whether the explanatory variables in the model have a consistent relationship with the dependent variable in both geographic space and data space. The null hypothesis for the Koenker BP statistic is that explanatory variables behave the same everywhere in the study area and the processes being modeled are stationary. When $p < 0.05$, the processes are nonstationary, and the null hypothesis will be rejected. Such rejections will spur the use of geographically weighted regression (GWR).

Geographically weighted regression

When the Koenker BP statistic from the OLS is significant ($p < 0.05$), the same explanatory variables will be run using a geographically weighted regression (GWR) model. GWR differs from OLS by using a local model of the dependent variable by fitting a regression equation to every feature in the dataset versus one global regression equation. Each equation will be constructed based on the explanatory variables of the features falling within the neighborhood of each target feature.

Model type will depend on the data available. When the dependent variable can take on a wide range of values (e.g., temperature), a Gaussian model will be chosen. If the range of values can only be binary, a logistic model will be chosen. When values are discrete and represent number of occurrences (counts), a Poisson model will be chosen.

Neighborhood conceptualization will be based on what is supported theoretically and/or in published literature as well as the size of the study area. When QNHVAs are being completed at regional scales, neighborhood conceptualization will be scaled appropriately. In any case, because GWR is intended to explain the causes and contributing factors to natural hazard occurrences, features nearest the location of the occurrence will be weighted more heavily than those further away in most cases. Specific weights to neighborhood features will be assigned using one of the following:

- Gaussian method: Smooth incremental decrease in weights as distances increase but weights will never reach 0; useful when neighboring features become less important with distance, but that influence is always present regardless of distance
- Bisquare method[2]: Smooth incremental decrease in weights as distances increase, but weights for features outside the neighborhood specified are 0, indicating they have no impact on the target feature.

After the GWR is run, the results for adjusted R^2 and AICc[3] will be compared to those of the OLS to determine the level of improvement. If the processes being modeled truly are nonstationary, these two criteria should reflect improvements post-GWR. GWR will be considered more reliable than OLS if the adjusted R^2 is increased by any amount and if the AICc is decreased by at least 3 points.

Forest-based classification and regression

Forest-based classification and regression is based on a random forest machine learning algorithm that creates models and generates predictions. This prediction model can be used to predict unknown values in a dataset that has the same explanatory variables. This process will help identify where natural hazards are likely even when historical data are missing.

All random forest models must first be trained by constructing a model based on the explanatory variables discovered and tested in the OLS and GWR. Ten percent of the training data will be excluded from training for validation purposes (out-of-bag (OOB) samples). Validation is performed by the model itself by predicting the values for the OOB

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[2] Bisquare method will be less common for modeling earth and environmental systems, as faraway conditions can sometimes have an impact on natural hazard manifestation.
[3] This is a measure of model performance. A model with the lower AICc value provides a better fit to the observed data. AICc is useful for comparing models applied to the same dependent variable. Comparing GWR AICc to OLS AICc is a common way to evaluate the benefits of using a local model over a global one.

samples and comparing the predictions with the actual observations. When the model is valid, the entire dataset will be used for prediction. OOB scores will be computed as the percent of correctly predicted values from the OOB sample. The forest model will be trained on at least several hundred features.

Forest-based models will not be used for extrapolation. They will only be used for classifying or predicting values within the range of values used in training. The default number of trees will be 100, but this number will increase with the complexity of the relationships between explanatory variables, size of the dataset, and the variable to predict. The number of trees parameter will be increased at least 3 times up to 500 trees to evaluate model performance.

Presence-only prediction

Presence-only prediction models spatial phenomenon given known presence locations and explanatory variables using a maximum entropy approach (MaxEnt). The tool provides output features and rasters that include the probability of presence and can be applied to problems in which only presence is known and absence is not known, such as many natural hazards that are capable of occurring across varied landscapes. MaxEnt does not assume nor require absence. MaxEnt is a general-purpose method for making predictions or inferences from incomplete information (Phillips et al. 2006). Given a set of known presence locations and given explanatory variables that describe the study area, MaxEnt contrasts the conditions between presence locations and the study area to estimate a presence probability surface.

The study area defines a landscape where presence is possible and is often represented by a set of unknown presence locations. These locations are also known as background points, and the MaxEnt method uses them to contrast the conditions between presence locations and the study area to estimate a presence probability surface. For QNHVA, the study area should be a statewide polygon feature class that includes all possible locations while removing areas where the hazard is not possible (e.g., a statewide polygon with waterbodies removed to model wildfire occurrences).

While theoretically possible, this approach has not yet been tested for use in our hazard analyses.

Non-spatial QNHVA method

It is possible that not every natural hazard will have the data quality and quantity needed to perform the complex analyses and modeling described above. In such cases, more basic descriptive and inferential statistical methods will be used as a substitute.

Descriptive statistics (e.g., mean, median, standard deviation) will be determined using Excel or Python. When data quantity is sufficient, natural hazard attribute data will be exported into a .csv or .xlsx format and a simple (bivariate) linear regression model will be created in Excel or Python. At a minimum, the data needed for the simple linear regression are the number of occurrences organized by date (e.g., number of wildfires per year). With very large datasets, a sample dataset may be used (minimum n=30). The following formula will be used to determine n, if we are unable to use the full dataset:

$$n = \frac{(1.96)^2 \times \sigma(1-\sigma)}{(0.1)^2}$$

Future hazard occurrences can be projected when R^2 is decent (> 0.50) by using the regression equation to forecast and report. The projected number of occurrences will be reported as a range of possible values and assume that environmental conditions that may influence hazard occurrence are unchanging.

When a sufficient amount of data is unavailable to perform the descriptive and inferential statistics above, the following statement (or similar) may be used:

“There are not enough previous occurrences of this natural hazard to accurately calculate the probability of future occurrences or identify specific causes and vulnerabilities. As such, we believe it to be highly unlikely (< 10% chance) for an event to occur within the general assessment window of 25 years. We will reevaluate this assumption during the next comprehensive update to the SEHMP and/or if new data become available.”

III. Stakeholder Engagement and Mitigation Strategy Development

Given the diversity of natural hazards present in Washington and the significant differences in regional hazard exposure across the state to these hazards, as well regional cultural differences in risk tolerance, we propose using region-specific vulnerability assessments to make the 2023 SEHMP more readily usable for local jurisdictions and tribes. This approach has been used before by other states, such as Oregon and Virginia.

Upon review of the 2018 SEHMP, we believe that some of the inaccuracies in the risk assessment stemmed from the fact that county-level risk assessments were distilled from the statewide risk assessments for each natural hazard, which required some guesswork when downscaling state-level analysis to county-level where data may be lacking and local knowledge was not used. We believe assessment at a regional scale allows for greater specificity and reliability for virtually all the natural hazards present in a given region and removes many of the inaccuracies resulting from downscaling in 2018.

Although we were unable to employ local stakeholder engagement during the 2023 update, future hazard analyses will be expected to incorporate stakeholder engagement methods following a participatory action process adapted from Halbe et al., 2018. This process follows five-stages of participation. Table 35 outlines the proposed stage sequence and participation levels.

Local stakeholders will be engaged as part of each regional planning team to ensure inclusive participation in the vulnerability assessment process. This will include, at a minimum, invitations to county and tribal emergency managers, State agency staff with specific expertise in the region itself or natural hazard(s), and NGO representatives with a staked interest in mitigation. We view this as an opportunity to engage the local mitigation community and ensure their input informs future SEHMPs as much as possible.

Table 35. Stakeholder engagement methodology

Stage	Proposed method	Completed by:
1. Problem definition and stakeholder analysis	Problem definition will be based on the statewide QNHVA. Stakeholders will be identified based on regional expertise, and should include county-level, Tribal, and NGO representatives at a minimum. A list of stakeholders will be generated by EMD with input from the Hazard Mitigation Working Group (HMWG).	EMD, HMWG
2. Process design	Regional vulnerability assessments based on the state of knowledge derived from the QNHVA will be completed by the Strategist/Planner and presented to regional stakeholders. Social vulnerabilities will be based on CDC's SVI with regional stakeholders' input via individual and group modeling.	EMD, HMWG
3. Individual modeling	Individual interviews with regional stakeholders identified in Stage 1. Interviews will center around the results of the QNHVA and initial identification of potential economic, environmental, and social vulnerabilities.	EMD (interviewer), interviewees
4. Group model building	Similar to Stage 3, but with the entire stakeholder group at once. It will include a state-of-knowledge report for the entire region and key takeaways from Stage 3. This stage will conclude with a draft summary of vulnerability for the region.	EMD (facilitator), regional stakeholder groups
5. Institutionalized participatory modeling	An overview of completed regional assessments by the HMWG. Results will be used to inform revisions to the 2018 mitigation strategy and find mitigation actions with direct ties to the identified vulnerabilities. These should be technologically feasible, culturally appropriate, and provide a high degree of confidence in their risk-reduction potential.	EMD, regional stakeholders, HMWG

Appendix D: Annual Reports

The following includes Annual Reports from 2019, 2020, and 2021. The 2022 Annual Report was delayed because of the final drafting stage of this update.

Washington State Enhanced Hazard Mitigation Plan

Annual Report 2019

January 2020

Our first annual report

This year marked the first full calendar year after the most recent update to the Washington State Enhanced Hazard Mitigation Plan (SEHMP) was completed in October 2018 (click here to read it). Although the 2018 SEHMP is still in its infancy, the work to maintain it, implement its mitigation strategy, and improve upon our hazard identification and risk assessments is always ongoing and evolving. In 2019, we accomplished important statewide and local-level mitigation goals toward implementing the SEHMP's mitigation strategy, continued development of multiple tools for improved hazard vulnerability analysis, kept our thumb on the pulse of hazard research throughout Washington and the US, and even updated a portion of the SEHMP.

Inside this report

Mitigation activity in 2019

Our SEHMP has already been updated!

This year, EMD's Mitigation and Recovery team updated the SEHMP to include more information about the risk of dam failure in order to meet the eligibility requirements under the new Rehabilitation of High Hazard Potential Dams (HHPD) Grant Program (click here for more information). Among these eligibility requirements is a state-level hazard mitigation plan that includes all dam risks. Unfortunately, the 2018 SEHMP was written and approved before the official guidance was released. As a result, even though the 2018 SEHMP includes a chapter on dam failure hazards and risk, there were a few gaps in the SEHMP that needed to be filled.

We worked with the Dam Safety Office (within the Department of Ecology) throughout 2019 to gather and synthesize all that Washington State is doing to assess dam safety, monitor high hazard potential dams, rehabilitate and restore dams, and analyze the risk of dam failure. In November 2019, we submitted our revisions to FEMA for its review, which is expected to be complete sometime in early 2020. Once the revisions have been approved, we will publish the new 2018 SEHMP and conduct outreach across state and local partners to share the information. Once the new information is officially included in the SEHMP, counties can include dam failure considerations in hazard mitigation plans and become eligible for HHPD Grant Program funds.

Data collection and information gathering

Filling hazard gaps and improving communication

Ongoing data collection for use in the next comprehensive update to the SEHMP continued throughout 2019. We are constantly searching for the most rigorous and methodologically sound ways of determining hazard risk and vulnerability to ensure we have the most holistic assessment of statewide risk possible. As such, we began preliminary research into best management practices for the quantification or semi-quantification of hazard risk and vulnerability and the collection of data around natural hazards that may be included in future versions of the SEHMP. These include environmental toxicological hazards, extreme heat, and air quality.

In addition to filling gaps in hazard identification, we are also working to develop ways to improve the SEHMP as a communication and learning tool. Our hope is the SEHMP can be a top resource for the public, government agencies, researchers, and planners to learn about the various risks facing Washington and the state's goals for reducing those risks.

Natural hazard spatial data

We engaged with the Office of the Chief Information Officer (OCIO) and other State agencies on aggregating natural hazard-specific datasets for the Washington Geospatial Open Data website. EMD and other agencies went through spatial data and determined which are applicable to natural hazards and shared them with OCIO. They are now on the website for both public use and improved State agency use for natural hazard analysis. We see this as a big win for improving interagency coordination!

New lidar data from Department of Natural Resources

The Department of Natural Resources completed the Washington State Lidar Plan in 2019. Lidar (light detection and ranging) is topographic mapping technology using laser beams to produce three-dimensional elevations of the land surface. The result is high quality spatial data that can be used in numerous applications, not the least of which is better analysis of land surface changes that may manifest in natural hazards such as flooding, landslides, and erosion. For example, because lidar technology provides the ability to image the ground even through dense forest canopies, it can reveal changes in the land surface that may be hidden from traditional satellite imagery. A prime example of using bare-earth lidar models is found along the Cedar River (King County), where lidar revealed five landslides that could impact the flow of Cedar River and a better understanding of landslide potential in the area (Figure 1). Bare-earth models also allow closer study of river channel migration by seeing through the vegetation to sense the evidence of stream erosion. Knowing the evolution of stream channels can help us determine the full extent of floodplains and potential erosion risks. Lidar is also being used by Washington State geologists to map faults, to study volcanoes (e.g., lahar hazard zones and the extent of past lava flows), glaciers, and model tsunami inundation.

Figure 1. Landslides in the Cedar River valley revealed through lidar bare-earth models (Source: DNR, 2017)

Interagency coordination

Among our top goals of the 2018 SEHMP is to coordinate across multiple agencies for the purposes of improving communication around and implementation of risk reduction activity. A big part of that effort is accomplished via the Hazard Mitigation Working Group (HMWG). The HMWG met quarterly in 2019. Topics included:

- How we can improve coastal risk assessments through better modeling (e.g., bringing the CoSMoS model to WA)
- Updating the State's Geoportal with hazard-specific spatial data
- Lessons learned from the Regional Resiliency Assessment Program's assessment of Washington State transportation systems
- Improved understanding and assessment of wildfire smoke and its impact on public health
- Improved interagency coordination for statewide hazard identification and risk analysis
- Use of state agency subject matter expertise in local hazard mitigation plan review
- Updates on other hazard mitigation-related initiatives that can inform the SEHMP (e.g., the Disaster Resiliency Work Group facilitated by the Office of Insurance Commissioner)

In addition to the HMWG, we also worked with numerous other interagency groups in 2019. These included the Interagency Climate Adaptation Network, Coastal Hazards Resilience Network, Infrastructure Assistance Coordinating Council, and the Disaster Resiliency Work Group. Each of these groups (and others) are important vessels for hazard risk reduction and resilience, and we are happy to be contributing.

State-level mitigation projects

"Risk Portal"

We contracted in 2019 with the University of Washington's Institute for Hazard Mitigation Planning and Research to develop a "risk portal." The goal of this project is to improve the ability of local jurisdictions and other planners to conduct robust and reliable hazard risk assessments. The "risk portal" itself will be a web-based GIS application that virtually anyone can use to determine risk to various community assets under a range of scenarios. With the basic application built out, we are now working with the UW team to ensure GIS data used are accurate and as up-to-date as possible, as well as identifying areas for improvement and data gaps. The finished product is expected sometime in early 2020.

We are particularly excited about this work given its utility for anyone conducting hazard identification and determining the spatial extent of hazard exposure. In fact, we see it as aligning perfectly with the SEHMP goals of providing technical assistance to local jurisdictions, developing comprehensive assessments of hazard risk, and improving our own internal capacity for mitigating hazards.

Coastal erosion risk assessment

We also contracted with the Department of Ecology's Coastal Monitoring and Analysis Program (CMAP) this year to perform a coastal erosion risk assessment for the Outer Coast. Coastal erosion was identified as a significant natural hazard in the SEHMP for the first time in 2018, which also acknowledged a need for a comprehensive understanding of erosion risk. This project is intended to support the collection of data and analysis to determine risk from active changes in geomorphology in key areas, such as population centers. Although the CMAP research team experienced some difficulty in accomplishing their data collection goals in 2019, the project is still scheduled for completion in Spring 2020.

Tsunami Workgroup, Modeling, and Mapping

The Tsunami Workgroup held five meetings in 2019. These included two for the Outer Coast Tsunami Workgroup, two for the Inner Coast Tsunami Workgroup, and one joint meeting. The next joint meeting is planned for February 2020.

The Inner Coast group focused heavily this year on making inner coast stakeholders more aware of tsunami danger as an effort to improve mitigation activity there. We've seen some traction as a result, including the Port of Bellingham's ongoing development of a Maritime Response and Mitigation Strategy for the port and surrounding areas. We hope to target other inner coast ports for similar strategy development in future years.

The Tsunami Workgroup also worked with DNR's Washington Geological Survey, University of Washington, and the Pacific Marine Environmental Lab to conduct tsunami modeling and mapping this year. The team produced several great tsunami simulations for both statewide and localized scenarios, as well as tsunami hazard assessments for Island, Skagit, and south King County, published evacuation walk maps for Port Townsend, Ilwaco, Long Beach/Seaview, and Westport, and assisted Pacific County Fire District #1 with site selection for a proposed vertical evacuation structure.

Local-level mitigation projects

Pre-Disaster Mitigation Program in 2019

In 2019, we received 92 pre-applications for FEMA's Pre-Disaster Mitigation (PDM) grant program. These pre-applications are among the best information we have regarding local-level interest in implementing hazard mitigation projects across Washington. The 92 pre-applications come from every part of the state, from the Olympic Peninsula to the Cascades to the Palouse Prairie. The projects detailed in each of the pre-applications reflect a need by local governments to address the hazards of earthquakes, tsunamis, wildfires and floods, as well as updating county-level hazard mitigation plans. The estimated value of these proposed projects total more than $277 million, representing a significant need for mitigation funding opportunities across the state. In December 2019, we reviewed and evaluated the pre-applications to determine which will be invited to submit a full application. The full applications will be reviewed by the State for completeness and ability to compete nationally.

Hazard Mitigation Grant Program in 2019

This year saw fewer disaster declarations than others in recent memory, with only one declared disaster in March. The result was a relatively small HMGP round, but we were able to submit about $3.5 million in mitigation project proposals to FEMA. Additionally, no fire management assistance declarations were issued this year, so no HMGP-Post Fire funds were made available. However, we made steady progress on projects funded under previous years' declarations, some of which go back to 2015 or earlier.

More HMPs on the books

This year, one of our top priorities was to increase the number of FEMA-approved county-level hazard mitigation plans (HMP). For what may be the first time ever, all counties in the state now have either a FEMA-approved HMP or are currently working on one. Now a majority of Washington has done the hard work of identifying hazards, assessing risk, and developing mitigation strategies to reduce risk. The jurisdictions covered by these HMPs are (or will become) eligible for mitigations grants. This is great news, representing the forward-thinking nature of Washington jurisdictions and an understanding of the value of strategic mitigation planning. Congratulations, local partners!

Highlighted local projects

Douglas/Okanogan Fire District 15: Backup Generators

The Douglas/Okanogan County Fire District 15 installed backup generators at the Brewster EMS Station, Brewster Fire Station, Pateros Fire Station, Methow Fire Station and Rocky Butte Fire Station. These generators allow critical public facilities to fully function during emergency events. The generators also enable safe and efficient station operations during power outages, provide lights and power for station operations, the ability to rapidly fill water trucks, keep radio communication and equipment operational, and prevent freezing of water in fire trucks and EMS liquids.

City of Auburn: Seismic Retrofit

The City of Auburn installed a seismic control valve at its largest reservoir, preventing water from escaping the reservoir in case of an earthquake. The retrofit of Reservoir 1 ensures adequate water supply exists after an earthquake for both personal needs and continuous firefighting efforts. It benefits all retail customers served by the city with an estimated population of 56,000.

The Evergreen State College: Seismic Retrofit

The Evergreen State College, located in Olympia and serving nearly 4,000 students with 1,500 staff, completed a seismic retrofit of its Central Utility Plant to withstand a severe earthquake. This retrofit will reduce fatalities, prevent an uncontrolled boiler explosion, provide for continued operations, and avoid reconstruction. The College also took advantage of the construction project to provide teachable moments around disaster preparedness, increase campus understanding of the College's comprehensive emergency management plan, and promote disaster planning.

Thurston County: Home Elevations

Thurston County Emergency Management successfully elevated two homes this spring and fall in the Deschutes River floodplain. Both homes had suffered multiple instances of flood damage in recent years. Elevating these homes above the flood stage of the Deschutes River will ensure that potential future occurrences of flooding are prevented.

Graham Hill Mutual Water Company: Backup Generator

In unincorporated southeast Pierce County, Graham Hill Mutual Water Company serves approximately 1,100 residential customers, an elementary school, a recreational vehicle park and office, and a church. This project provided funding for emergency generators to provide uninterrupted water to the local community and school children as well as the adjacent 50 square miles of forested areas that has no other water supply for fighting fires. With these generators, Graham Hill Mutual Water Company has nearly full operability to provide water during loss of grid power from wildland-urban interface fires, as well as wind, snow, and ice storms and earthquakes.

Town of Skykomish: Critical Areas Survey and Geotechnical Analysis

Skykomish received a Phase I FEMA award to complete much-needed surveying, analysis, and project design for a stormwater infrastructure project that will reduce flood risk. The project will bring new diversion of stormwater to the South Fork Skykomish River floodplain and increase the stormwater storage capacity. After completion of Phase I, the Town will pursue funding for Phase II, which will include construction. Upon completion, the Town expects fewer instances of nuisance flooding, improved water quality, and improved longevity of stormwater infrastructure.

City of Seattle: Columbia Street Areaway

To counteract further settlement and potential collapse of the Columbia Street Areaway, the City of Seattle installed engineered fill beneath the road surface to provide structural support for the adjacent retaining wall. This brought the areaway up to seismic design standards.

Priorities for 2020

Looking toward 2023

In 2020, we plan to continue collecting data via our contracted efforts with University of Washington and the Coastal Monitoring and Analysis Program, the Hazard Mitigation Working Group, and in-house research to ensure the next comprehensive update to the SEHMP in 2023 is as robust as possible.

State- and local-level mitigation projects

Mitigation wise, we are focusing efforts on repetitive loss/severe repetitive loss properties in the state's floodplains and coastal areas by targeting these properties for acquisition or elevation through FEMA's Flood Mitigation Assistance grant program. We are also excited to see more interest at the local level in defensible spaces to protect from wildfire on both sides of the Cascades, especially given the results of the 2015 Blue Creek Fire loss avoidance study. Defensible space has proven to work, and we are seeing an increase in grant pre-applications from our local partners for wildfire mitigation. Furthermore, the recommendations from the Resilient Washington Subcabinet for improving seismic resilience are still a high priority for 2020, as they were for 2019.

We are also prioritizing the development of more GIS-based tools for hazard identification and risk analysis and ensuring all the data collected across state agencies is used to its full potential. This includes new data being collected, such as lidar and erosion risk, as well as data already in use.

Disaster Resiliency Work Group

Per SB 5106, which mandates the creation of a disaster resiliency work group, EMD is required to participate in this statewide effort to evaluate Washington's need for a disaster resiliency program of some kind. We are happy to be participating and will maintain this activity as a priority for 2020, seeing as how it has direct ties to the SEHMP and how it gets implemented. A final report from this group is due on December 1, 2020, so its conclusions will likely be a significant portion of next year's SEHMP Annual Report.

Stay tuned!

This report was developed by the Mitigation and Recovery Section of the Washington Emergency Management Division. For more information about the material presented in this report, please contact the State Mitigation Strategist, Kevin Zerbe, at kevin.zerbe@mil.wa.gov or (253) 512-7467.

Washington State Enhanced Hazard Mitigation Plan Annual Report 2020

February 2021

Floods, Pandemic, Civil Unrest, Wildfires

It's no question that 2020 will go down in history as a pivotal and important year in emergency management. In Washington, we had damaging floods early on, followed immediately by the COVID-19 pandemic that has kept EMD and all of its partner agencies in response mode every day since January 22, 2020. All of which was further complicated by early summer civil unrest and late summer wildfires. An extraordinary year, to be sure. In the midst of it all, though, the State of Washington continued its commitment to comprehensive and statewide hazard mitigation and to accomplishing the goals laid out in the State Enhanced Hazard Mitigation Plan.

Inside this report

Mitigation activity in 2020

Mitigation goes virtual

The many lessons of 2020 included some difficult realities for all of us, but it also provided the needed time to workshop new, 21st century ideas and explore modern ways of conducting business.

Working from home became the norm for many of us, which upended some of the ways we go about mitigating Washington's hazards. In-person meetings stopped, conferences moved online, and community meetings mostly ceased altogether. This meant no mitigation planning charettes or forums, no presentations to the public about a new plan being developed, cancelled stakeholder meetings. Many of us scrambled in the early days of 2020 to find new ways of connecting, and that challenge proved just how adaptable we all can be.

Incorporating teleconferencing, cloud sharing, and other web-based technology into our normal mitigation work may prove to be the key to engaging stakeholders that may have been hard to reach in the past, whether they be State partners, local jurisdictions, or tribes. It also may mean we reach the public more efficiently and engage more effectively. While in-person meetings and traditional ways of doing business will eventually return, it may be the case that 2020 served to forever modernize the hazard mitigation field by opening new pathways for improving mitigation plans and our ability to confront our risks.

Hazard Mitigation Work Group

The Hazard Mitigation Work Group (HMWG), Washington State's interagency mitigation stakeholder group, had to adapt to the COVID-19 safety measures like all of us. Although the HMWG typically meets quarterly, the first half of 2020 was dominated by the immediate response to the pandemic, with many of its members directly involved, so the HMWG met only twice this year.

However, those two meetings were better attended than any previous in-person meeting with both having 30+ attendees, and both meetings included members from State agencies that had not been engaged before. This may just be evidence that people are more likely to attend meetings from the comfort of their homes, but it also is a hopeful indication that teleconferencing technology may become a boost for risk reduction work, rather than a hindrance.

The "dashboard"

2020 will forever be the year that the term "dashboard" entered common parlance, from Johns Hopkins's COVID-19 dashboard being used around the world to local level versions being developed by nearly everyone. Dashboards and web-based GIS technology proved invaluable to the pandemic response, but these technologies have a mitigation purpose as well. EMD's Mitigation team developed a web-based GIS application for tracking plan statuses (see pg. 5). The Department of Ecology has created a similar map for tracking coastal resilience projects.

What we are ultimately seeing is the improved communication of important mitigation-related data to our stakeholders and the general public. We have moved on from only telling our mitigation stories through reports and presentations. Now we are equipped with what used to feel futuristic in our everyday routine. Exciting tools for data analysis, visualization, mapping, and communication are no longer out of reach for most of us.

We will all look back on 2020 as an important year, and that could include being a benchmark year in the evolution of hazard mitigation.

2020 HHPD grant round

Last year, we updated the 2018 State Enhanced Hazard Mitigation Plan to include more information about the risks posed by high hazard potential dams across the state. This update included data from the Department of Ecology's Dam Safety Office, showing the distribution of the State's highest risk dams: those that could impact 300 people or more in the event of a failure. Those results are summarized in Figure 1 below, which indicates which counties are most at-risk based on the number of high hazard potential dams within the county. You can read the full update to the Dam Failure Hazard Profile here.

Because the update was approved by FEMA in July 2020, Washington became eligible for grant funding under FEMA's Rehabilitation of High Hazard Potential Dam Grant Program, which just finished its first-ever application round. Washington received $260,322 federal funds to be matched by $140,174 local and State funds for a total grant of $400,496. The Dam Safety Office received letters of interest from 7 dam owners and plans to issue 4 pass-thru grants pending FEMA approval. One dam owner plans to remove the dam, one is conducting seismic and slope stability assessments, and two plan to upgrade their undersized spillways. The ultimate goal of this funding is to target the dams referenced in Figure 1 so those numbers (and our risk) start to decline.

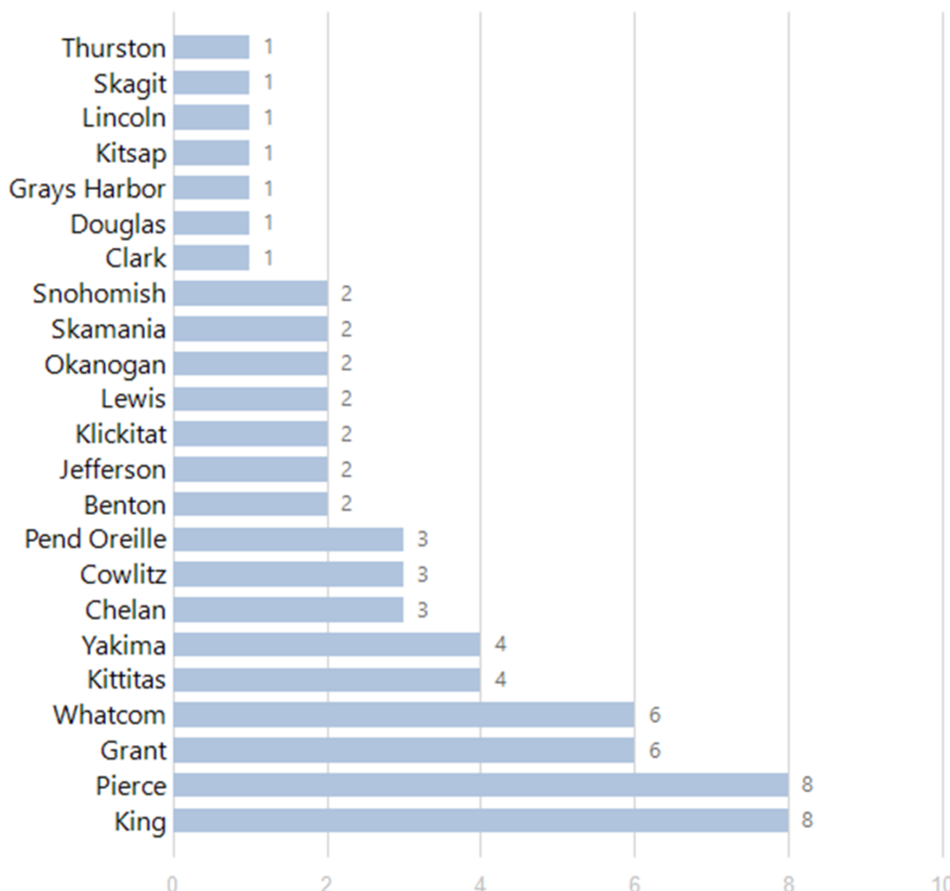

Figure 1. High hazard dams in Washington wherein dam failure would place more than 300 people at risk. This figure can be interpreted as a ranking of counties most vulnerable to dam failure.

Tsunami resilience updates

As one of the few states in the country exposed to earthquake-generated tsunami hazards, Washington capitalizes on every opportunity to improve our resilience to tsunamis and 2020 was no different. Here are some highlights:

- The Washington Department of Natural Resources published new inundation and current velocity simulations for Grays Harbor Bay and Willapa Bay
- EMD installed 22 new AHAB (all hazard alert broadcasting) tsunami sirens with State funding
- 500+ attendees for tsunami-related webinars (in lieu of the usual in-person Tsunami Roadshow)
- Distributed 120+ NOAA Weather Radios to local jurisdictions and the public
- Distributed 35+ tsunami wayfinding signs to local jurisdictions and are in the process of ordering more (including newly designed and workgroup-approved "entering tsunami hazard zone" and "leaving tsunami hazard zone" signs)

In 2021, our tsunami-related efforts will include completing the entire AHAB tsunami siren network, providing full-coverage for Washington's at-risk coastline as well as finishing the Pacific coast vertical evacuation shelter needs assessment.

UW mitigation courses

The University of Washington's Department of Urban Design and Planning (here) is training the next generation of hazard mitigation experts through its master's degree programs. Students learn about analyzing hazards geospatially, techniques for protecting critical infrastructure from natural hazards, various resilience concepts important for risk assessments and planning, the importance of land use in hazard mitigation, as well as other extremely important concepts needed to begin reducing our risks and vulnerabilities.

The University's Institute for Hazard Mitigation Planning and Research (here) is also hard at work finalizing the Washington Riskcape Atlas, which was mentioned in the 2019 Annual Report and includes work by a number graduate students at the Institute. Like many projects, COVID-19 has unfortunately delayed the public release of the new tool, which is currently under review at UW and EMD. Finalization and public release should happen in 2021.

Resilience Action Demonstration Project

The Washington Coast Resilience Action Demonstration (RAD) Project is an 18-month, NOAA-funded partnership between the Washington Coastal Zone Management Program and Washington Sea Grant showcasing the value of delivering multi-agency support to coastal communities developing fundable resilience projects.

In 2020, the RAD team developed an inventory of hazard impacts and needs across the Pacific coast. Initial outreach identified over 150 hazard resilience project ideas from Marine Resource Committees, tribes, emergency managers, ports, local governments, and others. RAD also conducted a study of existing state and federal funding program guidelines to shape a list of eligible community resilience project types, activities, characteristics, and intended outcomes.

The results of this study and outreach were used to develop a framework of guiding principles to help scope multi-benefit hazard resilience projects on the coast. By the end of 2021, the RAD project will result in 3-5 pilot resilience projects fully scoped and submitted for grant funding to support implementation. The RAD team will also continue to work with the Hazard Mitigation Working Group, Coastal Hazards Resilience Network, and Washington Coast Marine Advisory Council to inform the development of a project planning pipeline to align coastal communities with competitive grant programs and provide them with coordinated agency assistance to continue scoping resilient hazard mitigation projects.

State grant programs and planning

BRIC 2020

For our first-ever Building Resilient Infrastructure and Communities (BRIC) grant round we received more than 200 pre-applications from around the state, totaling more than $190 million in potential mitigation projects. Unfortunately, many of these projects were developed as “capacity and capability building” projects, a project type that was not given the level of funding from FEMA that many of us expected. As a result, EMD and our partners are putting our heads together to plan more strategically for future BRIC rounds, knowing that funding for C&CB projects may be limited. Regardless, the 2020 BRIC round included some very strong applications, including ones that we feel will expand the scope of what hazard mitigation can accomplish. We will be excited to discuss these in the 2021 Annual Report once funding awards are announced!

Hazard Mitigation Grant Program in 2020

Our first disaster event (severe storms/flooding) occurred on January 20 with its declaration (DR-4539) on April 23. The HMGP round for DR-4359 opened for applications on June 19 and we received 44 pre-applications and submitted 28 final applications in total. We also had a very active fire season, with ten FMAG declarations, triggering an HMGP-Post Fire round that opened on October 21. Total combined funding from both HMGP rounds in 2020 was more than $10 million.

Hazard Mitigation Plan Status Map

We are thrilled to report that we continued progress through 2020 toward our goal of all 39 counties with approved hazard mitigation plans (HMPs). Clallam, Douglas, King, Kitsap, Klickitat, Pierce, Skagit, Snohomish, Spokane, and Whitman Counties all completed their plan updates in 2020. This is a major accomplishment, especially considering so much time that would have been toward HMPs was dedicated to COVID-19 response. Big kudos to our local partners who were able to juggle both! To help us keep track of HMP statuses around the state, we developed a web-based GIS map that is now available to local and State partners, as well as the public (Figure 2). The map is updated regularly as statuses change.

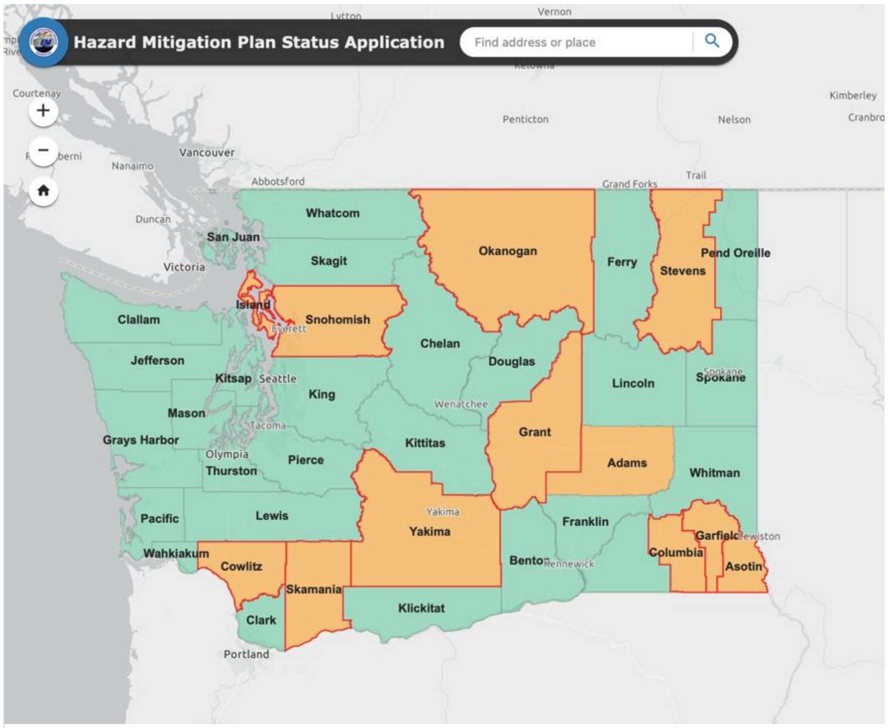

Figure 2. Screenshot of the HMP Status Map. Green is for approved plans, orange is for plans in-progress, and red outline is for expired plans. Current as of January 2021.

Local mitigation activity

City of Newcastle: Railroad Embankment Project

The Newcastle Railroad Embankment was constructed as part of the railroad line which transported coal from Newcastle to Seattle during the 19th and early 20th centuries. The embankment is 55 feet tall and 150 feet long. A vertical pipe, called a standpipe, was attached to the upstream end of the culvert traveling under the embankment to create a small pond. However, that standpipe is no longer functioning properly, and the pond level is increasing, creating a high hazard potential dam. Phase 1 of the project will remove the failing standpipe and install a new standpipe at the same location. Phase 2 of the project will remove the standpipe and culvert to restore free flow and fish passage to Newport Hills Creek.

King County: Hazard Mitigation Plan Update

King County received approval of its 2020 Regional Hazard Mitigation Plan in October. The plan covers the county along with 45 cities and special purpose districts. For the 2020 update, the County focused on the development of comprehensive mitigation strategies, a new method of prioritizing strategies, and the incorporation of equity and social justice principles into the plan. The result has been a plan recognized by FEMA at the national level for how to incorporate equity through the prioritization of mitigation funding and alignment of its plan strategies with the County's Determinants of Equity.

Chelan County Natural Resources Department: Mobile Mapping Database

This project was awarded in November 2019 and is currently being implemented. The purpose of this project is to develop a wildfire risk and hazard database of the Wildland -Urban Interface (WUI) via site assessments. The purpose of conducting assessments will be to gather WUI structure triage and wildfire risk and hazard data. The information collected will then be used for pre-fire planning, emergency response, and targeted mitigation and education efforts within the County.

Chelan County Natural Resources Department: Fuels Reduction in Chumstick Canyon

This project was awarded in August 2020. The purpose of this project will be to reduce the wildfire risk and improve overall public safety within Chumstick Canyon by reducing, approximately 10 linear miles, of fuels along the County road Right-of-Way (ROW). Reducing and manipulating fuel loads within the ROW will reduce the risk of roadside ignitions, improve visibility for ingress and egress routes and reduce the rate of fire spread in the area. All users of Chumstick Highway will benefit from improved visibility and clearly defined ingress/egress routes.

Foster Creek Conservation District: Douglas County Defensible Spaces Project

This project was awarded in January 2020 and is currently being implemented. The purpose of this project is to bring awareness, knowledge, and skills about creating defensible spaces to 40 landowners and 360 school-aged youth in the sagebrush shrub-steppe environment of Douglas County. It will achieve these goals by a creating comprehensive set of informational materials for landowners and school-aged youth, by training FCCD staff and staff from other agencies in the use of the materials, by disseminating informational materials through workshops, social media, on the internet, by working with landowners in Douglas County to create defensible spaces tailored to a high desert environment, and by providing technical assistance to landowners.

Priorities for 2021

2023 SEHMP Update

This year we developed a grant proposal to fund the next comprehensive update of the SEHMP under the HMGP round for DR-4539. This will be submitted along with the other applications we received in March 2021, but we will not wait for the award to get started. We are currently testing new spatial analysis approaches for risk assessment and are starting to see some exciting results we hope to include in 2021's Annual Report.

Flood mitigation and FMA funds

In the 2019 Annual Report, we mentioned that repetitive loss/severe repetitive loss properties in the state's floodplains will be a priority for us this year, so this year we developed a strategy for how to be more strategic in addressing RL/SRL properties, including how to make better use of the FMA program. This strategy includes using a geospatial approach to determine our highest-risk flood areas, though we are still in the early stages and hope to have more detail in 2021.

Disaster Resiliency Work Group takeaways

The Disaster Resiliency Work Group officially ended in November 2020 and submitted its recommendations to the Legislature for developing an ongoing state resiliency program that would involve some of the following activities:

- Develop a state resiliency strategy
- Coordinate and research funding for resiliency
- Conduct policy research and make recommendations
- Collaborate and educate others

Such a program would be instrumental in achieving our disaster mitigation and resilience goals and work continues in 2021 to make this a reality.

This report was developed by the Mitigation and Recovery Section of the Washington Emergency Management Division. For more information about the material presented in this report, please contact the State Mitigation Strategist, Kevin Zerbe, at kevin.zerbe@mil.wa.gov or (253)370-5432. Front cover photo: "Palouse Falls," by Taffy Raphael

Washington State
Enhanced Hazard Mitigation Plan

Annual Report 2021

February 2022

Climate Impacts at the Forefront

This year, we made new progress in updating the State Enhanced Hazard Mitigation Plan (SEHMP) before its expiration date in September 2023. Washington also made great, strategic use of the multiple hazard mitigation funding opportunities that came into our state. This year also saw the impacts of climate change at the forefront of our mitigation work all year long, with multiple interagency efforts to address climate resilience and dedicated funding to mitigate the impacts of climate-related hazards.

Inside this report

Mitigation in 2021

Progress on the SEHMP update

Like local hazard mitigation plans, our state plan is due for a comprehensive update every five years. Our next expiration date comes in September of 2023. We reported on the grant application we were developing to fund the update in the 2020 Annual Report, and this year we submitted that application under the Hazard Mitigation Grant Program (HMGP) round for DR-4539 with an estimated budget of $376,000. These funds will be used to bring the update entirely in-house, giving the state additional oversight of the planning process, risk and vulnerability assessment, and mitigation strategy development. These funds will also be used to increase local-level engagement during the update, with plans to engage directly with local emergency managers, mitigation practitioners, academia, tribal governments and nonprofits involved in hazard mitigation. We will also be developing a website dedicated to the SEHMP with interactive features, information about hazard risks and vulnerabilities around the state, and an ability to engage with us about the plan itself.

Efforts toward the 2023 SEHMP this year included a lot of data collection and organization, particularly geospatial data for use in our GIS-based approach to hazard analysis we're pursuing this time around. We also spent a considerable amount of time ensuring our spatial analysis methods are valid and appropriate. We tested our approach using wildfire location data (thanks to DNR's excellent dataset available here) and have already received some illuminating results about the ways wildfire risk may be changing over time. Members of EMD's Mitigation & Recovery section are set to publish these results in an upcoming issue of the *International Journal for Disaster Risk Science*. They will also be included in the 2023 SEHMP.

Our hazard analysis approach for 2023 consists of four phases:

1. Hazard characterization: Where did hazards occur? Have occurrence locations changed over time? Are there any hazard "hot spots"?
2. Identification of hazard causes: Why are hot spots located where they are?
3. Prediction of future occurrences: What do current hot spots tell us about where disasters might occur in the future?
4. Social and structural vulnerability: Are vulnerable people and assets located in hazard-prone areas? What makes them susceptible to disaster impacts?

Interagency coordination

We continued implementing the 2018 SEHMP's Mitigation Strategy, primarily through active and strategic interagency coordination to identify state-level mitigation projects and funding opportunities, which is directly related to Goal 1 in the 2018 SEHMP. Statewide efforts toward mitigation this year included regular gatherings of the Hazard Mitigation Working Group, Interagency Climate Adaptation Network, Washington Silver Jackets, and two climate change proviso task forces coordinated by the state's Department of Commerce and Office of Financial Management. These climate change task forces will result in improved guidance on addressing climate-related natural hazards in local comprehensive plans as well as recommendations to the Legislature for funding climate resilience efforts around the state.

Other tangible projects include the Office of the Chief Information Officer's development of a natural hazards-specific data portal (more below), and WA Sea Grant's nearing completion of its study into parcel-scale sea level rise vulnerability.

2021 Hazard Mitigation Assistance grant rounds

Building Resilient Infrastructure and Communities

This year saw millions of dollars come into the state for hazard mitigation. Among the most significant accomplishments is Washington's great success in the national competition for FEMA's 2020 Building Resilient Infrastructure and Communities (BRIC) grant round. We received news in early 2021 that Washington secured more than $61 million worth of federal funding in the 2020 BRIC round – first in the nation for per capita mitigation dollars and second in total dollars awarded. The bulk of that funding will go toward two vital disaster resilience efforts on our Pacific coast: a vertical evacuation structure in Westport and the construction of the North Shore Levee in Hoquiam. Also receiving funding is a flood mitigation project for the Kittitas County Waste Transfer Station.

The 2021 BRIC round opened on August 10, with full applications due to EMD for review on November 8. Of the 104 pre-applications we received, 11 were invited to apply, totaling more than $130 million of mitigation projects. With submission of those applications due to FEMA in early 2022, we hope to report further BRIC successes in the next Annual Report.

Hazard Mitigation Grant Program

Washington received two storm-related disaster declarations in March and April, triggering two HMGP rounds that were managed concurrently – DRs 4584 and 4593, worth an estimated $10 million. The state also had 8 Fire Management Assistance Grants (FMAGs) because of wildfires this summer, which triggered an HMGP Post Fire round worth $8.3 million.

In September, the Biden administration announced all 50 states will receive an HMGP round for the COVID-19 disaster (DR-4481). For Washington, this means an influx of $100 million of mitigation funds. In its announcement, the White House included a request for states to apply most of these funds to climate-related natural hazards and social vulnerabilities (more on that here), and we intend to do just that. EMD's Mitigation section held multiple ad hoc meetings with state agency representatives from the Departments of Ecology, Natural Resources, Commerce, Health, Transportation, WA Sea Grant and University of Washington regarding climate-hazard mitigation projects, goals and ideas. We also engaged directly with local governments via webinars about the opportunity. Pre-applications were due on November 30, and we received 140 from state and local agencies, totaling an astounding $1.4 billion in climate-related mitigation projects. EMD invited 60 to submit full applications, worth an estimated $725 million, reflecting just how competitive this round will be. We hope to report on successful project awards in next year's Annual Report.

Washington State Conservation Commission sponsors fire resilience trainings

The Washington State Conservation Commission sponsored several fire preparedness and resilience trainings during 2021 with the goal of providing robust and diverse training opportunities for professionals working in the field of wildfire preparedness and recovery. The Commission sponsored seven of the National Fire Protection Association's "Assessing Structure Ignition Potential from Wildfire Trainings" (ASIP) with attendance focused on various geographic regions of the state. More than 150 attendees participated in these ASIP trainings overall, and the trainings were taught by the National Fire Protection Association. The Commission also sponsored a Post-Fire Risk Mitigation and Assessment Training titled "World of Wildfire". This training was developed and delivered by the Okanogan Conservation District with 36 individuals attending. The final training sponsored by the Commission this year was titled "Outreach Strategies for Community Wildfire Preparation and Recovery". This training was developed and delivered by Conservation Commission and Lincoln County Conservation District staff and had 22 individuals in attendance. These trainings were attended by staff from conservation districts, state agencies, federal agencies, tribes, fire districts, local governments and non-governmental organizations.

Port of Bellingham's Tsunami Maritime Response and Mitigation Strategy

EMD's Hazards and Outreach team completed the first Tsunami Maritime Response and Mitigation Strategy (TMRMS) in the state for the Port of Bellingham this year. The Port of Bellingham TMRMS was built upon established maritime guidance from the National Tsunami Hazard Mitigation Program (NTHMP) that has been used to create maritime strategies in California, Oregon and Alaska. EMD expanded these existing strategies to create a maritime strategy that is not only tailored to the Washington coast's unique tsunami threat, but also includes detailed, actionable recommendations for both tsunami response and mitigation and site-specific tsunami mapping.

The strategy includes specific mitigation and response actions that the port can take to improve tsunami resilience. Port-specific tsunami inundation and current velocity modeling was completed by the University of Washington and the WA Sea Grant. The Washington Geological Survey (WGS) produced a suite of maps and graphics for the project including a modeled minimum water depth map, a first for the inner coast of Washington. These response and mitigation actions can help save lives, make the port more resilient and reduce the time it takes for the port to recover.

Pacific Coast Vertical Evacuation Gap Assessment Completed

EMD's Hazard and Outreach team, in partnership with UW's Institute for Hazard Mitigation Planning and Research, completed an assessment of vertical evacuation structure (VES) needs for the state's three most vulnerable Pacific coast counties (Pacific, Grays Harbor and Clallam). The team used their findings, combined with the 2010 Project SafeHaven reports, to develop four vertical evacuation options for each study location. Each community option was accompanied by maps showing proposed VES locations and minutes to high ground, satellite or street view photos of the proposed locations, the number of people within a 15–25-minute walk to high ground and charts comparing this data for all four options in an easily readable format.

Now that this assessment has been completed, Washington has a much more accurate idea of how many VESs it will take to ensure the most vulnerable communities on the Pacific coast can quickly evacuate in the event of a Cascadia tsunami. Now the real work begins at the local level – designing, planning and funding each VES project to transform the assessment's findings from wish list to reality.

Tsunami inundation and current velocity maps published by WGS

WA Geological Survey (WGS) released new tsunami modeling results from a large magnitude 9.0 Cascadia subduction zone megathrust earthquake scenario for the Puget Sound and adjacent waters. The results include 16 supplemental map sheets showing maximum tsunami inundation, estimated first wave arrival times, and current speeds for locations extending from the Washington—Canada Border to the southern extent of the Puget Sound. These are the first published tsunami hazard maps for many areas within the Puget Sound region using a Cascadia subduction zone scenario. The intent of the modeling is to encourage hazard planning and increase community resilience in Puget Sound and its adjacent waterways. The WGS recommends using this modeling as a tool to assist with emergency preparation and evacuation planning prior to a Cascadia subduction zone event.

Summary of findings

According to the WGS, the first tsunami waves generated by the offshore earthquake in the Pacific Ocean would travel through the Strait of Juan de Fuca and reach Whidbey Island within 90 minutes, causing large waves to travel north into the Strait of Georgia and south into the Puget Sound. The tsunami would arrive within 2–4 hours after the earthquake for most locations in Puget Sound (and the first wave may not necessarily be the largest). Some locations would experience inundation depths greater than 10 feet, and some waterways would experience destructive current speeds more than nine knots. Tsunami wave activity would likely continue more than 14 hours and remain hazardous to maritime operations for more than 24 hours.

Natural Hazards Data Portal project

The Office of the Chief Information Officer (OCIO) was tasked by the Legislature to develop a common data sharing platform for public organizations in Washington to host and share sensitive natural hazards mitigation geospatial data to assist with state hazard risk and resilience mapping/analysis. A secure common platform will provide sensitive (category 2 and 3) natural hazard mitigation data in standardized and compatible formats for use by the organizations and protect sensitive data needed for risk analyses.

Currently, there is no common platform for state, local and higher-education organizations to share existing state geospatial data on natural hazards risks. A lack of data in standardized and compatible formats results in organizations maintaining individual sets of data, creating redundant processes and leads to inconsistencies in how data is reported.

This project will provide consistent natural hazards data needed to map and analyze natural hazard risks and vulnerabilities around the state more accurately and improve information sharing and interagency coordination. The Legislature has identified $724,000 in funding to create this common platform and established an expectation for the data platform to be available by June 30, 2023. Work on the project began in July 2021. To find out more about the project, contact State GIS Coordinator Joanne Markert (joanne.markert@ocio.wa.gov) or GIS Data Administrator Kirk Davis (kirk.davis@ocio.wa.gov).

Local mitigation activity in 2021

Local hazard mitigation planning
Local mitigation planning continued across Washington in 2021, maintaining our track record of statewide participation in mitigation planning. Multiple counties, representing dozens of cities, towns and special purpose districts, received FEMA approval for their mitigation plans – including Asotin, Snohomish, Stevens and Whatcom Counties. Others made excellent progress toward completing their plan updates, including Cowlitz, Okanogan, Pacific, Skamania and Thurston Counties. Each of these plans are expected to be finished in 2022.

City of Westport vertical evacuation structure
Westport's vertical evacuation structure (VES) was mentioned above as one of the successful projects from BRIC 2020. Part of what led to its success in the national competition was the leveraging of an "advance assistance" Pre-Disaster Mitigation grant from 2018, which the city used for the engineering design and benefit cost analysis in the successful BRIC project. It's a great example of the benefits of advance assistance grants.

Jefferson County Snow Creek Road culvert upsizing
This project was awarded in March and is currently being implemented using HMGP funds. The purpose of the project is to replace an undersized culvert that has been repeatedly blocked with debris, threatening to wash out 14,000 cubic yards above Lake Leland and a private residence. The upsizing of the culvert will reduce a significant hazard to the public, private property and the environment.

King County Raging River property buyout
This project was awarded in February and is funded under HMGP DR-4539. The goal of the project is to acquire a particularly hazardous parcel, which became a landslide hazard after a 2020 flood on the Raging River eroded portions of the bank. The project will remove the residential structure now precariously close to the bank's edge and revegetate the space with native plants.

Priorities for 2022

2023 SEHMP Update

In 2022, the deadline for the 2023 SEHMP update looms larger than ever. With the grant award in hand, our priorities for this year are to focus heavily on updating the risk and vulnerability assessment (also called our Hazard Inventory and Vulnerability Assessment) as well as the mitigation strategy via the Hazard Mitigation Working Group.

Efficient, strategic use of HMA funds

With the massive influx of HMA funding coming into the state, and with no indication of fewer disasters occurring in our future, it has become more important than ever to make sure Washington is capitalizing on every opportunity to strategically reduce our hazard risks and protect our critical assets and people. Although the updated SEHMP will be a vital component of this more efficient use of HMA funding, we are not waiting until 2023 to get started. In 2022, EMD's Mitigation team will work to institutionalize mitigation-mindedness across EMD's programs and state agencies. Through ongoing conversations with our statewide partners, we can be more ready than ever to leverage our mitigation dollars and make a serious dent in reducing our hazard risks and vulnerabilities.

Flood risk reduction

Storms in late 2021 and early 2022 led to multiple flooding disasters that included several cascading impacts, such as stream channel migration, mudslides, and erosion. These events reiterated that flooding is one of the most prevalent natural hazards in Washington and deserves our attention. In 2022, we'll be prioritizing flood risk reduction in our grant rounds and in our update to the SEHMP.

This report was developed by the Mitigation & Recovery Section of the Washington Emergency Management Division. For more information about the material presented in this report, please contact the State Mitigation Strategist, Kevin Zerbe, at kevin.zerbe@mil.wa.gov or (253) 370-5432.

Appendix E: Adoption and Approval

The following appendix includes the letter that serves as the State's official adoption resolution for the 2023 SEHMP as well as a copy of the approval letter from FEMA Region 10.

STATE OF WASHINGTON
MILITARY DEPARTMENT
Camp Murray • Tacoma, Washington 98430-5000

September 12, 2023

TO: Directors of State Agencies, Boards, Commissions and Councils, and Presidents of State Colleges and Universities

FROM: Bret D. Daugherty, Major General
The Adjutant General

SUBJECT: Letter of Approval and Adoption for the 2023 Washington State Enhanced Hazard Mitigation Plan

With this notice, the 2023 Washington State Enhanced Hazard Mitigation Plan (SEHMP) is hereby approved and adopted. This formal adoption of the 2023 SEHMP keeps the state qualified to obtain federal funds for eligible mitigation activities through grants, available through the Robert T. Stafford Disaster Relief and Emergency Assistance Act, P.L. 93-288, as amended. We have requested the Federal Emergency Management Agency (FEMA) issue the official effective date for this plan as October 1, 2023. This plan is valid for five years from the effective date, with an expiration date of September 30, 2028.

The SEHMP is the result of a collaborative process involving state agencies, a multi-disciplinary Hazard Mitigation Working Group, staff from the Washington Military Department's Emergency Management Division, and various state and federal hazard experts. The SEHMP provides the framework for reducing the state's vulnerability to natural hazards. It contains an analysis of the state's natural hazards, assessment of risks and vulnerabilities, an inventory of state risk-reduction capabilities, and a concept of operations for the plan's implementation. It identifies goals, objectives, and strategies of state government to reduce risk and prevent injury and damage caused by natural hazards events.

Attachments (2)
(1) FEMA Region 10, Approval Pending Adoption Memo (17 Aug 2023)
(2) Washington State Enhanced Mitigation Plan

U.S. Department of Homeland Security
FEMA Region 10
130 228th Street, SW
Bothell, WA 98021-8627

FEMA

September 22, 2023

Robert Ezelle, Director
Washington Military Department
Emergency Management Division
20 Aviation Dr.
Building 20, MS TA-20
Camp Murray, Washington 98430-5122

Reference: Approval of the Washington State Enhanced Mitigation Plan

Dear Mr. Ezelle:

The United States Department of Homeland Security, Federal Emergency Management Agency (FEMA) Region 10 Mitigation Division, Risk Analysis Branch, has approved the updated Washington State Enhanced Mitigation Plan effective October 1, 2023, through September 30, 2028. This plan is approved in accordance with applicable mitigation planning regulations and policy requirements[1].

An approved mitigation plan is a condition of receiving certain FEMA non-emergency assistance and mitigation grants from the following programs:

- Public Assistance Categories C-G (PA C-G)
- Fire Management Assistance Grants (FMAG)
- Hazard Mitigation Grant Program (HMGP)
- Hazard Mitigation Grant Program – Post Fire (HMGP – Post Fire)
- Building Resilient Infrastructure and Communities (BRIC)
- Flood Mitigation Assistance (FMA)
- Rehabilitation of High Hazard Potential Dams Program (HHPD)

Approval of a mitigation plan does not guarantee funding under any FEMA program. Please refer to the individual FEMA non-emergency assistance and mitigation grant program policy and/or annual Notice of Funding Opportunity for specific application and eligibility requirements for the FEMA programs listed above.

[1] Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), as amended; the National Flood Insurance Act of 1968, as amended; Title 44 Code of Federal Regulations (CFR) Part 201; and the "Water Infrastructure Improvements for the Nation Act," or the "WIIN Act," on December 16, 2016, which amends the National Dam Safety Program Act (Pub. L. 92-367).

State mitigation plans must be updated and resubmitted to the FEMA Region 10 Mitigation Division, Risk Analysis Branch for approval. If the plan is not updated by the date indicated on this FEMA approval letter, the plan is considered lapsed, and FEMA will not obligate funds until the mitigation plan is approved. If at any time over the plan approval period, FEMA determines that the state is not complying with all applicable federal statutes and regulations in effect during the periods for which it receives funding or is unable to fulfill mitigation commitments, FEMA may take action to correct the noncompliance (44 CFR §§ 201.3[b][5] and 201.4[c][7]).

FEMA recognizes the state for the additional effort and commitment to mitigation. Under Section 322 (42 U.S.C. 5165(e)), additional Hazard Mitigation Grant Program funds of up to 20 percent of the total estimated eligible disaster assistance may be provided to states with enhanced hazard mitigation plans. The "Enhanced" designation is recognition for states that are leaders in implementing a comprehensive statewide hazard mitigation program that results in safer, more sustainable communities.

The state is responsible for communicating with local and tribal officials, as applicable, who are interested in applying for FEMA assistance through the state. FEMA encourages states to communicate with the appropriate officials regarding mitigation plan status and eligibility requirements. At a minimum of every six months, FEMA will provide to the state written information on mitigation plans, including, but not limited to:

- Local and tribal, as applicable, mitigation plan expiration dates.
- Consequences of not having an approved local or tribal, as applicable, mitigation plan with respect to eligibility for FEMA mitigation grant programs.
- Availability of mitigation planning training and technical assistance.
- Upcoming funding opportunities.

The state is responsible for reviewing and submitting approvable state and local mitigation plans to FEMA. If the state is not submitting approvable mitigation plans, FEMA will provide feedback as well as technical assistance or training to the state and local governments, as needed.

In addition, FEMA will provide a reminder at least 12 months before the plan expiration date of the consequences of not having an approved mitigation plan, which is required to apply for and receive funding for FEMA non-emergency assistance and mitigation grant programs. To continue to apply for and receive funding from the programs listed on page one, the state must submit a draft of the next plan update before the end of the approval period and allow sufficient time for the review and approval process. This includes any revisions, if needed, and formal adoption by the state following the determination by FEMA that the plan has achieved a status of "Approvable Pending Adoption."

We look forward to working with you to discuss the status of the state mitigation program each year over the approval period. If we can be of assistance, please contact Erin Cooper, Regional Mitigation Planning Program Manager, at 202- 856-1927 or erin.cooper@fema.dhs.gov with any questions.

Sincerely,

Digitally signed by WILLIE G NUNN
Date: 2023.09.22 15:59:47 -07'00'

Willie G. Nunn
Regional Administrator

cc: Stacey McClain, Washington Emergency Management Division
Tim Cook, Washington Emergency Management Division

Enclosures

EC:vl