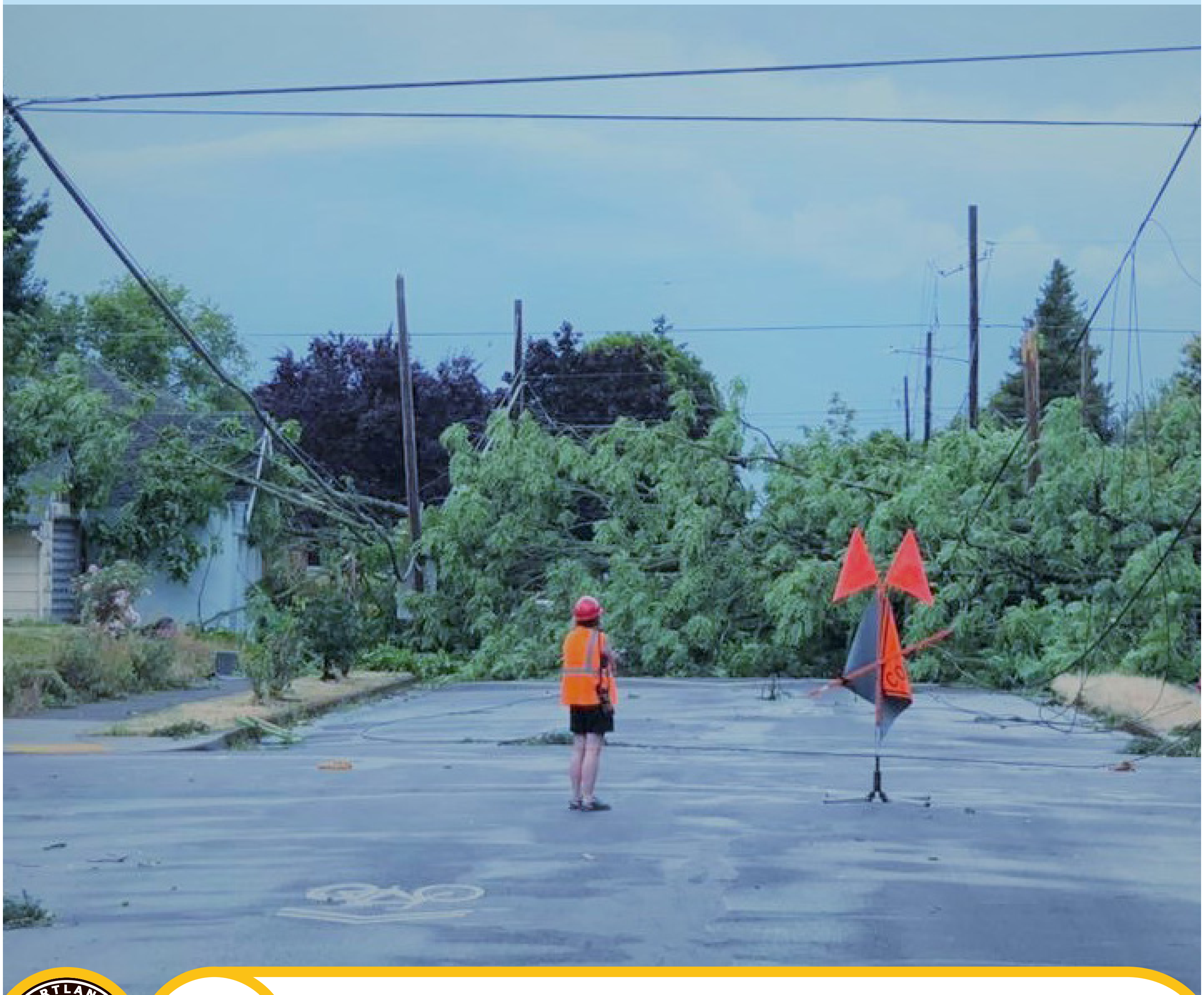
The Mitigation Action Plan

The City of Portland's 2021 Natural Hazard Mitigation Plan Update



PORTLAND BUREAU OF EMERGENCY MANAGEMENT

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The City of Portland's 2021 Natural Hazard Mitigation Plan Update

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Prepared for

City of Portland Bureau of Emergency Management
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Portland , Oregon 97266

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Contents

Mitigation Action Plan Introduction

What is a Natural Hazard Mitigation plan?

"Natural hazard mitigation" means sustained action taken ahead of a disaster to reduce the risk and harmful impacts of geological (land-based), meteorological (weather-based), or hydrological (water-based) hazards. In emergency management, 'preparedness' and 'mitigation' are strategies used to reduce the impacts of natural hazards. Mitigation means protections put in place ahead of the event to reduce harm, while preparedness focuses on being ready to respond.

Mitigation projects fall into the following categories:

- Planning and regulations
- Structural and infrastructure projects to make the built environment more resilient
- Natural systems protections that minimize harm to people and the built environment and restore the functions of natural systems
- Education and awareness programs that inform the public about natural hazards and ways to mitigate their impacts

The federal Disaster Mitigation Act (DMA) of 2000 requires state and local governments to develop hazard mitigation plans as a condition for Federal disaster grant assistance. The City's Mitigation Action Plan (MAP) fulfills the requirement for a local Natural Hazard Mitigation Plan (NHMP) and meets certain requirements for the City of Portland's participation in the Federal Emergency Management Agency's (FEMA) Community Rating System (CRS). The plan describes the natural hazards that pose a risk to the City of Portland and outlines the steps the City of Portland is taking to mitigate the harmful impacts of those hazards.

The MAP brings together mitigation work being done across the City. City of Portland bureaus manage infrastructure, plan for long-term capital improvement and community-level investments, and administer a wide variety of programs. These activities play a role in the City's resilience to natural hazards. There are many things that bureaus can do now as part of their normal activities—or things that bureaus can add to their portfolios when opportunities arise—to reduce Portland's risk from natural hazards and improve the City's ability to recover when incidents happen. While these projects and programs are represented in many other City documents, the MAP is the coordinating plan that brings together these efforts.

Emergency Management Definitions

Mitigation: Advance actions to reduce potential hazard effects or risk. Protections are already in place at the time a hazard event occurs.

Preparedness: Advance actions that strengthen the capability of government, residents and communities to respond to disasters.

Prevention: Building capabilities to avoid, prevent or stop a threatened or actual act of terrorism.

Recovery: A phase of emergency management in which activities are carried out to restore essential services and repair damage caused by a hazard event.

Resilience: The capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy and the environment.

Response: A phase of emergency management that consists of immediate actions to save lives, protect property and the environment, and meet basic human needs.

Federal Programs Guiding this Plan

Disaster Mitigation Act of 2000 (DMA): The DMA (Public Law 106-390) and is federal legislation enacted to encourage and promote proactive, pre-disaster planning as a condition of receiving financial assistance under the Robert T. Stafford Act. The DMA specifically addresses planning at the local level, and Portland's MAP is designed to meet the requirements of DMA, improving the City's eligibility for future hazard mitigation funds.

The DMA emphasizes planning for disasters before they occur and requires plans to be in place before Hazard Mitigation Grant Program funds are available to communities. Natural hazard mitigation is essential to post-disaster recovery. After disasters, repairs and reconstruction often just restore damaged property to pre-disaster conditions. The implementation of additional hazard mitigation actions leads to building smarter, safer, and more resilient communities that are better able to reduce future injuries and damage.

The DMA promotes sustainability for disaster resistance. Sustainable hazard mitigation includes the sound management of natural resources and the recognition that hazards and mitigation must be understood in the largest possible social and economic context. Efforts to reduce risks should therefore be compatible with other community goals, which may be related to equity, economic development, sustainability, public and environmental health, or other issues. As communities plan for new development and improvements to existing infrastructure, mitigation should be an important consideration.

In order to fulfill the requirements of the DMA and be eligible for federal disaster funding grant programs, a local hazard mitigation plan must contain a set of information as outlined in the Title 44 of the Code of Federal Regulations. An explanation of how the MAP meets these requirements is in the appendix.

Federal Emergency Management Agency (FEMA): Established in 1979, FEMA is an agency in the United States Department of Homeland Security responsible for assisting states and local communities to prepare for, respond to, and recover from disasters. FEMA is the federal body responsible for oversight to ensure that Portland's MAP meets the requirements of the DMA.

Natural Hazard Mitigation Plan (NHMP): The 2021 Mitigation Action Plan is the third comprehensive update to the City of Portland Natural Hazard Mitigation Plan (NHMP), which was first developed in 2004. This update identifies resources, information, and strategies for reducing risk from natural hazards. Natural Hazard Mitigation Plans can reduce damage to life and property by coordinating action through strategies that identify risks and foster resilience.

Community Rating System (CRS): The CRS is a voluntary program under the National Flood Insurance Program that rewards participating communities (provides incentives) for exceeding the minimum requirements of the National Flood Insurance Program and completing activities that reduce flood hazard risk. Flood insurance premiums are discounted to reflect the reduced flood risk resulting from community actions meeting the following three goals of the CRS: reduce flood losses, facilitate accurate insurance rating, and promote awareness of flood insurance. Portland participates in the NFIP and CRS. More about Portland's participation in the CRS and NFIP are included in the appendix.

What's new in 2021?

The City of Portland responded to the DMA by developing the initial City of Portland Natural Hazard Mitigation Plan (NHMP), which was approved on December 9, 2004. Since then it has been updated every five years in accordance with the DMA requirements. Over time the recommended processes and requirements of what to include in the Plan have changed, as have the planning context and awareness of our risks. In 2016, this plan was re-named the Portland Mitigation Action Plan. This plan meets the requirements of a Natural Hazard Mitigation Plan and FEMA's Community Rating System. The 2021 Portland MAP update (MAP) reflects changes that have taken place since 2016 as well as the unprecedented circumstances of 2020.

While we were planning and writing the MAP, the City was in the midst of the COVID-19 pandemic, large-scale social unrest, and an unprecedented houselessness crisis. For the first time, the planning process was carried out almost exclusively online (except for a few in-person community engagement events). The changes presented in this update are outlined below.

Changes in Development

A critical task of the MAP update is to report on any changes in the built environment since the prior MAP was approved that would increase or decrease vulnerability, especially in hazard-prone areas. Since 2016, Portland's population has increased, leading to new development (some of it in the hazard areas). But the Risk Assessment Team and stakeholders with technical backgrounds found that this new development did not increase vulnerability, as it is largely infill development pursuant with local programs and codes that reflect exposure to hazards that were described both in the 2016 MAP and in this 2021 Update. The City of Portland has adopted land use policies and building codes that help mitigate hazard risks identified in the 2016 Plan, and development is also guided by the City's comprehensive plan. Nonetheless, in developing this update, we employed new data, maps, and reports to assess vulnerability for all hazards. More detail about changes in the City of Portland are included in Chapter 2, and the methodology for our vulnerability assessments is included in Chapter 3.

Tilikum Crossing Bridge, ISS Portland State University

Focus on Frontline and Underserved Communities

The 2016 MAP built on the 2010 NHMP by not only meeting the federal requirements for community engagement and outreach, but including several events for public stakeholders that focused on building a dialogue between city government and the community to further the City's equity goals. The 2016 MAP employed an equity lens in developing projects for the MAP strategy for the first time. This community dialogue and equity work has continued at the City, and since 2016, the Portland Bureau of Emergency Management has done extensive work to engage communities in developing their plans and priorities.

> *"Equity is achieved when one's identity cannot predict the outcome."*
>
> From The City of Portland's Office of Equity and Human Rights (OEHR)

The 2021 MAP reflects the work that has been done since 2016 and the current planning context. Equity, community resilience, and social justice were at the forefront of our thinking in developing this plan, as these issues are closely tied to disaster mitigation. Frontline communities, or those most impacted by natural disasters, are most often also underserved communities that face barriers to maintaining secure housing, employment, and health care in normal times. Frontline communities often include Black, Indigenous, and other communities of color; refugee and immigrant communities; the elderly; and people with disabilities.

Natural disasters can exacerbate existing inequities. Mitigation work can protect these communities by preventing additional and disproportionate burdens, and can further equity by advancing projects and strategies that help to build resilience.

The 2021 Mitigation Action Plan Update aimed to include the priorities of frontline and underserved communities in all parts of the plan. The Mitigation Action Strategy development used the equity lens developed in 2016, and included community considerations in prioritizing the proposed actions. Community engagement efforts were less broad than in 2016 and specifically targeted frontline communities. The 2021 MAP also includes a "Community Voice" chapter that focuses on centering these voices in natural hazard mitigation.

Native American Student and Community Center, ISS Portland State University

Downtown Portland, ISS Portland State University

Changes to the Natural Hazards Described in the Plan

The set of hazards we addressed remains largely the same as in 2016: for example, earthquakes and floods still have the greatest potential impact on the City. But in the past five years, the City has experienced increased impacts from hazards linked to climate change, including record severe winter storms, windstorms, impacts from wildfire smoke, and an extreme heat event that led to the largest loss of life from a natural hazard in Portland's history. During each of these events, the same communities were hit the hardest. So while our risk assessments remain largely the same, we've incorporated lessons learned from these experiences: extreme heat has been elevated to a hazard with its own analysis in the risk assessment chapter, and smoke impacts have been made central to our description of wildfire risks.

New Data and Reports

The 2021 MAP Updates was completed using updated data when available. One change that impacted many sections throughout the plan was the availability of new population and demographic data. Many of the population and demographic statistics located throughout the plan, in particular Chapter 2 and in the Chapter 3 risk assessments were updated using this newly available data. The MAP utilizes Risk Reporting Areas, which are neighborhood-scale geographies, to describe Portland and vulnerability to natural hazards. In this update we adjusted the boundaries of the Risk Reporting Areas from 2016 to align with the census reporting boundaries so that we could better use census data as it is reported. This alteration resulted in little impact on our overall analysis. We also incorporated several new relevant studies and plans published since 2016, including:

- The Fifth Oregon Climate Assessment (Oregon Climate Change Research Institute)
- Earthquake Regional Impact Analysis for Clackamas, Multnomah and Washington Counties (DOGAMI)
- Impacts of a Cascadia Subduction Zone Earthquake on the CEI Hub (Multnomah County Office of Sustainability and Portland Bureau of Emergency Management)

Finally, key stakeholders and technical experts provided additional data and expertise. The 2021 MAP update reflects the information provided to us by the Steering Committee, reviewers, and technical consultants whose work is cited when relevant. A full list of the data sources used for this update is included in the Appendix. Sources developed since 2016 are highlighted.

Farmer's Market, ISS Portland State University

Building on The City's Resilience Work

The City committed to a number of natural hazard mitigation actions in the 2016 MAP. These actions represented only a portion of the City's work to build resilience. We created a status report for these actions, which is included in the Appendix. We also incorporated key lessons learned since 2016 into different parts of this update, including:

The Mitigation Action Strategy: We revised our criteria for actions to include in the update. We added additional information to better describe how the action would be implemented, and created a more consolidated set of actions that references rather than repeats mitigation work captured in other City plans.

The MAP Maintenance Strategy: Completing the status report also provided us with insights about how to improve the MAP update strategy. We knew that additional information should be collected beyond the specific actions outlined in the MAP to understand the full scope of mitigation work and needs in the City, and that we needed to adjust the structure in place for collecting and reviewing this information. These changes are explained in the MAP Maintenance Strategy chapter of the plan.

Since 2016, the City of Portland has completed other large-scale resilience initiatives that align with the MAP goals. In 2017 the City worked with the Institute for Sustainable Solutions at Portland State University to build infrastructure resilience in the face of a major natural disaster like an earthquake or flood. As part of this project, City staff completed surveys and participated in a workshop called the "Resilient Infrastructure Planning Exercise" to better understand the interdependencies between different infrastructure systems and develop priorities for getting infrastructure assets back online as soon as possible following a disaster. This work highlighted the need for improved collaboration and coordination between and within bureaus in all resilience work, including mitigation. These lessons are reflected in the MAP strategy, which considered opportunities for collaboration and coordination as significant criteria in prioritizing mitigation projects.

Mitigation Action Plan Update 2021 Overview

The Mitigation Action Plan is divided into six sections:

1. **Mitigation Action Plan Introduction**: This chapter details the regulations and requirements met by the Mitigation Action Plan update and the broad changes that have taken place since 2016.

2. **Natural Hazard Mitigation Planning in Portland:** This chapter describes the City of Portland and its characteristics, the City's planning capabilities, and the process that was used to develop this plan. It also provides top level details about the plan, including the Vision, Mission and Goals.

3. **Natural Hazard Risk Assessments:** This chapter provides an assessment of the natural hazards and their associated risks covered in this plan.

4. **Community Voice in Natural Hazard Mitigation Planning:** This chapter outlines the priorities of frontline and underserved communities in natural hazard mitigation planning.

5. **The Mitigation Action Strategy:** The Mitigation Action Strategy builds on the previous three sections to describe the work that the City of Portland will do to reduce the harmful impacts of natural hazards ahead of an event.

6. **The Plan Maintenance Strategy:** This chapter explains how the plan will be evaluated and updated on a regular basis with input from key stakeholders and the community.

Natural Hazard Mitigation Planning in Portland

Introduction

Portland's ability to mitigate and prepare for natural hazards revolves around the City's geography, climate, population, economy, and community priorities. All of these set the context for updating the Mitigation Action Plan (MAP). This chapter describes Portland's communities and the resources available for mitigation planning and projects. (Because this document is an update, some descriptions of geography and the community were taken from the 2016 Mitigation Action Plan.) In addition to describing Portland and its planning capabilities, this section relates the process we utilized to update the MAP: details the planning Vision, Mission and Goals; and sets the foundation for the chapters that follow.

MAP Planning Area

The planning area for the MAP is defined by Portland's city limits. The City of Portland is located primarily in Multnomah County in northwest Oregon, with small portions of the City extending into Washington and Clackamas counties (see Figure 2.1). The City covers 145 square miles, centered on the Willamette River and its confluence with the Columbia River. Portland is the center of commerce, industry, transportation, finance and services for a metropolitan area of more than 2 million people. It is the largest City in Oregon, the seat of Multnomah County and the second largest city in the Pacific Northwest (after Seattle).

Figure 2.1. City of Portland

The Columbia River, which separates Oregon from Washington, is the City's northern boundary. Major jurisdictions adjacent to the City are Beaverton, Tigard and unincorporated Washington County to the west; Lake Oswego, Milwaukie, Happy Valley and unincorporated Clackamas County to the south; and Gresham, Fairview and unincorporated Multnomah County to the east. The small City of Maywood Park is an island within the Portland city limits, in the northeastern part of the City.

Major transportation routes through the City are Interstates 5, 84, 205 and 405; U.S. Highways 26 and 30; the Willamette and Columbia Rivers, and several major railroad lines. Portland International Airport is located next to the Columbia River at the northern edge of the City. 10 vehicle bridges cross the Willamette River in Portland and two cross the Columbia River. Willamette River crossings also include a railroad-only bridge and a newer bridge serving only mass transit, bicycles and pedestrians. An aerial tram provides transportation from the South Waterfront area to the Marquam Hill neighborhood.

The City's park system includes almost 12,000 acres in developed parks, natural areas, and built acreage (Portland Parks & Recreation, 2016). This includes Forest Park, the largest urban forest in the United States, covering more than 5,000 acres (Forest Park Conservancy, n.d.).

Geography and Natural Features

Portland lies at the northern end of the Willamette River valley, at the Willamette's confluence with the Columbia River. The valley rises to the Oregon Coast Range in the west and to the Cascade Range in the east. The Willamette River begins at Waldo Lake near Eugene, on the western slopes of the Cascade Mountains, almost 200 miles south of Portland. From Portland, the Columbia River flows northwest about 100 miles to the Pacific Ocean. Upstream and to the east of Portland, the Columbia flows through the Columbia River Gorge, a gap in the Cascade Range.

Elevations in the City range from about 20 feet above sea level along the Willamette River to more than 1,000 feet in the Tualatin Mountains, more commonly called the West Hills (NHMP, 2010). The west side of the City is dominated by the West Hills, which rise from a narrow terrace along the Willamette River. The east side of the City is flat, with little elevation change except for a few volcanic buttes such as Mt. Tabor and Rocky Butte (BES, 2006).

Soils on the west side of the Willamette River vary from clay loam (a kind of soil) with low permeability (that is, water does not easily flow through it) and relatively high erosion potential to gravelly loams, which are relatively well-drained and moderately permeable. The flat areas along the west bank of the Willamette River are urban, with highly disturbed soil (due to development) and unstable fill. On the east side of the Willamette River soils are highly variable, similar to the west side. Much of the area along the Columbia River has been filled with dredged (dug-up) sand, which drains very well. In undisturbed areas along the Columbia River, percolation (water flow through soil) rates are very slow. In the southeast areas of the City, soils vary from very high to low permeability (NHMP, 2010).

Seismic and Volcanic Features

Most of the Pacific Northwest lies within the Cascadia Subduction Zone, where the Juan de Fuca and North American tectonic plates meet. The convergence of these plates puts most areas from western British Columbia to California at risk for a catastrophic earthquake with a potential magnitude of 9.0 or higher. Portland lies within this area of risk (NHMP, 2010).

Three major crustal fault lines run through Portland: the Portland fault, the East Bank fault and the Oatfield fault. Each is capable of generating moderately large (6.8) earthquakes (NHMP, 2010).

There are several active volcanoes near Portland, including Mt. St. Helens, Mt. Hood, Mt. Adams and Mt. Jefferson. Major eruptions of these volcanoes could cause significant ash fall in the Portland area (NHMP, 2010).

Portland also lies on top of the Boring Volcanic Field, a collection of cones (landforms) and lava flows formed during eruptions long ago. These include Mount Tabor, Rocky Butte, and Powell Butte in east Portland. All existing Boring Volcanic centers are extinct, and the probability of an eruption in the Portland Metro area is very low (USGS, n.d.-r).

Mt. Hood From the City of Portland

Surface Waters

Watersheds are areas of land that separate waters flowing to different rivers, basins, etc. The City of Portland lies within five primary watersheds:

Columbia Slough: A 'slough' is a wetland, like a swamp or shallow lake. The Columbia Slough extends from Kelley Point Park in the west to Fairview Lake and Fairview Creek in the east. Its watershed drains an area of 51 square miles, and includes portions of Portland, Troutdale, Fairview, Gresham, Maywood Park, Wood Village and unincorporated Multnomah County. Over the years, the watershed and waterway have been altered to accommodate industry and agriculture. Beginning in 1918, levees were built to provide flood protection. Wetlands and side channels were drained and filled to allow for development. Waterways were forced into channels, and dozens of streams were filled or diverted to underground pipes (BES, 2006).

Today, the Columbia Slough includes an 18-mile main channel, 30 miles of secondary waterways and many ponds and lakes, including the Smith and Bybee Lakes complex near the Slough's confluence with the Willamette. The Upper and Middle Slough waterways are managed by the Multnomah County Drainage District. The watershed includes the Portland International Airport, the Portland Metropolitan Expo Center, Portland International Raceways and a large industrial area; nearly 60,000 people work in the watershed. It is also home to nearly 160,000 people. Portland's Columbia South Shore Well Field, which supplies supplemental drinking water to a large portion of the region, is also in the Columbia Slough Watershed (BES, n.d.-f).

Johnson Creek: Johnson Creek originates in Clackamas County and flows west for 25 miles to its confluence with the Willamette River. The watershed covers 54 square miles and includes portions of the cities of Milwaukie, Portland, Gresham, and Happy Valley, and of Multnomah and Clackamas Counties. Crystal Springs Creek and Kelley Creek are Johnson Creek's main tributaries and contribute the largest amount of water to the main stem. Crystal Springs Creek is fed mostly by cold, clean groundwater from springs on the north side of Johnson Creek. Smaller tributary streams such as Mitchell, Errol, Deardorf, and Wahoo Creeks still flow, but about 38% of the watershed's historical tributaries are now piped or diverted to the combined sewer system. The northern watershed is characterized by large, flat floodplains, particularly in the Lents neighborhood. The land lying south of the main stem, where most of Johnson Creek's tributaries are located, is steep and varied. Approximately 175,000 people live in the Johnson Creek Watershed (Johnson, n.d.).

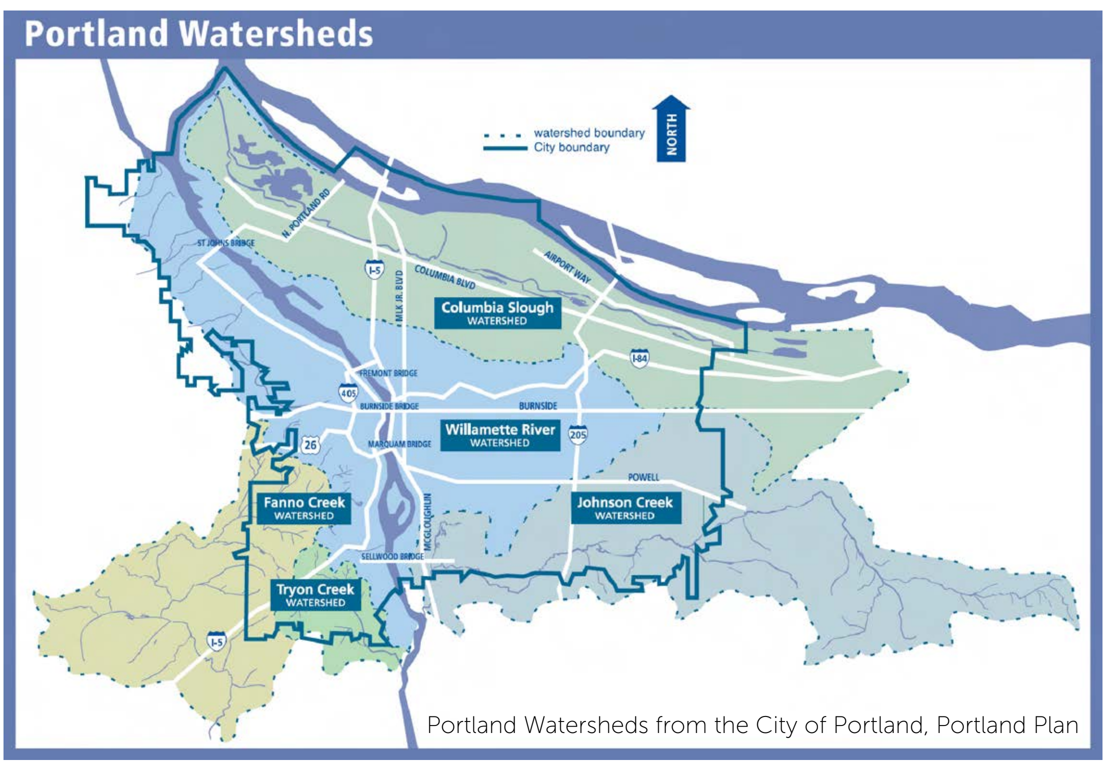
The watershed was significantly changed in the 1930s, when, in an effort to reduce flooding, the federal Works Progress Administration straightened and deepened the creek and lined it with rock, turning 15 of the Creek's 25 miles into an artificial channel. Unfortunately, this reduced the creek's ability to dissipate energy and absorb high winter flows, making it more likely to flood. Between 1940 and 2020, Johnson Creek flooded 44 times (BES, n.d.-g). In the last decade, the city's Bureau of Environmental Services and others have worked to restore the floodplain by purchasing land and actively restoring the natural flows of the Creek.

Fanno Creek: Fanno Creek flows southwest for about 15 miles from its headwaters in Hillsdale to the Tualatin River near Durham. The Fanno Creek Watershed covers 32 square miles, 4,529 acres of which are within the City of Portland, and the remainder is mainly in Washington County. The Fanno Creek Watershed has steep slopes, steep stream gradients, and soils that are slow to absorb rain. These characteristics cause relatively high stormwater volumes and velocities, stream bank instability and undercutting, erosion, in-stream sedimentation, and loss of stream bank vegetation. This means that during storms, more rainfall can enter the creek, making the creek larger and causing it to run faster, which in turn eats away at the bank, causing erosion and pulling soil and plants into the waterway. More than 80% of the watershed area in Portland is zoned for single-family residential development. Fanno Creek's main stem floodplain area has been cleared of plants and grasses and developed, which reduces the ability of the floodplain to absorb extra water during storms and means there is less wildlife habitat too (BES, n.d.-c).

Tryon Creek: The Tryon Creek Watershed covers about 6 square miles in southwest Portland. About 25% of the watershed lies outside the Portland city limits in Multnomah County, Clackamas County, and the City of Lake Oswego. It is divided into three sub-watersheds: Tryon Creek, Arnold Creek, and Falling Creek. Arnold Creek and Falling Creek are Tryon Creek's main tributaries. Other smaller tributaries from within and outside of Portland's city limits also flow into Tryon Creek. The main stem of Tryon Creek is about seven miles long from its headwaters near Multnomah Village (just north of Interstate 5 and Highway 99) to its confluence with the Willamette River in Lake Oswego at the Highway 43 crossing (BES, n.d.-d).

Many homes and roadways have been built in the upper watershed above SW Boones Ferry Road, which has negatively impacted the watershed. In some places, this development has created steep slopes, since the soils there are slow to absorb water, this means that more water flows into the creek during storms. This makes the creek run faster, and those fast and higher flows eat away at the river's edge, causing erosion and pulling soil and plants into the waterway. Additionally, this development has blocked the creek from its natural floodplain and decreased wildlife habitat.

Tryon Creek State Natural Area is a preserved forested area in the lower watershed, off of Terwilliger Blvd. The natural area covers more than 650 acres and contains hiking and equestrian trails and provides wildlife habitat. (BES, n.d-d).

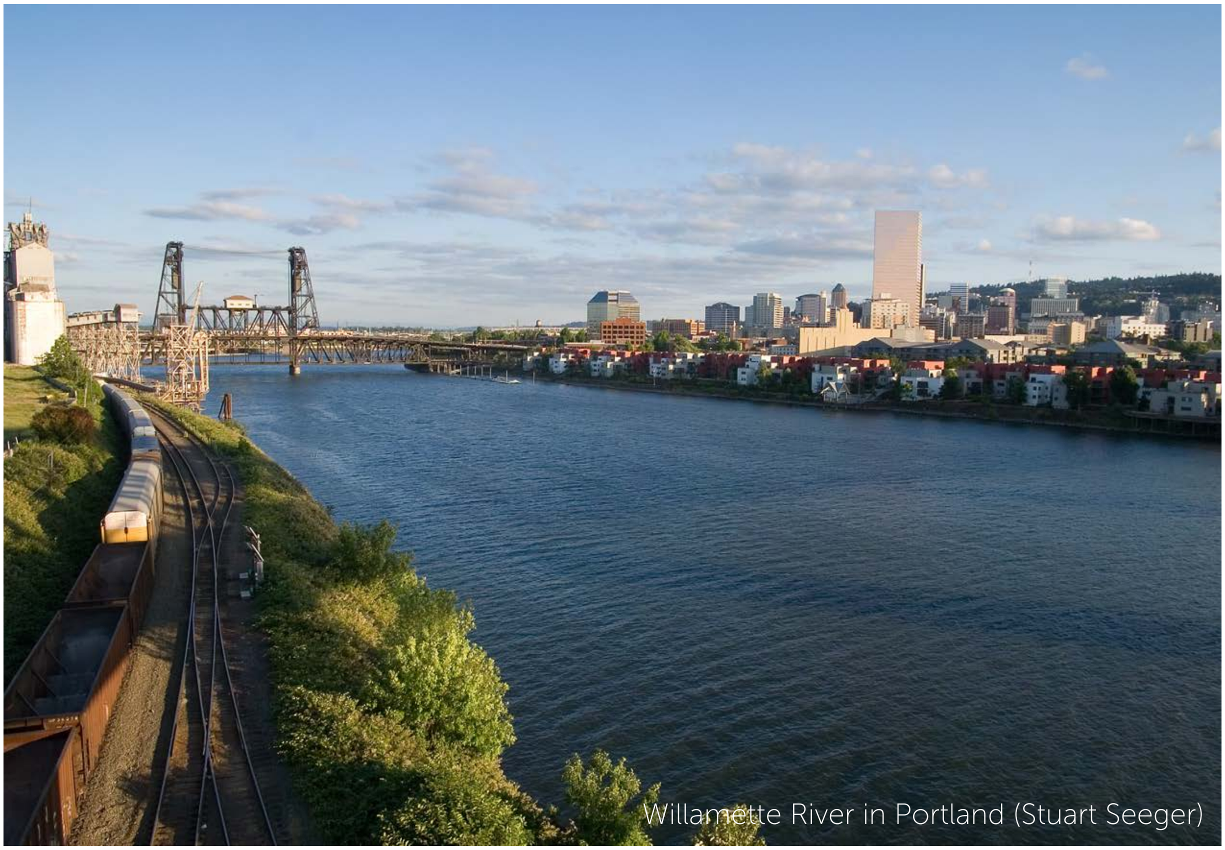


Portland Watersheds from the City of Portland, Portland Plan

Willamette River: The Willamette River drainage basin covers more than 11,000 square miles, 69 of which are in Portland, including Forest Park, the downtown commercial core, industrial districts on both sides of the river, and Portland's most densely-populated residential neighborhoods. The Willamette River watershed is the largest in the City and is divided into three parts: the mainstem; many miles of tributary streams on the West Side, including Stephens Creek, Black Creek and Tanner Creek; and East and Westside neighborhoods where most tributaries have been lost to development (BES, n.d.-e).

The Portland portion is the most highly-developed area of the entire Willamette River watershed. The east side is almost completely developed, and the small streams that once crossed the area have been diverted into pipes that drain into the sewer system. The steeper slopes in the West Hills are less densely developed, and most of the watershed's remaining open stream channels - that is, creeks that have not been piped, covered, and diverted - are on the west side. The watershed has been fundamentally changed by decades of development in the city, impacting how water moves through the area, how healthy it is, how well it can support plants and wildlife, and how likely it is to flood.(BES, 2006).

Upstream of Portland, human activity has had great impacts on the river, including the building of dams and reservoirs and the dredging, diking, and channeling of the main stem Willamette and its tributaries. The main stem has also been narrowed and deepened for flood control and navigation. Within Portland, the river bank is lined with retaining walls and riprap (rock), which prevents the river from moving naturally and interacting with the land surrounding it (BES, 2006).



Willamette River in Portland (Stuart Seeger)

Climate

Portland is in the 'marine west coast' climate zone, which means our weather is typically mild. The Coast Range to the west helps to shield the Portland area from Pacific Ocean storms, while the Cascade Range to the east offers a steep slope over which moisture-laden westerly winds rise, resulting in moderate rainfall for the region. The City averages 155 days of measurable precipitation a year, which falls mostly as rain. Average annual rainfall varies across the metropolitan area, from 60 inches in the West Hills to about 36 inches at the Portland airport. Nearly 90% of Portland's annual rainfall occurs between mid-October and mid-May; only about 3% occurs in July and August (NWS, 2019). Dry summers are common.

Winters can be mild to chilly. Average temperatures range from 37°F -42°F during the day and 37-38°F at night. The Cascades generally block colder air from Canada, although cold air occasionally enters western Oregon through the Columbia River Gorge. Very cold temperatures are rare; it has dropped below 0°F only six times since 1871 (the lowest temperature on record is –3 °F in February 1950). Snow accumulations are rare; the average total snowfall is 4.3 inches. Snow is most likely to fall in areas above 500 feet elevation or near the Columbia Gorge on Portland's east edge (NWS, 2019).

At the same time, occasional and hazardous winter storms do happen. Since 2016 Portland has experienced three such storms, each of which caused large transportation shutdowns and widespread power outages. The winter storms of 2016-2017 and 2020-2021 were especially devastating. In January 2017 Portland was blanketed with 11 inches of snow in less than 12 hours, leaving more than 30,000 citizens without power and shutting down businesses for up to a week (Dean & Loikith, 2017). More recently, in February 2021, an ice storm that hit the tri-county region (Multnomah, Clackamas, and Washington counties) left more than 300,000 people without power, some for as long as two to three weeks (Williams & Ramakrishnan, 2021). Thousands of power lines, trees, and houses were damaged during this storm. While the most severe damage occurred in Clackamas County southwest of Portland, the event demonstrates the potential risk of winter storms.

Spring is a transitional season. March and April are often damp and cool, with only a few warm dry days. During May and June the weather becomes warmer and drier; average high temperatures warm from 68°F in May to 73°F in June. These average temperatures have remained relatively stable since 2016, but hot weather seems to arrive sooner. Between 2016 and 2021, temperatures rose above 100°F in June in three separate years, and above 90°F in June in all years. Portland hit its highest recorded temperature of 116°F in June 2021 during a heatwave that lasted five days. In fact, Portland set a new record for high heat three times over three consecutive days of the June 2021 heat wave: 108°F on June 26, 112°F on June 27, and 116°F on June 28 (NOAA, n.d.). The previous highest recorded temperature was 107°F in August 1981 (NOAA, 2019). The June 2021 heat wave was responsible for 96 deaths statewide, 60 of whom were Portland residents (Templeton and Samayoa, 2021). Of Portland residents who died the average age was 71 years old, and most did not have air conditioning, suggesting that wealth inequality was a determinant for death.

High pressure builds over the Pacific Ocean in the summer, with northwesterly winds prevailing in the afternoons and evenings. This high pressure prevents moisture from flowing into the area, so that summers are often dry and warm. The average temperature in August is 69.5°F. Afternoon highs in the 80s occur with regularity beginning in early July. Temperatures above 100°F are historically rare, usually occurring in July or August. As noted, in the last six years temperatures have risen to 90°F or higher during June. Temperatures also rose to over 100ºF during July in two of the last six years and during August in three of those years.

By early to mid-October, fall arrives with an average high temperature of 63ºF. As the sun sets earlier, the valley cools more, allowing fog to form on clear nights. Fog can be thick during late night and early morning hours and can stick around for several days (NOAA, 2019).

Destructive storms are rare in Portland. Annual wind speeds average 7.5 mph and seldom exceed gale force (50 mph or greater). Thunderstorms can occur during any month but are not common. Thunderstorms in winter and spring are weak, producing small hail and brief, gusty winds, while summer thunderstorms can produce lightning, strong winds and large hail. Occasionally, thunderstorms will produce funnel clouds, but tornadoes are rare (NOAA, 2019).

On average, the first frost occurs around October 21, and the final frost near April 26. This makes for a long growing season (NOAA, 2019).

In summary, in the five years since the last MAP, the City of Portland has experienced increases in heat and cold extremes. Portland's summer temperatures have been rising, with far more extreme heat events than is historically normal, while winter snows and ice-storms have become more frequent.

Demographics and Population Growth

The City of Portland is home to 654,394 people and has grown by almost 14% since 2010. While growth has slowed, the City has continued to see an increase in population every year. Population growth results from two factors: more births than deaths and more people moving here than moving away. It is expected that population growth may slow as a result of the COVID-19 pandemic and the accompanying slowdown in the economy (PSU PRC, 2020).

It is now well understood that underserved and frontline communities experience the first and worst impacts from disasters in our communities and thus, natural hazard mitigation planning should focus on these demographic groups. They also often face the most barriers in receiving government support following a disaster (Flavelle, 2021). FEMA has acknowledged the need to focus disaster preparedness, mitigation, response, and recovery on these communities in order to "drastically improve" emergency management:

Table 2.1 Overall Population Growth in Portland

Year	Portland Population
2010	583,776
2011	591,678
2012	597,167
2013	600,930
2014	604,207
2015	607,920
2016	616,311
2017	627,303
2018	640,658
2019	653,961
2020	652,503
2021	654,394

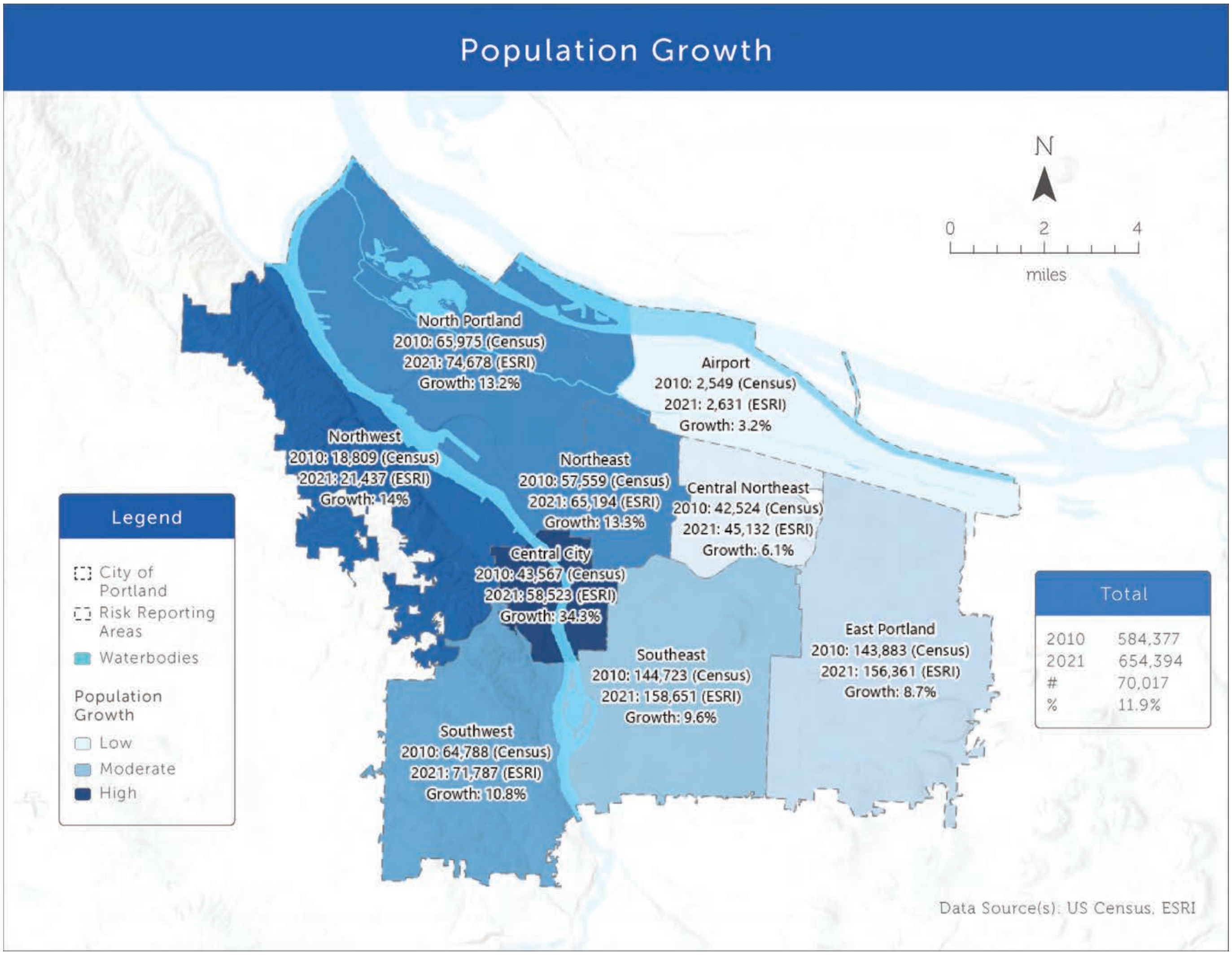
> *"Disasters are often depicted as great levelers, victimizing rich and poor alike. The effects of disasters on populations are anything but random... The disaster vulnerability of individuals and groups is associated with a number of socioeconomic factors that include income, poverty, and social class; race, ethnicity, and culture; physical ability and disability; language competency; social networks and social capital; gender; household composition; homeownership; and age... The same factors that disadvantage members of society on a daily basis also play out during disasters" (Kathleen Tierney quoted in FEMA, 2020c, p.12).*

Table 2.2 2019 ACS Data related to Frontline and Underserved Communities

	Total Population	Percent %
	652,503	100%
Race		
White	504,864	77.37%
Black	36,862	5.65%
American Indian or Alaska Native	4985	0.76%
Asian	53,265	8.16%
Native Hawaiian or other Pacific Islander	2184	0.33%
Some other race	14,216	2.18%
Two or more races	37,091	5.68%
Hispanic or Latino	63,142	9.68%
Median Household Income	$76,231	
Poverty	79,044	12.30%
Renters	13,3915	46.60%
Adults with Less than 12th Grade Education		5.70%
Limited English Proficiency	22,548	3.45%
Disability	78,300	12%
Age over 65	88,689	13.59%
Age under 5	32,761	5.02%

Table 2.2 shows data related to frontline and underserved communities in Portland, but no single set of variables represents these communities or individuals. In the Risk Assessment Chapter of this plan, we provide a more detailed look at these communities and the risks they face from natural hazards.

Figure 2.2. Population Growth in Portland by Risk Reporting Area



Development

Since 2016, the City of Portland has continued to grow. It remains committed to the vision of growing 'up not out', focusing on building within the Metro Urban Growth Boundary. This means that most growth within the City has and will continue to take place in existing neighborhoods. State land use laws require that the City dedicate land uses in accordance with predictions of future growth in the City. The table below shows how land within the City is mostly used. This information is used in the Risk Assessment Chapter for each hazard that can impact the built environment.

Table 2.3 Categories of Land Use in Portland

Land Use	Acres	% Of Total
Residential	5,456	54.8
Commercial	3,168	31.8
Industrial	659	6.6
Religious	116	1.2
Government	159	1.6
Education	404	3.1
Total	9,962	100

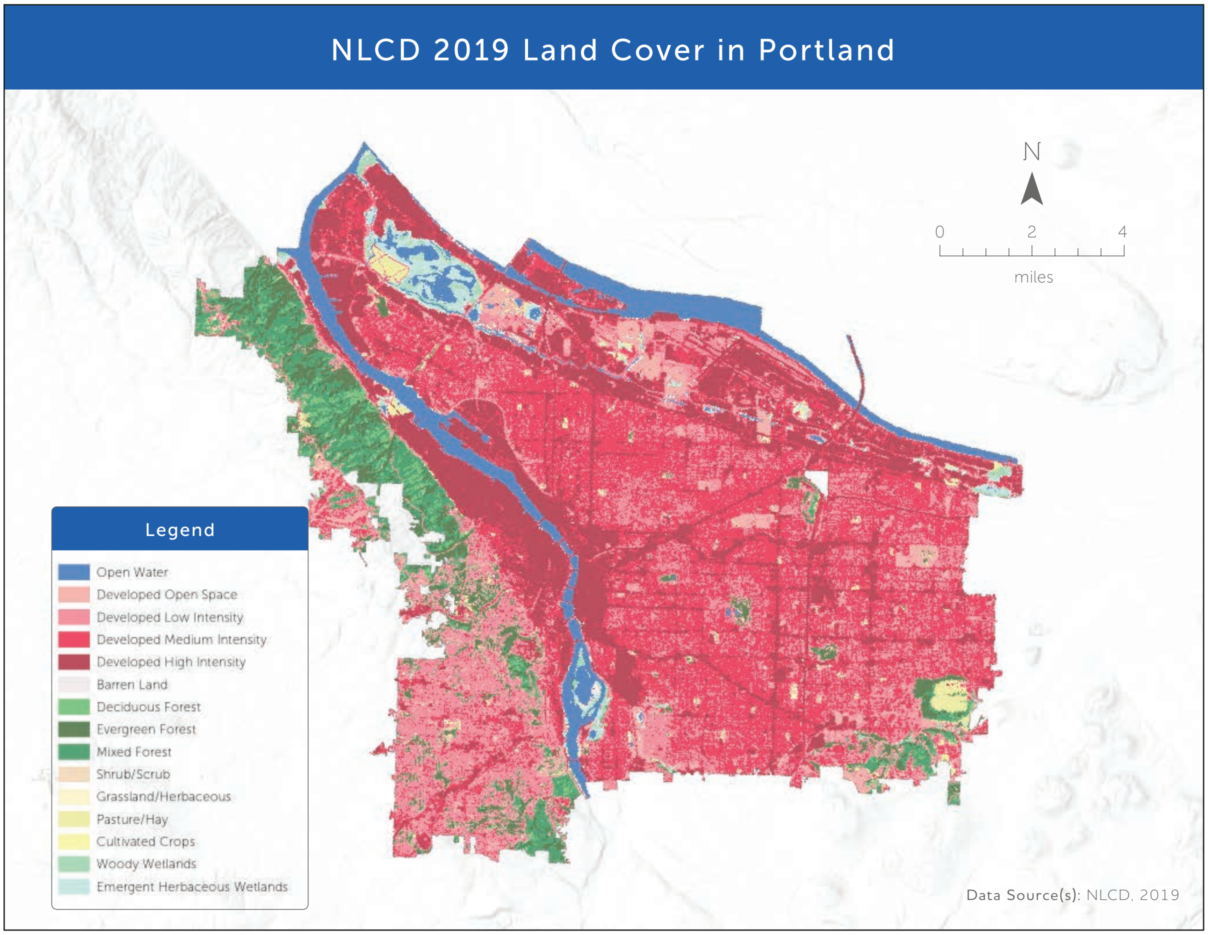
Table 2.4 .Number of Structures by Risk Reporting Area

	Number of Structures						
RRA	Residential	Commercial	Industrial	Religion	Government	Education	Total
Airport	580	842	203	8	78	8	1,719
Central City	2,780	1,823	205	98	48	121	5,075
Central Northeast	16,668	579	44	32	19	66	17,408
East	43,558	1,278	60	164	56	193	45,309
North	24,577	1,449	417	93	92	134	26,762
Northeast	21,840	679	35	87	38	133	22,812
Southeast	53,465	1,896	163	201	71	225	56,021
Southwest	22,985	544	53	63	56	128	23,829
Northwest	6,111	675	244	24	55	36	7,145
Total	192,564	9,765	1,424	770	513	1,044	206,080

Table 2.5. Area of Structures by Risk Reporting Area

	Area of Structures (Acres)									
	Airport	Central City	Central NE	East	North	NE	SE	SW	NW	Total
Residential	73	981	608	1,842	927	1,025	2,137	1,354	505	5,456
Commercial	577	1,282	105	269	744	191	376	253	282	3,168
Industrial	155	76	16	17	379	16	54	13	164	659
Religious	11	40	10	28	14	13	37	12	4	116
Government	24	97	3	9	11	16	10	4	19	159
Education	3	149	24	114	58	56	114	85	10	404
Total	843	2,623	766	2,280	2,134	1,316	2,727	1,721	984	9,962

Figure 2.3. Current Land Use Within Portland



Current land uses were derived from the National Land Cover Database (NLCD)

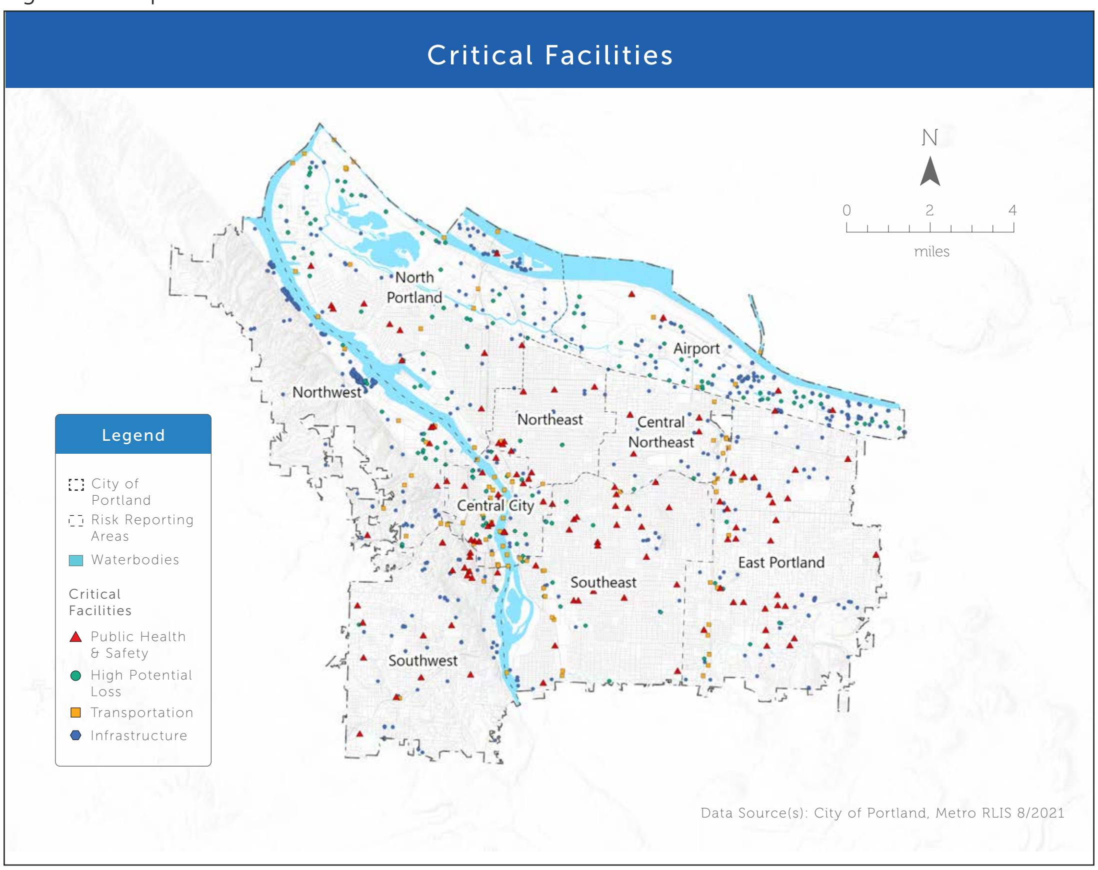
Critical Facilities

As part of the City's resilience goals, the City has worked to identify critical buildings and infrastructure - that is, those structures, such as hospitals or water and sewer systems, that are especially important to protect during a disaster and/or restore as soon as possible afterward, as damage to them could cause harm to many.

Figure 2.4 shows the general location of critical facilities and infrastructure in the following categories (due to the sensitivity of this information, a detailed list of facilities is not provided):

- **Public Health & Safety:** Medical Facilities, Fire Stations, Police Stations, Emergency Operations Centers, Eldercare Facilities
- **High Potential Loss**: Schools, City Facilities, Military Facilities, Prison Facilities, Hazardous Materials, Nuclear Power Plants, Zoo
- **Infrastructure:** Wastewater, Potable Water, Oil, Natural Gas, Electrical, Communication, Dams
- **Transportation:** Airports, Bus Facilities, Rail Facilities, Light Rail Facilities, Highway Facilities, Port Facilities

Figure 2.4 Map of Critical Facilities



There are also 75 critical facilities located outside of the city limits. These are facilities owned or operated by the Portland Water Bureau and are associated with the Bull Run Reservoir, which provides Portland's drinking water. These include three high potential loss facilities and 72 potable water facilities. Critical facilities and infrastructure are discussed in the Risk Assessments Chapter where relevant.

Economy

The City of Portland experienced 126 straight months of significant economic expansion prior to the COVID-19 pandemic. By 2018, the City had the third highest Median Household Income (MHI) growth in the U.S., rising from 26th to 13th overall, which is comparable to top cities such as Austin and Salt Lake City. In 2019, job growth increased by 2%, outpacing the national average of 1.6%. While corporate giants such as Nike and Intel cemented their economic influence in the region, Portland's manufacturing sector also grew substantially, surpassing national growth statistics.

This prolonged period of economic expansion increased domestic and global demand for products manufactured or designed in Portland, generating a GDP worth $164.4 billion and adding 2,587 manufacturing jobs in Portland. In total, 23,617 jobs were created in the City and 31,100 jobs were created in the Portland Metro by 2019 (PBA, 2020 & OED, 2019). Industries such as Transportation and Warehousing saw the most growth (11.3%) followed by Construction (6.2%) and Information (3.6%). Leisure and Hospitality and Financial Activities rounded out the bottom two industries.

Despite increased prosperity and productivity, the City still experienced an unequal distribution of incomes, specifically in the higher income percentiles (PBA, 2020). Portland also had the lowest share of total population employed at 48% (PBA,2020). Although the City continues to raise the minimum wage (to correspond with inflation by 2023), the cost of living is becoming more expensive and wages have not kept pace with rising housing prices. The region's growing population has put a strain on the housing stock as more long-time residents, often non-white populations, are displaced from their communities. From 2010 to 2018, communities of color have seen gradual economic traction but overall, they are still left behind in MHI, especially Black and Hispanic/Latinx households (PBA, 2020).

Table 2.4 2019 American Community Survey (ACS) One-year Estimates for Portland Income Data

Median Household Income	$76,231
Per Capita Income	$43,035
Income of $100,000 or more	38.2%
Income below $50,000	32.5%
Families 2018-2019 below poverty level	6%
Residents 2018-2019 below poverty level	12.3%

Current Context and Future Outlook

Portland's natural and built environments, demographics, and economy remain similar to what was described in the 2016 MAP, and some of the changes we have experienced since 2016 were predicted in that plan. But some unique circumstances provide additional context for this MAP update, and present some uncertainties about the future outlook. This includes the COVID-19 pandemic, a housing and houselessness emergency, a racial justice movement, and social unrest.

COVID-19 Pandemic: The 2021 MAP update was completed during the COVID-19 pandemic. The City's rate of COVID infections was comparatively low, thanks to public safety measures put in place. These measures saved an estimated 2,000 lives, but also negatively impacted our economy (PBA, 2021). The Portland Business Alliance's (PBA) "State of the Economy" report, released in February 2021, describes how the "COVID-19 pandemic shut down our economy and a massive recession followed" (PBA, 2021, n.p.). In the first days of April 2020, at the start of the pandemic, Portland and the State of Oregon reported a 40% decrease in consumer spending and a nearly 15% spike in unemployment, which affected every sector, but especially retail and food services (PBA, 2021). In August 2021, the State of Oregon's Employment Department reported that Portland and the Metro region's unemployment rate was now at 4.9%, up from around 3% before the pandemic. Consumer spending has largely recovered, although people are still spending less on dining out, hotel stays, recreation, and entertainment.

The economic outcomes of the COVID-19 pandemic in Oregon disproportionately affect women, people of color, and people with lower incomes. Oregon's unemployment rate is 2% higher for women than men (PBA, 2021). Nationwide, the unemployment rate was higher for men (7%) than women (6.1%) in February 2021 (Kochhar & Bennett, 2021), suggesting that recovery for women may be more difficult in Oregon. Additionally, national unemployment rates are higher for Black and Hispanic men and women compared to their White counterparts (Kochhar & Bennett, 2021). Based on national samples, Asian, Black, and Hispanic or Latino households experienced "difficulty paying usual monthly expenses" at 10%-15% higher rates than White households (PBA, 2021). Finally, national samples show that pandemic-related job loss was four times worse for low-wage employees compared to middle-wage employees, and that high-wage employees saw almost no increase in unemployment by the end of 2021 (PBA, 2021).

Housing and homelessness emergency: While we prepared this plan, Portland has been experiencing an ongoing housing and houselessness emergency. This reminded us of the importance of considering the impacts of natural hazards on houseless individuals.

The City of Portland declared a 'state of emergency' on housing and homelessness in 2015 (Vespa, 2019), which has been renewed annually and is in place through April 2022 (Ellis, 2021). Every two years, the City of Portland and Multnomah County perform a 'Point in Time' count of houseless people. In January 2019, the number of people living on the streets was 4,015, a small decrease from 4,177 in 2017 (City of Portland, 2019). Due to health and safety risks relating to the pandemic, the City has delayed the 2021 count to January of 2022 (Vespa, 2021).

At the start of the pandemic, Portland's City Council adopted ordinances to limit the eviction of homeless encampments throughout the City. Thus, the number of houseless encampments has grown considerably throughout the City (Hayden, 2021b). Portland's City Council is now actively assessing and updating guidelines to reduce the number of encampments, especially around schools and public property (Hayden, 2021a). At the same time, federal and state eviction moratoriums have protected renters in Portland from eviction due to financial hardship stemming from the pandemic. From April 2020 through July 2021 renters were able to defer rent payments to February 28, 2022, and a host of other eviction limitations were also in effect (PHB, n.d.). According to Dr. Marisa Zapata, the Director of Portland State University's Homelessness Research & Action Collaborative (HRAC), the eviction moratoriums likely helped to keep more people from becoming houseless (Arden, 2021).

Now that the eviction moratoriums have expired and the deadline for delayed rent payment approaches, researchers expect that the City of Portland and the State of Oregon will see a surge in evictions (Bates et al., 2021). HRAC estimates that as many as 125,000 households in Oregon are at risk of eviction, with potential costs for the State estimated to range from $720 million to $4.7 billion (Bates et al., 2021). It is unclear how many of these at-risk households are located in Portland. If the distribution of these at-risk households matches the population distribution in the State, then as many as 18,750 households may be at risk of eviction in the City of Portland alone. Bates et al. (2021) recommends quick and decisive action to curb this potential disaster.

Racial Equity: Readers can find comprehensive information on the status and history of residents of color in Multnomah County and the City of Portland in a series of six reports from the Coalition of Communities of Color and Portland State University, each subtitled An Unsettling Profile (Curry-Stevens et al., 2010). While these reports examine multiple races and identities, in this MAP update, we combine all people of color into a single group to compare against their White counterparts. There is no single experience for people of color and some races face different and greater barriers than others. When compared to the White population, however, there are many examples of inequalities between these two groups.

The State of Oregon, Multnomah County, and the City of Portland's histories are filled with colonialist and racist policies and practices. For example, a report from the City of Portland (BPS,2019) states:

> "Portland, like many U.S. cities, has a longstanding history of racist housing and land use practices that created and reinforced racial segregation and inequities. Exclusionary zoning, racially restrictive covenants, and redlining are examples of this, with their effects still visible today. These discriminatory practices have all played a role in shaping the city's urban form—and in exacerbating inequities along lines of race and class (p. 4)."

Throughout Portland's history a select few neighborhoods have been treated by policy makers to be of greater importance than other areas of the City. The neighborhoods of most importance were overwhelmingly White and affluent, while the least important neighborhoods contained most of the City's population of people of color. In the 1980s and 1990s, the City of Portland faced problems of abandonment and exceedingly high poverty rates in many of its long-neglected urban neighborhoods (Gibson, 2008). Efforts to reinvest in these so-called "blighted" communities resulted in large-scale gentrification and displacement, as investments increased property values, which forced existing residents out and brought in more affluent White families (Gibson, 2007).

More than 26% of Multnomah County's population are people of color. These people and their communities face disproportionate rates of poverty, unemployment, educational disparities, healthcare disparities, higher rates of juvenile detention and adult imprisonment.

As of 2008, communities of color in Portland face poverty rates double those of Whites and child poverty rates over 20% higher than White children (Curry-Stevens et al., 2010). More recent census data shows that in Multnomah County, poverty rates overall have decreased from an average of 18.5% of people in poverty from 2010-2014 to an average of 13.8% of people in poverty from 2015-2019 (Portland State Population Research Center, 2020). However, statewide data shows that despite this overall decrease, adults and children of color fare much less well than White residents. Around 13% of White adults in Oregon are in poverty compared to 27% of Black adults, 19% of Hispanic or Latino adults, and 24% of Native American adults. 13% of White children in Oregon are in poverty compared to 34% of Black children, 29% for Hispanic or Latino children, and 27% for Native American children. Economic inequalities compound with educational inequities that begin with lack of access to preschool programs and persist into high school. 7% of White students and 30% of students of color do not graduate high school. For a more complete examination of existing disparities and the historical and contemporary factors contributing to them, see Communities of Color in Multnomah County: An Unsettling Profile. The authors of that report argue that the disparities experienced by citizens of Multnomah County are significantly worse than national averages and the comparable King County in Washington state, home to Seattle.

As it pertains to this MAP update, Portland is home to a sizable population of people of color, and due to historical discrimination and contemporary inequities, these populations are at higher risk of harm to natural hazards. Systematically disadvantaged communities face greater challenges in accessing resources in times of crisis, and a lack of wealth in these communities and families makes recovery following a disaster more difficult. Furthermore, decades of racist and discriminatory policies undermines trust between these communities and city officials. It is imperative that resilience work in the City of Portland fosters relationships with communities of color to develop trust and supports those communities at highest risk of harm.

Civil Unrest: Beginning in the final days of May 2020, with the killing of George Floyd in Minneapolis, the City of Portland experienced a wave of civil unrest, with large marches and demonstrations occurring daily for four months through the end of September 2020. Sporadic demonstrations have continued since. During the summer of 2020, anger over racial inequities combined with anxieties over the COVID-19 pandemic and large-scale job loss. The ongoing and often destructive effects of this civil unrest has impacted the economy and public perception of Portland.

Most demonstrators in the summer of 2020 were peaceful. Many heartfelt moments inspired empathy and brought Portland residents together in solidarity, as when thousands of demonstrators laid down on Portland's Burnside bridge for nine minutes to symbolize the time that George Floyd was restrained before he died. As citizens called for systemic change in the City, new social movement networks developed and a some policy changes occurred at the City, including a reallocation of funds from the Portland Police Bureau to the new, un-armed Portland Street Response team (Dooris, 2020).

Some protesters had less peaceful intentions, and a culture of violent opposition persisted throughout the protests. The Portland Police Bureau (PPB,2020) reported a total of 30 riots within the City from May through November, half of which occurred in the month of August. Over this time period, hundreds of instances of vandalism were reported, dozens of fires were started, hundreds of illegal fireworks and mortars were set off, and hundreds of projectiles were thrown at police officers. In total, the Portland Police Bureau arrested 960 people in association with the riots and illegal activities. The City of Portland and the Portland Police Bureau have been criticized by protesters for excessive use of force and other illegal activities during the protests. The Multnomah County District Attorney's Office has opened 21 cases for review about alleged police use of excessive force, one of which has resulted in an indictment at this time (Wilson & Levinson, 2021).

The long-term costs of the civil unrest remain unknown, but the damage to Portland's national and local profile, especially its downtown core, will certainly have an economic impact. At the local level, the City of Portland allocated more than $1 million to assist businesses in making repairs and cleaning up graffiti (Goodwin, 2021). In a survey conducted by The Oregonian, residents described downtown Portland as "unsafe," "trashed," or "destroyed," and said they avoided visiting it (Goldberg and Rogoway, 2021). National indicators are similarly gloomy. In a survey of tourists in the United States in 2021, for the first time more people considered Portland an unappealing destination than appealing, and from the beginning of 2020, the percentage of tourists who considered Portland an appealing destination dropped from 54% to 32% (Goldberg, 2020). These surveys suggest a difficult path to recovery for the City of Portland, especially for the downtown area and the hotel and hospitality sectors of the economy.

The 2021 Portland MAP update is taking place during a time of unprecedented challenges for the City of Portland. Compared to peer regions, the City of Portland has a higher unemployment rate and is experiencing more dramatic decreases in apartment construction rates and a sharp drop in real estate market ranking (PBA, 2021). The Portland Metro area, and the Central City in particular, have seen a significant decline in the number of apartments being rented compared to surrounding cities and smaller neighborhoods (PBA, 2021). These indicators suggest that fewer people are moving to Portland compared to pre-pandemic levels. At the same time, many of the standard economic, development, and growth indicators used to describe the City in this plan appear stable; it's uncertain how this context will impact the City in the next five years. In the coming years, mitigation planning and all resilience work will need to address recovery from these crises.

Planning Capabilities and Strengths

The City of Portland operates under a commission form of government that was established in 1913. An elected mayor and four commissioners make up the City Council and have both legislative and administrative duties. City Council approves budgets, establishes laws and regulations, and oversees City bureaus and departments. The Mitigation Action Plan is adopted by the City Council as a coordinating document that brings together the work of many of the City's Bureaus. The City of Portland has extensive resources for completing this type of planning. A list of City resources that add to Portland's capabilities in completing the MAP is in the appendix. This list was developed as part of the 2016 MAP and updated for this plan.

The Portland Bureau of Emergency Management leads the planning, programs, and policies that advance the City's mitigation, preparedness, response, and recovery capabilities. Their work supports ongoing programs that facilitate planning for the MAP and further the work described in the Mitigation Action Strategy chapter of this plan. This includes community engagement related to disaster resilience and emergency response, supporting continuity of operations planning (COOP) for the City of Portland and local businesses and community organizations, and working with regional partners and across City bureaus to support the collaborations necessary for hazard mitigation work.

Collaboration is an essential component to natural hazard mitigation. City Bureaus that deal with infrastructure (e.g., water, transportation, environmental services, parks and recreation), planning and development (e.g., Planning and Sustainability, and Development Services), emergency response (Emergency Management, Police and Fire), and social services (Community and Civic Life) are all engaged in their own resilience work on a regular basis. Due to Portland's form of government and the specialized nature of each bureau, there are groups that foster cross-bureau collaboration to work on issues related to disaster resilience. The following list is a few of the most notable collaborative groups:

The Disaster Policy Council is a cross-bureau leadership group that promotes inter bureau cooperation to further the City's emergency management goals. The group advises the mayor on policy matters during an emergency, approves plans related to emergency management, and monitors ongoing work and plan.

Regional Disaster Preparedness Organization: The City of Portland participates in this regional, five county partnership of government, non governmental organizations, and private-sector stakeholders to increase disaster resilience.

The Climate Change Preparation Team is a group of staff from several City bureaus who collaborate on climate preparation, adaptation and resilience. The group was founded around the City's 2015 Climate Change Preparation Strategy, and continues to meet regularly during the year to share lessons learned and identify cross-bureau actions for citywide climate resilience.

The Disaster Resilience and Recovery Action Group (DRRAG) provides a forum for cross-bureau collaboration around building resilient infrastructure and coordinating resilience and recovery planning among infrastructure bureaus.

The City Asset Managers Group (CAMG) includes representatives from infrastructure, development permitting, financial, and planning bureaus. They meet regularly to share best practices, policy, and approaches to maintain city assets.

The Emergency Management Steering Committee (EMSC) is established by City Code to advise PBEM on programs and plans. It includes emergency management representatives of all the public safety and infrastructure bureaus, plus some other critical functions like IT and HR. The group meets monthly, and representatives from outside agencies like the County, hospitals, and the Port of Portland often attend.

The groups mentioned above are actively engaged with work related to hazard mitigation in Portland. These groups and the City bureaus they bring together are engaged in ongoing work to build resilience and have created plans, programs and policies to mitigate risk from natural hazards. Many of these plans are mentioned in more detail as part of the Mitigation Action Strategy chapter of this plan.

Plan Update Approach

The official kick-off to the Mitigation Action Plan update began in January of 2021. The City of Portland selected the Institute for Sustainable Solutions to lead and collaborate with the Portland Bureau of Emergency Management (PBEM) on the planning process. With the 2016 MAP expiring in November 2021, the planning process took place on an expedited time frame, which required a unique and diligent approach to completing the MAP update. During this time, COVID-19 still loomed large—the City and most key stakeholders were working remotely and dealing, in real time, with response and recovery efforts related to the pandemic, regional wildfires, and other contextual challenges described elsewhere in this plan. The planning process was organized according to four teams that led different pieces of the update:

The Planning Team: The Planning Team served as central organizing unit leading the planning process. The planning team managed the project, brought together research and deliverables produced by the other teams, conducted public outreach and outreach to stakeholders outside the City, and drafted the Plan. The Planning Team consisted of Jonna Papefthimiou, Interim Director of PBEM, and Beth Gilden and Rica Perez from the Institute for Sustainable Solutions. This team had worked together over the last several years to further disaster resilience in the City of Portland, and this experience served as the foundation for collaborating on the 2021 MAP update.

The Steering Committee: The Steering Committee brought together stakeholders from the City of Portland and neighboring jurisdictions whose work aligns with the Mitigation Action Plan. Participants included emergency managers, asset managers, planners, and policy makers. The role of the Steering Committee was to make key decisions related to the Plan update. They established geographies for analysis; set the Vision, Mission, and Goals; and developed the Mitigation Action Plan Strategy. The Steering Committee met regularly during the planning process to review work done by other teams; provide updated resources, data, and information; and acted as ambassadors of the Plan to the people they work with by sharing plan updates and soliciting feedback.

The Risk Assessment Team: The Risk Assessment Team focused on the hazard analysis and vulnerability assessment. They updated the 2016 hazard profiles to reflect new data/research, changes in the development of the built environment, and to add in new experiences from recent natural hazards. In addition to these updates, the Risk Assessment Team also improved on the 2016 plan by better describing risks to frontline populations, integrating climate change into their description of the hazards, and improving the readability of the hazard descriptions and accompanying maps.

The Community Engagement Team: The Community Engagement Team identified community needs and priorities to be reflected in the Plan. They focused on frontline and underserved communities who may be left out of typical public involvement activities yet who would be most impacted by many of the natural hazards described in this plan.

A description of each team, and the focus of their work is in the figure below. Once each team had been established, work plans were developed to coordinate across teams. Each team started their work in January or February and came together regularly at Steering Committee meetings to make key decisions.

Table 2.5 MAP Roles and Responsibilities

	Team Members and Represented Organizations	Stakeholder Engagement
Planning Team		
Planning, coordination, collaboration, final decision making, information sharing and document preparation	Jonna Papefthimiou. Planning Manager and Interim Executive Director of Portland Bureau of Emergency Management Beth Gilden, Collaborative Projects Manager, Institute for Sustainable Solutions, Portland State University Rica Perez, Graduate Research Assistant Institute for Sustainable Solutions, Portland State University	Public information Neighboring jurisdictions and regional partners Agencies and individuals involved with mitigation planning Key external stakeholders including those involved with the 2016 MAP
Steering Committee		
Key decision making to guide the plan, advisory and review of other team's work, provide new data and reports, professional ambassadors of the plan, develop MAP strategy	**Portland Bureau of Emergency Management** Jonna Papefthimiou, *Interim Director* and Aaron Fox, *Operations Specialist* **Bureau of Environmental Services** Nishant Parulekar, *Resilience Team Lead* and Kate Carone, *Enviornmental Program Coordinator* **Portland Parks and Recreation** Chris Silkie, *Asset Management Program Manager* and Laura Lehman, Senior Environmental Planner **Bureau of Planning and Sustainability** Sallie Edmonds, *Environmental Planning Manager* and Mindy Brooks, *Enviornmental Planner* **Office of Equity and Human Rights** Nickole Cheron, *ADA Title II and Disability Equity Manager* **Portland Police** Edina Na Songkhla, *Operations Specialist* **Portland Water Bureau** Kim Anderson, *Emergency Manager* **Portland Bureau of Transportation** Emily Tritsch, *Asset Manager* and Courtney Duke, Senior Transportation Planner **Bureau of Development Services** Ericka Koss, *Geotechnical Engineer* and Anne Castelton, *Emergency Management Project Manager* **Portland Fire** Kim Kosmas, *Senior Public Education Officer* Louisa Jones, *Emergency Management Liaison* and Steve Bregman, *Emergency Operations Chief* **Clackamas County** Jay Wilson, *Resilience Coordinator* **Multnomah County** David Lentzner, *Senior Emergency Management Analyst*	Colleagues in mitigation work City leadership Technical experts who could provide updated information and data related to the plan

Table continued on next page

Table 2.5 MAP Roles and Responsibilities continued

	Team Members and Represented Organizations	Stakeholder Engagement
Risk Assessment Team		
Reviewing natural hazards risk, incorporating new data and reports into risk assessment, completing vulnerability analysis, creating relevant maps and figures	Dr. Peter Dusicka, Professor of Civil and Environmental Engineering at Portland State University Dr. Yu Xiao, Associate Professor in the Toulan School of Urban Studies and Planning at Portland State University Zachary Boyce, Risk Assessment Student Researcher	Technical experts
Community Engagement Team		
Identifying priorities of frontline and underserved communities, direct outreach to community	Dr. Amy Lubitow, Professor Sociology at Portland State University Rica Perez, Graduate Research Assistant Institute for Sustainable Solutions, Portland State University	City staff and community leaders working with frontline and underserved communities Direct outreach to community in Portland Parks

Reviewing the 2016 Plan

The first task for the Planning Team was to review the 2016 MAP with the Steering Committee and other key stakeholders. The Steering Committee and key technical stakeholders were asked to provide new research and data that should be incorporated in the update. Some of the new research that the reviewers thought should be included in the plan were:

- The Fifth Oregon Climate Assessment (Oregon Climate Change Research Institute)
- Earthquake Regional Impact Analysis for Clackamas, Multnomah and Washington Counties (DOGAMI)

They also provided contacts for obtaining updated growth and land use information. These new reports and data were incorporated into the relevant sections of the plan--in particular the Risk Assessment. Reviewers also provided feedback on the overall plan, how it could be improved and what major changes they would like to see. They suggested that the update should be more readable, that it goes further to center equity and community, and that the plan should increase focus on more frequent but less catastrophic hazards like heat and ice storms.

During this review period, the Planning Team collected notes and status reports on all projects listed in the 2016 Mitigation Action Strategy and developed a summary report. Some of the key findings from the Mitigation Action Strategy evaluation included:

- Stakeholder opposition, lack of political will, or low staff capacity and resources caused projects to stall or be discontinued.
- Implementation actions were grouped by lead agency which led to multiple cross-bureau projects with unstandardized language and heavy overlap. A disaggregated list of actions hindered inter-bureau collaboration and communication.
- The Mitigation Action Strategy contained passive language such as encourage, support, and advocate this made it difficult to assess progress for many actions.
- Community engagement projects and programs progressed incrementally. There is an opportunity to reassess the Strategy's equity perspective which may help determine culturally appropriate actions and foster trust with frontline and underserved communities.

The suggested changes described above influenced the 2021 MAP Update and can be seen throughout the rest of this plan.

Engaging Stakeholders and Public Involvement

Each MAP update team was responsible for engaging with different types of stakeholders. The Planning Team took on outreach to neighboring communities, local, and regional agencies involved in hazard mitigation; regulators; special interest groups; and community-based organizations. Due to COVID-19 all engagements were done virtually. Since many of these stakeholders were engaged in response and recovery work related to the pandemic and other crisis, the engagement strategy emphasized bringing planning questions and updates to existing meetings. The Planning Team also met individually with stakeholders who represented important parts of the community or held specific technical information.

The 2021 Plan Update benefited from many concurrent planning efforts. The Multnomah County Natural Hazard Mitigation Plan update provided a forum for the Planning Team to collaborate and coordinate with the County, where the majority of Portland sits. A Metro-led effort to develop a "Social Vulnerability Tool" for the region allowed the Planning Team to connect with organizations and technical experts who were assessing social risks from Natural Hazards. And finally, a regular meeting organized by the Regional Disaster Preparedness Organization of a "Mitigation and Recovery Committee" allowed the Planning Team to connect with regional partners engaged in resilience work throughout the planning process. A full list of the stakeholders the Planning Team engaged with is located in the appendix.

The Planning Team also took on some of the basic functions of public outreach. The Team created an "opt-in" email list for plan updates. They sent out a survey to 500 community members who had participated in or shown interest in the 2016 MAP. They posted meeting notes, plan updates, and draft plan sections for comment on the plan website, and presented information about the plan and planning process at industry and community groups. Supporting documents that detail these outreach activities are included in the appendix.

Targeted outreach was done by the Risk Assessment and Community Engagement Teams. The Risk Assessment Team worked with technical experts to provide information and feedback for their analysis. A full list of the technical experts who consulted on the risk assessment is included in the appendix along with the data sources used for the risk assessments. The Community Engagement Team focused on engaging frontline and underserved communities who may have been missed by other public outreach. A complete description of their work is included in the "community voice" chapter and their activities are detailed in the appendix.

Key Decisions

The Steering Committee was responsible for making the key decisions for the plan. This involved setting the Vision, Mission, and Goals of the plan; the geography used for analysis; the hazards to be considered and prioritized; and the development of the Mitigation Action Strategy.

Establishing the Vision, Mission, and Goals: Early in the planning process, the Steering Committee established the Vision, Mission, and Goals for the 2021 MAP update. The Vision, Mission, and Goals combined what was established in the 2016 MAP with more recent resilience work. The Vision, Mission, and Goals were revisited at the start of every Steering Committee meeting to ensure they still reflected the priorities and information learned through the planning process.

Vision: "Portland is a prosperous, healthy, equitable and resilient city where everyone has access to opportunity and is engaged in shaping decisions that affect their lives" (BPS, 2020).

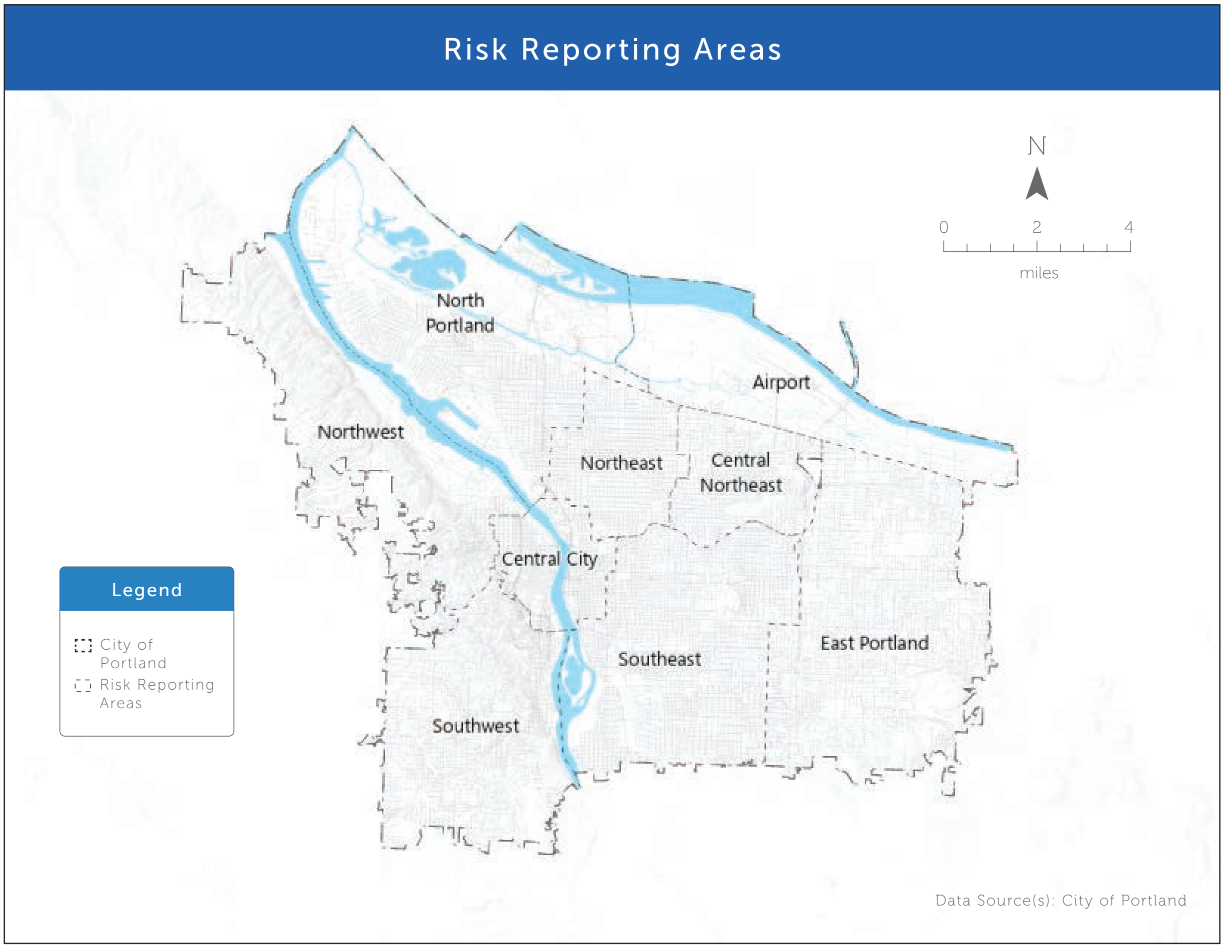
Mission: To equitably reduce risk and the adverse impacts of natural hazards by building community resilience through collaborative, cost-effective actions and strategies.

Goals

- Protect life and reduce injuries.
- Engage and build capacity for the whole community.
- Minimize public and private property damage.
- Protect, restore, and sustain natural systems.
- Minimize the disruption of essential infrastructure and services.
- Integrate mitigation strategies into existing plans and programs.
- Prioritize multi-objective actions that can further sustainability and equity goals during "ordinary times"
- Build on collaborations and lessons learned from resilience work that has occurred since 2016
- Incorporate community voice and reflect the priorities of frontline and underserved communities

Defining the Geography: The Steering Committee was also tasked with defining the geography of the MAP. This included establishing not only the planning area—which is the area within Portland's political boundary, but to also identify other geographical units to be used in the MAP. In 2016, City Budget areas were used to present local-level information about development, people, hazards, risks and mitigation projects. These areas are referred to as "Risk Reporting Areas" The Steering Committee felt that using these smaller geographies was a helpful tool for communication, but wanted to ensure that the geographies would also be useful for analysis. For the plan update,the City-budget area boundaries were moved slightly to reflect updated census geographies. A map of the "Risk Reporting Areas" is below.

Figure 2.6 MAP Risk Reporting Areas



Prioritizing the Natural Hazards to Include: The Steering Committee identified and prioritized the Natural Hazards to include in the plan. They drew from the lists of hazards in the 2016 MAP, reviewed the Oregon Natural Hazard Mitigation Plan, and considered personal experiences with recent natural hazards in Portland. The Steering Committee selected the following list of hazards.

- Earthquake
- Flooding and Dam Failure
- Wildfires and Smoke
- Landslides
- Extreme Heat
- Winter Storms (Snow, Ice, Cold)
- Drought
- Volcanoes
- Windstorms

Some of the weather-related hazards were disaggregated from their format in the 2016 MAP for the plan update. The impact of smoke was added to assessment of wildfires, and extreme heat was prioritized after the City experienced multiple heat waves in recent years. The Steering Committee revisited this list throughout the planning process as the Risk Assessment Team presented them with results from their analysis.

Midway through the planning process, the Steering Committee was asked to rank which hazards were of most concern. The hazards were ranked according to the average score assigned by Steering Committee members. Earthquake was selected as the most concerning hazard by more than half of the Steering Committee, while others selected Flood, Wildfire and Smoke, and Extreme Heat as the hazard they were most concerned about. Windstorms and Volcanoes were universally ranked as hazards of least concern.

1. Earthquake
2. Flood
3. Wildfire and Smoke
4. Extreme Heat
5. Winter Weather
6. Landslide
7. Drought
8. Windstorms
9. Volcano

Steering Committee members selected earthquakes as the most concerning due to the potential scale of impacts the Cascadia Earthquake could cause, while flood, wildfire and smoke, and extreme heat were ranked highly due to the frequency of occurrence and impacts on marginalized communities. These rankings are reflected in the level of analysis completed for each hazard and their reasons for concern are addressed in the Risk Assessment chapter.

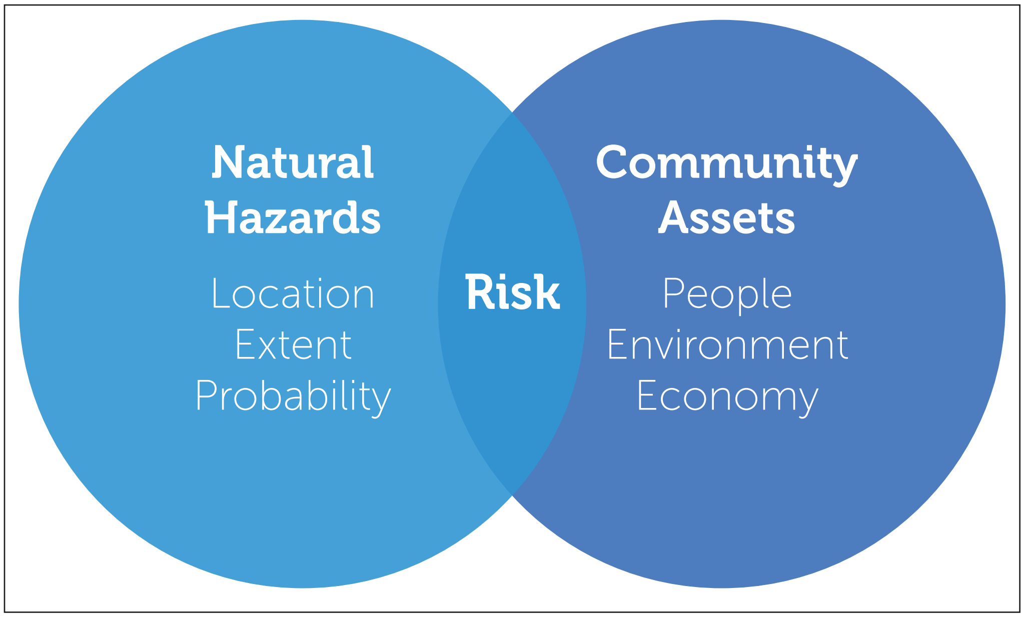
Risk Assessment

Risk Assessment

Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage that can result from natural hazards. It allows emergency management personnel to establish planning and response priorities by identifying potential hazards and vulnerable assets. The process focuses on the following elements:

- **Vulnerability identification**—Identify the people, property, environment, economic assets, and lands of Portland that could experience loss from natural hazard events.
- **Cost evaluation**—Estimate the cost of potential damage or the cost that could be avoided by taking steps to mitigate the risk.

Figure 3.1 Components of risk diagram



The full range of natural hazards that could impact the city of Portland were considered for this chapter. The Steering Committee identified those hazards that present the greatest concern. The process incorporated a review of state and local hazard planning documents and information on the frequency, magnitude, and costs associated with hazards that have impacted or could impact the city. The MAP Steering Committee selected the following hazards for further consideration:

- Earthquake
- Flood
- Wildfire & Wildfire Smoke
- Landslides
- Winter Storms
- Extreme Heat
- Drought
- Volcanic Activity
- Windstorms

For the 2021 update, we wanted to improve the readability of the hazard descriptions and their potential impacts, so we have reduced technical descriptions and defined some terms that may not be familiar to the average reader. The MAP Steering Committee, in consultation with issue experts, re-prioritized the natural hazards considered in the 2016 plan. In that plan, various weather-related hazards were combined as one, 'severe weather.' Since 2016 Portland has experienced worsening impacts from extreme heat, wind, and winter storms, so those hazards are treated individually in the 2021 MAP. A discussion on wildfire smoke impacts was added to the wildfire hazard, as episodes of smoke-related poor air quality in Portland from fires outside Portland's boundaries have increased in recent years. Similarly, impacts of climate change have been integrated into all relevant hazards.

Impacts on Frontline & Underserved Communities

In our discussion of potential impacts, we have highlighted the effects on frontline and underserved communities, as these communities tend to suffer more negative and lasting impacts from natural hazard events. The term 'social vulnerability' is still frequently used to describe the uneven impacts of natural hazards on different groups and extensive research has been done to develop indices and identify demographic data to describe social vulnerability. But the 2021 MAP Steering Committee, based on feedback from impacted communities, has rejected this term. The phrase 'social vulnerability' implies a negative quality that is in some way innate to a community. In fact, community resiliency is impacted greatly by external pressures, such as structural racism (including the history of redlining), fragmentation and displacement of communities resulting from gentrification, historical economic inequalities, and public services and infrastructure that often don't reflect or respond to the needs of communities with different abilities, ages, and cultures even in blue-sky (non-disaster) times. Additionally, communities that are often referred to as 'vulnerable' may in fact have a high level of social resilience due to cultural and community resources. For these reasons, we refer instead to 'frontline and underserved' communities. Communities that experience the worst and most impacts are referred to as frontline communities. Communities that are underserved with resources and information that could protect them from these impacts are referred to as underserved communities. There is no one single set of demographic variables that has been agreed upon to identify these communities, but the following are some of the characteristics that we want to especially consider in natural hazard planning:

Poverty and income: A person's financial situation can impact their ability to prepare for and adapt to the impacts of natural hazards. Individuals with more resources may be able to complete seismic upgrades on their homes in advance of an earthquake, purchase air filters ahead of a smoke event, or turn on the heat during a winter storm. Financial security also allows people to rebuild when their home is damaged or live through periods of unemployment resulting from a natural disaster. Additionally, research has shown that natural hazards also exacerbate inequality; people with resources can afford to move from areas with repeated natural hazards while the poor are forced to stay, with a resulting increase in poverty (Boustan, 2017).

Race: Black, indigenous, and other people of color (BIPOC) experience more and worse impacts from natural hazards due to historical and existing systemic racism. Institutional racism has prevented many BIPOC from accumulating wealth and property that provides a safety net during natural disasters. Government has failed to provide the same level of services to these communities—investing less in the infrastructure and programs that could mitigate disaster risk in the areas where many BIPOC communities live (Norwood, 2021). Finally, emerging research shows that Black and Latino families receive less disaster aid following an event. In addition to widening the wealth gap as described above, natural disasters are contributing to disparities between BIPOC and White communities (Flavelle, 2021).

Language: Limited English proficiency can make it difficult for individuals to access public information and properly prepare for natural disasters. Linguistic isolation may make it difficult to assert labor and housing rights, access insurance, and/or interact with aid workers following a disaster.

Transportation: People unable to use or access a car may experience greater hardship during a natural hazard event. Winter storms and other hazards can disrupt public transportation and make sidewalks and bike lanes impassable, making it difficult to get to work, school, childcare, the grocery store, or other essential services. It may be more difficult to evacuate due to a fire, earthquake, or flood. Extreme heat may impact public transportation, making it difficult for people to travel to cooling centers.

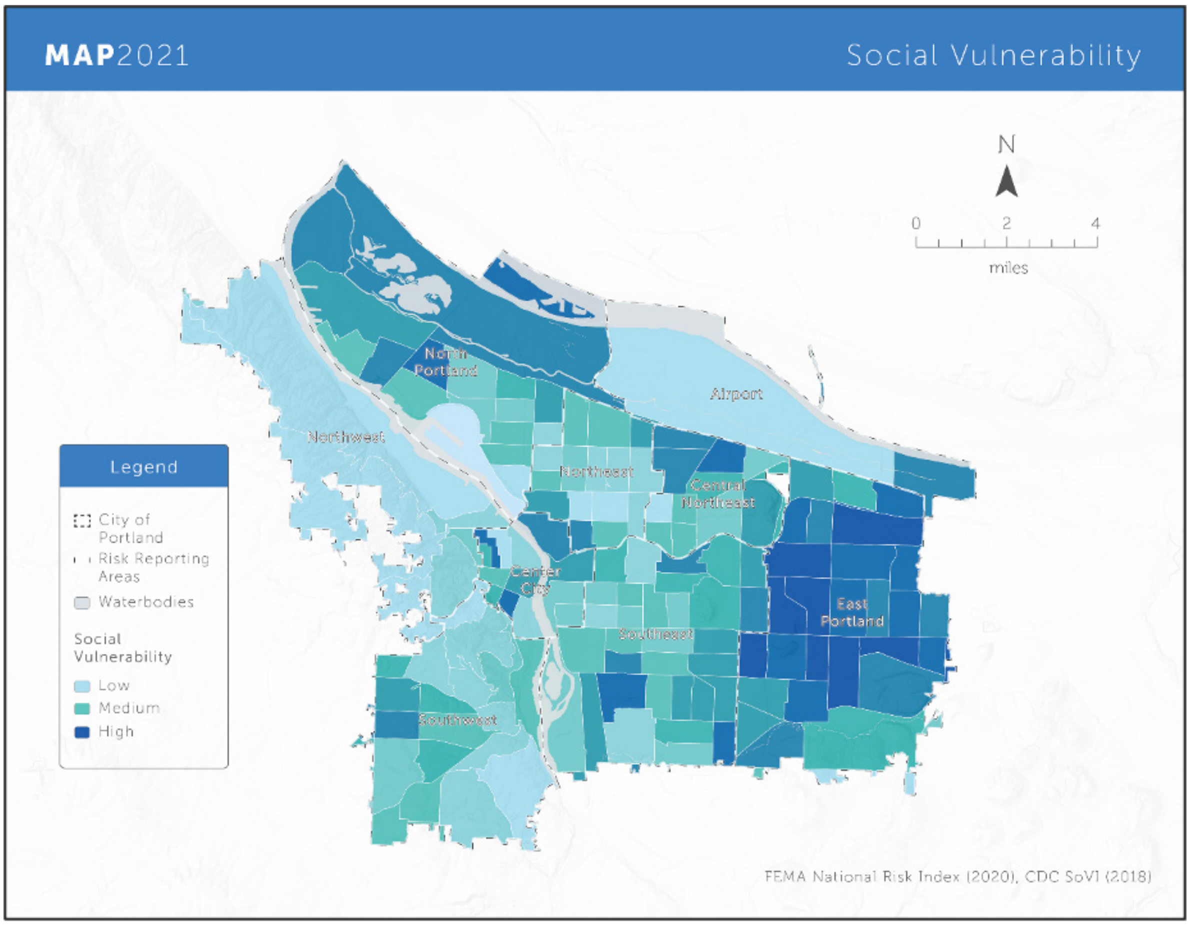
Age, and existing health conditions: Children, elderly people, and those living with chronic illnesses may be more severely impacted by natural hazards. Elderly and ill adults may have a harder time preparing for natural disasters or moving out of harm's way when one occurs. Exposure to wildfire smoke, while dangerous for all, can especially impact the health of children and people with respiratory illnesses, while extreme heat can be more dangerous for older adults. Additionally, older people and those with chronic illnesses often rely on support from external services, such as medical care or home aides. Access to these services may be disrupted as result of a natural hazard event.

Disability: Disability. People with disabilities face additional challenges during natural hazard events, especially when evacuations are necessary. Those with vision or hearing challenges may not be able to access emergency information; those with intellectual abilities may not comprehend or act on the information in the expected way; while those with mobility needs may need additional assistance to evacuate. In an emergency situation, it may be difficult to meet these additional needs.

Housing type and tenure: The type of structure a person lives in, its location, and whether they own or rent it can influence their exposure to and ability to prepare for and recover from natural hazards. In Portland, some homes are built with unreinforced masonry (brick buildings), and/or have insufficient insulation, airflow, or heating and cooling options, which can leave individuals exposed to greater risk from earthquake, weather extremes, and poor air quality from wildfire smoke. Where a home is located and how it is built can impact its risk of flooding or ability to withstand a windstorm. Renters are less able to make improvements to their homes that could mitigate their risk, are often displaced after a disaster, and are not eligible for aid to rebuild their housing (Hersher and Benincasa, 2019). People experiencing houselessness are the most at risk, as they face direct exposure during any event.

Family composition: Families of different sizes and types have different needs related to natural disasters. Homes headed by single mothers have been shown to receive the least support for natural hazard mitigation and recovery. These families generally face extra challenges that may make it more difficult to prepare for and recover from a natural disaster (Hersher and Benincasa, 2019).

Figure 3.2. FEMA Social Vulnerability (SoVI) map for Portland



In addition to these categories, there are other characteristics that can influence how people and communities experience the shock of natural hazards and how they adapt to them, including education, culture and social isolation. FEMA uses a 'social vulnerability index' (SoVI) developed at the University of South Carolina to help us identify areas where the populations we need to plan for live and to visualize how this corresponds with natural hazard impacts. The index is a well-researched composite of many of the indicators described above. Figure 3.2 shows a map of the SoVI in Portland with our risk reporting areas highlighted.

While the SoVI can help us understand where some frontline and underserved communities align with natural hazard exposure, it is not a perfect tool. The data behind the SoVI is based on the US Census, which undercounts many of these at-risk populations (Ordway, 2019). The index is also generalized to every hazard regardless of geography and situation, but as we know from our engagement with communities through this process, planning for underserved and frontline communities requires a more targeted approach. In our assessment of the hazards of greatest concern to Portland, the list above and the SoVI provide a general picture of the communities of highest concern, but we also point out when and how hazards may have worse impacts on a specific community or demographic group.

Methodology

The risk assessments evaluate the risk of all key hazards of concern to Portland. Each chapter describes the hazard, Portland's exposure and vulnerability, and probable event scenarios and/or summaries of past events. The planning team reviewed existing studies, reports, and technical information to determine the best available data to use in the risk assessment. Information from these sources was incorporated into the hazard profiles and forms the basis of the exposure and vulnerability assessment. The following steps were used to assess the risk of each hazard:

1. Profile each hazard—The following information is given for each hazard:
   - Definition and characteristics
   - Geographic area most affected
   - Frequency (estimates of how frequently the event is likely to occur)
   - A discussion of the possible severity of the hazard event
   - Warning time likely to be available for response
   - Impacts on underserved and frontline communities
   - Event scenario and/or summary of past events
   - Key issues related to mitigation of the hazard in Portland
   - Secondary hazards or compounding factors associated with or resulting from the hazard of concern

2. Determine exposure to each hazard—Exposure was determined by overlaying hazard maps with demographic information and an inventory of structures, facilities, and systems to determine which would be exposed to each hazard. The best available data was used to delineate the area of

effect for each hazard. Data available in a Geographic Information System (GIS)-compatible format, with coverage of the full extent of Portland, was used when available.

3. Assess the vulnerability of exposed assets—Vulnerability of exposed structures and infrastructure was determined by interpreting the probability of occurrence of each event and assessing the potential level of damage to structures, facilities, and systems exposed to each hazard. Vulnerability of populations is generally discussed qualitatively, although some model outputs are used to describe quantitatively the number of people vulnerable to the hazard event. FEMA's hazard-modeling program, Hazus-MH, was used to perform this assessment for some hazards; GIS-based spatial analyses or qualitative assessments were used for others.

National, state, and local spatial databases were reviewed for this planning effort. Maps were produced using GIS software to show the spatial extent of identified hazards when such data was available. These maps are included in the corresponding hazard profiles in this chapter. Additional maps that show more detailed geographic data are included in the appendix.

Assessing Earthquake & Flood

Flood: The Hazus Flood Assessment Structure Tool (FAST) calculates building-level flood impacts with user-provided building and flood depth data. FAST uses the Hazus Flood model methodology to assign depth damage functions to buildings according to their occupancy type, first floor elevation, foundation type, and number of stories. Flood depth is then extracted at every building and used as a depth damage function parameter to calculate flood losses in dollars. Flood-generated debris is estimated using building area in square feet. For more information about how FAST calculates flood impacts, please refer to the Hazus Flood Technical Manual (FEMA 2020).

Earthquake: Earthquake analysis relied on DOGAMI's 2018 study, O-18-02 (DOGAMI, 2018), which used Hazus-MH with user specified inputs.

A point-level building file was used to re-aggregate model outputs to align with the smaller neighborhood-scale geographies we used in our analysis (Risk Reporting Areas or RRA) using GIS software. Results were exported and summarized for inclusion in the report.

Earthquake

Problem Statements

- An earthquake can happen in Portland at any time. Portland has several faults within the city and faces a major threat of earthquake from the nearby Cascadia Subduction Zone. A Cascadia Subduction Zone (CSZ) earthquake event over magnitude 8.0 has a 16-22% chance of occurring within the next 50 years (Goldfinger et al., 2017).

- A CSZ earthquake would severely disrupt the physical environment and economic systems of the city of Portland and throughout the region (ECONorthwest, 2020).

- A major earthquake would lead to extensive building destruction and damage throughout the city, especially to the estimated 1,600 unreinforced masonry buildings in the city that have not been retrofitted (BDS, n.d.).

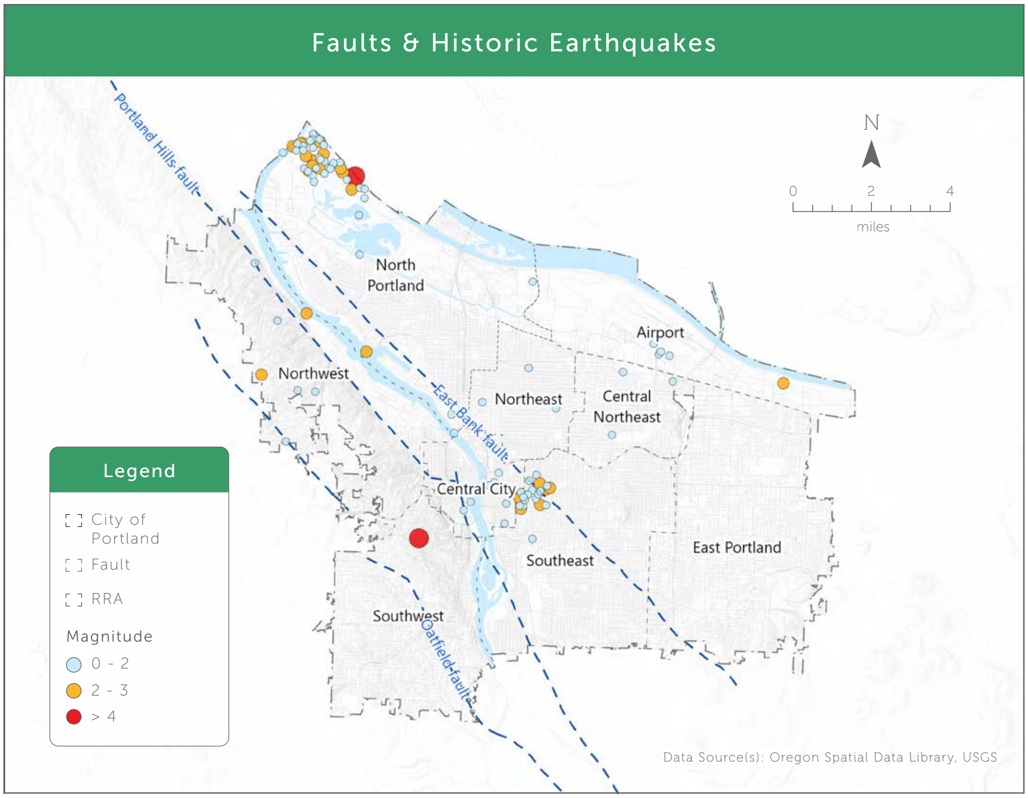
- A major earthquake would lead to extensive building destruction and damage throughout the city, especially to the estimated 1,600 unreinforced masonry buildings in the city that have not been retrofitted (BDS, n.d.).

- Transportation systems and infrastructure, including utilities, may be severely damaged or destroyed as the result of an earthquake.

What is an Earthquake?

An earthquake is the shaking of the Earth's surface following a release of energy in the crust, or surface layer, of the Earth. This energy is released either by a shift in the crust or, more rarely, a volcanic eruption. Shifts in the crust happen when two masses of rock that are pressing against each other suddenly break and slip into a new position (USGS, n.d.-m). In the process of breaking, vibrations called seismic waves are generated. These waves travel outward from the source of the earthquake through the earth, resulting in shaking throughout **Shallow crustal earthquakes** are the most common type of earthquake.

Figure 3.3. Location of faults and historic earthquakes in Portland



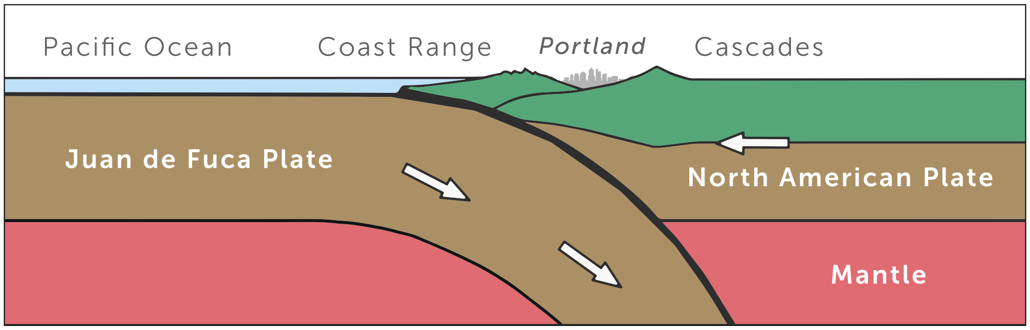
Earthquakes tend to reoccur along faults, which are breaks in the Earth's crust. Faults in Portland include the Portland Hills, Oatfield, and East Bank faults, none of which has been recently active (Wong, et al., 2001). Outside of Portland, off the western coast of Oregon, lies the Cascadia Subduction Zone (CSZ) fault, described in greater detail below. The following map shows the location of historic earthquakes and faults that can produce damaging earthquakes in Portland.

There are four types of earthquakes: subduction zone, shallow crustal, deep intraplate, and those caused by volcanic activity. Portland is most at risk from both subduction zone and shallow crustal earthquakes.

A subduction zone is where tectonic plates (slabs of rock) that make up the surface of the Earth meet. One plate subducts (slides beneath) another plate, creating a sloping boundary between the now-overlapping plates (see Figure 3.5). This process happens slowly and continuously over hundreds or thousands of years. Tension builds between the two plates until it is eventually released, causing an earthquake. Subduction zone earthquakes typically have magnitudes (size) of 8.0 or larger.

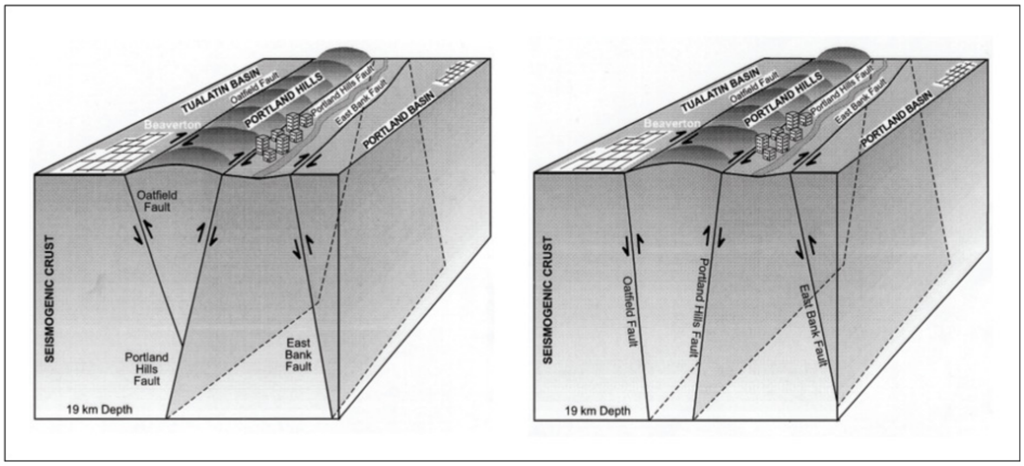
- The Cascadia Subduction Zone (CSZ) is a fault more than 800 miles (1300 km) long, where the Juan de Fuca, North American, Gorda, and Explorer plates meet. It runs from northern California to British Columbia in Canada, about 70-100 miles off the Pacific coast shoreline. Shaking in a CSZ earthquake may last up to five minutes (USGS, n.d.-m; Walton, et al., 2021).

Figure 3.4 Cascadia Subduction Diagram



Shallow crustal earthquakes are the most common type of earthquake. These occur roughly six to 20 miles below the earth's surface. These types of earthquakes happen often in the Pacific Northwest, but the vast majority don't cause damage or produce shaking that can be felt (PNSN, n.d.-a; CREW, n.d.). Shallow earthquakes cause the most destruction near the quake's epicenter (the point on the earth's surface directly above the focus of an earthquake), where the shaking is strongest. For shallow crustal earthquakes, shaking may last up to 60 seconds (CREW, 2009; CREW, n.d.). Faults in Portland that could cause shallow crustal earthquakes include Portland Hills, Oatfield, and East Bank.

Figure 3.5. Subduction Zone Diagram



- The Portland Hills Fault is approximately 30 miles long and is located along the west bank of the Willamette River, running northwest to south-east through Portland (see Figure x). This fault "starts roughly on the northern edge of Forest Park and runs along the foot of Portland's West Hills before turning east on West Burnside Street for a few blocks and then turning southeast again through the heart of downtown. The fault then crosses the Willamette River between the Marquam and Ross Island bridges to Milwaukie and ends about a mile south of the Clackamas River near Oregon City and Gladstone" (Wong, et al. 2001).
- The Oatfield Fault runs west of Northwest Skyline Road from Sylvan Hill to Germantown Road through Bonny Slope (Wong et al., 2001).
- The East Bank Fault on the east side of the Willamette River runs under the University of Portland, Mocks Bottom, Oregon Convention Center, Lloyd Center and Benson and Central Catholic high schools. It appears to have been active within the last 11,000 years (Wong et al., 2001).

Characteristics of Earthquakes that Impact Portland

Shaking from an earthquake event in Portland might last anywhere from a few seconds up to several minutes. In any scenario, after the initial event, there are likely to be several aftershocks as the earth settles into a new position (Gomberg and Bodin, 2021). The impacts of and recovery from a Cascadia Subduction Zone (CSZ) or Portland Hills Fault (PHF) earthquake will be long-lasting, taking years for the city to return to pre-earthquake conditions.

Earthquakes are usually classified in one of two ways: magnitude and intensity. An earthquake's magnitude is a measure of the energy released at the source of the earthquake. It is usually measured on the 'moment magnitude' scale, with the follow degrees of magnitude:

Table 3.1. Moment Magnitude Scale

Moment Magnitude	Description
< 3	Micro
3 - 3.9	Minor
4.0 - 4.9	Light
5.0 - 5.9	Moderate
6.0 - 6.9	Strong
7.0 - 7.9	Major
> 8.0	Great

The intensity of an earthquake is based on the effects of ground shaking on people, structures, and natural features, such as trees. The 'Modified Mercalli Intensity Scale' ranks the intensity of an earthquake based on how strong the shock felt to people who experienced it (NOAA, n.d.). Table 3.1 summarizes earthquake intensity as expressed by the Modified Mercalli scale.

Table 3.2. Modified Mercalli Scale

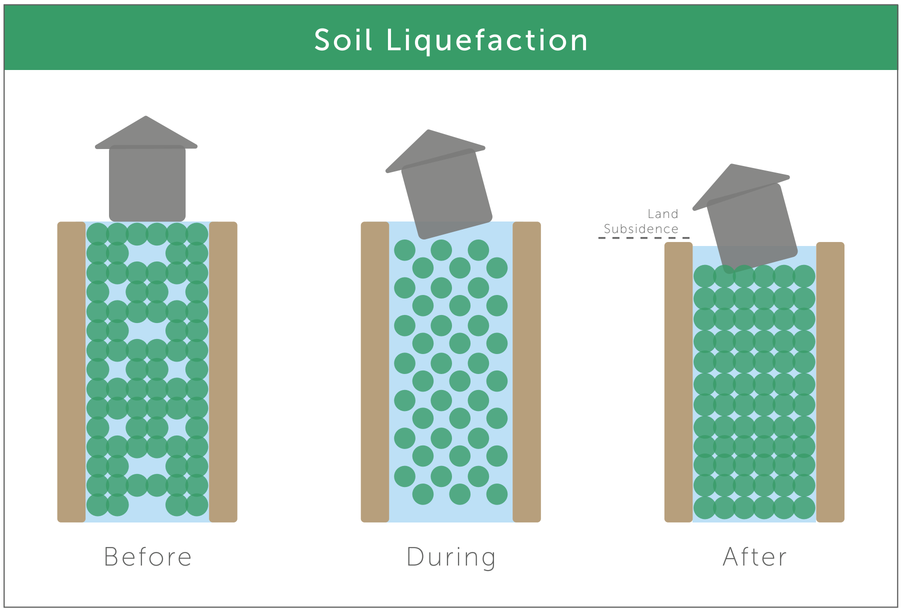
Modified Mercalli Scale	Perceived Shaking	Potential Structure Damage		Estimated PGA (%g)
		Resistant Buildings	Vulnerable Buildings	
I	Not Felt	None	None	<0.17%
II-III	Weak	None	None	0.17% - 1.4%
IV	Light	None	None	1.4% - 3.9%
V	Moderate	Very Light	Light	3.9% - 9.2%
VI	Strong	Light	Moderate	9.2% - 18%
VII	Very Strong	Moderate	Moderate/Heavy	18% - 34%
VIII	Severe	Moderate/Heavy	Heavy	34% - 65%
VIV	Violent	Heavy	Very Heavy	65% - 124%
X – XII	Extreme	Very Heavy	Very Heavy	>124%

One way to predict how severe an earthquake might be is to figure out the 'ground motion accelerations' (how much the ground will move). Instruments called accelerographs record levels of ground motion due to earthquakes at different stations throughout our region. These readings are recorded by state and federal agencies that monitor and predict earthquake activity.

- Peak Ground Acceleration (PGA) is how fast the ground movement changes during earthquake shaking at a location. PGA is what is experienced by something close to the ground. PGA can help understand how short buildings, up to about seven stories, will be affected, which includes over 99% of the buildings in Portland (USGS, n.d.-g; Wong et al., 2001).
- Peak Ground Velocity (PGV) is the greatest speed reached by the ground shaking caused by an earthquake. PGV is used to understand how buildings taller than seven stories will respond (Douglas, 2003).

Ground shaking from an earthquake can cause liquefaction (see Figure 3.6), which is when soils lose their form and move like a liquid. Liquefaction generally occurs in soft, loosely packed, or saturated soils. Structures that are built on these soils are damaged when liquefaction occurs.

Figure 3.6. Liquefaction Diagram



Predicting an Earthquake in Portland

Warning Time

Earthquakes cannot be predicted (USGS, n.d.-b), but sensitive instruments can record seismic waves during an earthquake, potentially alerting those who are at risk before shaking begins. The USGS ShakeAlert Earthquake Early Warning System is available in Oregon as of March 11, 2021, a date that coincides with the 10th anniversary of the magnitude 9.1 earthquake in Tōhoku, Japan. ShakeAlert detects significant earthquakes quickly and sends a real-time message alert automatically to compatible cell phones and other mobile. These important alerts make a distinctive sound and display the text message: "Earthquake Detected! Drop, Cover, Hold On. Protect Yourself." ShakeAlert does not predict when or where an earthquake will occur or how long it will last. It detects earthquakes that have already begun, offering seconds of advance warning that can allow people to take actions to protect life and property from destructive shaking.

ShakeAlert™ Because seconds matter.

Probability

Different timescales can be used to provide probability estimates for how likely an earthquake is to occur over a period of time. The likelihood of a CSZ earthquake and a PHF earthquake are explained below using a 50-year time scale.

Cascadia Subduction Zone: The most recent CSZ earthquake, estimated at magnitude 9.0, occurred 321 years ago on January 26, 1700, at around 9PM. Geological evidence and indigenous oral histories support this precise estimate (Ludwin et al., 2007).

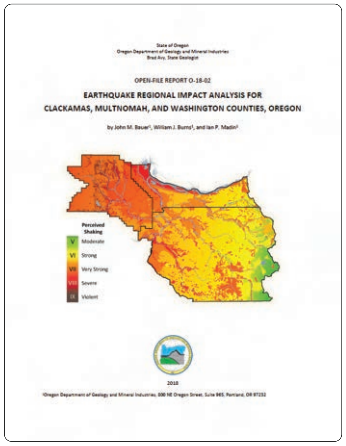
Studies suggest that there is a 16-22% chance that the same kind of earthquake, a megathrust event over magnitude 8.0, will happen again within the next 50 years (Goldfinger et al., 2017). In fact, we are overdue: the elapsed time since the last great CSZ earthquake already exceeds two of the recurrence intervals (periods between earthquakes) observed in the historical record (Petersen et al., 2002). Geological evidence indicates that such great earthquakes have occurred at least 16 times in the last 3,500 years (Petersen et al., 2002). Over the last 10,000 years, the CSZ fault has produced at least 43 major earthquakes, 19 of these were megathrust events (Walton et al., 2021).

The CSZ fault is divided into roughly four segments (Priest, 2014; Bodmer et al, 2018). Based on evidence from past earthquakes, the entire fault may rupture at the same time, or just some of the segments. A full rupture can generate a magnitude 9.1 event. (Goldfinger, 2016). The average recurrence (time between) for CSZ megathrust earthquakes in the last 7,000 years is 370-420 years. For the six most recent events, the average recurrence is 260-270 years (Nelson et al., 2021).

Portland Hills Fault: This fault has the potential to produce a magnitude 6.0-7.0 earthquake (Allen, 2008). There is a 1% estimated likelihood of this fault producing an earthquake in the next 50 years (USGS, 2016d). In 2000, DOGAMI suggested the next earthquake on this fault would happen in 2,000 years (Wong et al., 2000). Evidence suggests that there have been two ruptures in the past 15,000 years (Liberty et al., 2003).

Impacts of an Earthquake

Because we have no recent examples of a major earthquake in Portland, we considered various scenarios to understand the potential impacts of this hazard. In 2018, DOGAMI performed modeling using FEMA's HAZUS (data and tools used for estimating earthquake risk) to estimate the potential impact of an earthquake in Portland (Wong et al., 2000). Four scenarios were considered in that study:



1. A Cascadia Subduction Zone (CSZ) earthquake, magnitude 9.0, with wet soil conditions
2. A Cascadia Subduction Zone (CSZ) earthquake, magnitude 9.0, with dry soil conditions
3. An earthquake along the Portland Hills Fault (PHF), magnitude 6.8, with wet soil conditions
4. An earthquake along the Portland Hills Fault (PHF), magnitude 6.8, with dry soil conditions

Past Events

We also considered past earthquake events to get a sense of the historical pattern and to understand the impact of lower-magnitude quakes.

March 25, 1993: The largest recorded earthquake with an epicenter near Portland occurred in Scotts Mills, Oregon, about 40 miles away. With a 5.6 magnitude, it caused minor damage to some buildings in Portland. The shaking was intense enough that bridges and other structures in Portland were inspected for damages. Federal disaster declaration DR-985, issued in response to this earthquake, applied to neighboring Clackamas and Washington Counties.

There is geologic evidence that a magnitude 6.5 event may have occurred in the Portland Hills fault zone within the past 10,000 years, but no events on that fault have been recorded in historic times (Wong et al., 2001). Table X lists all earthquakes believed to have been felt or to have caused damage in Portland from before the current era (BCE) to the present day.

Table 3.3 Past earthquake events near Portland

Date	Location	Magnitude
February 2001a	Nisqually, Washington	6.8
March 25, 1993b	33.5 miles from Portland	5.6
1989b	82 miles from Portland	5.1
1981b	38 miles from Portland	5.5
1980b	60 miles from Portland	5
1980b	53 miles from Portland	5
March 27, 1964 b	Prince William Sound, Alaska	9.2
December 1963a	Portland area	4.5
November 1962a	Portland area	5.5
November 1961a	Portland area	5
December 1953a	Portland area	4.5
April 1949a	Olympia, Washington	7.1
December 1941a	Portland area	4.5
February 1892a	Portland area	5
October 1877a	Portland area	5.2
January 1700a	Cascadia Subduction Zone	About 9.0
1400 BCE, 1050 BCE, 600 BCE, 400 BCE, 400, 750, 900a	Cascadia Subduction Zone	Probably 8.0-9.0

Impacts on People

Impacts on Frontline and Underserved Communities

The impacts on people from an earthquake will be influenced by the extent of destruction around them. All residents are at risk of injury or death from immediate impacts and may face ongoing challenges resulting from damage to housing, community infrastructure, and systems that help them secure their basic needs. The map below shows where FEMA SoVI relates to areas of the city that are physically vulnerable to earthquakes:

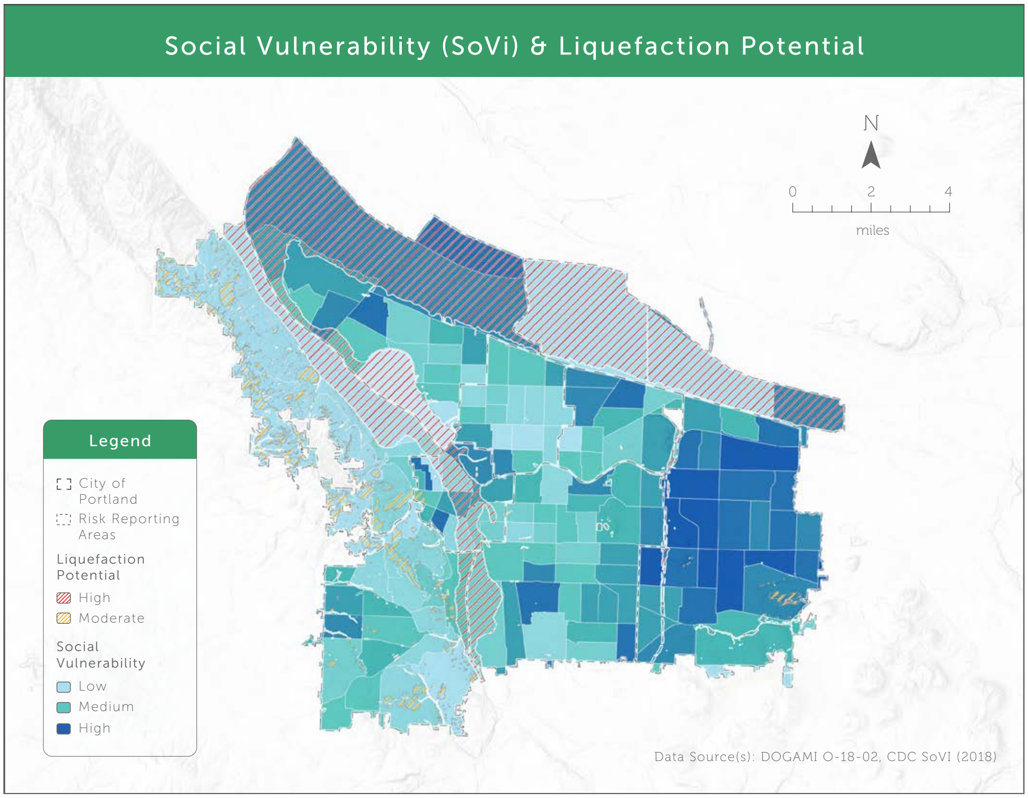
Injury & Loss of Life

Injury, death, and damage estimates are different depending on whether the earthquake happens during a typical weekday or at nighttime. This is because of where most people will be at those times. At 2am, at least 95% of people will be in their homes; at 2pm on a typical weekday, most people will be distributed across schools, workplaces, and homes (DOGAMI, 2018a).

Based on HAZUS estimates, we can expect between 2,491 to 14,748 injuries (levels 1 to 3) and between 119 to 896 deaths to result from a CSZ 9.0 earthquake. In a PHF 6.8 earthquake, injuries will number from 8,646 to 41,414 and deaths will range from 427 to 2,173.

The most recent official Census population totals available in 2018, when DOGAMI conducted these studies, were from 2010. Portland's population has grown considerably since 2010, from 584,377 (US Census, 2020) to 654,394 (PSU PRC, 2020), a difference of 70,017 people. Therefore, a population growth factor was applied to the model outputs per Risk Reporting Area. The resulting increase in exposure is for comparison purposes only, as there are limitations in the data for the specific density of population at the building level. Full injury and loss of life tables are in the appendix.

Figure 3.7. Social Vulnerability (SoVI) and Liquefaction Potential



Impacts on Physical Infrastructure and Environment

Buildings

The same scenarios were used to estimate building losses (no difference between daytime and nighttime scenarios).

For a CSZ 9.0 event, damages and losses (structures and contents) combined are estimated to range from $26 to $39 trillion, depending on the soil conditions. Building repairs alone are estimated to be $671 billion across all scenarios.

For a PHF 6.8 event, damages and losses (structures and contents) combined are estimated to range from $63 to $39 trillion, depending on the soil conditions. Building repairs alone are estimated to be $671 billion across all scenarios.

Figure 3.8. Perceived shaking and damage potential for a PHF 6.8 earthquake event.

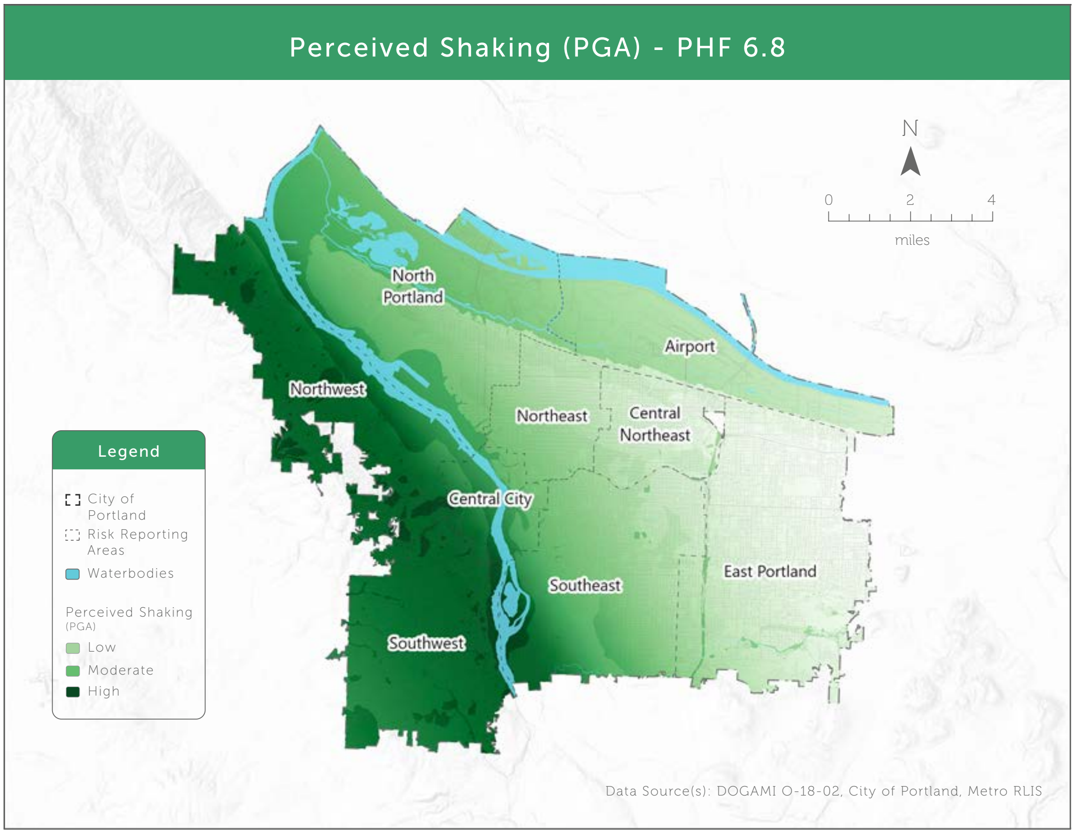
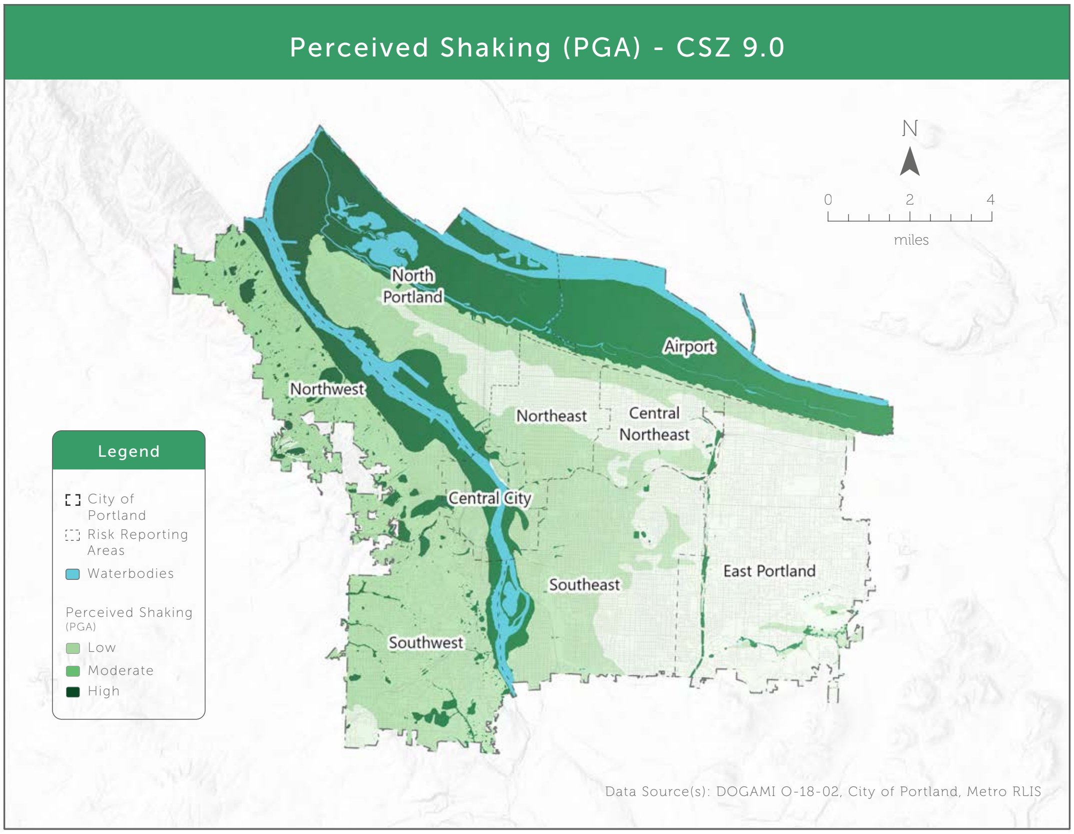


Figure 3.9 Perceived shaking and damage potential for a CSZ 9.0 earthquake event.



For full building damage estimate tables, see the appendix

Critical Facilities

Many critical facilities will be impacted by an earthquake. The maps below show the locations of critical facilities along with the shaking intensity from a CSZ or Portland Hills Fault Earthquake. As these maps indicate, a number of critical facilities are located in areas that intersect with intense shaking. Perhaps the most significant of these is the Critical Energy Infrastructure Hub, which is highlighted in the following maps.

Figure 3.10 Critical Facilities & Portland Hills Fault

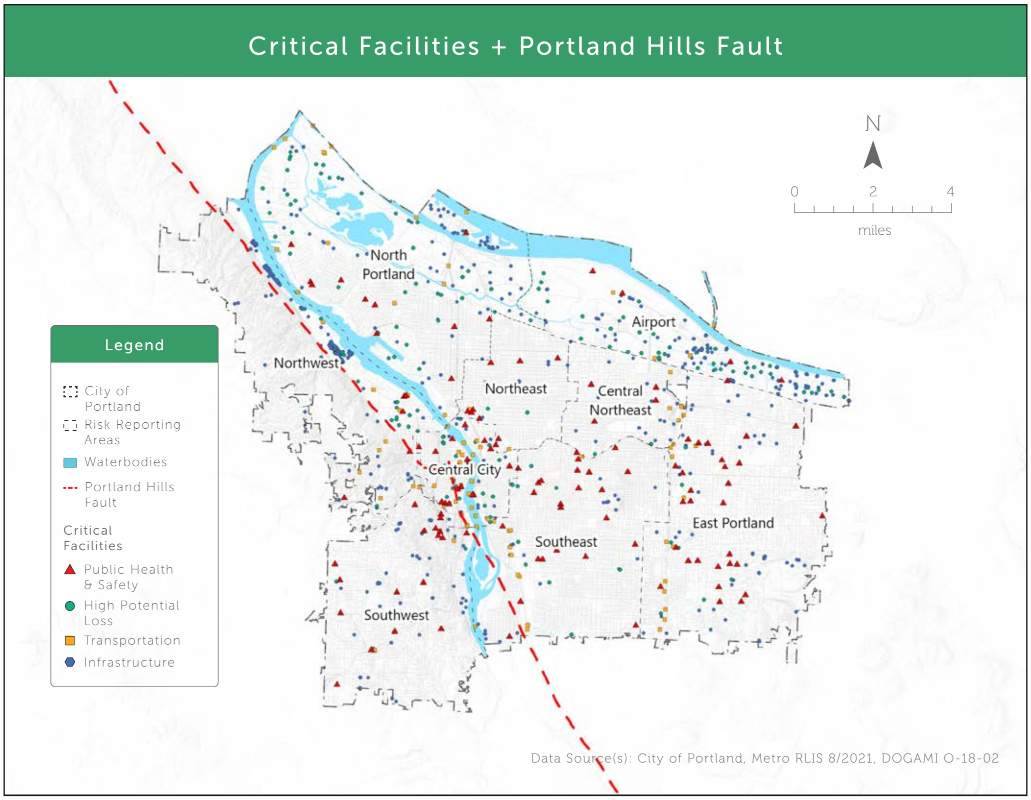
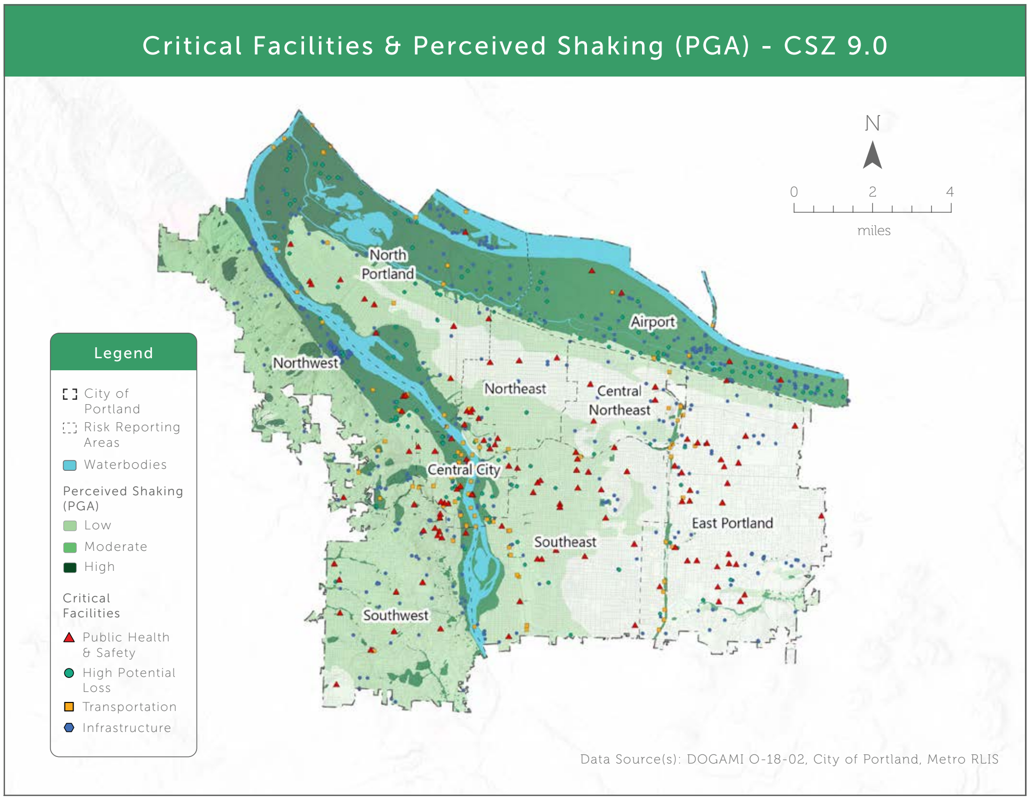


Figure 3.11 Critical Facilities & Perceived Shaking (PGA)



CEI HUB

The Critical Energy Infrastructure Hub (CEI Hub) is a six-mile area in Northwest Portland along the Willamette River. In 2021, ECONorthwest conducted a seismic risk analysis of this the CEI Hub. Information below is taken from that report (ECONorthwest, 2021, p.3).

More than 90% of the state's liquid fuel supply is transported through CEI Hub facilities, including gasoline and diesel. Roughly 70% of the fuel arrives by pipe and another 30% arrives by tanker barge. The CEI Hub supplies all the jet fuel to Portland International Airport. In addition to the fuel storage facilities, the CEI Hub also contains liquid fuel and natural gas pipelines and transfer stations, a liquefied natural gas storage tank, storage of other non-fuel materials, a high-voltage electrical substation, and transmission lines.

The CEI HUB is located on top a high-risk liquefaction zone, as the NW Industrial Area was developed on top of the Willamette River Floodplain.

Table 3.4 Potential Releases from CEI HUB (ECONorthwest, 2021)

Spill Location	Number of Tanks with 50 – 100 percent failure	Number of Tanks with up to 10 percent failure	Volume Released Min (gal)	Volume Released Max (gal)
Ground	269	21	53,882,252	111,183,900
Water (Including potentially in water)	96	11	40,751,753	82,503,352
Total	365	32	94,634,005	193,687,251

In total, 397 tanks could release materials in a CSZ earthquake. Based on tank age and location, approximately 365 tanks could release 50% to 100% of their materials and 32 tanks could release up to 10% of stored materials. Together, the total potential releases from the materials stored in tanks at the CEI Hub range from 94.6 million to 193.7 million gallons. Approximately 57% of the total potential releases would be released onto ground and 43% could flow into the Willamette River.

A fire at the CEI Hub involving the fuels stored on-site is a likely scenario following a CSZ earthquake. Many fuel storage tanks have a metal floating lid which in an earthquake could scrape against the metal perimeter, creating a spark and potentially a fire. Fires within tanks could result in large explosions, further threatening people, property, and environmental resources. There are also power lines throughout the CEI Hub which could fall due to the earthquake and serve as a potential ignition source.

Of the 393 active tanks that are not empty and have known contents at the CEI Hub, 200 tanks (approximately 51%), have materials that are known to be flammable. Based on the total estimate of releases, approximately 93% of releases will be of flammable materials. The total capacity of tanks with flammable materials is 298.7 million gallons. Therefore, the contents of these tanks all have the potential to burn, either on land or in the water. Because burning requires both a fuel and an ignition source, the specific amount of materials that would burn are a function of location and event-specific factors.

Infrastructure

It is almost certain that a magnitude 9.0 CSZ earthquake will cause all private and public utilities to fail initially; this means there will be no municipal water or sewer service, no electricity, no telephone, and no television, radio, or internet (OSSPAC, 2013). The State of Oregon, the City of Portland, and local institutions such as the Port of Portland have done research to understand the impacts of a CSZ 9.0 earthquake on our transportation, wastewater, water, parks, information systems, and community infrastructure.

Table 3.5 Infrastructure Service Restoration of Service Estimations (OSSPAC, 2013)

Critical Service	Time
Electricity	1 to 3 months
Police and Fire Stations	2 to 4 months
Water and Wastewater	1 month to 1 year
Top-priority highways (partial)	6 to 12 months
Healthcare Facilities	18 months

The City's infrastructure systems are highly interdependent, which means they rely on one another to function well. Therefore, a failure in one system can trigger a failure in another: for example, a broken water pipe could release water that washes out a road. Blocked or damaged roadways would severely limit the potential repair and recovery of other systems.

This interdependence also means that strengthening one system can help to strengthen another: for example, hardening the lining of irrigation wells owned by Portland Parks & Recreation so that these could provide (non-drinkable) water sources during recovery (City of Portland and PSU ISS, 2018).

Table 3.6 Utility Systems Within Potential Liquefaction Areas (PWB, 2016)

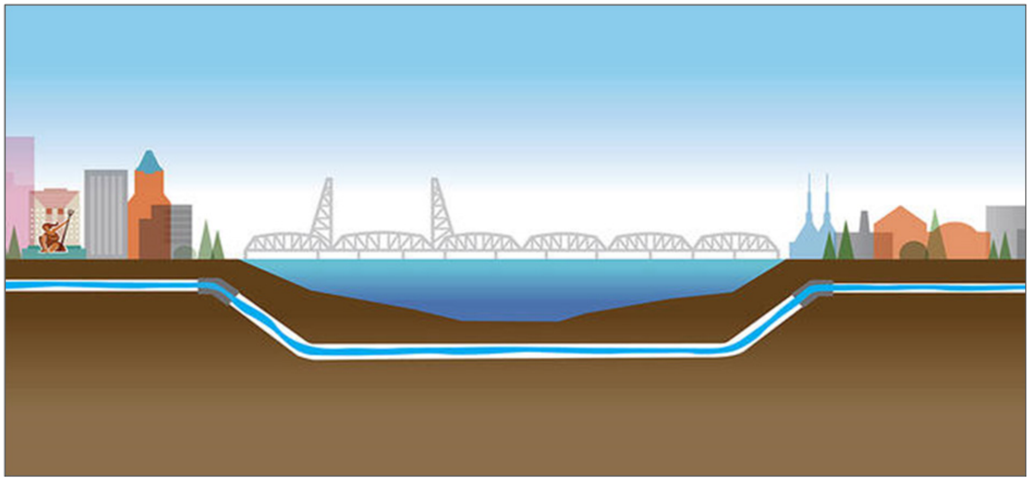
Infrastructure Type	High Liquefaction Potential Areas		Moderate Liquefaction Potential Areas	
	Mileage	%	Mileage	%
Potable Water Backbone	27.49	18.80%	8.8	6.20%
Wastewater System Collection Pipes	406.47	15.40%	165.01	6.20%
Major Power Lines	112.17	23.50%	49.44	10.40%
Major Gas Lines	21.05	25.20%	15.58	18.70%

Water (Portland Water Bureau): In 2016, the Portland Water Bureau (PWB) conducted a Seismic Study to assess the vulnerability of its system to a CSZ 9.0 earthquake event (PWB, 2016). The results produced damage estimates, summarized below.

- **Pipelines & Crossings:** Between 1,500 and 3,000+ pipes in the region's water system are expected to break during a CSZ 9.0 earthquake. Three of the six total pipes that carry water from Portland's East side to the West side are expected to break (Ellis, 2019), while approximately 70 to 600+ backbone pipelines and 1,100 to 9,700 distribution pipelines are expected to require repairs.
- **Wellfield** The Columbia South Shore Wellfield, which provides a secondary drinking water source and supplements Portland's Bull Run water supply, is in an area of high risk of liquefaction. It is expected that most of the production wells would be damaged during an earthquake, resulting in scarce water availability from this site.
- **Pumping System:** Out of 38 pump stations, four (11%) are at moderate risk, one (2%) is at moderate to high risk, five (13%) are at high risk, and one (2%) is at very high risk. There are three critical pump stations with high failure probabilities.
- **Storage Tanks:** Seismic assessment of PWB's 58 water storage tanks shows that most have a low landslide risk, with only the Portland Heights tanks showing a high risk of landslide hazard. None of the existing tanks have been seismically retrofitted (PWB, 2016). All but six are more than 30 years old and were not designed to recent seismic design standards.

PWB has worked for the past several decades to increase the number of water supply facilities that can withstand earthquakes. Newer reservoirs at Kelly Butte, Powell Butte, and Washington Park all meet seismic standards (PWB, n.d.).

Figure 3.12. Willamette River Crossing diagram (PWB, n.d.)



Portland's water mains that cross the Willamette River are more than 50 years old and will probably not survive a major earthquake. The Willamette River Crossing Project, which will build an earthquake-resilient water line under the Willamette River, is part of the PWB's investment in preparedness.

At present, restoring service to 90% capacity following an earthquake will take at least five days, with 40 crews working 12-hour shifts, and assuming the damage is within the median expected range. The target recovery time goal set by Oregon Resilience Plan's is 24 hours; this estimate falls short of that (Figure 3.10). The Oregon Resilience Plan also set a recovery goal of one to two weeks to restore the distribution system to 90%, but it is estimated that such repairs will take five weeks or more. (OSSPAC, 2013).

Figure 3.10 Oregon Resilience Plan Target States of Recovery for Water (OSSPAC, 2013)

Target States of Recovery: Water System

	0–24 hours	1–3 days	3–7 days	1–2 weeks	2 weeks –1 month	1–3 months	3–6 months	6 months –1 year	1–3 years	3 + years
Potable water available at supply source (WTP, wells, impoundment)	R	Y		G			X			
Main transmission facilities, pipes, pump stations, and reservoirs (backbone) operational	G					X				
Water supply to critical facilities available	Y	G				X				
Water for fire suppression at key supply points	G		X							
Water for fire suppression at fire hydrants			R	Y	G			X		
Water available at community distribution centers/points		Y	G	X						
Distribution system operational		R	Y	G						

G 80–90% Y 50–60% R 20–30% X Current Conditions (to 90% operational)

Stormwater + Wastewater (Bureau of Environmental Services)

Portland's Bureau of Environmental Services (BES) completed a Seismic Resiliency and Recommendations report in 2019, which included a risk assessment for its backbone system and estimated levels of service following a CSZ event.

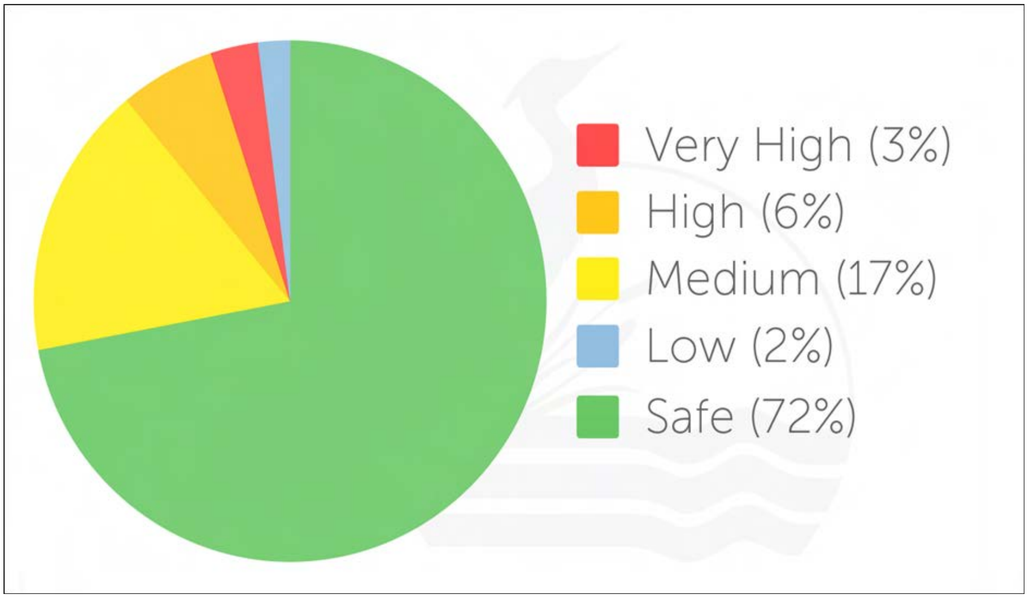
A geospatial analysis of resilient pipelines associated with buildings in the City of Portland was conducted by BES to estimate how many buildings may continue to have sanitary service after the CSZ event. Based on the information available, an estimated 65% (F of buildings are expected to have sanitation services after an earthquake (BES, 2019).

BES identified several "resilience gaps", or differences in times of service restoration, between current collection system conditions and the proposed 50-year targets of the Oregon Resilience Plan (ORP). These gaps are illustrated below.

Figure 3.13 Seismic Vulnerability of BES Collection System Pipes (BES 2019)

Building Type	Limited to No Sanitation Service	Sanitation Service Preserved	Total
Commercial/industrial/institutional	1,400	600	2,000
Multi-family residential	7,000	9,300	16,300
Single-family residential	63,400	124,800	188,300
Total	71,800	134,700	206,500
Percentage of total	**35%**	**65%**	**100%**

Figure 3.14 Seismic Vulnerability of BES Collection System Pipes (BES 2019)



According to the Oregon Resilience Plan, sewers and pump stations in liquefiable areas would be heavily damaged. Large pump stations along rivers would likely settle or tilt, shearing off connecting piping. Sewage would likely overflow into the Willamette River. In areas distant from water bodies, sewage would likely flow into gutters and ditches, making its way through the surface water drainage system. Sewage would also likely back up into homes and businesses. (OSSPAC, 2013).

In many locations it would take a year before the sewage system is functioning and three years before major pipelines and treatment plants are fully restored to their pre-earthquake functionality. (OSSPAC, 2013).

Figure 3.15 Oregon Resilience Plan Target States of Recovery for Wastewater (OSSPAC, 2013)

Target States of Recovery: Wastewater System

	0-24 hours	1-3 days	3-7 days	1-2 weeks	2 weeks -1 month	1-3 months	3-6 months	6 months -1 year	1-3 years	3 + years
Threats to public health & safety controlled		R	Y		G			X		
Raw sewage contained & routed away from population	R		Y			G		X		
Treatment plants operational to meet regulatory requirements				R			Y	G		X
Major trunk lines and pump stations operational				R		Y	G			X
Collection system operational						R	Y	G	X	

G 80–90% Y 50–60% R 20–30% X Current (to 90% operational)

Electrical Power Transmission

Electrical facilities and network components – including power plants, substations, transmission lines – are vulnerable to damage from ground shaking and ground failure, but especially from landslides, soil liquefaction, and lateral spreading (Mate et al., 2021; DOGAMI, 2018a).

A CSZ event will cause the failure of numerous power system components, and over half of the region's electrical grid may suffer medium to high damage on all grid levels. Outages and blackouts will occur even in areas that were not directly affected by the earthquake. In the I-5 corridor, considerable damage to power generation and distribution facilities may result in the loss of over half of the system's capacity. (Mate et al., 2021)

Because Portland has three separate electricity providers – Bonneville Power Administration (BPA), Portland General Electric (PGE), and Pacific Power (PP) – it is difficult to accurately assess impacts to the entire system. Of those providers, only BPA has conducted a thorough seismic study, "Liquefaction Assessment, Bonneville Power Administration Facilities, Portland Metropolitan Region," which was completed in 2008 (BPA, 2008).

The current estimated restoration time of the electrical grid after a CSZ 9.0 event ranges from 1-3 months. See Figure 3.14 below for Oregon Resilience Plan 50-year targets for recovery.

Figure 3.16 Oregon Resilience Plan Target States of Recovery for Energy (OSSPAC, 2013)

Target Timeframe For Recovery: Energy Sector

	0–24 hours	1–3 days	3–7 days	1–3 weeks	3 weeks -1 month	1–3 months	3–6 months
Electric							
Transmission					X		
Substation						X	
Distribution					X		
Natural Gas							
Transmission					X		
Gate Stations					X		
Distribution					X		
Liquid Fuel							
Transmission							
Storage							

G 80–90% Y 50–60% R 20–30% X Current (to 90% operational)

Communications & Technology

A CSZ event would result in catastrophic impacts to the information and communications systems throughout western Oregon. Well-engineered structures may perform well, but many older structures would likely fail, including central offices and buildings supporting antennas. One of the major impacts in the central valley, especially in the Portland Metro area, would be from liquefaction: extensive alluvial and fill deposits along rivers would lose strength, lose bearing capacity, and move towards riverbanks. Liquefaction could adversely impact buried utilities as well as antenna towers and buildings. (OSSPAC, 2013)

Figure 3.17 Oregon Resilience Plan Target States of Recovery for IT and Communications (OSSPAC, 2013)

Information and Communications Technology Sector

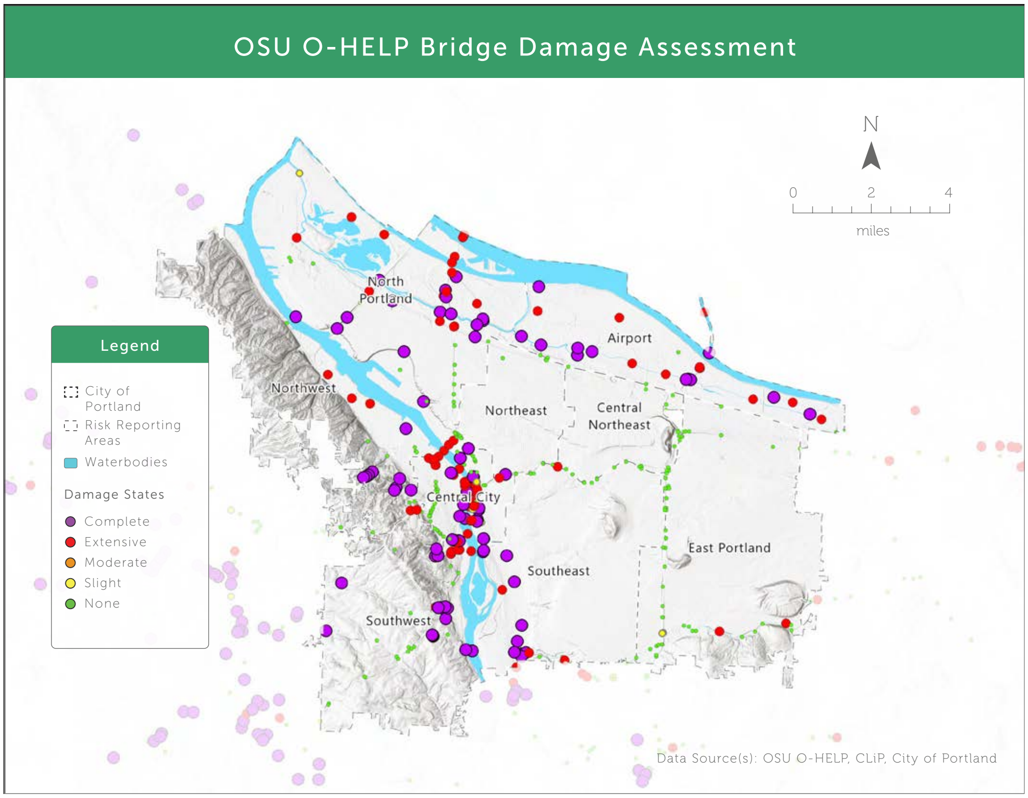
ZONE 3: VALLEY		R		Y	G					
Buildings										
• Repair								X		
• Replace									X	
Equipment in Buildings						X				
Towers						X				
Underground Lines						X				
Overhead Lines					X					

G 80–90% Y 50–60% R 20–30% X Current Conditions (to 90% operational)

Transportation

Earthquake-induced ground failure can damage roads, which can block access routes for emergency services and residents. A compromised transportation network is likely to severely limit recovery efforts.

Figure 3.18 Bridge Damage Assessment from (OSU OHELP, n.d.)



Bridges

All the older bridges crossing the Willamette River are expected to be seismically damaged in a major earthquake. Some are expected to collapse, and none are expected to be usable immediately following an earthquake. In addition, the east side access roads to the Morrison, Steel and Broadway bridges pass under and/or travel on aging I-5 overpasses that are expected to collapse in a major earthquake, thereby blocking access to those river crossings (ODOT, 2014; ERBB, 2017).

The state-owned Ross Island, Marquam, Fremont, and St. Johns bridges, like the other older bridges crossing the Willamette River, were designed and built before the Cascadia Subduction Zone fault had been identified and understood. ODOT expects all these bridges to be unusable immediately following a CSZ earthquake and have classified expected damage as "collapse" for the Ross Island Bridge, "extensive" for the St. Johns Bridge, and "moderate" for the Fremont and Marquam bridges. ODOT anticipates that the main river portion of the Marquam Bridge, following inspection and repairs, could potentially be serviceable four weeks after a CSZ earthquake. However, because the I-5 viaducts/ramps on the east side are expected to suffer "extensive" damage, there may be no way to access the Marquam crossing. ODOT has identified seismic retrofit needs and priorities for the state highway system from the coast to east of the Cascades. Estimated costs are in the billions and ODOT has suggested that implementation could occur in five phases over several decades. The Oregon Highways Seismic Plus Report indicates that the state-owned Willamette River crossings are not the first priorities for the state system, in part because of the high cost of retrofitting or replacing these bridges (ODOT, 2014).

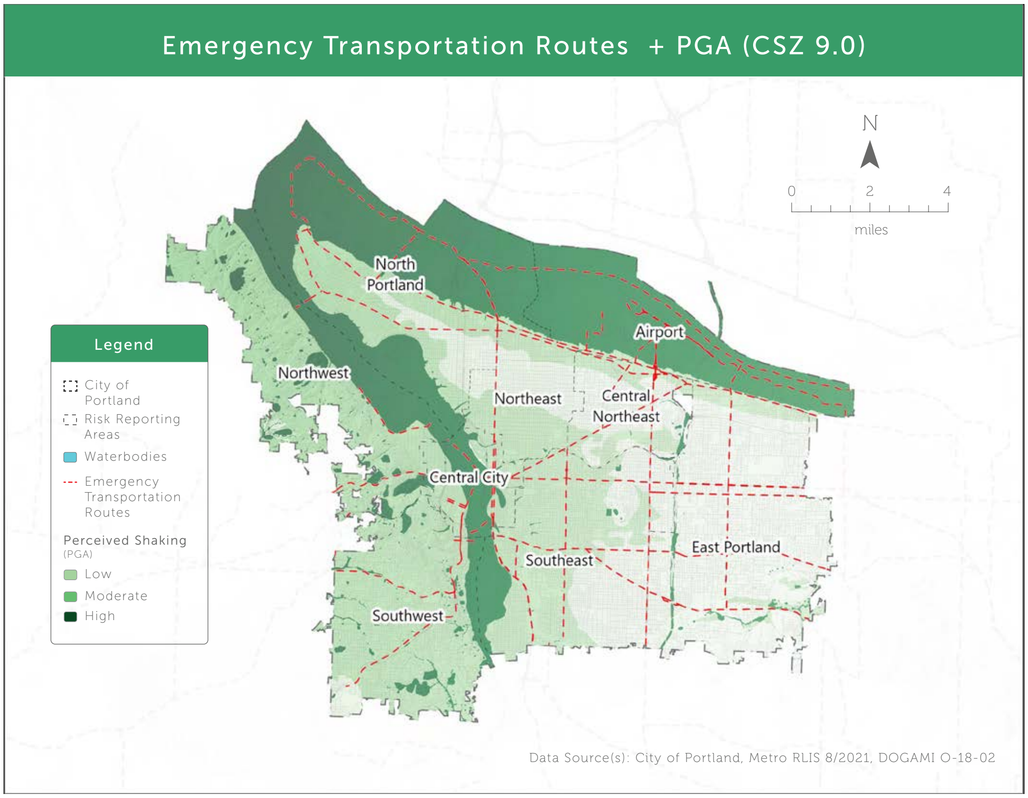
The newest Willamette River bridges, Sellwood and Tilikum, are not expected to collapse in a CSZ earthquake. The Sellwood Bridge was designed to survive a CSZ earthquake and be back in service quickly after the event. Multnomah County also stabilized a landslide-prone area near the west end of the bridge. However, landslides could be an issue in the hills above Highway 43 on the west side away from the bridge area, and access to the downtown core and Burnside lifeline route would require approximately ten miles of out-of-direction travel via the Sellwood Bridge. The Sellwood Bridge could serve a lifeline function following a major earthquake but would not serve the same broad area, population, or downtown core that is served by the Burnside Bridge and Burnside lifeline route.


Tilikum Crossing

The transit-oriented Tilikum Crossing Bridge, serving light rail transit, streetcar, buses, bikes, and pedestrians, is also expected to survive and be serviceable following a CSZ earthquake. However, because it is not a designated lifeline route nor intended for vehicle use, the approaches to the bridge were designed to "life safety" standards and not intended to provide lifeline functions. Life safety standards result in a structure that will preserve lives by avoiding collapse in a major earthquake but is not necessarily expected to be usable immediately following such an event. In addition, the west side access to the bridge crosses under several seismically vulnerable I-5 and I-405 viaducts that, in their current condition, would be likely to suffer severe damage in a major earthquake and block the route to the bridge. It must also be recognized that the Tilikum Crossing is not connected to any identified Priority 1, 2, or 3 seismic lifeline route.

In addition to bridge and overpass damage, roads could be blocked by debris from collapsed or damaged Unreinforced Masonry (URM) buildings following a major earthquake.

Figure 3.19 Emergency Transportation Routes and PGA (Peak Ground Acceleration)

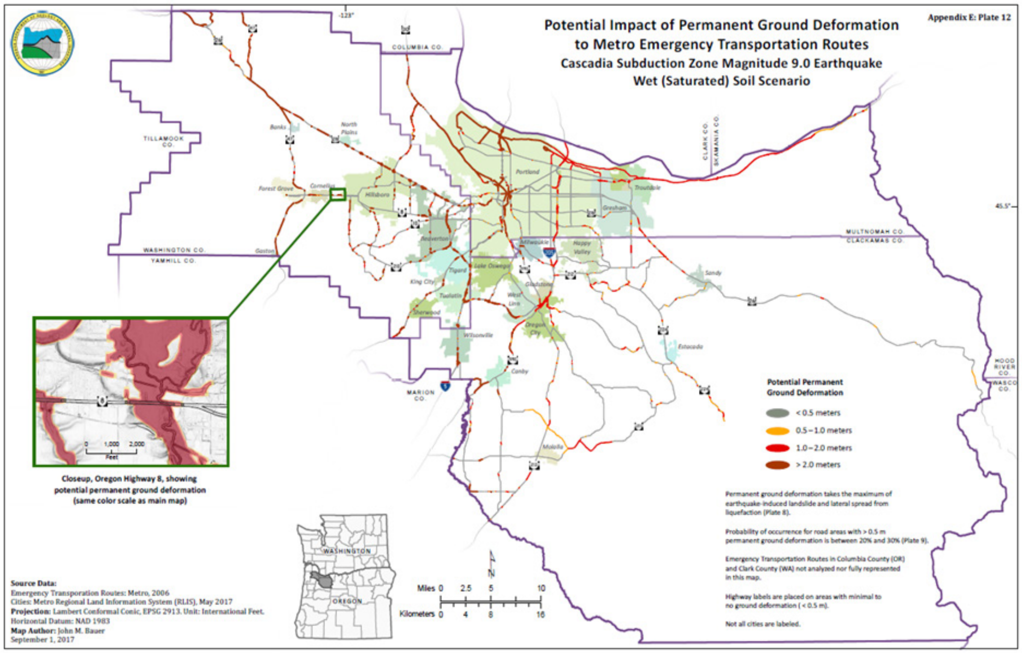


Emergency Transportation Routes

In 2021, the Regional Disaster Preparedness Organization, which is a partnership of government agencies, non-governmental organizations, and private-sector stakeholders in the Portland metropolitan region, and the regional government body Metro updated the designated 'Regional Emergency Transportation Routes' for the five-county Portland-Vancouver metropolitan region. A second phase is proposed for 2022-2023 to prioritize the updated routes and develop operational guidance for route owners/operators.

DOGAMI also assessed 'Potential Ground Deformation on Emergency Transportation Routes', seen in Figure 3,20 showing most of the critical routes within Portland experiencing more than two meters of displacement.

Figure 3.20 Impacts to Emergency Transportation Routes (DOGAMI, 2018a)



Economic Impact

The impacts from a major earthquake event will fundamentally alter Portland's economy (DOGAMI, 2018a). There will be direct, damage-related costs (as shown for buildings above in the Earthquake Estimated Building, Structure, and Content Loss tables in the appendix), and indirect costs, which are expected to exceed the direct costs (OSSPAC, 2013). Ground failure could permanently alter land use in Portland, especially in high liquefaction areas. Portland's already-strained housing market will likely suffer a reduction in the supply of available housing stock (Portland Housing Bureau, 2021).

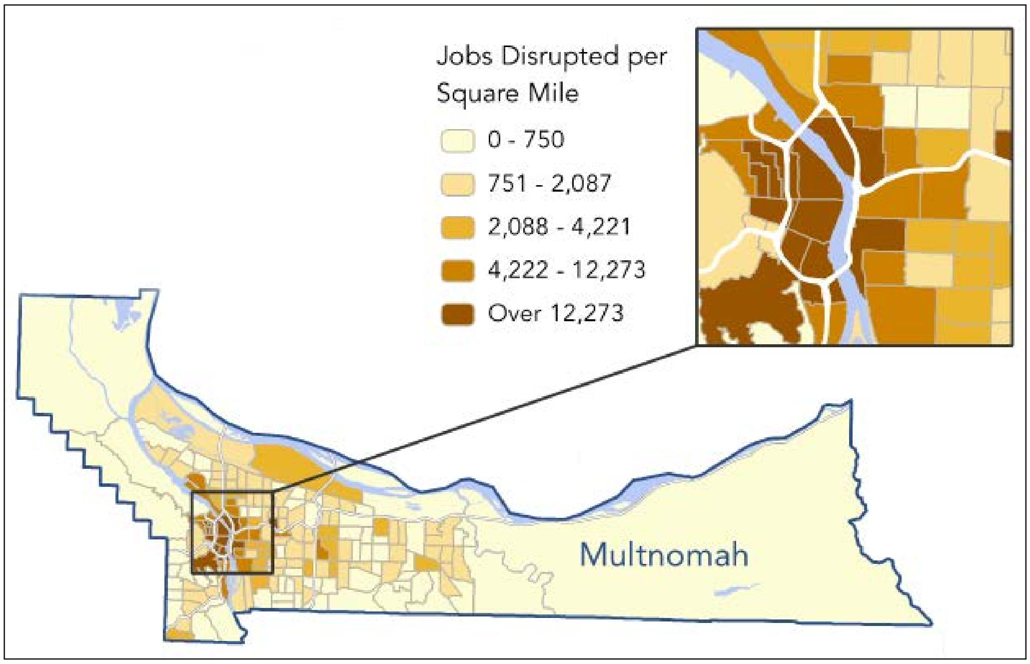
Normal economic activity will be severely disrupted in the short- and long-term. Population is expected to decline in the wake of an earthquake event, studies suggest up to 12% (ECONorthwest 2020), potentially changing the positive trajectory of Portland's economy, which has seen steady growth since 2000. As of 2020, Portland had the 23rd largest metropolitan economy in the United States (Statista, 2021a).

In 2019, the Portland Metro-area economy produced $175 billion GDP according to the US Bureau of Economic Analysis (2020). This represents more than three-quarters (77%) of Oregon's total annual economic output, which is approximately $225 billion (Statista 2021b). Losses statewide are estimated to be in excess $30 billion (OSSPAC, 2013), falling largely on the Portland area. If Portland's economy is impacted proportionally, local losses could be over $20 billion.

A CSZ earthquake is likely to worsen entrenched economic inequalities among Portland residents by benefiting those who have the resources to respond and recover (i.e., relocate or repair) and further harming those who don't, deepening the existing economic divide.

Businesses in Portland will face great impacts from an earthquake. While the exact timeline of the broader physical recovery from the CSZ event is unknown, the extent of the impacts will be broad, with roughly 70% of businesses likely having to close temporarily, affecting around 1,000,000 jobs. Just one month of such closures will result in a loss of over $4.3 billion in income

Figure 3.21. Job disruption estimates for Multnomah County (ECONorthwest, 2020)



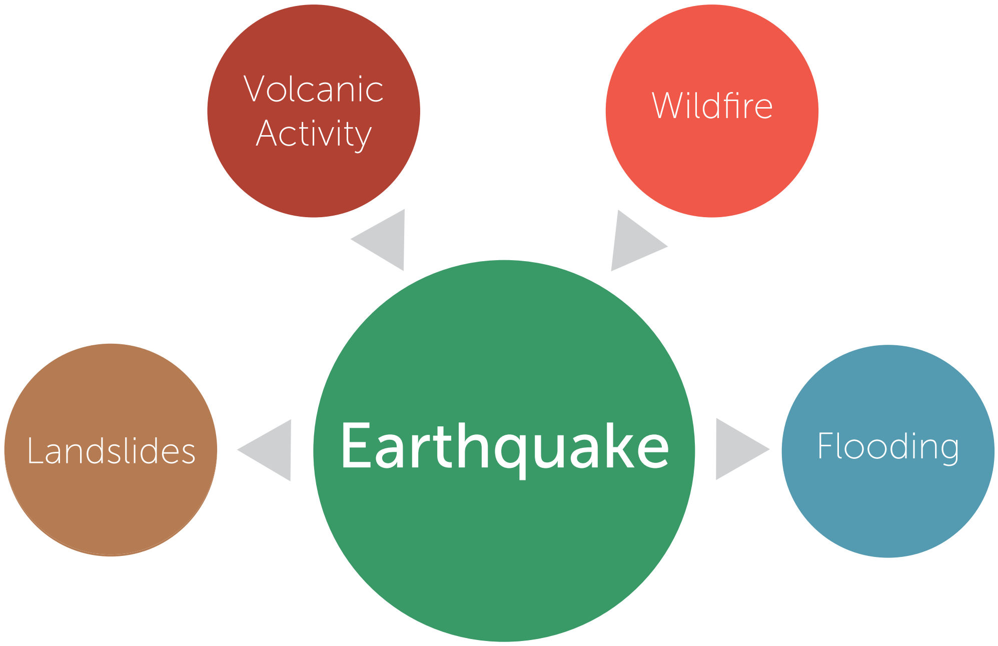
in the region. Impacts on jobs and income will be the largest in the health care and manufacturing sectors (ECONorthwest, 2020, p.15). The county-level share of jobs disrupted by square mile is displayed in Figure 3.19.

Some retail businesses, such as home repair, plumbing supply, hardware, lumberyards, etc., will likely see their sales increase during the immediate aftermath of a CSZ earthquake. Demand is likely to exceed supply, reducing the number of people who can resettle in Portland.

Estimated Recovery Period

As things stand now, Portland would be unable to recover in a timely manner without significant investments in infrastructure resilience in the coming decades. While some bureaus are working to improve resilience, current City investments will not meet the State's goals for recovery within the 50-year time frame (City of Portland and PSU ISS, 2018).

While no exact estimates exist, it will take years at minimum to fully recover from the impacts of a major earthquake event.



Connected Hazards

Landslide: Shaking from earthquakes can cause landslides. Landslides caused by either a Cascadia Subduction Zone earthquake or a Portland Hills Fault earthquake are estimated to damage between 1,344 and 4,992 buildings and displace between 600 and 2,761 residents. The risk of a landslide being triggered by an earthquake significantly increases when soil is wet. Any earthquake event is likely to trigger landslides in landslide-prone areas (DOGAMI, 2018b).

Flooding: Debris from earthquake-induced landslides can enter stream channels and block them, causing flooding. An earthquake can also damage dams or levees, which could lead to flooding.

Volcanic Activity: Earthquakes typically happen before volcanoes erupt and can cause volcanic eruptions.

Wildfire: Facilities with combustible materials that are located near trees and grasses, such as the CEI Hub, may create wildfires if they are damaged due to

Flooding

Problem Statements

- It is estimated that 1.3% of structures in the city of Portland are currently at risk of flood (FEMA, 2020).

- Many of Portland's original wetlands and floodplains (lands bordering rivers that absorb floodwaters) that provided natural flood protection have been drained and/or paved over through the years (BES, n.d.-a), leaving communities in such areas especially at risk for flooding.

- The federal government has determined that the 27 levees along the Columbia River in the Portland Metro are "inadequate" (Levee Ready Columbia, n.d.).

- Changes in weather patterns due to climate change means that flood risks in Portland will likely increase in the coming years (OCCRI, 2021, p67).

What is Flooding?

Flooding happens when water covers land that is normally dry. This usually results from a stream or river overflowing due to rainfall, snowmelt, or a broken levee or dam. In Portland, floods happen every year. Because it is a naturally recurring phenomenon, flooding is considered hazardous only when it impacts people or property.

The four major causes of flooding in Portland are riverine (river-related), stormwater (when runoff exceeds the capacity of stormwater infrastructure), levee failure, and dam failure. Portland is most at risk for the first two of these.

Riverine flooding occurs when rainfall or snowmelt exceed the capacity of a river system, and water flows over the banks and into the surrounding area. Portland is most likely to experience flooding from the Columbia, Willamette, as well as from creeks and streams within these river systems.

Stormwater flooding occurs when rainwater and runoff exceed the capacity of stormwater systems in urban areas. Stormwater systems consist of stream channels, ditches, and storm drains. Some structures in stormwater systems are designed to help catch, filter, or divert rainfall to reduce the amount of water traveling through the system.

Levees are made of earth and prevent rivers from overflowing. They can be breached (broken through) by rising, fast-flowing waters. There are 27 levees along the Columbia River in the Portland metro area that help prevent overflow. The catastrophic Vanport Flood in 1948 was due to a levee failure.

Table 3.7. Condition of dams in Portland (OWRD, 2021)

County	Dam Name	Condition
Multnomah	Portland #1 (Mt.Tabor)	Satisfactory
Multnomah	Portland #3 (Washington Park)	Satisfactory
Multnomah	Portland #4 (Washington Park)	Satisfactory
Multnomah	Portland #5 (Mt.Tabor)	Satisfactory
Multnomah	Portland #6 (Mt.Tabor)	Satisfactory

Dams are human-made structures that hold back water. There are five dams in Portland: three in Mt. Tabor Park and two in Washington Park. They are operated by the Portland Water Bureau. The Oregon Water Resources Department has rated these dams "Satisfactory" according to Federal Emergency Management Agency (FEMA) classifications. Under normal conditions, dams are generally not likely to fail. Events that might cause dams to fail include:

- An extreme flood that overpowers the dam
- Internal erosion (wearing away) within a dam caused by extended high-water levels
- Damage due to an earthquake or landslide

Figure 3.22. Dams within ten miles of Portland

Table 3.8 Dams in Portland (OWRD, 2021)

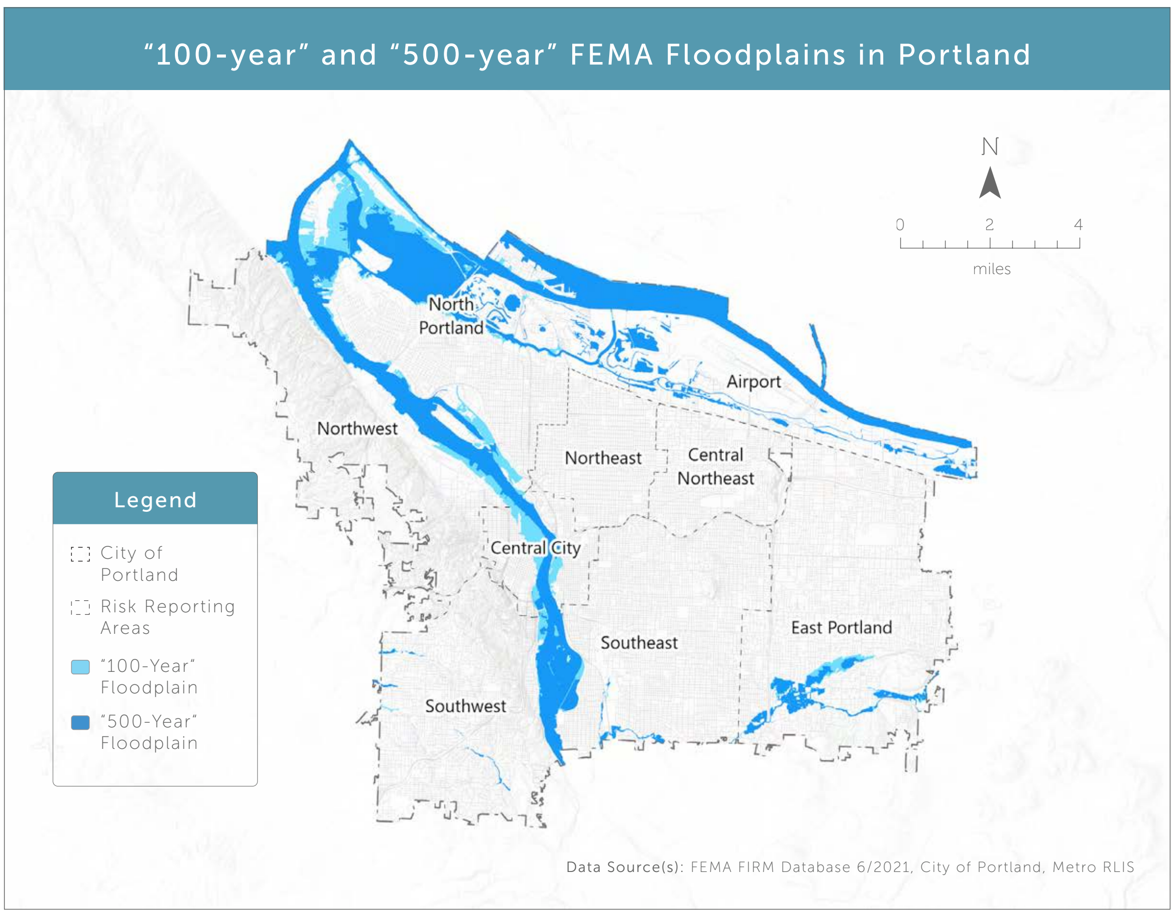
Name	National ID #	River	Height (feet)	Storage Capacity (acre-feet)	Last Inspection	Hazard Class
Bonneville Dam	OR00001	Columbia	110	277,000	4/3/2008 (Federal)	High
Bull Run Lake Dam	OR00300	Bull Run River	55	14,500	4/28/1995 (Federal)	Low
Bull Run Dam 1 (upper)	OR00327	Bull Run River	194	33,760	6/12/2012 (Federal)	High
Bull Run Dam 2 (lower)	OR00317	Bull Run River	125	21,000	6/12//2012 (Federal)	High
Mt. Tabor Reservoir #1	OR00667	Bull Run River (off-stream)	30	37	11/12/2015	High
Mt. Tabor Reservoir #5	OR00670	Bull Run River (off-stream)	55	153	11/12/2015	High
Mt. Tabor Reservoir #6	OR00671	Bull Run River (off-stream)	28	230	11/12/2015	High
Washington Park Reservoir #3	OR00668	Bull Run River (off-stream)	53	50	11/12/2015	High
Washington Park Reservoir #4	OR00669	Bull Run River (off-stream)	60	54	11/12/2015	High
Portland International Airport De-icing Lagoon	OR03822	N/A	20	67	3/15/2011	Low
Smith-Bybee Lakes	OR00680	Columbia Slough	14	4,100	8/25/2010	Low
Willamette Falls	OR00596	Willamette River	37	17,000	8/28/2012	High

Characteristics of Flooding in Portland

The Willamette River Basin is the largest watershed in the state, with 13 major tributaries. Although the city of Portland occupies only 1% of the Willamette River's drainage basin, it is the most urbanized area in the basin. There are more than 53 miles of buried or piped streams in Portland (BES, n.d.-b) and several major creeks, especially on Portland's West side.

FEMA Flood Insurance Rate Maps for Portland show where floods have occurred in the past and define most of the flood-prone streams. These maps also outline areas where major floods may occur. Major floods are often referred to as "100-year" and "500-year" floods, which sounds like these kinds of floods happen only every 100 or 500 years. But in fact, what this means is that in any year, there is a 1% or 0.2% chance of such a flood occurring in those areas. In fact, a 100-year flood could happen two years in a row, if the conditions for flooding are right (USGS, n.d.-l).

Figure 3.23. "100-year" and "500-year" Floodplains in Portland (FEMA)



A floodplain is any area of land along the banks of a river that is covered with water during a flood. In Portland, communities and structures that are located within floodplains are at significantly higher risk when flooding occurs. Floodplains are a natural part of the Portland environment. Understanding and protecting their natural functions can reduce flood damage and protect people and property. The benefits of preserving floodplains include:

- Controlling floodwaters - Floodplains are like natural sponges, storing and slowly releasing floodwaters. This reduces the heights of floods and how fast rivers flow. When a river is cut off from its floodplain by levees and dikes, flood heights often increase, and downstream damage can be greater.
- Improving water quality – Plants in floodplains serve as natural filters of water that moves through it, trapping sediments and capturing pollutants. Floodplains help to moderate temperatures that can harm fish and other aquatic life.
- Recharging (refilling) groundwater - Floodplains help to recharge underlying aquifers (natural areas where water is contained underground).
- Providing habitat for fish and wildlife habitat – Floodplains provide breeding and feeding grounds for fish and wildlife, create and enhance areas for waterfowl, and protect habitat for rare and endangered species.

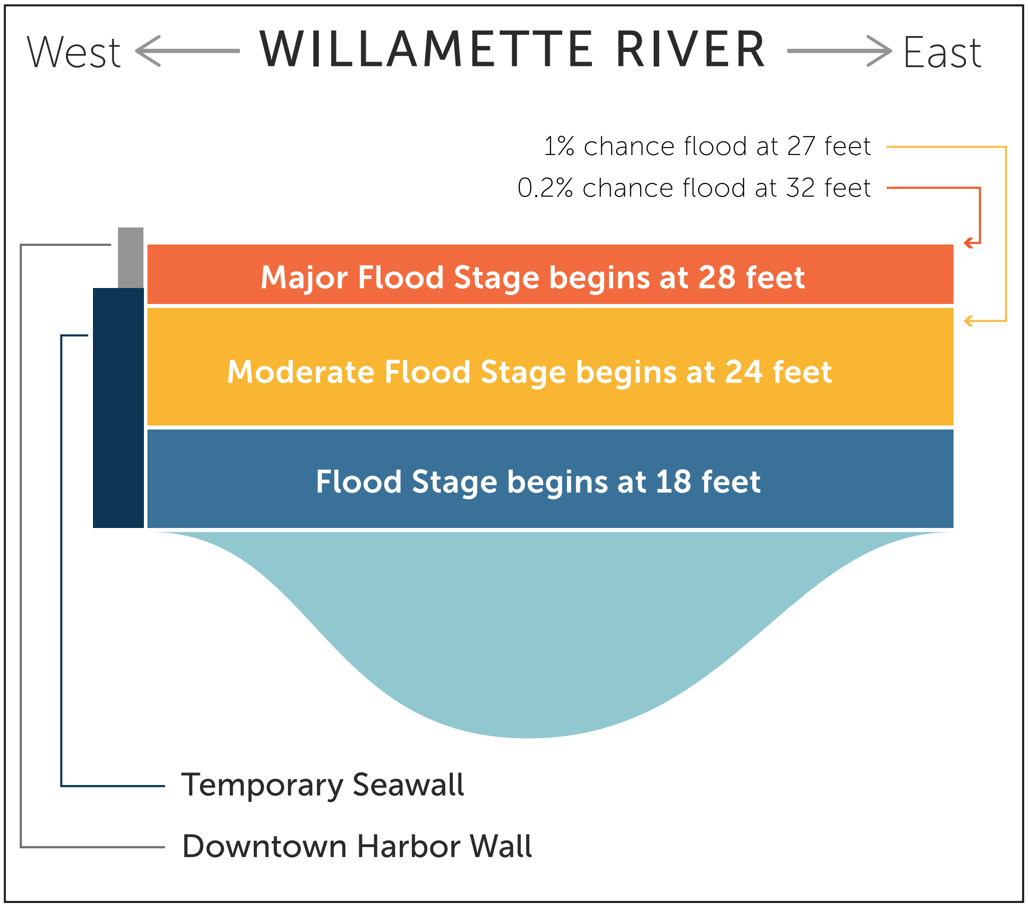
People have settled within floodplain areas throughout history because they provide many benefits: water is readily available, land is fertile and suitable for farming, transportation by water is easily accessible, and the land is flatter and easier to build on.

Human activity in floodplains frequently interferes with their natural functions and leads to an increase in flooding problems. Altering or confining natural drainage channels reduces the stream's capacity to contain higher flows and can make the water in a flood run faster, making floods more damaging. Creating areas that can't absorb water, such as paved roadways and roofs, increases stormwater runoff and flood risk. But it is possible to mitigate some of these effects and restore natural functions within floodplains.

Approximately 78% of Portland is developed land according to the National Land Cover Dataset (Dewitz and USGS, 2021), with around 36% of that area made up of impervious surfaces (surfaces that can't absorb water, such as parking lots and streets). Creating proper drainage infrastructure, such as storm drains and gutters, is necessary to mitigate the risk of flooding in these areas.

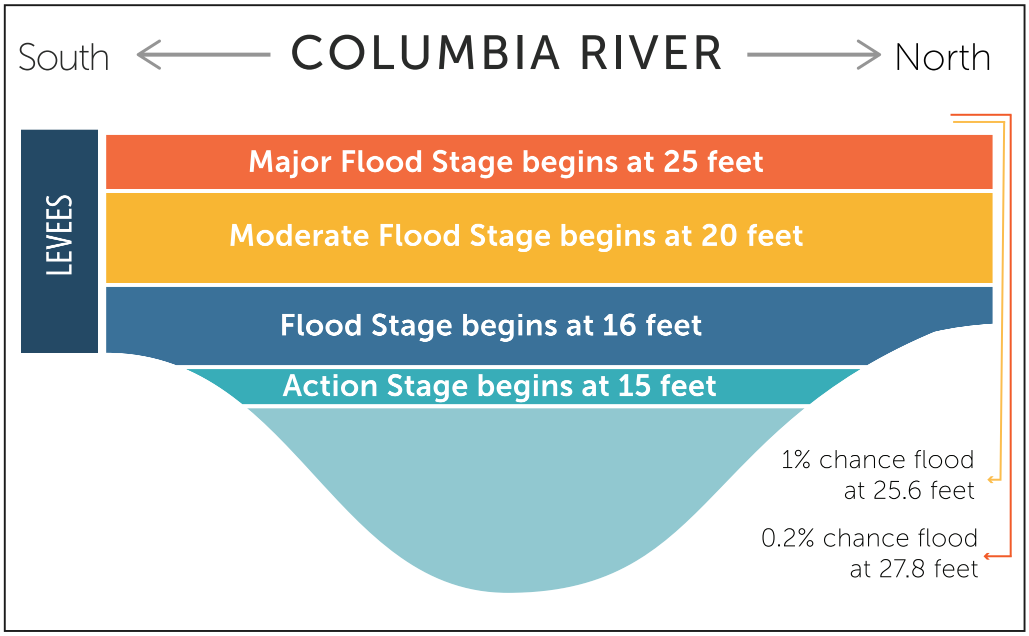
The major sources of flooding in Portland are from The Willamette River, the Columbia River and Johnson Creek.

Figure 3.24. Flood Stages of the Willamette River (PBEM, 2019)



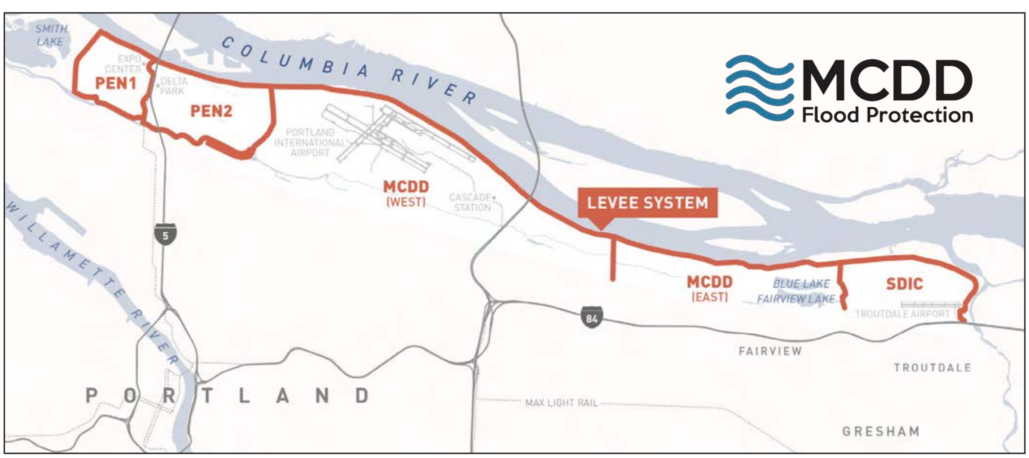
The Willamette River flows through Portland from the south to the north, dividing the city into its west and east sides, and flows into the Columbia River near Vancouver, WA. Flooding on the Willamette River is relatively rare, in large part due to the dams, levees, and other infrastructure built on it and its tributaries that are designed to prevent flooding. A 'flood stage' is the river water level at which some type of damage occurs. For the Willamette, minor flood stage starts when the river rises to (crests at) 18 feet over the riverbank (not the harbor wall). Historically high crests have been 33 feet in 1894, 30 feet in 1948, and 29.8 feet in 1964. Most of the highest floods occurred before the regional dam system was fully constructed. The most recent flood was in 1996 and crested at 28.55 feet. While this flood was considered a '100-year' flood (1% chance of such a flood happening in a year), areas beyond the '500-year' flood zone were also inundated, highlighting the uncertainty around mapping flood risk (PBEM, 2019). Figure 3.23 above shows the flood stages for the Willamette at the Morrison Bridge gauge. One hazard of note for a Willamette River flood is that docks and floating homes can break free in a major flood event.

Figure 3.25. Flood Stages of the Columbia River (PBEM, 2019)



The Columbia River is the largest river in the Pacific Northwest and forms the boundary between Oregon and Washington before flowing into the Pacific Ocean near Astoria, OR. Like the Willamette, flooding on the Columbia River is relatively infrequent in Portland, due to dams and other infrastructure upstream, and the levee system that is maintained by the Multnomah County Drainage District (MCDD). FEMA flood zones do not show areas that would flood should the levees be compromised. In 1948, the Columbia River crested at 31 feet and broke through portions of the levees, destroying the city of Vanport and displacing 18,500 residents. Figure 3.24 shows the flood stages for the Columbia River at the Vancouver WA gauge. As with the Willamette River, 'flood stage' refers to the level over the river's bank, and does not account for the levees, which also provide flood risk reduction from the Columbia Slough. Floating homes on the Columbia River are at risk in a major flood event.

Figure 3.26 MCDD Levee System (MCDD website)



The Multnomah County Drainage District (MCDD) operates and maintains flood management systems including 27 miles of levees and 45 miles of ditches, sloughs, streams and culverts along the Columbia Slough and the lower Columbia River (MCDD, n.d.). The ditches and sloughs were constructed and are maintained to accommodate a '100-year' (1% annual chance) flood. Stormwater enters these ditches and sloughs through pipes that drain water from the streets and parking lots of Portland. About 20 miles of levees protect the city from flooding due to high water in the Columbia River and Lower Columbia Slough (see Figure 3.25). The system has been extensively improved since the 1996 flood. Pump station, levee, and conveyance system upgrades, as well as a series of computers, repeaters and antennas that allow 24-hour real-time monitoring from remote locations, all make the system a reliable means to protect the managed floodplain from catastrophic flooding.

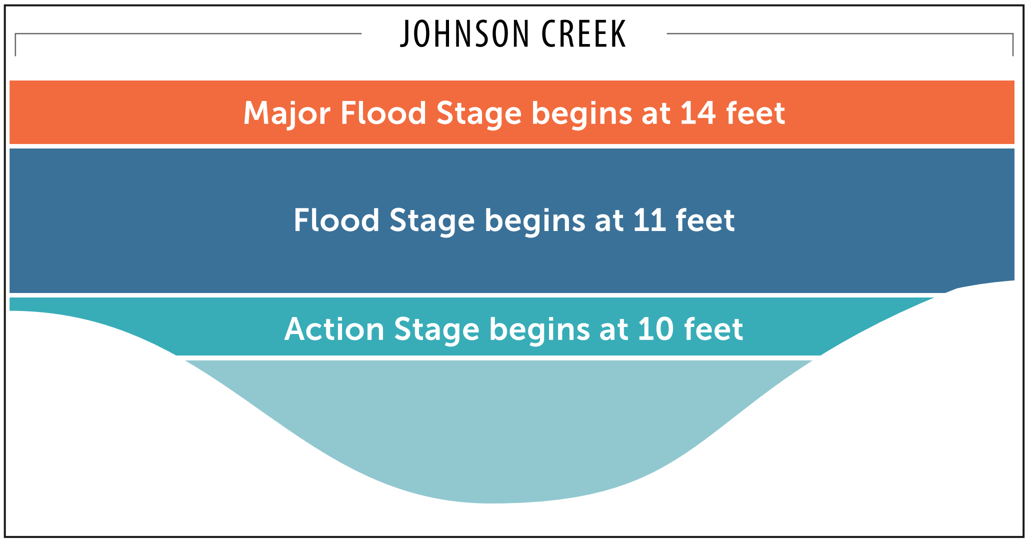
Properties protected by the MCDD system of levees are valued at more than $5.5 billion. The levees protect approximately $16 billion in economic activity, including the Portland International Raceway, the Portland Expo Center, the Portland International Airport, the Columbia Industrial Corridor, several residential neighborhoods, and the City's drinking water well system (MCDD, n.d.). The cost of replacing the infrastructure protected by Multnomah County Drainage District would be devastating. Flood control storage reservoirs have substantially reduced flood potential along the Columbia River and other major waterways. Upstream of Multnomah County, the Columbia River has 22 major reservoirs, and the Willamette River has 11. These reservoirs have reduced but not eliminated flood potential.

Table 3.9 Summary of results for a levee breach and 100-year flood in the Columbia corridor drainage districts (DOGAMI SP-50, Appleby and Bauer, 2018)

	SauvieIsland Drainage Improvement Company	Peninsula Drainage District 1	Peninsula Drainage District 2	Multnomah County Drainage District-West
Initially displaced residents	381	13	2,270	1,799
Number of exposed buildings	486	42	1,075	1,115
Total repair cost (building, content, and inventory)($ millions)[1]	$133.3 to 150.0M	$33.2 to 39.8M	$672.6to 760.2M	$3,588.5 to 4,746.0M
Number of businesses initially closed due to flooding	29	11	237	1,310
Number of employees initially unable to return to work	170	902	4,259	35,275

[1] Range indicates the standard and long-duration (> 3 day) flood assessment values.

Figure 3.27. Flood Stages of the Johnson Creek (PBEM, 2019)



Johnson Creek flows through Southeast Portland and provides habitat for several native species of salmon. Historically, frequent flooding of the creek caused substantial damage to nearby property and bridges. Floods used to impact the area surrounding SE Foster Road every other year on average. Recent and ongoing flood mitigation efforts have significantly reduced these impacts. The City of Portland has invested over $40 million in floodplain restoration. Public acquisition of homes and land in Johnson Creek's floodplain have allowed for the removal of flood-prone structures, and projects like the Foster Floodplain Natural Area have added over 240 acre-feet of flood storage. The area surrounding SE Foster Road now floods approximately every six to eight years (BES, n.d.-c). These efforts have reduced flood impact, but they have not eliminated flood risk. Flooding still occurs in the area, and the creek can rise and fall rapidly. A historic crest of 15.33 feet in 2015 led to considerably less property damage than previous floods, but additional flood events need to be studied to determine the impact of mitigation efforts on flood severity (PBEM, 2019). Figure 3.26 shows the flood stages for Johnson Creek at the Sycamore gauge.

National Flood Insurance Program

Please see the appenedix for: Information on the National Flood Insurance Program, the Community Rating System and Portland's participation.

Floods can last from minutes to weeks. This timing often depends on the duration of rainfall and the shape and type of land on which it occurs. In relatively flat areas, for example, shallow, slow-moving flood water may cover the land for days or even weeks. In areas with impervious surfaces (surfaces that don't absorb water, like parking lots) and/or in instances of extreme rainfall, flash floods can move through in minutes or hours.

Excessive rainfall from winter storms is the most common cause of flooding between the months of October and April. From May to July, snowmelt and runoff are more likely causes. Typically, the most severe floods are winter rainfall floods between December and February, when heavy or prolonged rain or snowmelt creates water flows that exceed the carrying capacity of river channels or other water courses and storage facilities. As storms from the Pacific Ocean move across the Oregon Coast Range, air rises and cools and heavy rainfall develops. Severe and prolonged storms can raise rivers and streams to their flood stages for three to four days or longer.

The following factors contribute to the frequency and severity of riverine (river-related) flooding:

- Rainfall intensity and duration
- Existing moisture in the air or ground
- Features of the watershed, including steepness of hills, soil types, amount and type of vegetation, and density of development
- Existing natural features such as wetlands and lakes and human-built features such as dams
- Flood control features, such as levees and flood control channels
- How fast the water in the river is moving
- The heights of tides and rise of seawater level in the ocean the river feeds into
- If the banks of the river are prone to erosion (wearing away) and if there is sediment in the river

Depth and velocity (speed) of flood waters are commonly used to measure how severe a flood is, as these two factors can indicate the likelihood of damage or injury. The deeper and faster a flood is, the more damage it can cause; and shallow flooding at high speeds can cause as much damage as deep flooding at a slow speed. Typical flood damage can include the following:

- Water damage inside buildings
- Erosion of stream banks, road embankments, foundations, footings for bridge piers and other features
- Damage from the impact of debris and swift-moving water
- Buildup of debris on bridge piers and in culverts
- Destruction of croplands
- Release or runoff of sewage and hazardous or toxic materials from damaged pipelines, tanks, and facilities
- Economic loss (local facilities, utilities, communications, agriculture)

A flood's severity is also evaluated based on its 'peak discharge'. Discharge is the amount of water that passes through a specific area over a certain period (also known as the speed of the flow, or 'flow rate'). Discharge measurements from past flood events can be used to map floodplains, because they reveal how far and how quickly flooding has previously occurred.

Table 3.10 Summary of peak discharges in Portland creeks

		Discharge (cubic feet/second)			
Source/Location	Drainage Area (sq. mi.)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Johnson Creek					
Downstream of confluence with Crystal Springs Creek	53	1,890	2,590	2,780	3,230
Upstream of confluence with Crystal Springs Creek	49	1,890	2,590	2,780	3,230
At 82nd Ave	46	1,830	2,660	2,970	3,640
At USGS Gauge 14-211500 (near RM 10.2	28	2,120	2,810	3,090	3,670
Fanno Creek					
At Beaverton-Hillsdale Highway	5.12	940	1,140	1,250	1,550
At extension of 65th Avenue	3.38	600	740	825	1,000
At extension of 59th Avenue	3.24	590	725	800	975
At Southwest 56th Avenue	2.53	470	620	670	800
At Southwest Shattuck Road	2.43	490	625	675	820
At Southwest 45th Avenue	1.71	350	460	490	590
Crystal Springs Creek					
500 feet upstream of Southeast 28th Street	3.6	16	24	28	40
1,200 feet upstream of McLaugh lin Street	n/a	22	70	92	169
Upstream of Railroad Bridge	n/a	44	100	126	212
Upstream of confluence with Johnson Creek	n/a	45	60	70	80

Predicting Flooding in Portland

It is unusual for a flood to occur without warning, as certain weather patterns need to happen first. Warning times can be issued for floods 24-48 hours before they occur. Flash flooding can be less predictable, but potential hazard areas can be warned of possible flash flooding danger.

The Portland Bureau of Emergency Management (PBEM) sends out advisories relating to flooding. The Bureau of Environmental Services (BES) serves as technical expert to PBEM and other bureaus on local flooding and hydrology. Both PBEM and BES rely upon USGS real-time river gage data and the National Weather Service's (NWS) flood prediction service. The NWS sends severe weather and emergency email briefings to BES and other City staff. BES performs additional monitoring and analysis of USGS data and NWS predictions throughout the wet season (typically November 1 through March 31). Up to 10 BES staff each year are designated as emergency managers.

During periods of heavy rainfall or when they are many days in a row of moderate rainfall, some BES staff monitor real-time online USGS river gage data

and NWS hydrograph predictions. USGS gages continuously collect discharge rates, water surface elevation, and temperature data and transmit that data every 15 minutes. Data is accessible online via USGS and NWS websites within an hour of collection. NWS predictive hydrologic models are run every 12 hours using the most current gage data and are also shared online. The following are the primary USGS gages monitored by the City of Portland:
Portland's most frequent disruptive flooding occurs along Johnson Creek; as a result, much of the City's flood risk monitoring and response planning efforts are focused in this geographic area.

Once water levels are within three feet of 'bank-full levels', BES staff set into motion a number of monitoring activities. They review hydrologic data

Table 3.11 Summary of peak discharges in Portland creeks

Gage Number	Waterway	City Gage Location	Specific Gage Location
USGS 14144700	Columbia River	Vancouver, WA	Under the I-5 Bridge
USGS 14211820	Columbia Slough	Portland, OR	N Lombard St. & N Kelly Point Park Rd.
USGS 14206900	Fanno Creek	Portland, OR	SW 56th Ave. & SW Seymour Ave.
USGS 14211315	Tryon Creek	Portland, OR	G Ave. & Cumberland Pl.
USGS 14211720	Willamette River	Portland, OR	Under the Morrison Bridge
USGS 14211550	Johnson Creek	Milwaukie, OR	SE Millport Rd. & SE McBrod Ave.
USGS 14211500	Johnson Creek	Portland, OR	SE 152nd Ave. & SE Foster Rd.
USGS 14211499	Kelley Creek	Portland, OR	SE 159th Dr. & SE Foster Rd.
USGS 14211400	Johnson Creek	Gresham, OR	SE Regner Rd. & SE Roberts Rd.

multiple times a day and continue monitoring until the threat has passed. BES issues a Level 1 event advisory in Johnson Creek when the Sycamore Gage height reaches 10 feet (approximately three feet below bank-full). Coordinated monitoring intensifies at that point to include emergency conference calls, field checks of gages and river levels at locations most likely to flood, and interpretation of additional data. Technical staff review the hydrograph (a graph that shows how much and how fast water is flowing at a specific point in a river) in depth and assess how quickly discharge rates are increasing at different points along the system; discuss predictions with NWS staff and request models be updated more frequently if conditions are rapidly evolving; review precipitation levels over preceding days, assess soil conditions (saturation, freezing levels, presence of snow, etc.) and likely impacts on river levels; compare current conditions against historic patterns and flood outcomes; and review flood inundation maps to anticipate possible outcomes.
Portland typically experiences flooding after more than three days of heavy rainfall. Based on previous floods, there is about a 33% chance of a flood occurring in any given year. Since flooding typically follows heavy rainfall, one of the best ways to assess the likelihood of flooding is to measure precipitation.

The chances that a flood will happen is also affected by a range of factors, including existing water conditions; watershed conditions (e.g., steepness of terrain, amounts of plants and grasses, and density of development); and flood control features (such as levees or flood control channels). These factors are analyzed together to help determine if flooding might happen, and how severe the flooding might be.

El Niño and La Niña are climate patterns that refer to interactions between trade winds and changes in water temperature in the Pacific Ocean. They can impact weather around the world. These patterns can occur anywhere from two to seven years apart, and typically last around nine to 10 months (NOAA National Ocean Service, 2021a). During a La Niña event, abnormally strong trade winds bring cold water to the Pacific ocean's surface, which in turn pushes the jet stream (a band of air currents circling the Earth) farther north than usual; in turn, clouds heavy with precipitation arrive from the western tropical Pacific, where ocean temperatures are well above normal . These conditions have different effects throughout the world and its ecosystems. Here in Portland, La Niña brings colder winter weather, more rain, and therefore greater potential for flood events to occur. Several major flood events in Oregon that impacted Portland have been attributed to La Niña, including in February 1996 and Winter 2007 (NHMP, 2020).

Climate change is likely to increase winter rain-on-snow periods and spring floods, which are postulated to cause more extreme flooding events. These flows are regulated by the Columbia River system of dams. Simulated increases in winter flow were estimated at 40% on the Columbia River, and 20% on the Willamette River, in extreme (yet plausible) conditions. These simulations are based on a moderately wet and warm general circulation model, and a moderate scenario for future greenhouse gas emissions (Wherry et al., 2018).

- Historical hydrologic patterns can no longer be solely relied upon to forecast future conditions.
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management and ecosystem functions.
- Extreme climatic events will become more frequent, necessitating improvement in flood protection, drought preparedness and emergency response.

According to the Fifth Oregon Climate Assessment Report, climate change will lead to more intense heavy rainfall events (Dalton and Fleishman, 2021, p.114). Climate change is also likely to make droughts (extended periods of low or no rainfall) happen more often and be more severe. Droughts and dry summers leave soils less able to absorb water. In these conditions, heavier winter rains are much more likely to cause flooding. According to the Oregon Natural Hazards Mitigation Plan, western Oregon basins (including the Portland area) are projected to experience increased flood risk in future decades due to climate change (NHMP, 2020). Flood protection facilities such as dams, bypass channels, levees, sewers, and storm drains will all need to be designed and operated with increased safety measures.

Impacts of Flooding on Portland

The HAZUS FAST (Flood Assessment Structure Tool) was used to analyze flood exposure and vulnerability. FAST calculates building-level flood impacts with user-provided building and flood depth data. FAST uses the HAZUS flood model methodology to assign depth damage functions to buildings according to their occupancy type, first floor elevation, foundation type, and number of stories. Flood depth is then extracted at every building and used as a depth damage function parameter to calculate flood losses in dollars. Flood-generated debris is estimated using building area in square feet.

Past Events

We also looked at past events to understand what the impacts of these floods could be on Portland. Significant historic flooding occurred in the Willamette and Columbia River basins in 1861, 1880, 1881, 1909, 1913, 1927, 1928, 1942, 1946, 1948, 1961, 1964/65, 1996 and 2007. (NHMP, 2010). The list of Federal Disaster Declerations in the appendix summarizes flood events for which federal disaster declarations have been issued. No significant floods have occured since the previous MAP was completed. The sections below provided narrative descriptions of the most significant historical Portland floods.

December 2015

A moist front produced heavy rain across Northwest Oregon on December 8th through December 9th resulting in river flooding, urban flooding, and sink holes. This rain occurred around 24 hours after another moist front that resulted in flooding across the area (NOAA NCEI, n.d.).

January 2009

The sudden warming of heavy snowpack at the beginning of January 2009 caused significant flooding of local streams. Johnson Creek was most affected, cresting at 3.7 feet above its flood stage. FEMA received 187 flood loss claims from the Portland area, six of which were from repetitive loss properties. This flood was ranked the third largest flood in Johnson Creek in terms of stream flow (2,430 cubic feet per second), and second highest in terms of stream level (14.69 feet).

December 2007

Statewide severe storms, winds, mudslides, landslides, and flooding shut down roads and highways–including Interstate 5–between December 1 and 17, 2007. Public infrastructure, homes and personal property were damaged. 73,000 Oregon residents were without power. A major disaster was declared for the State of Oregon on December 8, 2007.

Winter 1996-97

In November 1996, a tropical air mass brought record-breaking precipitation across Oregon. The stormy weather continued into early January and combined with snowmelt, raising 26 major rivers to flood stage. The extensive flooding was connected to widespread landslides, erosion, power outages, damaged homes and businesses, and closed roads. It resulted in

February 1996

Warm temperatures, heavy snowpack, and four consecutive days of rain raised rivers and creeks throughout the Willamette River watershed to 100-year flood levels in February 1996. The floods destroyed hundreds of homes, forced thousands of people into shelters, and killed five people statewide. Portland erected makeshift barriers to prevent floodwaters from entering the downtown area. On February 9, 1996, the Willamette River crested just inches away from overtopping the barriers. The Columbia River crested at 11'2" above flood stage, testing the strength of levees that protect Portland International Airport and areas north of Columbia Boulevard. Johnson Creek crested at 6'5" above flood stage.

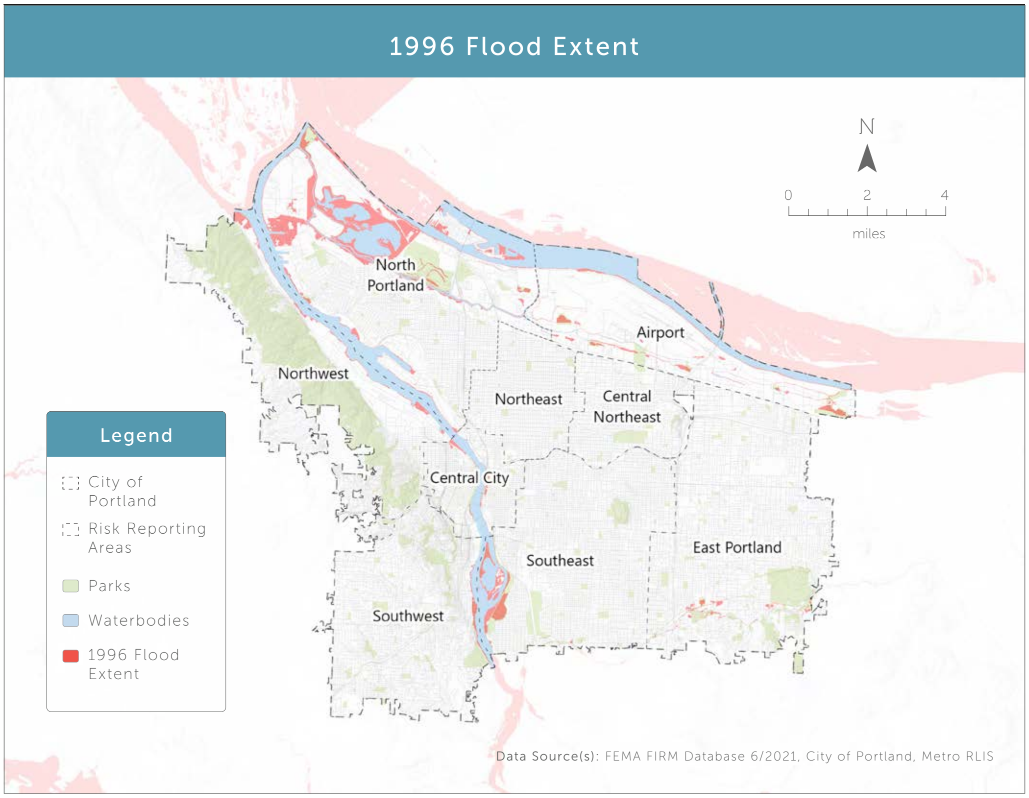
December 1964

Record-breaking levels of precipitation caused nearly every river in Oregon to surpass its flood stage in what is now known as the Christmas Flood. Debris flows, bridge failures, and flooding forced thousands to evacuate. Airports, railways, and hundreds of miles of roads were closed across the state. Ultimately, the event caused more than $157 million in damage and 20 people were killed.

May 1948

The town of Vanport was destroyed by a flood event. Located between Portland and the Columbia River, the town was home to 18,500 people, most of whom were low-income and including many African Americans. The community was completely encircled by a levee system and embankments because it was located several feet below the river's normal

Figure 3.28. Extent of February 1996 Flood in Portland



water level. On Memorial Day of 1948, heavy rain flooded the river, which breached one of the railroad embankments. Debris-laden water 10 to 20 feet deep covered the entire town. Most buildings were substantially damaged or destroyed. At least 18 people lost their lives; many others were never found but not officially recorded as fatalities. All survivors were permanently displaced.

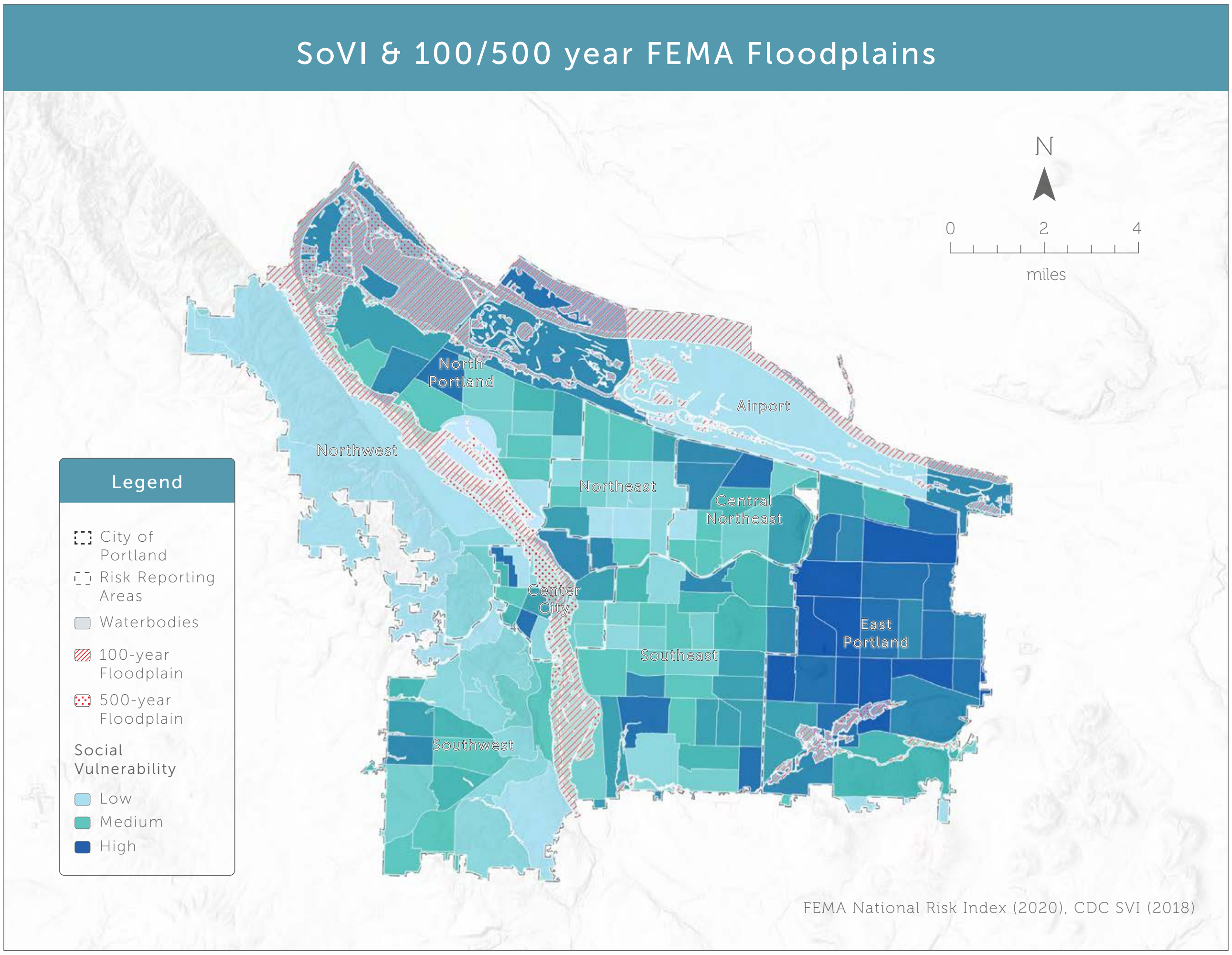
Figure 3.29. Vanport Flood in Portland, May 1948 (Jelsing, 2016)

Impacts on People

Impacts on Frontline and Underserved Communities

It is estimated that 11,709 people will be displaced from their homes after a major flood and 10,622 of these people will seek shelter in public shelters (PBEM, 2016a, 8). But not all people will experience the same impacts from damage to the built environment and the interruption of public services. Flooding can damage or destroy people's homes, places of work, critical facilities such as hospitals, and infrastructure services like roads and water/sewer systems. The negative impacts of this destruction will be amplified in some communities. The maps below show where frontline and underserved communities are living in areas with high flood risk.

Figure 3.30. Social Vulnerability (SVI) + FEMA Floodplains in Portland



Injury and Loss of Life

Population counts of those living in the 100-year (1-percent) and 500-year (0.2-percent) floodplains were derived using 2021 Census block-level population estimates verified against 2020 Census totals. The estimated total number of exposed population is 7,976 (1.22% of the total population) for the 100-year flood and 26,022 (3.98% of the total population) for the 500-year flood. These estimates exclude houseless people, who are typically not included in the census. However, many houseless individuals camp in floodplains. Houseless residents are the first to be impacted and face the greatest risks from floods.

Public Health and Safety

Floods and their aftermath present numerous threats to public health and safety:

Unsafe food

Floodwaters contain disease-causing bacteria, dirt, oil, human and animal waste, and farm and industrial chemicals. Their contact with food items, including food crops in agricultural lands, can make that food unsafe to eat.

Refrigerated and frozen foods are affected during power outages caused by flooding. Foods in cardboard, plastic bags, jars, bottles, and paper packaging may become unhygienic due to mold contamination.

Contaminated drinking and washing water and poor sanitation

Flooding impairs clean water sources with pollutants. The pollutants also saturate into the groundwater. Flooded wastewater treatment plants can be overloaded, resulting in backflows of raw sewage. Private wells can be contaminated by floodwaters. Private sewage disposal systems can become a cause of infection if they overflow.

Table 3.12 Population Exposed in the 1% Annual Chance Flood Hazard Area

		1% Annual Chance ("100-year") Flood Hazard Area		
RRA	Population	Population Exposed	% of Total Pop	% RRA
Airport	2,631	123	0.02	4.68
Central City	58,523	22	0.00	0.04
East Portland	156,361	3,120	0.48	2.00
North Portland	74,678	1,609	0.25	2.15
Northeast	65,194	-	-	-
Central Northeast	45,132	-	-	-
Southeast	158,651	628	0.10	0.40
Southwest	71,787	2,474	0.38	3.45
West/Northwest	21,437	-	-	-
Total	654,394	7,976	0.38	1.22

Table 3.13 Population Exposed in the 0.2% Annual Chance Flood Hazard Area

		0.2% Annual Chance ("500-year") Flood Hazard Area		
RRA	Population	Population Exposed	% of Total Pop	% RRA
Airport	2,631	123	0.02	4.68
Central City	58,523	10,909	1.67	18.64
East Portland	156,361	6,141	0.94	3.93
North Portland	74,678	3,421	0.52	4.58
Northeast	65,194	-	-	-
Central Northeast	45,132	-	-	-
Southeast	158,651	628	0.10	0.40
Southwest	71,787	3,499	0.53	4.87
West/Northwest	21,437	1,301	0.20	6.07
Total	654,394	26,022	3.98	3.98

Mosquitoes and animals

Floods provide new breeding grounds for mosquitoes in wet areas and stagnant pools. Leptospirosis—a bacterial disease associated predominantly with rats—often accompanies floods in developing countries, although the risk is low in industrialized regions unless cuts or wounds have direct contact with disease-contaminated floodwaters or animals. The public should dispose of animals killed by flooding only in accordance with guidelines issued by local animal control authorities.

Mold and mildew

Excessive exposure to mold and mildew can lead to upper respiratory tract disease, especially in people with allergies and asthma. Molds can grow in as short a period as 24 to 48 hours in wet and damp areas of buildings and homes, such as water-infiltrated walls, floors, carpets, and bathrooms. Very small mold spores can be easily inhaled and, in large enough quantities, can cause allergic reactions, asthma attacks, and other respiratory problems. Infants, children, elderly people, and pregnant women are considered most vulnerable to mold-induced health problems.

Carbon monoxide poisoning

In the event of power outages following floods, some people may be forced to use alternative fuels for heating or cooking, such as small gasoline engines, stoves, generators, lanterns, gas ranges, charcoal, or wood, in enclosed or partly-enclosed spaces. Carbon monoxide from these sources can poison people and animals.

Hazards when re-entering and cleaning flooded homes and buildings

Flooded buildings can pose significant health hazards to people re-entering them. Electrical power systems can become hazardous. Gas leaks can trigger fire and explosion. Flood debris—such as broken glass, boulders, branches, building fragments—may cause injury. Flood debris may also contain hazardous chemicals. Dust and mold can circulate through a damaged building.

Mental stress and fatigue

People who live through a devastating flood may experience long-term psychological impact. Property damage and the expense and effort required to repair flood-damaged homes can place severe financial and psychological burdens on the people affected. Post-flood recovery can cause anxiety, anger, depression, lethargy, hyperactivity, and sleeplessness. There is also a long-term concern of their homes flooding again in the future.

Impacts on Physical Infrastructure and Environment

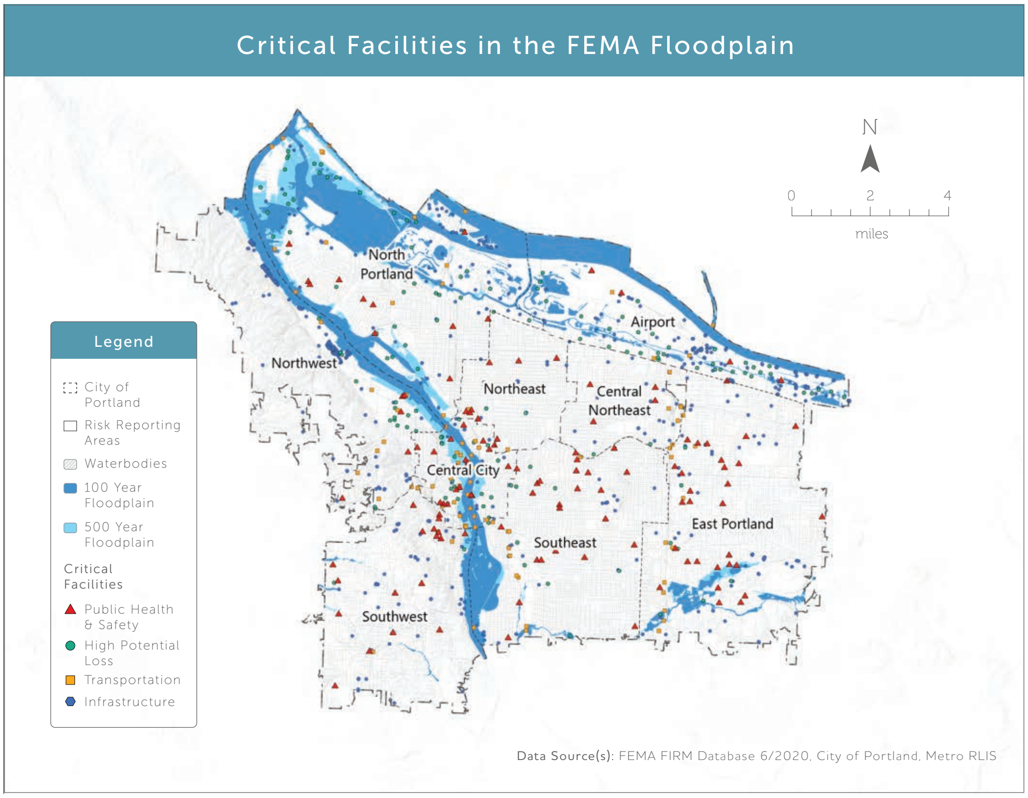
Buildings

Buildings will be impacted within all areas of Portland except for the Northeast. City areas with the greatest number of buildings include North Portland (1,567), East Portland (1,456), and Central City (573), for a total of 4,536 buildings. Of these, nearly 50% (2,261) of them are expected to be impacted by the flood event, resulting in more than $1.9 billion in damage. In total, damage would account for about 1.1% of the total value of Portland. More than 65,307 tons of debris would be created by the flood event, which will require approximately 2,612 truckloads to remove. Most debris (more than 15,000 tons) will be in the Central City, North Portland, and Southeast areas.

Critical Facilities

There are 43 critical facilities located in the 1%-annual-chance (100-year) flood hazard area and 95 critical facilities located in the 0.2%-annual-chance (500-year) flood hazard area.

Figure 3.29 Critical Facilities in the 100-year and 500-year Floodplain



Infrastructure

The most significant impacts of flooding on Portland's infrastructure will be on our transportation systems. In a worst case-scenario there can also be impacts to water and wastewater systems.

Roads and railways may become covered with water and made impassable. This can isolate residents and block evacuation routes. It can also block emergency responders' access to frontline communities and repair sites. Flood waters can damage railway lines and block them with debris. 11 major Portland roads pass through the 1% annual chance flood hazard area, so parts of them are therefore more exposed to flooding. Some of these roads are built above the flood level, and others function as levees to help prevent flooding. Still, in severe flood events, these roads may be blocked or damaged, and thus prevent access to some areas of the city:

- SE Foster Rd.
- SE Holgate Blvd.
- SE Johnson Creek Blvd.
- SE McLoughlin Blvd.
- SE 111th Ave.
- SE 122nd Ave.
- SE Harold St.
- SW Moody Ave.
- SW Shattuck Rd.

Bridges (highway, road, and light-rail) may be washed out or blocked during flood events. This could have severe ramifications in Portland as bridges are the only entry and exit points to some of the city's neighborhoods. Three light rail bridges and four highway bridges are within, or cross over, the 10%-annual chance flood hazard area. Three other light rail bridges, and seven highway bridges, cross through the 1%-annual chance flood hazard area. Five light rail bridges and seven highway bridges fall in the 0.2%-annual chance flood hazard area.

Water and sewer drainage systems may back up, and can cause localized urban flooding. Culverts blocked by debris during flood events can also contribute to a flood's severity. Sewer systems can be backed up by floodwaters, potentially causing wastewater to spill into rivers, streams, and homes.

Economic Impact

The economic impact of flooding is generally felt most by those who own property in the floodplains. The tables below show the impact on structures and their contents in the 100 and 500-year floodplain. Total potential damage for the 100-year flood is estimated at about $189 million, whereas for the 500-year flood it is estimated at roughly $2 trillion, with most of the damage occurring in downtown Portland where there is high building density.

If flooding occurs where people work, it can also impact the economy. Two of the City's most important employment districts are located on the Willamette River (The Central City) and Columbia River (The Columbia Corridor). 65,000 jobs are located in the Columbia Corridor which is protected by levees on the Columbia River. It is also home to the region's largest concentration of industrial and warehouse jobs. If flooding were to occur in these areas it could cause significant economic hardship to workers whose jobs are impacted.

Figure 3.14. Value of Structures in the 500-year Floodplain

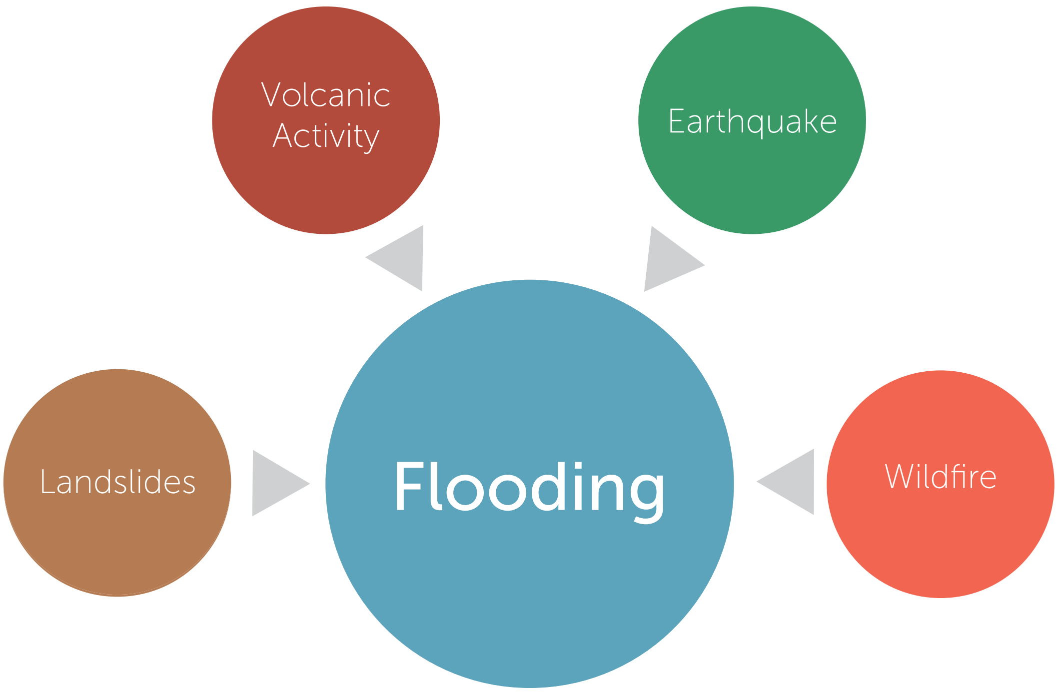
		Value Exposed ($)			
RRA	Buildings Exposed	Structure	Contents	Total	% of Total Replacement Value
Airport	51	1,371,220	3,086,787	4,458,007	0.05%
Central City	391	316,096,701	480,014,139	796,110,841	2.28%
Central Northeast	0	-	-	-	0.00%
East Portland	1137	32,420,990	24,833,783	57,254,772	0.26%
North Portland	431	260,946,528	694,454,037	955,400,565	4.91%
Northeast	0	-	-	-	0.00%
Southeast	66	12,685,907	56,261,940	68,947,848	0.26%
Southwest	103	45,963,179	46,450,634	92,413,812	0.66%
Northwest	106	14,420,641	48,230,703	62,651,344	0.61%
Total	2,285	683,905,166	1,353,332,023	2,037,237,189	1.16%

Figure 3.15 Value of Structures in the 100-year Floodplain

		Value Exposed ($)			
RRA	Buildings Exposed	Structure	Contents	Total	% of Total Replacement Value
Airport	40	972,045	1,871,523	2,843,568	0.03%
Central City	6	9,820,037	23,359,915	33,179,952	0.09%
Central Northeast	0	-	-	-	0.00%
East Portland	752	22,418,841	16,778,987	39,197,827	0.18%
North Portland	145	27,229,683	45,312,589	72,542,272	0.37%
Northeast	0	-	-	-	0.00%
Southeast	59	4,523,813	29,405,230	33,929,043	0.13%
Southwest	50	3,833,216	2,908,291	6,741,507	0.05%
Northwest	10	192,939	874,177	1,067,116	0.01%
Total	1,062	68,990,575	120,510,711	189,501,286	0.11%

Estimated Recovery Period

Depending on the magnitude of the flood, the recovery period will vary.



Connected Hazards

Landslide: Severe storms which cause flooding are also likely to saturate hills and cause landslides. Landslides can also cause flooding when loose material from landslides enter waterways and cause blockages.

Earthquake: An earthquake could damage dams and levees. This could result in severe flooding if the earthquake occurs when water levels are high.

Winter Storms: Excessive rainfall over a short period can cause river levels to surge. It can also oversaturate soils or run off impervious surfaces like parking lots and roofs, forming channels that can contribute to flooding.

Drought: Topsoil that is dried out from prolonged drought resists water saturation and effectively becomes an impervious surface for rainfall, which can lead to flooding.

Wildfire: Areas burned by wildfire also resist water saturation, making precipitation more likely to run off in channels rather than absorb into the soil. Vegetation burnt by wildfires can no longer absorb rainfall and reduce runoff. Therefore, burned areas are at higher risk of flash flooding. The risk remains heightened until vegetation returns, which can take up to five years after a fire occurs (FEMA, 2020a). In addition, when water moves across barren burned ground, it has greater potential to pick up soils and debris that can cause greater damage when it enters floodwaters.

Wildfire & Wildfire Smoke

Problem Statements

- The Portland metropolitan area is classified as a wildland-urban interface community in the Oregon Natural Hazards Mitigation Plan (NHMP, 2020). This means that some homes and other structures in the city are close to or within natural areas or forests.

- The city's population has grown significantly in recent years, bringing housing developments ever closer to at-risk natural areas such as parks and forested areas.

- Given the effects of climate change, wildfires are now more common in the region, driving dangerous wildfire smoke into the city.

- Portland has several natural areas considered to be 'fire-prone' (where fires are more likely to occur), More than 8,000 homes and other structures worth more than $2.5 billion are located within or close to these areas (PP&R, n.d.). More than 70,000 people would be directly threatened by a fire in Forest Park alone (Peel, 2021b).

What is Wildfire and Wildfire smoke?

A wildfire is an unplanned, uncontrolled fire. Wildfires typically occur in areas that contain natural fuels like plants and trees. 'Wildland-urban interface' (WUI) wildfires happen in areas where homes and other structures are built near or in woodlands or forests (Fire Marshal, n.d.). Wildfires can cause significant property damage and can threaten public health and safety. They also create harmful smoke, which can travel hundreds or even thousands of miles into urban areas. Wildfires also threaten forests and natural areas within the city and nearby, and can damage urban trees, reduce water quality in streams and rivers, and harm wildlife.

Wildfires are usually caused by human activity, by someone setting a fire on purpose (arson) or by accident (sparks from campfires, cigarettes, fireworks, etc.). They can also be caused by natural events such as lightning strikes or strong winds that push trees into power lines. The following three factors contribute significantly to wildfire behavior, and can be used to identify areas that are at risk of wildfire:

Topography is the shape of land, including its elevation above sea level; whether the land is flat or rises, and how steep the slope is; the direction a slope faces; and features such as canyons, valleys, and rivers. Each of these characteristics can help or hinder the spread of wildfire. For example, rivers can create natural barriers to a fire spreading, while canyons can create wind tunnels that fan a fire's flames. In general, areas with steep slopes are at greater risk of wildfire, because fires move more quickly uphill. South-facing slopes are more likely to have wildfires because they face the sun, which can dry out plant matter. Gulches and canyons can funnel air flow, which can increase fire intensity.

Fuels are materials that can burn. The makeup of plant matter or other materials in a fire's path determine how quickly or intensely the fire will burn. These factors include how wet or dry the materials are, what they are made of, and how thick the growth is. Dense or overgrown plant material increases the amount of fuel for the fire, especially if the plant matter is dry. The risk of fire increases significantly during periods of prolonged drought (unusually low rainfall), as living and dead plant matter dries out. Fire risk also increases where plant diseases or pests have damaged plant matter; where undergrowth (smaller trees and brushy plants) has built up on the forest floor; where the trees are mostly of the same type, rather than a mix; and where invasive species (plants and trees that are not native to the area) are common.

Weather characteristics such as temperature, humidity, wind, and lightning can impact the likelihood that a fire starts and/or spreads. Extreme weather, such as high temperatures and low humidity (the amount of water vapor in the air), can lead to extreme wildfire activity. In contrast, cooler temperatures and higher humidity can help to reduce the chance of wildfires starting or help to contain existing wildfires.

Wildfire smoke can harm the quality of life for people throughout the city by reducing visibility and making it difficult to breathe. Wildfire smoke can travel hundreds or even thousands of miles through the atmosphere, so the fire does not need to be close to Portland to have an impact.

Wildfire smoke contains harmful emissions (pollutants in the air). The content of these emissions depends on the types of material burned by the fire. Smoke generated by wildfire can contain particulate matter (soot, tar, minerals); gases (carbon monoxide, carbon dioxide, nitrogen oxides); and/or toxic compounds (formaldehyde, benzene).

Characteristics of Wildfires and Wildfire Smoke in Portland

The length of time and severity a wildfire burns can depend on the weather, topography, and available fuel. Wildfires in forested areas can last days, weeks, or months, while smaller brush fires can often be extinguished within hours. A wildfire's severity can be measured by its size—typically in acres—or by the amount of damage it causes. A wildfire can burn anywhere from a few acres to hundreds of thousands of acres. A large fire usually begins as several smaller fires.

The Portland metropolitan area is considered a 'wildland-urban interface area' in the Oregon Natural Hazards Mitigation Plan (NHMP, 2020). The city's population has grown significantly in recent years, increasing the number of homes and other structures that are close to natural areas such as parks and forests. Wildfire hazard areas in Portland include Forest Park, Mt. Tabor Park, Powell Butte Nature Park, Rocky Butte Natural Area, Oaks Bottom Wildlife Refuge, and Marquam Nature Park. The Oregon Department of Forestry and Portland Fire and Rescue identify these areas as high risk because they are close to high-density commercial and residential development.

Forest Park is the nation's largest urban forest, covering around eight square miles along the northeast slope of the Tualatin Mountains (West Hills). Forest Park has a mix of trees—deciduous (trees that lose their leaves every year, such as oaks) and coniferous (mostly evergreen trees and shrubs, such as firs and pines)—which helps to reduce wildfire risk. But it also faces risks: the park is bordered in places by grasslands and large patches of invasive species, Portland General Electric power lines cross over it, and it is close to the Critical Energy Infrastructure Hub in NW Portland, which stores 90% of Oregon's fuel supply. Factors like these increase the chance that a wildfire could start in Forest Park, or spread into it from nearby, especially in dry conditions.

Wildfires can cause significant losses when they reach urban areas. Even small fires can cause significant property damage and casualties. The indirect effects of wildfires, such as bad air quality from smoke, can harm human and environmental health.

The severity of wildfire smoke is typically measured by the amount of particulate matter in the air, which is reflected in the AQI (Air Quality Index). These levels can vary throughout the city and change depending on wind patterns, ranging from "Good" (green) to "Hazardous" (maroon).

When inhaled, wildfire smoke can harm sensitive groups and healthy adults. Smoke can worsen respiratory (breathing) conditions such as asthma, COPD (chronic obstructive pulmonary disease), bronchitis, and pneumonia; it can impact cardiovascular (heart) issues; and it can cause eye irritation, sore throat, wheezing and coughing, and anxiety.

Figure 3.32 Air Quality Index (IQAir, 2020)

US AQI Level		PM2.5 ($\mu g/m^3$)	Health Recommendation (for 24 hour exposure)
Good	0-50	0-12.0	Air quality is satisfactory and poses little or no risk.
Moderate	51-100	12.1-35.4	Sensitive individuals should avoid outdoor activity as they may experience respiratory symptoms.
Unhealthy for Sensitive Groups	101-150	35.5-55.4	General public and sensitive individuals in particular are at risk to experience irritation and respiratory problems.
Unhealthy	151-200	55.5-150.4	Increased likelihood of adverse effects and aggravation to the heart and lungs among general public.
Very Unhealthy	201-300	150.5-250.4	General public will be noticeably affected. Sensitive groups should restrict outdoor activities.
Hazardous	301+	250.5+	General public at high risk of experiencing strong irritations and adverse health effects. Should avoid outdoor activities.

Predicting wildfire in Portland

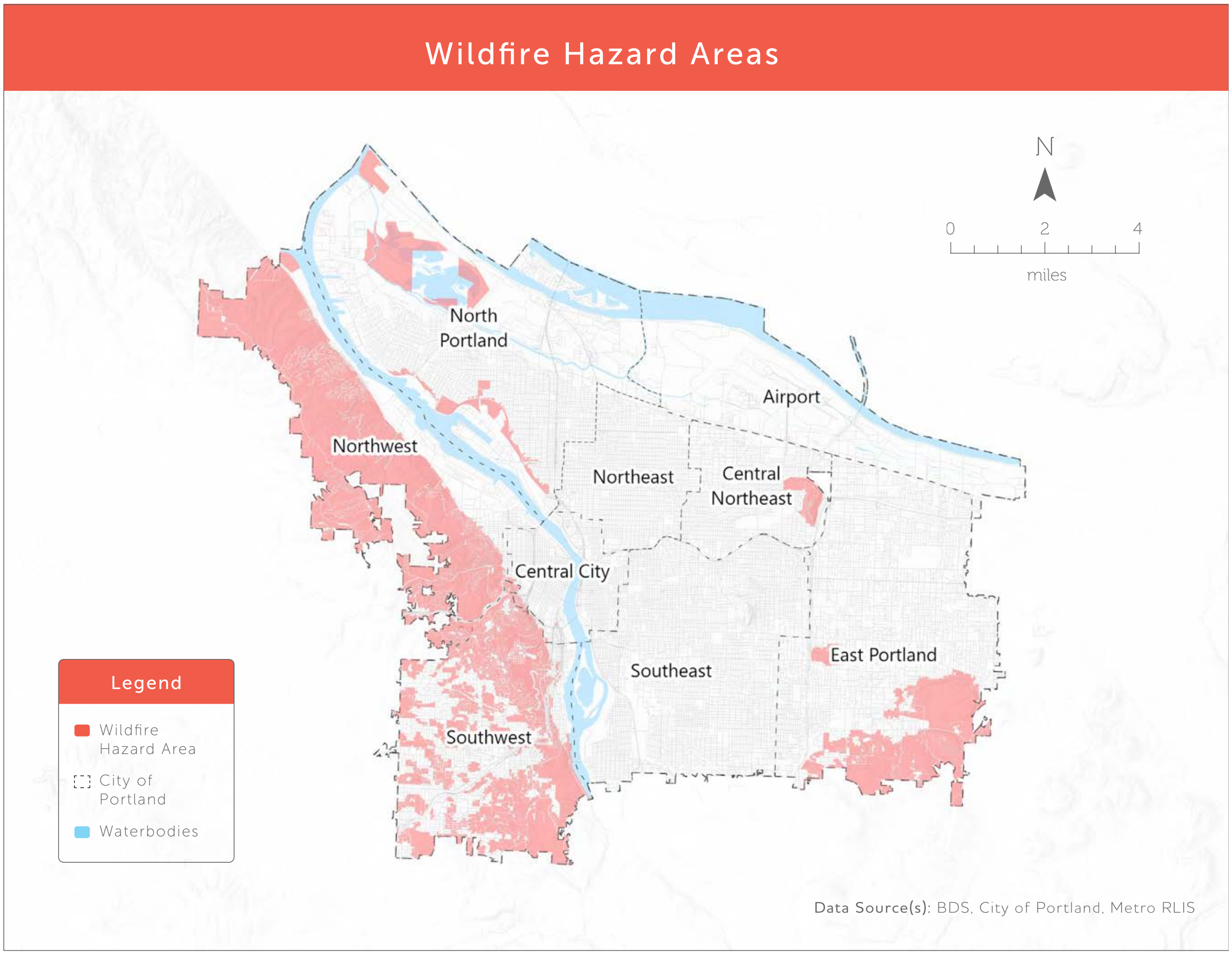
Oregon's wildfire season normally begins in late June, peaks in August, and ends in October. However, higher temperatures and/or low rainfall can¬ cause the fire season to start earlier or end later.

As climate change increases the frequency and severity of drought conditions, wildfire seasons are likely to grow longer. Summers in Oregon have become longer and drier over the past decade (Flavelle and Fountain, 2020), and there has been an increase in the size and frequency of wildfires.

Impacts of Wildfire in Portland

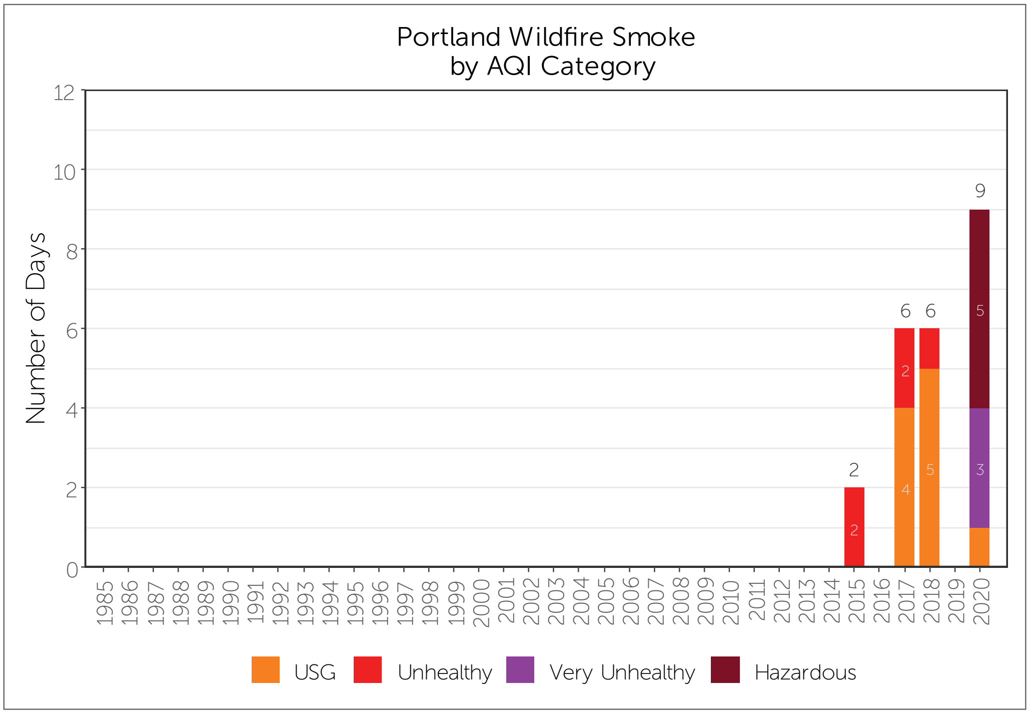
There are no recent examples of wildfire within the City of Portland; Figure 3.31 identifies potential “wildfire hazard areas” based on topography and vegetation.

Figure 3.31. Wildfire Hazard Areas



An increasingly-common wildfire hazard in Portland is dangerous smoke levels caused by wildfires in the region. Figure 3.32 shows the number of days between 1985 and 2020 that wildfire smoke caused unhealthy air quality in Portland.

Figure 3.34. Wildfire Smoke Trends in Portland (DEQ, 2021)



Past Wildfire Smoke Events

September 10-18, 2020
Smoke and ash blanketed Portland for nine days after high winds stoked the Riverside and Beachie Creek wildfires south and east of the city. Air quality citywide reached record-breaking hazardous levels and was considered the worst in the world for several days (Green, 2020; Peñaloza, 2020). Levels of airborne particulate matter measured as high as 477 micrograms per cubic meter (ug/m3). This far surpassed the previous record high rating of 157ug/m3, recorded in 2017 during the Eagle Creek Fires in the Columbia Gorge, north and east of Portland.

September 2017
Smoke and ash from the nearby Eagle Creek Fire, a massive blaze in the Columbia River Gorge, reduced air quality to unhealthy levels throughout the Portland metropolitan area. Schools were forced to cancel outdoor activities or close altogether due to record-breaking poor air quality.

Impacts on People

People who live in or near wildland-urban interface areas are at higher risk of wildfires, which can damage property and cause injury or even death. Warning systems typically allow enough notice for at-risk individuals to evacuate, but some individuals may be difficult to reach with warning systems, especially if there are interruptions to power, internet, and cellular services, and people without cars may find it difficult or impossible to evacuate.

Impacts on Frontline and Underserved Communities

In the event of a wildfire, or wildfire smoke, not all people will experience the same impacts from damage to the built environment, the interruption of public services, or impacts on public health. Wildfires can damage or destroy people's homes, places of work, critical facilities such as hospitals, and infrastructure services like roads and water/sewer systems. Wildfire smoke can make breathing difficult and inhaling it is dangerous. But these negative impacts will be amplified in some communities. Wildfire smoke can especially impact the young and old, individuals with existing respiratory and cardiac conditions, and people who work outside.

Injury and Loss of Life

No deaths due to wildfire have been recorded in Portland. Loss of life nonetheless remains a potential risk in the event of a wildfire, especially near high-density housing or commercial areas.

Impacts on Physical Infrastructure and Environment

Wildfire presents a risk when it intersects with buildings, infrastructure, and people. Fire is a natural process that can have benefits to the natural environment, although fire also reduces vegetation and leaves natural areas more susceptible to landslides and flooding. Smoke will not have an impact on buildings and physical infrastructure. However, the smell and residue of smoke can permeate homes. Following the 2018 Cully scrapyard fire, some residents reported they incurred a significant financial burden to clean or replace curtains, sofas, and other furnishings that smelled strongly of smoke.

Table 3.16 Exposure and Value of Structures in Wildfire Hazard Areas

RRA	# Buildings Exposed	Value Exposed			Exposed Value as % of Total Replacement Value
		Structure	Contents	Total	
Airport	0	$0	$0	$0	0.00%
Central City	79	$97,606,665	$60,662,292	$158,268,957	0.50%
Central NE	259	$162,630,647	$103,979,744	$266,610,391	2.40%
E Portland	3,328	$928,498,538	$484,931,548	$1,413,430,086	5.40%
N Portland	344	$543,255,169	$641,920,056	$1,185,175,224	5.00%
Northeast	0	$0	$0	$0	0.00%
Southeast	0	$0	$0	$0	0.00%
Southwest	10,277	$5,453,618,530	$4,337,521,920	$9,791,140,450	55.00%
Northwest	4,949	$2,161,912,229	$1,230,447,391	$3,392,359,620	24.40%
Total	**19,236**	**$9,347,521,776.57**	**$6,859,462,951.32**	**$16,206,984,728**	**9.50%**

Economic Impacts

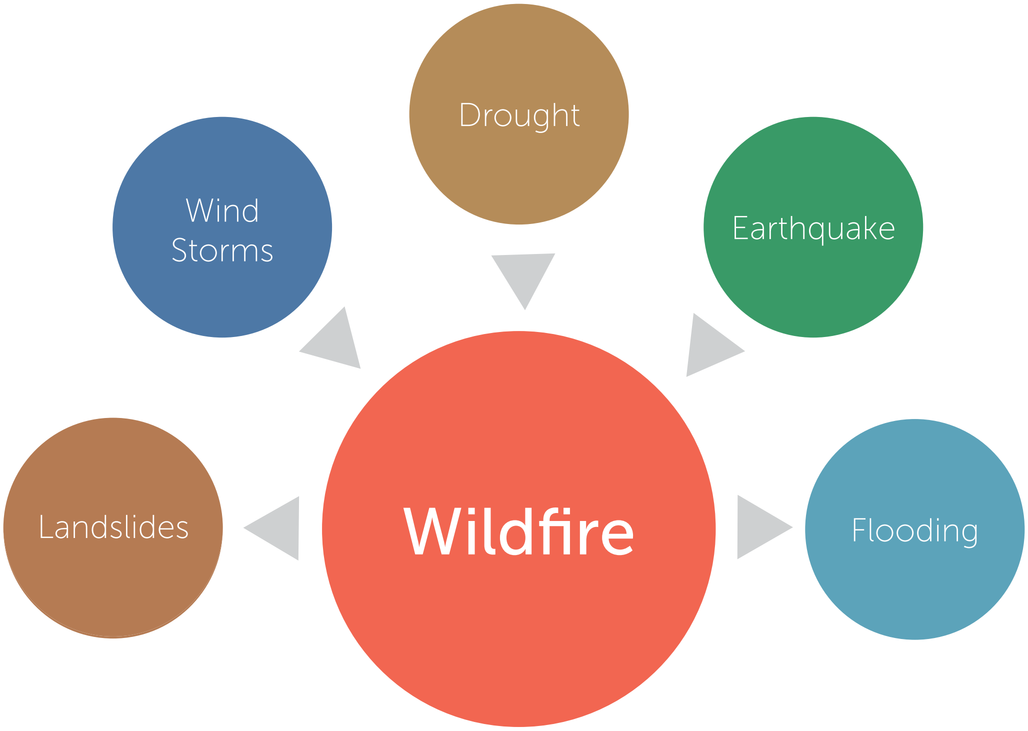
From a long-term perspective, the potential impact of Oregon's recent wildfire seasons is that fewer households and investments may be attracted to the region moving forward. Oregon's primary comparative advantage remains its ability to draw skilled workers away from other states. To the extent that local quality of life has been reduced, or if Oregon is perceived as a riskier or costlier place to live and do business, this advantage will be less pronounced.

Increased risk of wildfire lowers growth prospects. If investors and households view Oregon as a riskier place, businesses, property owners, and governments will face higher costs moving forward. (OOEA, 2018)

Figure 3.35 Economic Impacts from 2017 Wildfire Season (Travel Oregon, 2018)

Nearly $14.2 million in tourism revenue was lost in Portland in 2017 due to wildfires in the Columbia Gorge and elsewhere, according to a study conducted by Travel Oregon. (Travel Oregon, 2018) The study measured the economic impact of tourism in the state. Because Portland is a hub of regional tourism, continued impacts to air quality and the increasing probability of fire closer to the city are likely to impact various tourism-dependent businesses, such as hotels and cultural institutions.

In 2019, the Portland metro area generated $5.6 billion in direct spending, and 8.8 million overnight stays. The travel industry supports 36,930 jobs in the Portland area, generating $1.6 billion in earnings. (Travel Portland, 2021) These figures are likely to decrease if visitors are discouraged by persistent wildfire conditions.



Connected Hazards

Landslide: Wildfire damages the soils on slopes, reducing their ability to absorb rain, thus increasing the chance of landslide. Wildfires also remove plants and trees, killing the roots which strengthen soils. Debris flows (fast-moving landslides) caused by fire damage can strip plants and trees from the soil and block drainages and can occur even years after a fire during intense rainfall (USGS, n.d.-q).

Flooding: Wildfire impacts that increase landslide risk also increase flood risk. Land burned by wildfire does not absorb water as easily, so rainfall may run off it in channels instead. Plants and trees that are burned by wildfires also don't absorb as much water, leading to more runoff. Due to these factors, burnt-over areas are at higher risk of flash flooding (floods that happen suddenly). Flooding risks remain until the plants and undergrowth has grown back, which may make take up to five years (FEMA, 2020a, 1). In addition, when water moves across barren burned ground, it may to pick up more soils and debris and cause greater damage when it enters floodwaters.

Earthquake: Earthquakes can damage power or gas lines, which can spark fires.

Drought: During a drought (unusually low rainfall), living and dead plant matter dries out, which increases fuel available for a wildfire. Droughts can also reduce the amount of water available to fight a wildfire.

Windstorms: Winds add energy to fires, making them burn hotter and move faster.

Landslide

Problem Statements

- Landslides are a frequent and serious natural hazard in the City of Portland which pose a threat to life safety, the environment, and private and public property.

- Most landslide risk is concentrated on the West side of the Willamette River, in the West Hills. Historical development patterns have resulted in many residential enclaves situated on historical deep landslides or on slopes that are landslide-prone.

- Landslides can deposit debris into streams and other waterways, which can harm wildlife and cause blockages downstream.

What are Landslides?

A landslide is when a mass of soil, rock, or organic material moves down a slope or hillside. The same term is used to describe the landforms created by such an event. Landslides happen when pressure from weight or water saturation overpowers the strength of the soil or rock that forms the slope. They are most often caused by excessive rainfall during winter storm events, which occur annually in Portland.

Characteristics of Landslides in Portland

Landslides can occur on any hillside, cliff, or mountainous area with steep slopes, typically at 20% or steeper grades. The likelihood of a landslide occurring tends to increase with the steepness of the slope.

Within Portland, landslides are usually triggered by long periods of rainfall. They are most common in or around the Tualatin Mountains (West Hills), and in steep-sloped natural areas such as Forest Park, Terwilliger Wildlands, and Marquam Nature Park. Some features of the land or weather can make a slope more prone to landslides, including:

- Deposits from previous landslides
- Saturated soil from rainfall, flooding, or leaking sewer/water lines
- Steepened slopes or damaged vegetation from erosion or construction
- Freeze/thaw cycles
- Shaking from earthquakes
- Burnt areas from forest or brush fires

As the above factors indicate, development projects and other human influences often contribute to landslides. A Portland State University study found that changes to the slope through cutting or filling increased the risk of 76% of inventoried (reported) landslides in the Portland Metro region (Burns et al., 1998).

Landslides in Portland can be categorized as "shallow" or "deep-seated". According to DOGAMI, deep-seated landslides are those in which the maximum slip surface exceeds 15 feet (Burns & Madin, 2009). In the Portland area, deep-seated landslides typically happen with long-term rainfall over weeks or months. They have historically been slow moving and large, typically spanning multiple properties. The nature of these slides allows for adequate time to address life safety issues, but often result in significant damage to structures and utilities located on the slide mass. Shallow landslides in Portland are typically initiated by storm events that occur after the soils are already saturated. Shallow landslides in Portland are typically fast-moving and often pose a significant hazard to life safety and structures. Shallow landslides can transform into debris flows, especially in steep drainages. Debris flows are a particular type of extremely destructive landslide.

Predicting Landslides in Portland

Landslides in the Portland area tend to occur annually between the months of October and May, when we experience increased rain and snow. DOGAMI estimates that there are an average of 20 landslides per year in Portland, but severe winter storms can trigger hundreds more: of the 1,700 landslides that occurred within the City of Portland between 1928 and 2016, approximately 830 of these occurred during the severe storms of 1996 (DOGAMI, 2018b).

Figure 3.36. Headscarp (top) of an active deep-seated Landslide in SW Portland, 2016

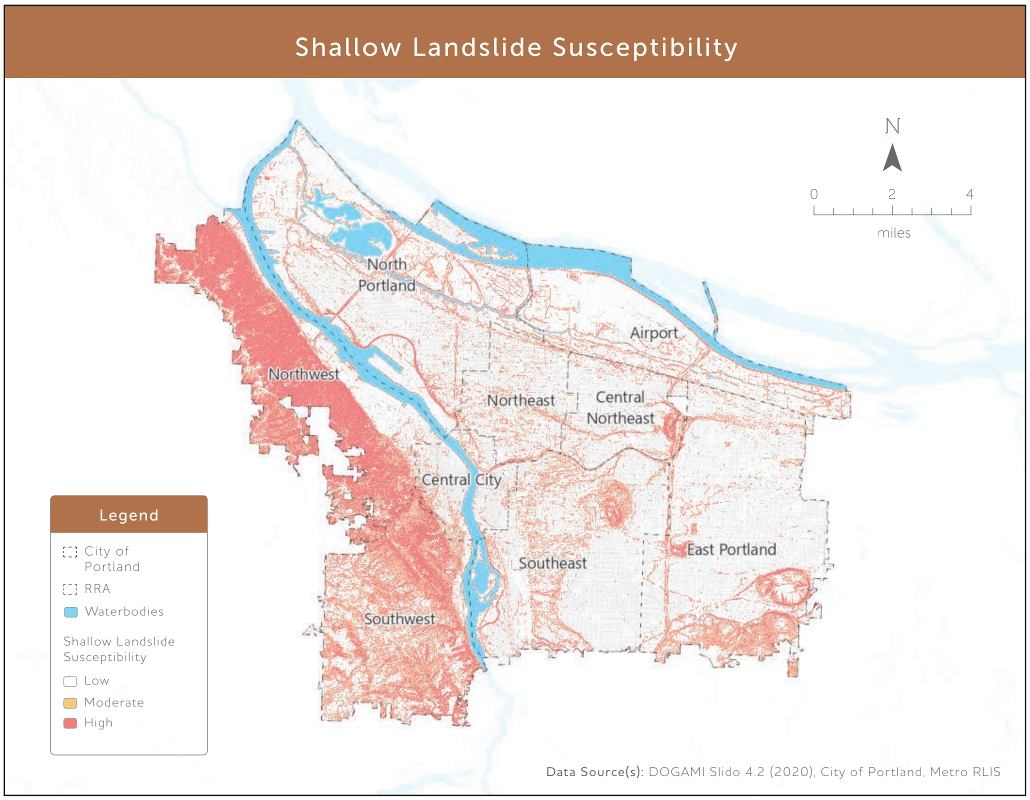
The effect of climate change on landslide risk is uncertain. According to the Fourth Oregon Climate Assessment Report, climate change is likely to cause more frequent and intense winter precipitation (Mote et al., 2019). This can saturate slopes and thus increase the likelihood of landslides. Climate change is also likely to decrease summer precipitation, while increasing the frequency and severity of drought conditions and wildfires. This can reduce the vegetation that strengthens soils on slopes, and further reduce soils' threshold for water saturation, thus potentially leading to more landslides.

Impacts of Landslides in Portland

Mapping landslide potential and historic landslides in Portland can help us understand which areas will be impacted. The map below shows shallow landslide susceptibility based on the steepness of the slope and the strength of the underlying geologic deposit (sediment, soil, and rocks).

Historical landslide data is useful when mapping landslide risk because landslides typically happen where they have happened before. They often leave distinct physical features which are detectable using LiDAR technology. DOGAMI (Oregon's Department of Geology and Mineral Industries) uses LiDAR and other data in creating SLIDO (State Landslide Identification Database of Oregon), which tracks mapped landslides throughout Oregon. SLIDO was most recently updated to version 4.2 in 2020. In 2018, DOGAMI released IMS-57, a report based on SLIDO data which more specifically maps landslide risk areas in the Portland area (Burns et al., 2018).

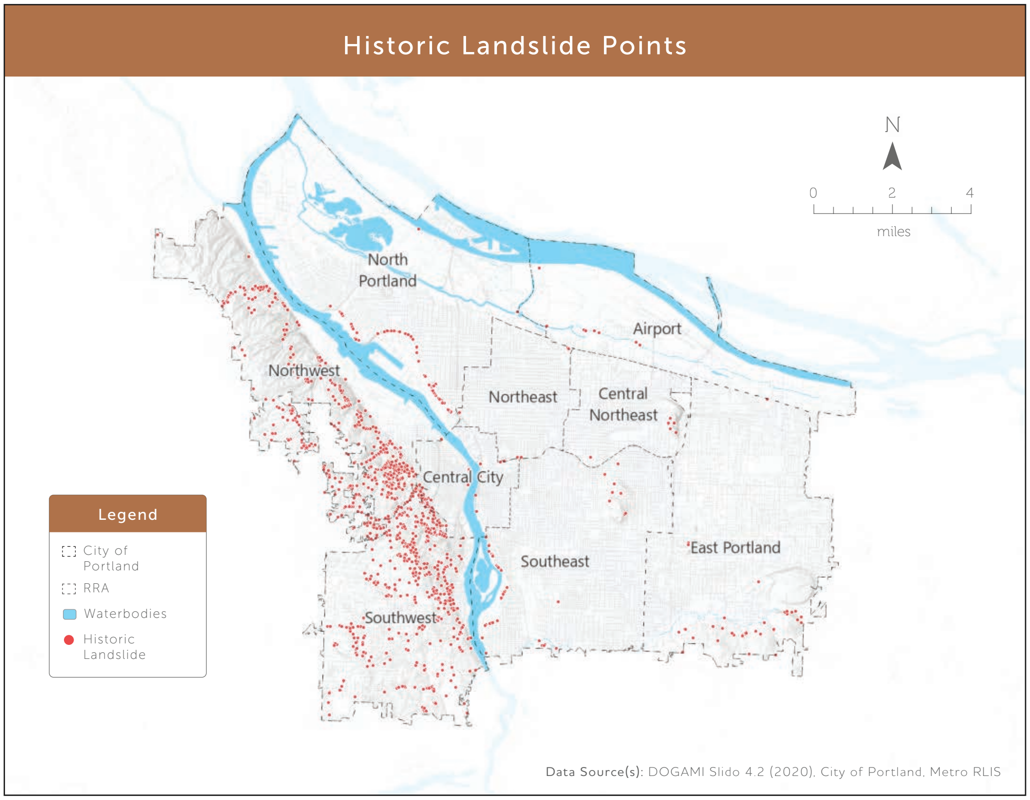
Figure 3.37. Shallow Landslide Susceptibility



Past Events

To understand the potential impacts of landslides in Portland, we considered past landslides, for which there are numerous examples. 1,996 landslides that occurred in Portland and surrounding cities are mapped in DOGAMI IMS-57. These slides are referred to as "historic", meaning they happened within the last 150 years, or "prehistoric," those that happened more than 150 years ago (DOGAMI, 2018b). 1,567 of these landslides are in the City of Portland. While shallow landslides are relatively common in parts of the city, some events are particularly notable.

Figure 3.38 Historic Landslide Points



January 2021

A severe winter storm caused flooding, power outages, and landslides throughout the Portland Metropolitan Area. A series of landslides caused week-long closures in parts of Northwest Germantown Road and West Burnside Street, both arterial roads through the Portland Hills which are prone to frequent landslides. One landslide on Burnside Street resulted in damaged power lines and sent large trees and hundreds of cubic yards of debris into the roadway.

Figure 3.39 Shallow landslide on West Burnside Street, 2021

Figure 3.40. Shallow landslide on West Burnside Street, 2021

February 1996

A 100-year storm event caused a record 700 landslides in the Portland Metropolitan region. The Joint Interim Task Force on Landslides and Public Safety reported that 17 homes were destroyed and 64 were badly damaged in Portland (Burns et al., 1998).

The Zoo Landslide and the Washington Park Landslide are both deep-seated prehistoric landslides within Portland city limits. Human activities have caused portions of both slides to reactivate. Systems have been implemented to reduce the likelihood of further movement.

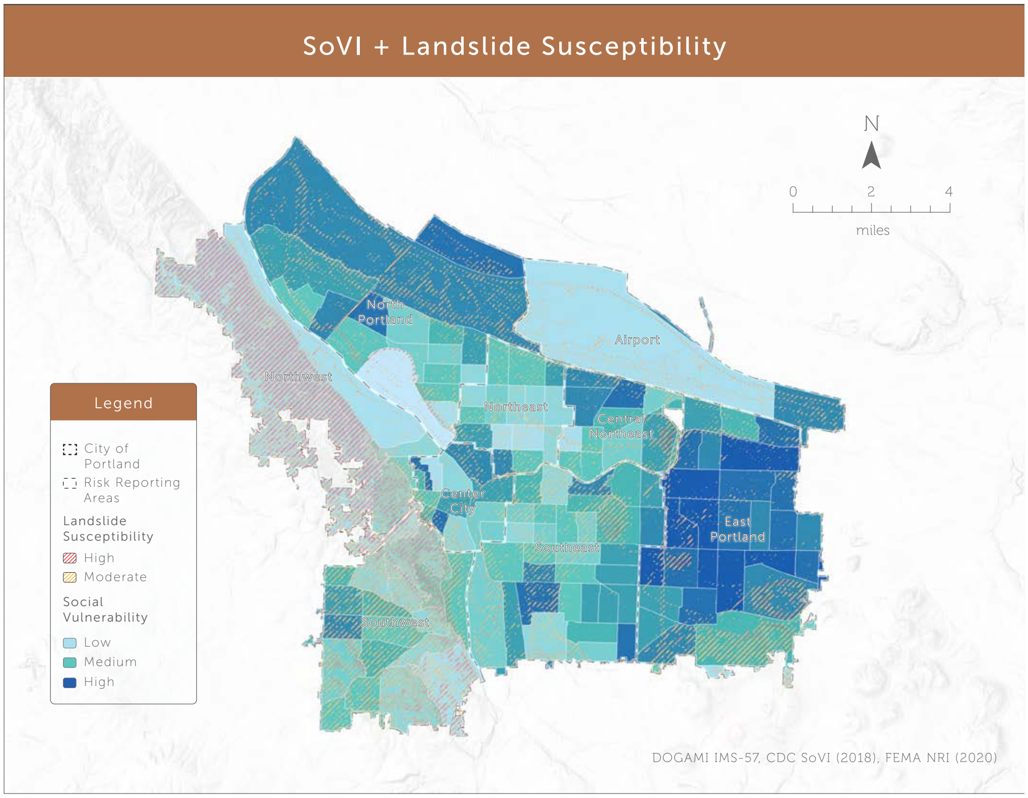
Impacts on People

According to DOGAMI's Interpretive Map Series - 57 hazard analysis (DOGAMI, 2018b) (which includes Portland and surrounding cities), approximately 8,000 people live in the deep landslide high susceptibility zone and approximately 29,000 live in the shallow landslide high susceptibility zone (Burns et al., 1998). Around 6,700 people live on top of existing landslides.

Impacts on Frontline and Underserved Communities

Not all people will experience the same impacts from damage to the built environment and the potential interruption of public services. Landslides can damage or destroy people's homes and interrupt public transportation systems. The negative impacts of this destruction will be amplified in some communities. The map below shows where landslide risk intersects with frontline and underserved communities.

Figure 3.41 SoVI + Landslide Susceptibility



Injury & Loss of Life

There are no recorded deaths from landslides in Portland. Their potential to cause harm is significant. The Oso mudslide in 2014 provided a significant warning for the destruction landslides can cause in the Northwest--forty three people died.

Impacts on Physical Infrastructure and the Environment

While landslides occur naturally, they can cause destruction to the natural and built environment. Landslides can carry debris into streams that may significantly impact fish and wildlife habitat, as well as affecting water quality. Hillsides that provide wildlife habitat can be lost for prolonged periods of time due to landslides. In Portland, areas with landslide risk also threaten the built environment.

Roads

Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems and delays for public and private transportation. This can result in economic losses for businesses. Many major roads in Portland cross through mapped landslide hazard areas, including:

I-205, I-5, I-84, I-405, N Interstate Ave., N Willamette Blvd., NW Cornell Rd., NW Germantown Rd., NW Skyline Blvd., NW St Helens Rd. (US Hwy 30), SE Foster Rd., West Burnside St., Beaverton-Hillsdale Hwy., SW Barbur Blvd., SW Boones Ferry Rd., SW Terwilliger Blvd.

Bridges

Landslides can significantly impact road bridges. They can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous to use.

Power Lines

Power lines are generally elevated above steep slopes, but the towers and poles supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses. There are 87.61 miles (18.4% of the city-wide system) of power lines in mapped landslide hazard areas.

Gas Lines

There are 12.43 miles of major gas lines in landslide hazard areas. Almost half of this exposure is in West/Northwest; another 43% is in Southwest.

Rail Lines

25.51 miles (6.8%) of rail lines and 4.09 miles (7.7%) of light rail lines are in mapped landslide hazard areas.

Figure 3.42 Leaning power pole damaged by a shallow landslide, SW Portland 2021

Buildings

Table 3.17 shows the potential losses in property in different areas of Portland, based on the amount of damage to existing buildings. Damage of more than 50% is considered substantial by most building codes and usually requires total reconstruction of the structure.

Table 3.17 Loss Potential for Landslides

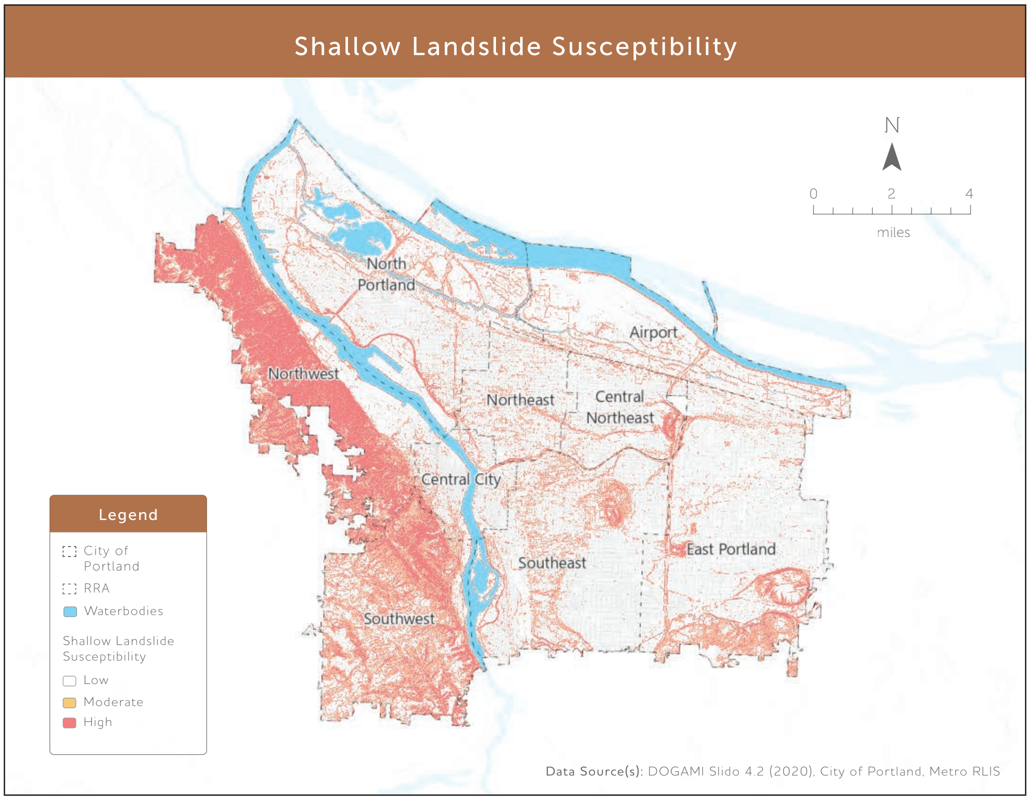
Risk Reporting Area	Exposed Value
Airport	$0
Central City	$532,967,278
Central Northeast	$141,588,635
East Portland	$454,704,349
North Portland	$912,207,088
Northeast	$179,186,615
Southeast	$588,007,563
Southwest	$14,098,055,479
West/Northwest	$3,789,704,748
Total	**$20,696,421,756**

Critical Facilities

Schools, police stations, fire stations, and hospitals are all considered critical facilities in the DOGAMI IMS-57 landslide hazard report.

There are almost 200 critical facilities exposed to the landslide hazard to some degree. No loss estimation of these facilities was performed due to the lack of established damage functions for the landslide hazard. A more in-depth analysis of the mitigation measures taken by these facilities to prevent damage from mass movements should be done to determine if they could withstand impacts of a mass movement. At this time, all infrastructure and transportation corridors identified as exposed to the landslide hazard are considered vulnerable until more information becomes available.

Figure 3.43 Critical Facilities & Landslide Susceptibility

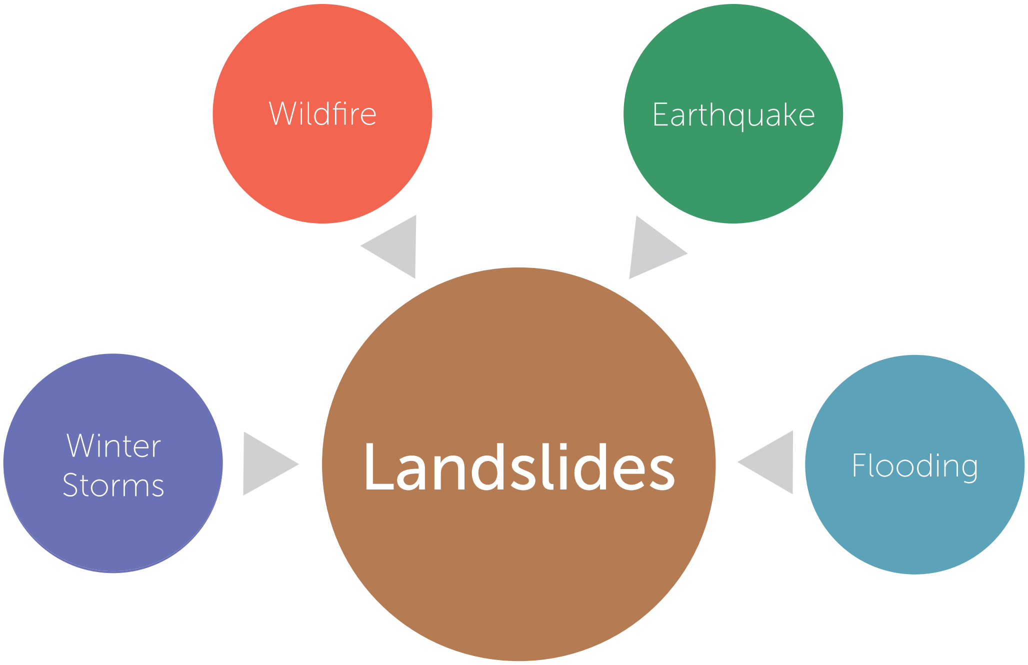


Economic Impact

Based on historical data, annual landslide-related losses in the City of Portland are estimated to cost between $1.5M and $3M. During years with severe winter storms, these estimates rise to between $64M and $81M (Burns et al., 2018). Around $1.65 billion in land and buildings are on top of existing landslides.

Estimated Recovery Period

Time needed to recover from landslides varies greatly depending on the size and location of the slide. It may also be impacted by factors such as post-slide site accessibility and stability. Small slides can often be addressed in a few hours, while larger slides may pose major engineering challenges and block roads for months. Often, multiple slides occur at the same time, which will reduce the resources available to respond and can also lengthen the recovery period.



Connected Hazards

Severe Storms: Severe storms are characterized by long periods of heavy rainfall, which is the most common cause of shallow landslides.

Flooding: Severe storms which cause flooding often also cause landslides.

Earthquake: Shaking from earthquakes can cause weakened slopes to fail. In a study area of Portland and surrounding cities, landslides caused by either a Cascadia Subduction Zone earthquake or a Portland Hills Fault earthquake are estimated to damage between 1,344 to 4,992 buildings and displace 600 to 2,761 residents (Burns et al., 2018). The risk of a landslide being triggered by an earthquake significantly increases when a slope's soil is wet.

Wildfire: Wildfires damage the soils in slopes, diminishing their ability to absorb rainwater. Wildfires also remove vegetation, killing the roots which strengthen soils. Post-fire debris flows are a heightened risk for several years after a slope has burned. Additionally, over longer time periods, wildfires have the potential to destabilize pre-existing deep-seated landslides (USGS, n.d.-q).

Extreme Heat

Problem Statements

- Extreme heat events are a potentially lethal health hazard to Portland residents. During the four-day "heat dome" event in June 2021, when temperatures reached at least 116°F in the city, 54 Portland residents are confirmed to have died from hyperthermia (very high body temperature) (Multnomah County, 2021; Templeton and Samayoa, 2021). This is the most deadly natural hazard described in our plan.

- In the city of Portland, average temperatures are rising, extreme heat events ("heat waves") are increasing in magnitude, frequency, and duration due to climate change, and these trends are projected to increase. Most of Portland's infrastructure and housing was not built to protect from these heatwaves and many homes are without air conditioning.

- Within the city of Portland, the "urban heat island" (UHI) effect has been shown to cause a disparity of 17°F in air temperature, with historically underserved neighborhoods in outer Southeast and East Portland at higher risk for heat exposure (Voelkel and Shandas, 2017).

- Extreme heat events are disruptive to the city's economy. Many businesses are forced to close, and people who work outside (such as delivery drivers and utility and agricultural workers) are at greater risk of heat-related illnesses. High temperatures can damage public transportation systems and physical infrastructure such as roads and bridges. At the same time, public resources must be directed to protecting residents from heat effects (Layne, 2021; Stites and Thompson, 2021).

- Extreme heat events cause an increase in energy demand, putting excessive pressure on the city's electrical grid and energy resources that can lead to blackouts and power spikes for customers at critical times (De La Garza, 2021).

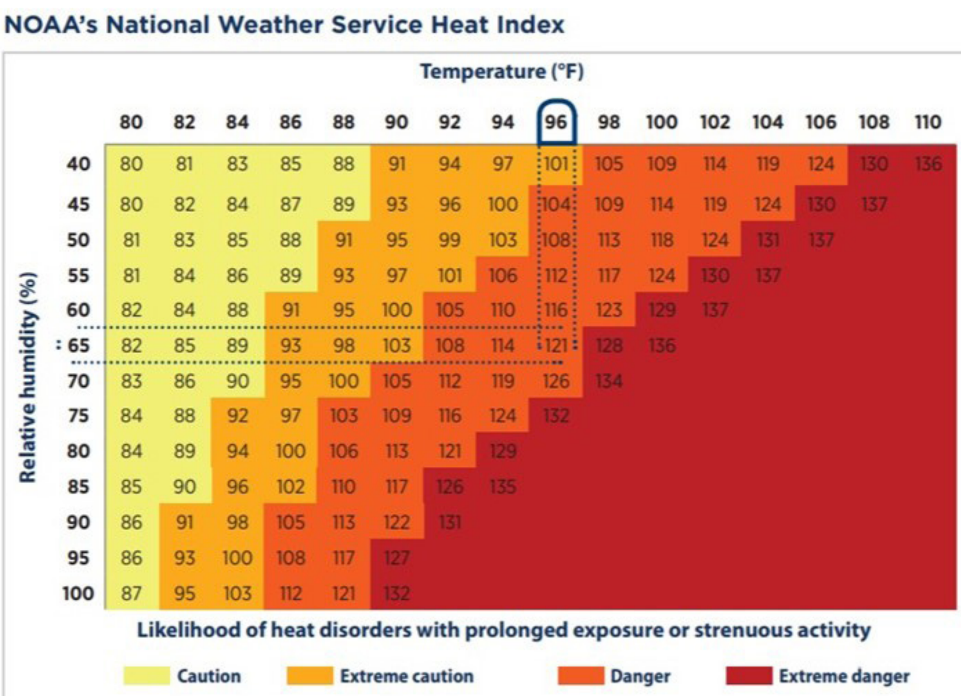
- Extreme heat events can have devastating environmental consequences, impairing water and air quality, damaging urban trees, and increasing wildfire risk.

What is Extreme Heat?

Extreme heat is a relative term referring to unusually high temperatures for a given place and time (CDC, 2017). In Portland, highs typically range from about 36 °F to 80°F throughout the year (City of Portland and Multnomah County, 2014), a heat index measurement at or above 90°F is considered extreme. A series of two or more extremely hot days is considered an excessive heat event, or "heat wave" (NWS, n.d.-b). Extreme heat and heat waves most often impact Portland in the summer months of May through August.

The heat index illustrates perceived heat more accurately than temperature readings alone. It accounts for humidity that can impact the feeling of heat and the body's ability to keep cool. The National Weather Service (NWS) and public health officials typically refer to the heat index when determining the severity of extreme heat events.

Figure 3.44 National Weather Service Heat Index (NWS, n.d.-e)



NOAA's National Weather Service Heat Index

Temperature (°F)

Relative humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of heat disorders with prolonged exposure or strenuous activity

Caution | Extreme caution | Danger | Extreme danger

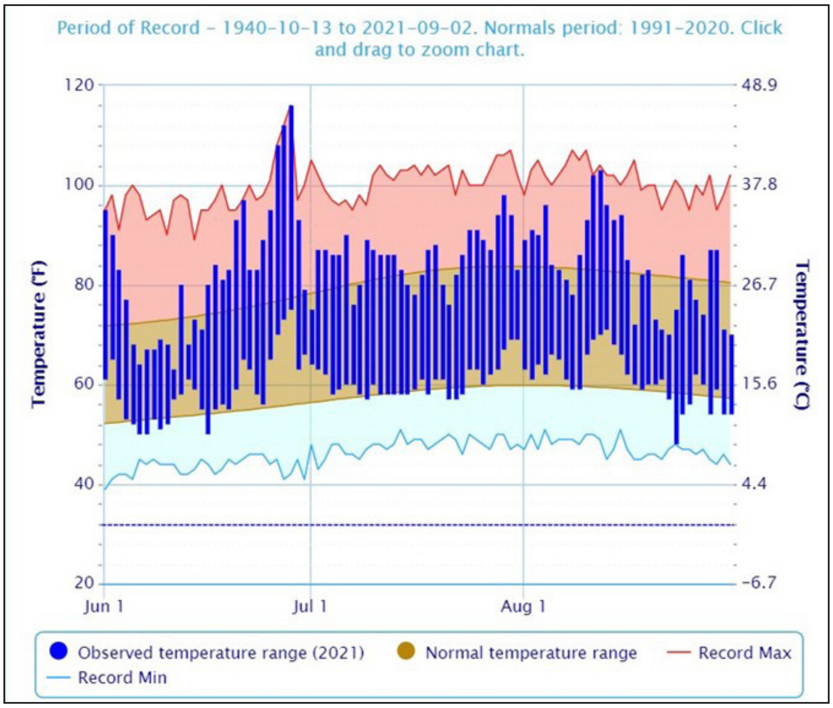
This chart shows that as the temperature (horizontal axis) and relative humidity (vertical axis) each increase, they combine to create a heat index (colored values) that feels hotter than the actual temperature. For example, when the temperature is 96°F, with 65 percent humidity, it actually feels like 121°F (indicated by the blue lines in the chart above). Source: NOAA National Weather Service, 2016[1]

Characteristics of Extreme Heat in Portland

Heat waves in Portland are typically the result of high-pressure climate systems that form off the Pacific coast. Meteorologists can somewhat reliably predict the onset of a heatwave up to 10 days in advance. Rarely, high-pressure atmospheric conditions can combine with influences from La Niña to trap sweltering heat under a high-pressure lid, or "dome" (NOAA National Ocean Service, 2021b). This heat dome phenomenon occurred in Portland in June 2021, causing record-breaking high temperatures for three consecutive days (Wikipedia, 2021).

Extreme heat can last anywhere from a few hours on a summer afternoon, to several days or weeks of consistently high temperatures. While two consecutive days of extreme heat is enough to count as a heat wave, previously, Multnomah County activated extreme heat advisory protocols only when there are three consecutive days of heat index highs above 95°F (City of Portland and Multnomah County, 2014). Since the 2021 heat dome, the City and County will activate different protocols depending on the National Weather Service HeatRisk forecast. The longer a heatwave lasts, the greater the risk it presents to public health and infrastructure. The longest recorded extreme heat event in Portland was in the summer of 2009, with ten consecutive days of highs at or above 90°F.

Figure 3.45 Daily temperature data for Portland (NWS, n.d.-g)



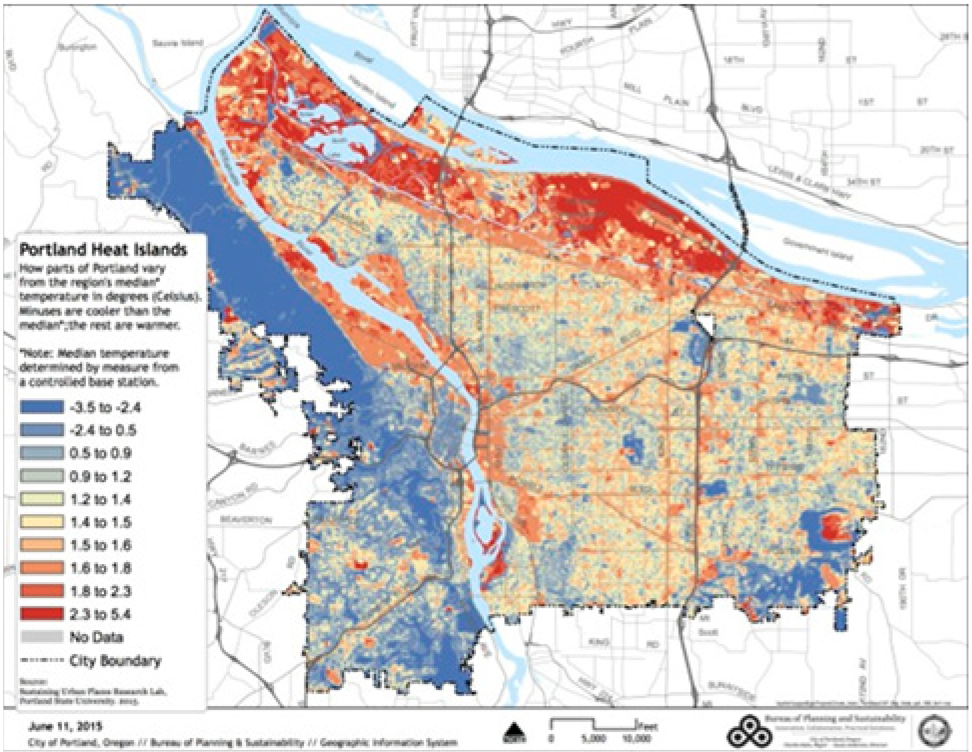
Extreme heat severity can be understood in several different ways:

- Comparing a temperature or heat index against an established threshold. Thresholds can vary across regions and organizations. In the City of Portland, 90°F is the heat index threshold (NHMP, 2020). Heat is considered more extreme the further the index rises above 90°F. At night, the threshold is slightly lower – around 75 - 80° (NWS).
- Comparing temperatures to historical normals. Temperature normals are the average temperatures from the same days or months in previous years. When comparing a day or month's highest temperatures against those in earlier years, the difference can clearly illustrate the extremity of the heat event. The National Weather Service offers an online tool that visualizes daily temperatures against previously recorded average, maximum, and minimum temperature readings for the same days.
- Counting the consecutive days in which the temperature remains at, or rises above, the threshold of 90°F. Heat waves present greater risk to public health the longer that they last.
- Counting the number of days that reach or exceed 90°F across a span of time. For example, we know that the summer of 2015 was particularly hot because it had 29 days of highs over 90°F, more than any previous summer.
- Counting the number of heat waves in a year or season.
- Measuring the season length. Season length is the number of days between the first and last heat wave of a given year. Longer heat seasons are considered more severe (EPA, 2021).

Extreme heat impacts the entire city, but parts of Portland are prone to higher temperatures. The Urban Heat Island (UHI) effect is when temperatures rise in an area of a city where buildings, roads, and other human-made structures (that absorb heat) have mostly or entirely replaced trees, grasses, and plants (that offset heat) (Risk Assessment). UHIs in Portland have recorded afternoon temperatures as much as 17°F higher than non-UHI areas (see Figure 3.43) (NOAA Climate Program Office, 2019).

Portland's Urban Heat Islands are in the industrial North, Northeast, Southeast, and along major arterials including 82nd Ave., Sandy Blvd, Foster Road, and Martin Luther King Jr. Blvd. These areas contain busy roads and parking lots, have higher concentrations of commercial and industrial development, and have relatively few trees. Neighborhoods in this area contain groups with limited adaptive capacity, including people living in poverty and non-white populations. In contrast, neighborhoods in the West Hills and near Forest Park have higher concentrations of trees, making them cooler than their surrounding regions by as much as 4-8°F degrees (City of Portland and Multnomah County, 2014).

Figure 3.46 Urban Heat Island Map for Portland (Voelkel and Shandas, 2017)



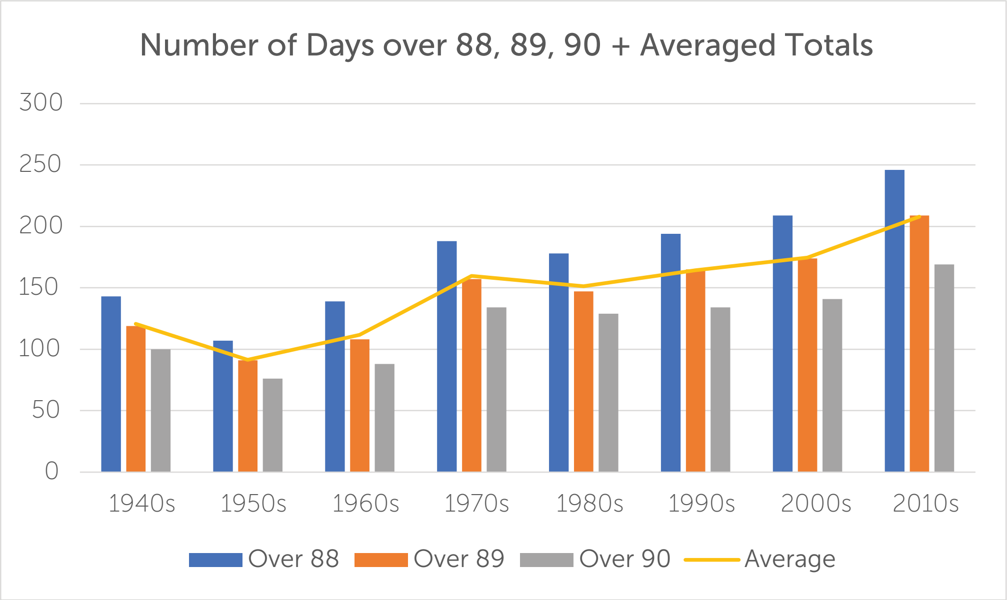
Predicting Extreme Heat in Portland

Because heat severity is predictable, the NWS can provide warnings in advance of extreme heat events. The NWS can issue four different alerts depending on how soon and how severe a heat event is expected to be:

- Excessive Heat Outlook: An excessive heat event may occur in the next 3-7 days. This alerts those who need considerable lead-time to prepare for the event, such as public utilities, emergency management, and public health departments.
- Excessive Heat Watch: An excessive heat event is likely in the next 24 to 72 hours. A Watch is used when the risk of a heat wave has increased, but its occurrence and timing is still uncertain.
- Heat Advisory: Extreme heat conditions are likely within the next 12 hours. This usually means the heat will be very uncomfortable, and potentially dangerous if precautions are not taken.
- Excessive Heat Warning: This is the most serious heat alert. It means that within 12 hours the heat index will be at least 105°F, and precautions must be taken to avoid threat to life or property (OHA, 2011).

Extreme heat and heat waves can be natural fluctuations in day-to-day summer temperatures. But as Earth's climate warms, extreme heat events are becoming more frequent and extreme (EPA, 2021). According to the Fifth Oregon Climate Assessment, Oregon's annual average temperature has increased by about 2.2°F per century since 1895, and, if greenhouse gas emissions remain at current levels, is projected to increase on average by 5°F by the 2050s and 8.2°F by the 2080s (Dalton and Fleishman, 2021). Maximum temperatures will increase, and minimum temperatures will also be higher (Dalton et al., 2013).

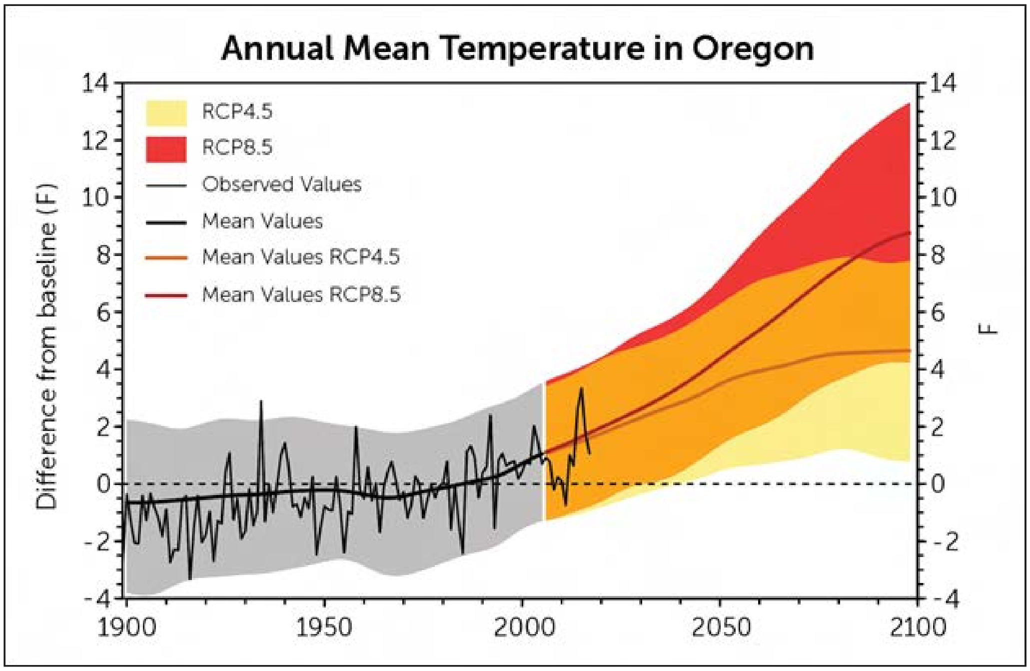
Figure 3.47. Number of days over 88-90 degrees with averaged totals



During the 2010s Portland experienced 169 days with temperatures of 90°F or above, which is more than any other decade on record (OregonLive, 2021).

A study of the "extraordinary heatwave" on the Pacific Coast of the US and Canada in June 2021 found that the unusual heat dome phenomenon "was virtually impossible without human-caused climate change" (Philip et al., 2021). The Pacific Northwest will likely continue to see an increase in heat wave intensity, and heat dome events like the one in June 2021 may become more frequent.

Figure 3.48 Climate Change Scenarios from the Fourth Oregon Climate Assessment Report (Mote et al., 2019)



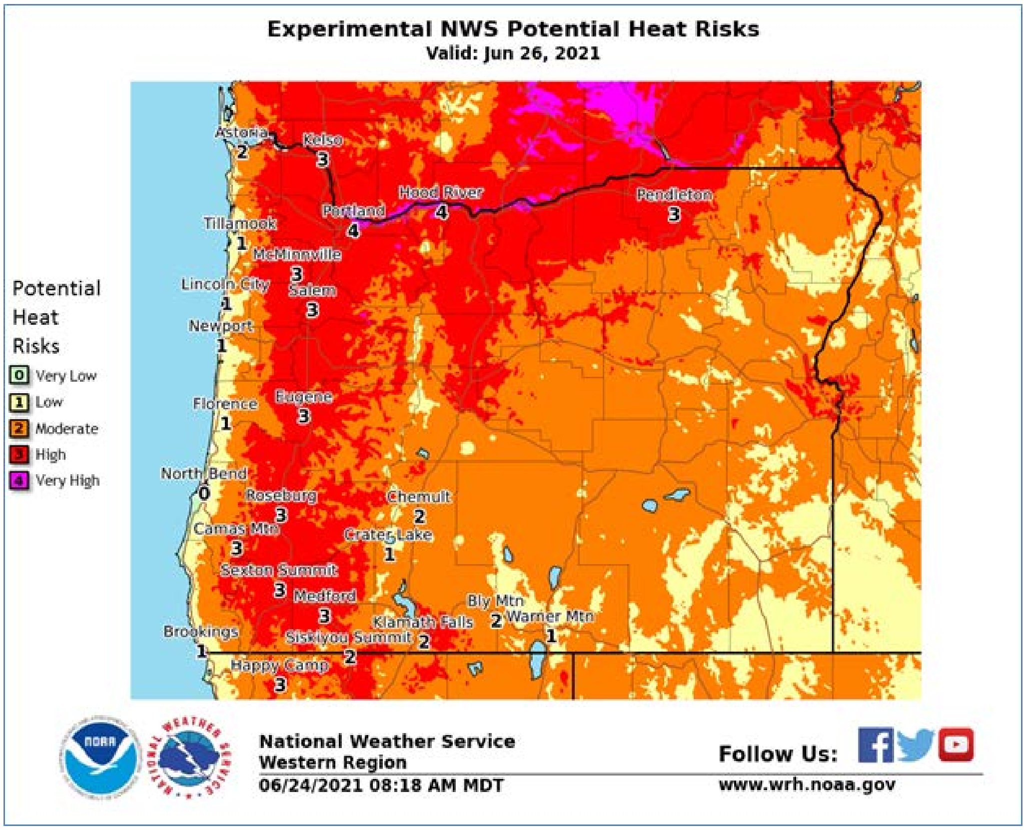
Observed, simulated, and projected changes in Oregon's mean annual temperature from the baseline (1970–1999) under a low (RCP 4.5) and a high (RCP 8.5) future emissions scenario. Thin black lines are observed values (1900-2017) from the National Centers for Environmental Information. The thicker solid lines depict the mean values of simulations from 35 climate models for the 1900-2005 period based on observed climate forcing (black line) and the 2006-2099 period for the two future scenarios (orange and red lines in the top panel, blue and grey in the bottom panel). The shading depicts the range in annual temperatures from all models. The mean and range have been smoothed to emphasize long-term (greater than year-to-year) variability. Representative Concentration Pathway(s) (RCP) are scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs), aerosols, and chemically active gases, as well as land use/land cover (IPCC, n.d.).

Figure 3.45 shows that Oregon's average temperature will increase by 1°F to 13°F in coming years, depending on if more (RCP 8.5) or less (RCP 4.5) emissions that cause climate change are released into the atmosphere. The thin black line is Oregon's temperature from 1900-2017. The thick black line from 1900-2005 shows the impact of climate on temperature from 35 climate models. The 2006-2099 period shows two future scenarios, depending on emissions. The shading depicts the range in annual temperatures from all models. The average and range have been smoothed to emphasize long-term variability.

Impacts of Extreme Heat in Portland

Since 2018, Multnomah County has utilized the National Weather Service's (NWS) 'Experimental Heat Risk Tool' to evaluate risk due to excessive heat. This tool factors in humidity, the length of heat waves, potential for cooling marine winds, and nighttime lows to determine potential risks (Multnomah County, 2018).

Figure 3.49. Experimental Potential Heat Risks



Past Events

To understand the potential impacts of extreme heat on Portland, we looked at past and significant extreme heat events to learn what their impacts were and who was most affected by them.

August 10-15, 2021

In Portland's second heat wave of the year, temperatures rose above 90°F for six consecutive days, peaking at 103°F on August 12th, 2021. Oregon Governor Kate Brown and Portland Mayor Ted Wheeler both declared a State of Emergency in advance of the heatwave, citing concerns about public health and potential power outages (Golden, 2021). Many restaurants and other businesses were forced to close due to the potential health risks.

June 25-30, 2021

An unprecedented heat dome enveloped Portland, reaching a record-breaking peak temperature of 116°F on June 28, 2021. This surpassed the previous day's record high of 112°F, which in turn broke the record set the day before of 108°F. These temperatures reached around 30-40°F higher than the average normals for these days in previous recorded years (see graph below). The heat caused roads and sidewalks to crack and forced closures of the Portland Streetcar public transit system. Portland's Bureau of Emergency Communications (BOEC) saw a surge of 911 calls, receiving over 240 calls related to heat incidents between June 24-30, 2021 (KGW, 2021a). The Multnomah County Medical Examiner found 71 deaths caused by this heat wave, 54 of which were formally ruled as deaths by hyperthermia (very high body temperature) (Multnomah County, 2021). According to the State of Oregon's "Initial After-Action Review" of this heat event, a lack of air conditioning was a common factor in most of these deaths; other factors included age and housing conditions (living in manufactured housing or higher stories of building) (OEM, 2021).

Summer 2017

A heat wave event from July 31st to August 4th raised temperatures over 90°F for five consecutive days, and over 100°F for two days. The highest temperature during this heat wave was 105°F on August 3, 2017.

August 18-20, 2016

Three consecutive days broke their previous record highs, reaching 99°F, 100°F, and 100°F, respectively.

Summer 2015

This was the hottest summer on record, with 29 days reaching temperatures at or above 90°F. It broke the record for the warmest average temperature, averaging 72.2°F. The longest heatwave during this summer lasted from June 29th to July 6th, 2015 – eight consecutive days over 90°F. The peak temperature of the summer was 103°F, recorded on July 30th, 2015.

Summer 2009

The summer of 2009 was considered the hottest on record by number of days above 90°F, before it was surpassed by the summer of 2015. July 2009 held the record for hottest month in Portland until it was broken in June 2021. From July 25th to August 3rd, 2009, an intense heat wave brought ten consecutive days of temperatures above 90°F, with three consecutive days above 100°F. The hottest days were July 28th & 29th, both reaching highs of 106°F (Spencer, 2009).

Impacts on People

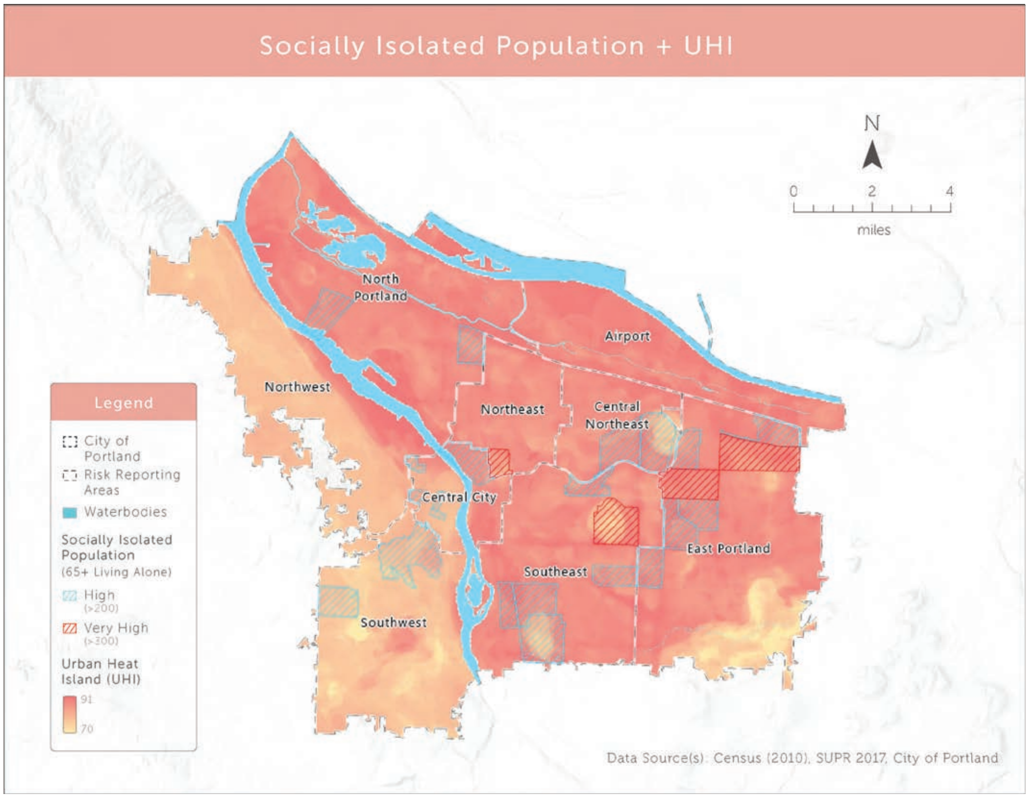
As previously discussed, both humidity and the urban heat island effect can impact how people experience heat. Several other weather, geographic, and human factors can further increase the impacts of extreme heat on people. These include:

- **Overnight heat**. When temperatures remain high through the night during a heat wave, people's bodies do not have the chance to cool down. Consecutive days with warm overnight temperatures can significantly increase heat-related illnesses, hospital visits, and fatalities. Night-time heat waves have a greater influence on human health than daytime heat waves, and they have become more frequent in the Northwest since 1901 (NHMP, 2020).
- **Early season heat.** A heat index of 95°-100° will have a greater impact during the first few occurrences, in May or June, whereas later in the summer it may take a heat index of 100°-105° to have the same effect. This is because people become better able to cope and prepare for extreme heat as the season progresses.
- **Human factors.** Sun exposure, physical exertion, alcohol consumption, certain medications, and some medical conditions can all increase the severity of heat impacts (NWS, n.d.-f).

Impacts on Frontline and Underserved Communities

In an extreme heat event, not all people will experience the same impacts from dangerously high temperatures and the interruption of public services. Extreme heat can lead to power outages and damage infrastructure services like roads and public transportation systems. These negative impacts will be amplified in some communities. The communities at most immediate risk of extreme heat are those that are more socially isolated. People who are 65 and older and who live alone can serve as an example of that most at-risk group. Below is a map of where those people live in Portland, and where Urban Heat Islands are located.

Figure 3.50 Socially Isolated Population & Urban Heat Islands

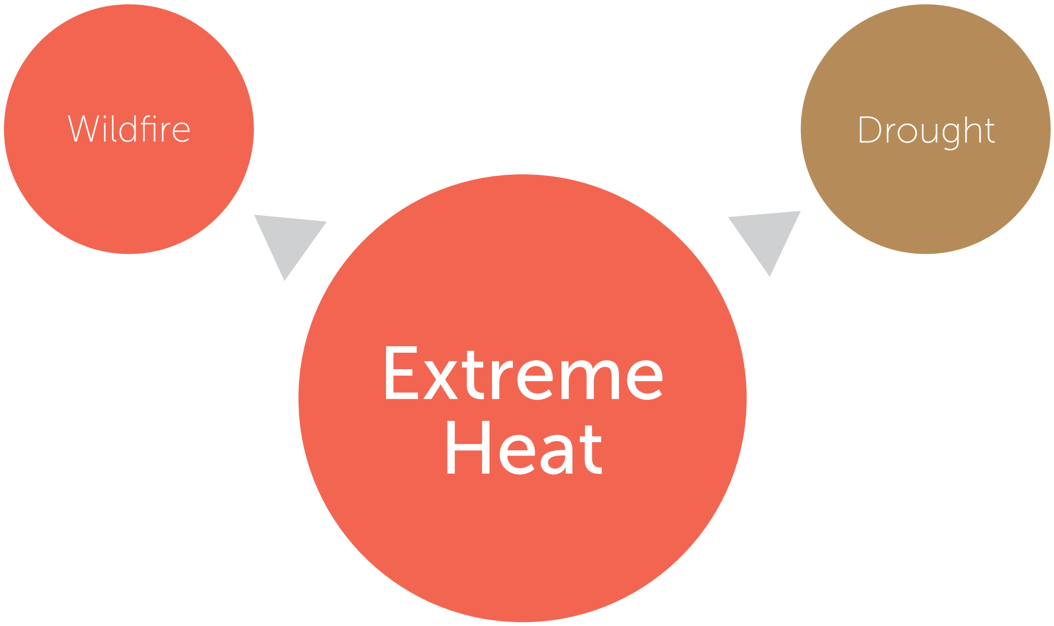


Loss of Life

Extreme heat events are a potentially lethal health hazard to Portland residents. The City of Portland and Multnomah County's 'Climate Change Preparation Strategy' report notes that "between 2000 and 2009, Oregon had approximately 33 heat-related hospitalizations and two heat-related deaths per summer" (City of Portland and Multnomah County, 2014). During the four-day 'heat dome' event in June 2021, when temperatures reached at least 116°F in the city, 71 people died, 54 of whom were formally ruled as deaths by hyperthermia (very high body temperature) (Multnomah County, 2021). There were at least 97 emergency department and urgent care clinic visits for heat illness in Multnomah County on those days (Peel, 2021a).

Impacts on Physical Infrastructure and Environment

Extreme heat puts tremendous pressure on power facilities as demand for electrical and other power increases to run fans and air conditioners. As Portland experienced in 2021, heat can impact infrastructure by warping bridges, causing roads to buckle, melting runways, and more. It can also negatively impact the health of the environment, most notably urban trees, putting them at greater risk for limb loss and failure.



Connected Hazards

Wildfire: Extreme heat reduces the likelihood of precipitation, which leads to drier vegetation that can fuel wildfires.

Drought: Extreme heat events and drought are occurring together more often. Heat waves can make the effects of drought worse (Schwartz, 2020).

Drought

Problem Statements

- Despite the natural abundance of water in the Portland region, the city of Portland is still vulnerable to the impacts of drought.

- As Oregon's largest metropolitan area, Portland relies heavily on the import of various agricultural goods. This supply could be limited by drought happening elsewhere and cause a food shortage.

- Drought is expected to increase in frequency and intensity with ongoing climate change.

- Low water levels in local rivers and streams caused by drought can lead to the rapid growth of cyanobacteria in waterways. These bacteria are harmful to people, animals, and the environment.

- Drought dries out the earth, making dust more common. Dust can affect the health of people with breathing difficulties (such as asthma) and can reduce visibility.

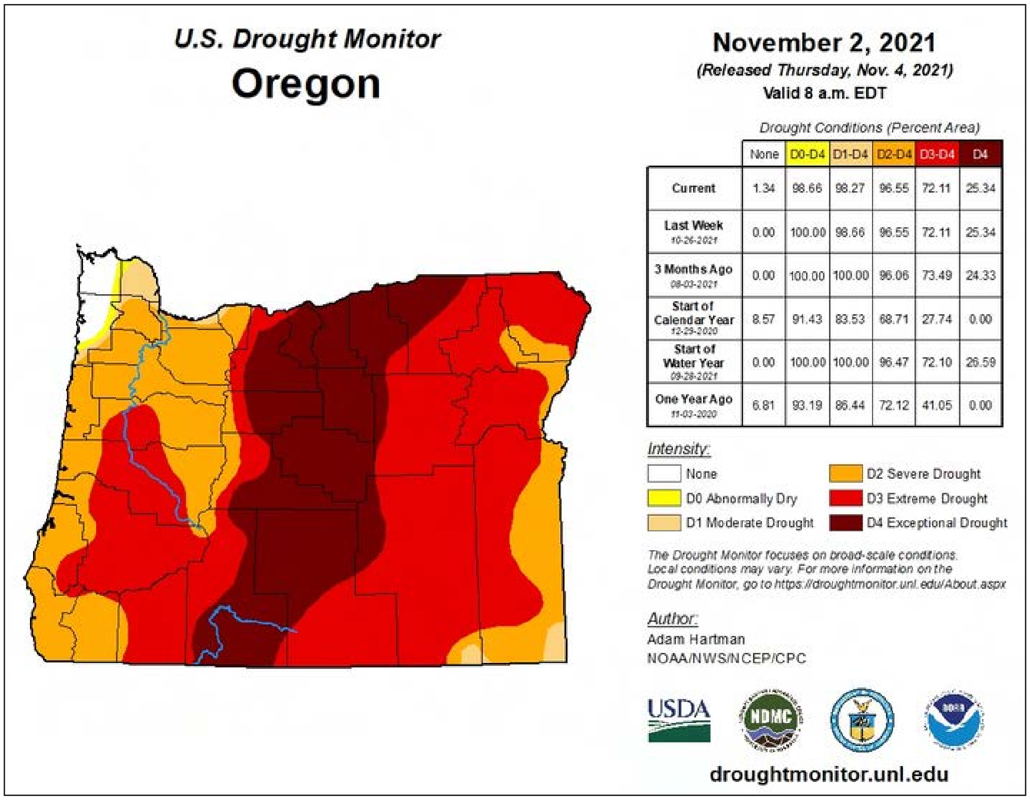
- Drought conditions can lower water levels in rivers and reservoirs, thereby impacting hydroelectric power plants, which generate around 70% of Oregon's electricity. This could impact the City of Portland with potential increases to the cost of power. (U.S. Energy Information Administration, 2016).

What is Drought?

Drought is an unexpected shortage of water that results from periods with less rainfall or lower snowpack. While drought is a natural and recurrent feature in all climates, more extreme and long-lasting drought events constitute a natural hazard. Drought differs from other hazards because its onset is slow and hard to detect, and it can have subsequent long-lasting impacts. Persistent periods of drought-like conditions pose risks to urban water supply, recreational activities, and ecological systems (Dilling, et al., 2019).

- Meteorological Drought is a difference in precipitation from 30-year normal levels over a period of time, most often seasonally.
- Agricultural Drought occurs when there is not enough soil moisture to meet the needs of a particular crop at a particular time.
- Hydrological Drought is characterized by deficiencies in surface and subsurface water supplies. It is measured based on stream flow as well as lake, reservoir, and groundwater levels.
- Socioeconomic Drought occurs when the demand for an economic good (such as bread) exceeds supply as a result of a weather-related deficit in water supply (NWS, n.d.-a).

Figure 3.51 US Drought Monitor for November 2, 2021



Characteristics of Drought in Portland

Drought within the City is of relatively low concern, but drought in other places can have far-reaching effects; for example, drought conditions in Oregon's agricultural areas can negatively impact food supply in Portland. The most impactful type of drought would be one that threatens Portland's drinking water supply, which originates outside of the city.

Drought events can last weeks, months, or be multi-year events. It is typically measured using the Palmer Drought Severity Index (PDSI), which considers temperature and the balance of evaporation and precipitation to determine drought intensity on a scale of -10 (dry) to +10 (wet). Drought severity is often considered relative to its impacts on agriculture, environmental effects, and social impacts.

Predicting Drought in Portland

Drought has historically been difficult for scientists to monitor and predict, but recent advances in remote sensing show promise for drought early warning systems and more reliable detection. Drought.gov is a federally maintained drought modeling tool. Drought data is available at the county-level (Multnomah) weekly, since 2000 (USDM), monthly (SPI), since 1895, and annually (LBDP), since 0, supplemented by tree-ring data.

The Oregon Natural Hazards Mitigation Plan classifies Region 2, which includes Portland, as Very Low probability for drought (NHMP, 2020, 626). Though severe drought is infrequent in the Portland region, climate models project warmer, drier summers for Oregon (NHMP, 2020; Matsumoto, 2019). These summer conditions coupled with projected decreases in mid-to-low elevation mountain snowpack due to warmer winter temperatures increases the likelihood that Region 2 would experience increased frequency of one or more types of drought with climate change.

In the Portland region, climate change would result in increased frequency of drought due to low spring snowpack (very likely, >90%), low summer runoff (likely, >66%), and low summer precipitation and low summer soil moisture (more likely than not, >50%). In addition, Region 2, like the rest of Oregon is projected to experience an increase in the frequency of summer drought conditions as summarized by the standard precipitation-evaporation index (SPEI) due largely to projected decreases in summer precipitation and increases in potential evapotranspiration (Dalton et al., 2017).

Impacts of Drought in Portland

The most likely and severe impacts from drought on the City of Portland would result from drought occurring outside the city, disrupting agriculture, our natural environment (rivers and streams and their habitats), water supply in nearby municipalities, and the economic activities like food production, farm work, and recreation that are linked to these impacts (NHMP, 2020).

Impacts on People

The City of Portland can minimize any impacts on residents and water consumers should several consecutive dry years occur. The Bull Run Watershed is a predominantly rain-fed source, but there is a supplemental aquifer-fed water source in the Columbia South Shore Wellfield, which ensures that Portland residents will continue to have sufficient water even during dry years. No significant direct life or health impacts are anticipated due to drought within the planning area.

Table 3.18 Historic droughts in Region 2 (2020 Oregon NHMP)

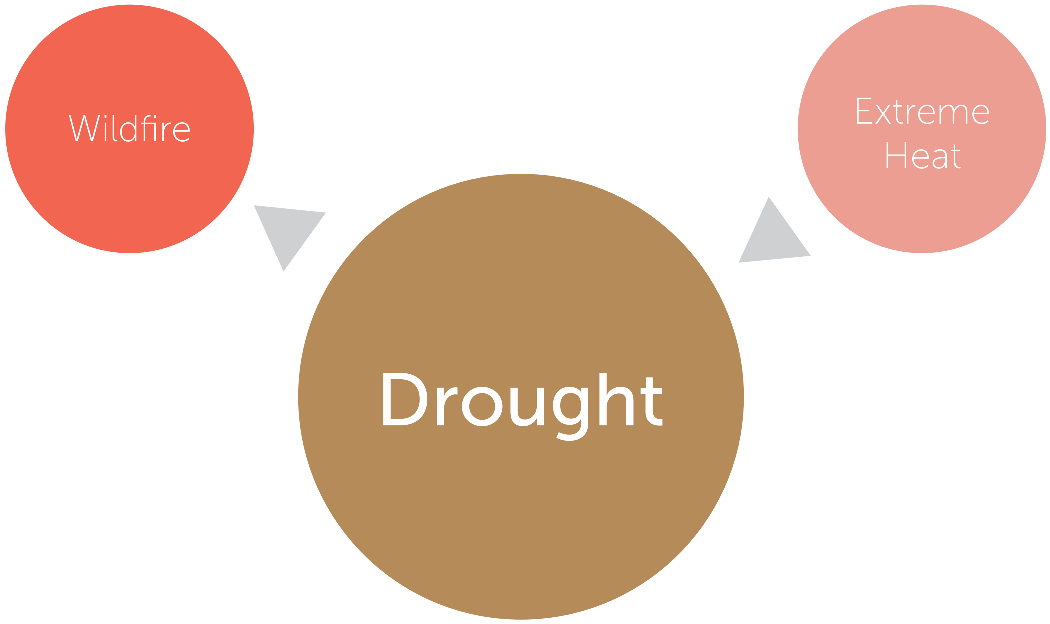
Date	Location	Description
1924	Statewide	Prolonged statewide drought that caused major problems for agriculture
1930	Regions 1–3, 5–7	Moderate to severe drought affected much of the state; the worst years in Region 2 were 1928–1930, which kicked off an era of many drier than normal years
1939	Statewide	The 1920s and 1930s, known more commonly as the Dust Bowl, were a period of prolonged mostly drier than normal conditions across much of the state and country
1992	Statewide, especially Regions 1–4, 8	1992 fell toward the end of a generally dry period, which caused problems throughout the state; the 1992 drought was most intense in eastern Oregon, with severe drought occurring in Region 1
2001	Regions 2–4, 6, 7	The driest water year on record in the Willamette Valley (NOAA Climate Division 2); warmer than normal temperatures combined with dry conditions
2015	Statewide	All 36 Oregon counties receive federal drought declarations; No counties in Region 2 received a Governor's declaration.
2021	Statewide	Much of the state faced prolonged drought conditions through 2021.

Impacts on Physical Infrastructure and the Environment

The built environment will be unimpacted by drought, but the City's natural environment may suffer from reduced precipitation and groundwater.

2021 Statewide

Much of the state faced prolonged drought conditions through 2021. In Portland, important pieces of green infrastructure--like street trees may be harmed by drought. This can impact our resilience to other natural hazards.



Connected Hazards

Wildfire: Drought conditions increase the amount of dry vegetation which can become wildfire fuel. Diminished water supplies can also inhibit the ability to fight wildfires.

Extreme Heat: Extreme heat events and drought are occurring together more often. Heat waves make drought worse by increasing evapotranspiration (Schwartz, 2020).

Winter Storms

Problem Statements

- Snow, sleet, and ice can create dangerous conditions on roadways and sidewalks for drivers and pedestrians.

- Winter storms may make it more difficult for people requiring assistance, such as some elderly people and some people living with disabilities, to get the help they need.

- Winter storms, especially those that include sleet or snow, can cause power lines to fall, disrupting utility services when they are critically needed. More than 200,000 households in Portland suffered power losses during an ice storm event in Portland in February 2021 (OPB, 2021).

- Winter storms that include high winds or rainfall can damage property due to ice buildup, falling trees and tree limbs, or falling power lines.

- Winter storms can disrupt public transportation systems (buses and trains), impacting the ability of residents to get to work, school, medical appointments, grocery stores, etc.

- Sleet and ice can severely damage Portland’s urban tree canopy by causing tree limbs or entire trees to fall.

What is a Winter Storm?

A winter storm is a period of significant precipitation (rain, snow, freezing rain, or sleet) (NWS, n.d.-j). Extreme cold is another hazard associated with winter storms. Rainstorms are common during Portland winters and are considered hazardous when heavy, because of their potential to cause landslides and flooding. Thunderstorms and lightning are additional risks related to winter storms. These will not be addressed, because they are not common hazards in Portland and therefore do not pose significant threats.

Winter storm events can happen anywhere in Portland, and extreme cold events are likely to be felt throughout the city. Snow accumulation can occur anywhere but is more likely at higher elevations such as in the Tualatin Mountains (West Hills).

Characteristics of Winter Storms in Portland

Winter storms are characterized by cold air, moisture, and lift (when warm air is forced to rise over cooler air). These storms produce ice, snow, extreme cold, and wind chill. Ice can form anywhere there is moisture when the temperature is at or below freezing (32°F), but it takes different forms depending on how and where it is created:

Freezing rain: Super-chilled liquid rain that freezes upon contact with the ground or exposed surfaces. Ice from freezing rain can accumulate on surfaces, potentially forming black ice. A period of freezing rain is considered an ice storm when ¼-inch or more of ice accumulates.

Black ice: Patches of ice that form on a road and are entirely clear, appearing black as the asphalt beneath. Black ice presents significant risk to drivers, bicyclists, and pedestrians because it is extremely slippery and difficult to see.

Sleet: Small ice pellets formed during precipitation (NWS, n.d.-c; NSSL, n.d.-b). This happens when rain droplets freeze just before touching the ground, often bouncing upon impact. This can also happen when snow melts as it falls, only to re-freeze just before touching ground. Sleet pellets can accumulate much like snow and differ from freezing rain in that they do not freeze onto surfaces (NWS, 2013b).

Most precipitation that forms in wintertime clouds starts as snow, but it only falls as snow when the temperature below cloud level remains at or below 32°F (NWS, 2013b). Several types of snow events are possible in Portland:

Snow Flurries: Light snow falling for a short duration, usually without accumulating.

Snow Showers: Snow falling at varying intensities for brief periods of time. Some accumulation is possible.

Blowing Snow: Wind-driven snow that reduces visibility and causes significant drifting. Blowing snow may be snow that is falling and/or loose snow on the ground picked up by the wind.

Blizzards: A blizzard happens when the wind blows over 35mph and falling and blowing snow reduce visibility to ¼ mile or less for at least three hours (NSSL, n.d.-c).Blizzards have the highest potential to harm people or cause structural damage. Snow flurries and snow showers are far more common in the City of Portland. Here, snowfall is considered "heavy" when it accumulates to four inches or more in a 12-hour period, or six inches or more in a 24-hour period. Although major snow events are historically uncommon in Portland, cold air from east of the Cascades often moves westward through the Gorge and into the Portland area; if a wet Pacific storm happens to reach the area at the same time, larger-than-average snow events can result (Taylor and Hannan, 1999).

Anytime a winter storm involves snow or ice, extreme cold is a concurrent risk. "Extreme" is a relative term; in Portland, where temperatures are typically moderate and very rarely dip below freezing, any temperature near or below freezing (32°F) is considered extreme. "Wind chill" describes how cold the air feels to human skin and is measured by factoring the temperature with the wind speed. Wind chill can be cooler or much colder than the air temperature and can exacerbate risks associated with cold weather.

Figure 3.52 How Wind Chill is Measured (NWS, 2001)

Wind Chill Chart

Temperature (°F)

Wind (mph)	Calm 40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph) *Effective 11/01/01*

Winter storms are generally brief, lasting no more than a few days. Ice buildup during a winter storm generally ranges from a trace to one inch. Accumulations between ¼ and ½ inch can cause small tree branches and faulty limbs to break, while accumulations of ½ to one inch can cause more significant breakage. Ice storms accompanied by high winds can have especially destructive impacts, especially on trees, power lines, and utility services.

While sleet and hail can create hazards for motorists, freezing rain can cause the most dangerous conditions in Portland. Even a trace of black ice can cause vehicle accidents. Ice buildup can bring down tree limbs, communication towers, and utility wires, creating dangerous hazards for travelers of all types.

Predicting Winter Storms in Portland

Winter storms hit Portland every year with varying intensity. Based on historical observation, severe winter storms appear to occur about every four years in the Portland region. However, there are no solid statistical data available to confirm this, as there is no statewide program to study the past, present, and potential impacts of winter storms in the state of Oregon at this time (NHMP, 2020).

No current research is available to explain the impact climate change will have on winter storms in Oregon. However, the warming climate will likely result in less frequent extreme cold events and high-snowfall years (NHMP, 2020).

Figure 3.53 A downed tree during the February 2021 Winter Storm. (OPB, 2021)

Impacts of Winter Storms in Portland

Past Events

To understand the potential impacts of winter storms in Portland, we considered a past event.

February 2021

The National Weather Service issued a Winter Storm Warning in the Portland Metropolitan Area due to snow, freezing rain, and below-freezing temperatures (KGW, 2021b). The Multnomah County Sheriff's office announced the closure of portions of NW Germantown Road and West Burnside Street in Portland's West Hills due to dangerous driving conditions and multiple stalled vehicles (2021). Parts of Southeast Portland experienced power outages due to cable damage from freezing rain.

Impacts on People

Impacts on Frontline and Underserved Communities

In the event of a winter storm not all people will experience the same impacts from damage to the built environment and the interruption of public services. Winter storms can cause power outages and damages to homes, places of work, and critical facilities such as hospitals. Downed trees and power lines can block roadways and shut down public transportation systems. These negative impacts will be amplified in some communities. Individuals without sufficient shelter and heat sources will be more exposed in a winter storm. In Portland, winter storms often lead to school and childcare closures that force some families to miss work or result in other cascading impacts. Winter storms can also be especially problematic for people with limited mobility—navigating sidewalks and closures in public transportation cause an extra burden for these communities.

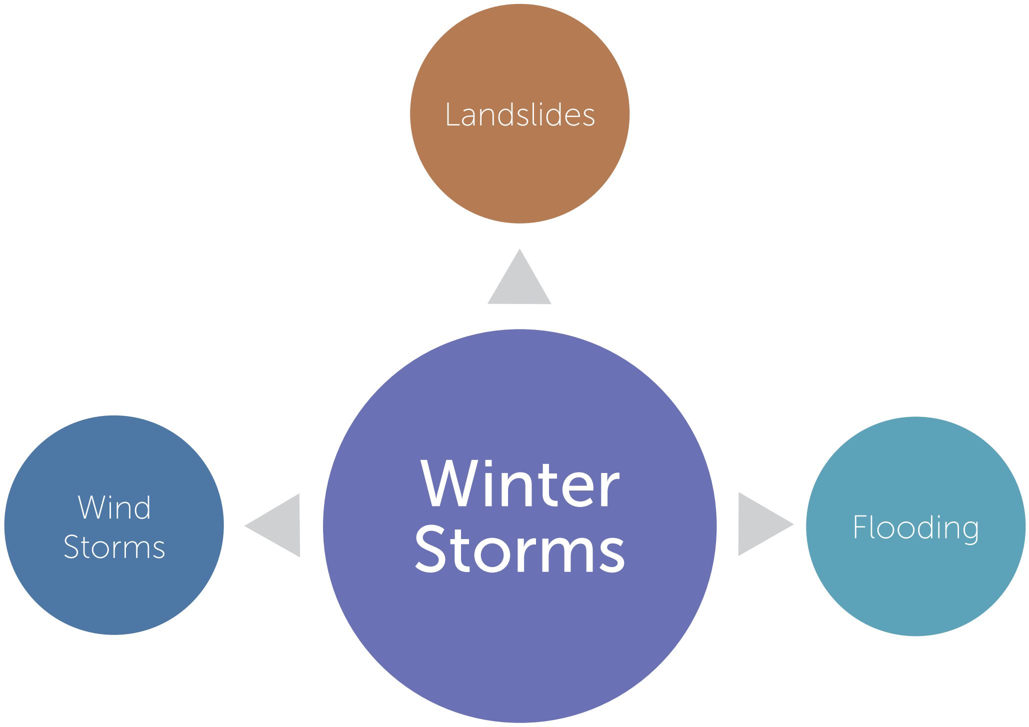
Loss of Life and Injury

The houseless population and those without sufficient shelter are particularly at risk during winter storms. Extreme cold can lead to hypothermia, which most commonly impacts individuals without sufficient shelter. During a winter storm that hit in January of 2017, six unsheltered houseless people died of hypothermia on city streets (Schmid, 2018).

Injury and death can also result from secondary causes related to the weather event, such as from traffic accidents on icy roads. Icy road conditions and low visibility can make it difficult for emergency personnel to travel, which poses a secondary threat to life when police, fire, and medical personnel cannot promptly respond to calls for help.

Impacts on Physical Infrastructure and Environment

Damage to roads or access to them are the primary transportation failures resulting from severe weather, mostly associated with secondary hazards. Landslides caused by heavy prolonged rains can block roads. Snowstorms in higher elevations can significantly impact the transportation system and the availability of public safety services. Of particular concern are roads providing access to isolated areas and to the elderly. Severe windstorms, downed trees, and ice can create serious impacts on power and above-ground communication lines. Freezing can cause power and communication lines to break, disrupting electricity and communication. Loss of electricity and phone connection would leave certain populations isolated as residents would be unable to call for assistance.



Connected Hazards

The most significant secondary hazards associated with severe weather are floods, falling and downed trees, landslides, and downed power lines. Rapidly melting snow combined with heavy rain can overwhelm both natural and human-made drainage systems, causing overflow and property destruction. Landslides occur when the soil on slopes becomes over saturated and fails (NHMP, 2020).

Flooding: Heavy rain from winter storms can overwhelm both natural and man-made drainage systems, causing overflow and property destruction. Excessive rainfall over a short period can also cause river levels to surge. Furthermore, rainwater can oversaturate soils or hit impervious surfaces, forming channels that can contribute to flooding.

Landslide: Winter storms are a primary cause of landslides because landslides occur when the soil on slopes becomes over saturated (NHMP, 2020). Landslides are highly likely to happen any time a severe winter storm hits Portland.

Windstorm: When a windstorm happens during a period of heavy snowfall, a blizzard can result (this is a rare occurrence in the Portland area). In areas of recent snowfall, a windstorm can blow the snow and reduce visibility throughout the affected area.

Volcanic Activity

Problem Statements

- A major volcanic eruption from Mt. Hood or Mt. Saint Helens could result in ashfall in Portland that could limit visibility and have negative health effects.

- Lahars (mudflows) from a Mt. Hood eruption could carry debris into the Columbia River, which may cause flooding. There is a potential for landslides from the eruption to affect Portland's water supply at Bull Run.

What is volcanic activity?

A volcano is a vent or opening where lava (molten rock), pyroclastic materials (fragments of rock), and gases are erupted onto the Earth's crust, known as the lithosphere (PBEM, 2016b). Underneath the surface of a volcano is a system of chambers in which magma is stored before being forced onto the surface through intrusions such as dykes and sills (Huff and Owen, 2013). During an eruption, thicker lava can pour out slowly or more fluid-like lava can shoot out violently alongside columns of tephra (rock shards), ash, and gas (USGS, n.d-l). And with each event, the shape of the volcano changes, transforming into towering mountains or crumbling under the weight of solidified rock and debris (USGS, 2019).

Ashfall is formed when rock fragments are blasted into the air. Rock fragments can range in size from the largest "bombs" to 0.1-inch ash particles. Larger pieces tend to fall within two miles of the eruption vent whereas small particles can accumulate into ash columns/clouds. Depending on its accumulation, ashfall can extend for hundreds to thousands of miles downwind and produce impacts at varied levels of severity (PBEM, 2016b).

Blast Effects occur during violent eruptions and often shoot upward, but lateral blasts are also a possibility. The Mount St. Helens eruption was a lateral blast with impacts spanning 17 miles from the blast site (PBEM, 2016b).

Lahars occur when pyroclastic flows rapidly melt masses of ice and snow, creating flows of mud, rock, and water that travel downward at 20 to 40 miles per hour (PBEM, 2016b).

Landslides happen when rock or earth materials move rapidly in a downward direction. Movements can be small and consist of loose debris or significant collapses that break apart summits or chunks of volcanoes (PBEM, 2016b).

Lava Flows are eruptions of molten rock. Nearby Cascade volcanoes are associated with viscous lava flows that impact areas near the volcano vent and tend to form cone shaped volcanoes. Lava flows can also form mafic volcanoes that take up a broad shape (PBEM, 2016b).

Pyroclastic Flows are fast moving avalanches of hot ash that can reach 1500 degrees Fahrenheit, rock fragments, and volcanic gases. They can move downslope at 100 to 150 miles per hour (PBEM, 2016b).

Characteristics of Volcanoes that Impact Portland

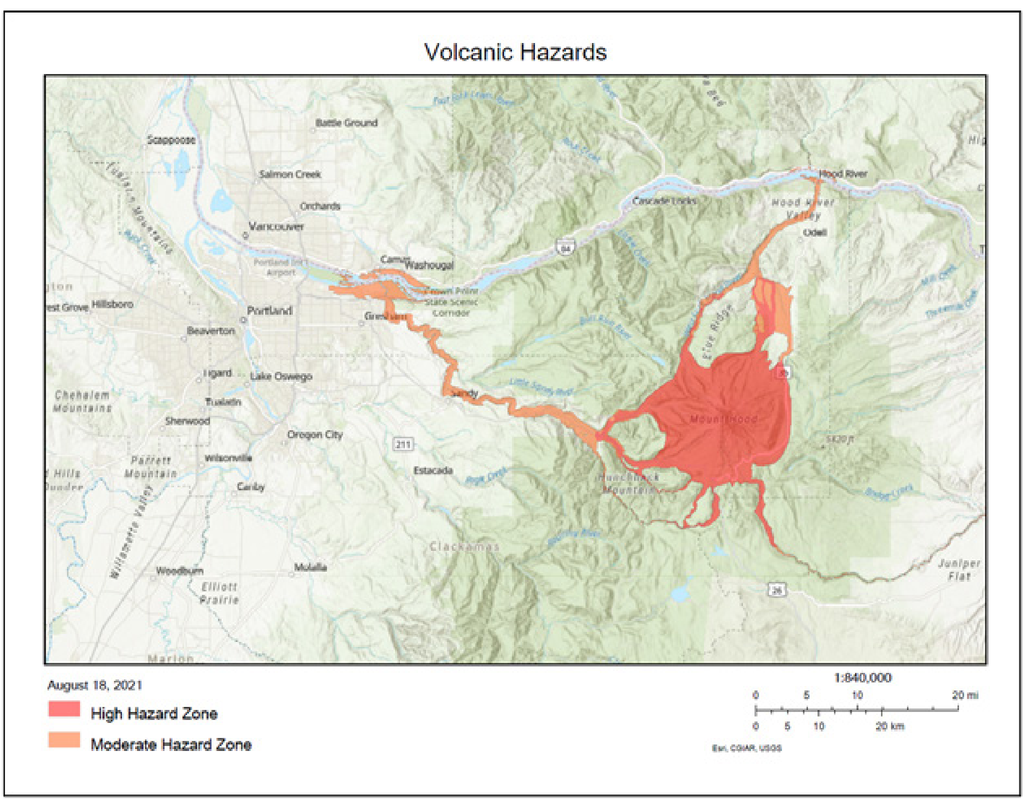
There are two types of volcanoes within the Portland Metropolitan Area:

Cinder Cones are formed when fragmented pieces of hardened lava (cinder) and ash are erupted on the earth's surface. The particles accumulate around the vent or can be carried downwind and deposited (USGS, n.d.-n). Examples of cinder cone volcanoes in the Portland region are Mount Tabor and Powell Butte (now extinct) (PBEM, 2016b).

Stratovolcanoes are formed by alternating layers of lava flows, volcanic ash, cinders, and blocks, resulting in steep-sided, symmetrical cones. The Cascade Range consists of stratovolcanoes, which present seven types of hazards: pyroclastic flows and surges, lava flows, tephra, lahars, debris avalanches, volcanic gases, and lateral blasts. Mount Hood and Mt St Helens are local examples of a Stratovolcano.

The Cascade Range is an 800-mile-long chain of volcanoes located near the City of Portland and spans from northern California to southern British Columbia (PBEM, 2016b). The subduction of the Juan De Fuca plate beneath the North American plate created 20 volcanoes, six of which have a history of volcanic activity: Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens, Mount Adams, and Mount Hood (USGS, n.d.-f). All of the volcanoes in the Cascade Range are classified as stratovolcanoes.

Figure 3.54 Volcanic Hazards near Portland (DOGAMI, n.d.)



The four volcanoes closest to the Portland region are Mount Adams, Mount Hood, Mount St. Helens, and Mount Jefferson.

- **Mt. Hood** is approximately 57 miles southeast of Portland located in the Mt. Hood National Forest and is a popular recreational and scenic attraction for tourists and locals. The volcano can be accessed by US Highway 26 from the south/west and Oregon Highway 35 from the east (PBEM, 2016b). It is also the state's highest peak at 11,239 feet which is distinguishable against the Portland skyline (USGS, n.d.-d).
- **Mt. St. Helens** is located approximately 50 miles northeast of Portland in Skamania County, Washington. Mount St. Helens is a stratovolcano with an elevation of 8,365 feet and can be accessed by State Route 504 from the west (PBEM, 2016b).
- **Mt. Adams** is approximately 31 miles east of Mt. St. Helens in Washington State. It sits in the middle of the Mount Adams volcanic field which spans 500 square miles and is comprised of 120 basaltic volcanoes (USGS, 2018). It is the largest active volcano in the state with a peak of 12,276 feet and can also be distinguished by its glaciers and ice cap summit.
- **Mt. Jefferson** is approximately 70 miles southeast from Portland and is Oregon's second highest peak at 10,497 feet (PBEM, 2016b). The volcano is located in the Mount Jefferson Wilderness area and the Warm Springs Indian Reservation and can be accessed by Highway 22 east from Salem and US Forest Service roads (PBEM, 2016b).

Table 3.19 Volcanoes near Portland

Volcano	Location	Type	Last Eruption	Threat Potential
Mount Hood	Oregon	Stratovolcano	1865	Very High
Mount Jefferson	Oregon	Stratovolcano	>15,000 yrs ago	Low/Very Low
Mount Adams	Washington	Stratovolcano	3,800 yrs ago	High
Mount St. Helens	Washington	Stratovolcano	1980; 2004 - 2008	Very High

Historically, eruptions at Cascade volcanoes have lasted a few days to tens of years. Volcanic activity is not an everyday experience for Portland, but the eruptions at Mount St. Helens in 1980 are reminders of the risks associated with volcanoes. The greatest threat to Portland would occur from downwind ash clouds that can travel several miles. The ash could cause visibility problems, which may impact people's driving abilities and cause engine damage, and people may experience respiratory and breathing issues. Ash fall could also damage critical facilities such as sewage and water systems and cause mechanical equipment failure. Slowed business and cleanup time will most likely lead to economic losses.

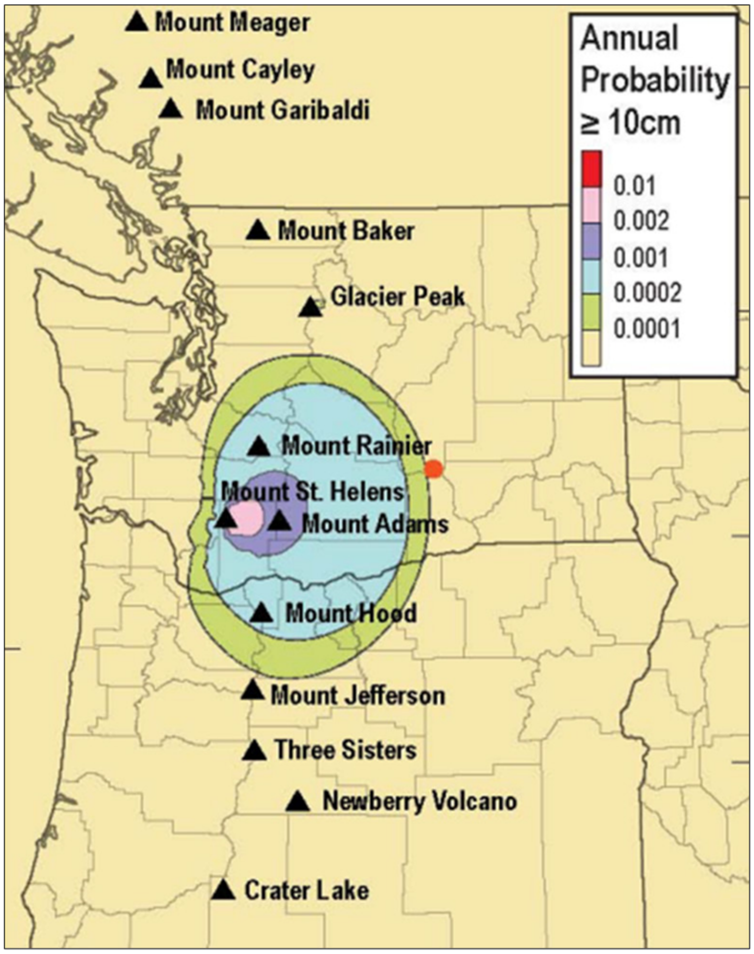
The accumulation of ash will also worsen water clarity, thus impacting human and aquatic life and increasing the need for water treatment. Under the weight of heavy ash fall, which can average 10 pounds per square foot, critical structures can deteriorate or entirely collapse. Also, ash is corrosive, which could burn human skin or cause structural and electronic system damage (PBEM, 2016b).

Volcanic eruptions also often lead to secondary hazards such as lahars (mudflows) and landslides which devastate nearby communities and drastically transform the volcano's surrounding environment. For the City of Portland, direct impacts from Mount St. Helens and Mount Hood are possible but limited by how strong the eruptions are (PBEM, 2016b).

Predicting Volcanic Activity in Portland

Over the past 4,000 years there have been about two eruptions a century in the Cascade Range (Myers and Dreidger, 2008). Although eruptions will not be common in the Portland region, the Cascade volcanoes will be active again in the foreseeable future and several of Portland's surrounding volcanoes are considered high threats (USGS, n.d.-f). Mount St. Helens, for example, has a very high threat potential and is the most active volcano in the Cascade Range, with a series of eruptions occurring in 1980 and between 2004-2008 (USGS, n.d.-e). However, the probability of Mount St. Helens erupting is still extremely low. Figure 3.50 is a map that shows the one-year probability of accumulation of one centimeter (0.4 inch) or more of tephra (volcanic rock fragments) from Cascadian eruptions (USGS, 2013). During a Mount St. Helens eruption, Portland would experience 0.02% probability of accumulated tephra fall while eastern Multnomah County would experience a mere 0.1% probability (USGS, 2013). Other Cascadian volcanoes such as Mount Hood had periods of eruptive activity about 1,500 years ago (USGS, n.d.-h).

Figure 3.55 Probabilistic Hazard Map of Tephra Accumulation



Impacts of Volcanic Activity

To consider the potential impacts of volcanic activity in Portland, we examined past events. No significant volcanic activity has occured since the last MAP was completed.

Past Events

Mount St. Helens: October 2004 – January 2008

A swarm of small earthquakes on September 23rd, 2004, were the first warning of renewed activity in Mount St. Helens. The lava dome left over from the 1980 eruption began to grow, eventually spewing steam and ash. This gave way to lava flows which continued until January 2008. In that time, about 92 million cubic meters (equivalent to 36,800 Olympic swimming pools) of lava erupted onto the crater floor, and two explosions occurred (USGS, n.d.-k). Since then, Mount St. Helens has been downgraded to inactive, but another eruption is predicted to occur in the foreseeable future.

Mount St. Helens: Spring 1980

On March 16th, 1980, a series of small earthquakes were the first signs of Mount St. Helens' activity in over 100 years. By March 27th it had begun to erupt, starting with steam explosions and the slow formation of a bulge (cryptodome) along its north flank. On May 18th, 1980, a 5+ magnitude earthquake and a debris avalanche removed St. Helens' north flank along with part of the cryptodome, causing a hydrothermal blast. This ultimately a resulted in a 9-hour long Plinian eruption. Lahars "poured down the volcano into river valleys, ripping trees from their roots and destroying roads and bridges." One lahar destroyed bridges and homes on its way into the Cowlitz River (USGS, n.d.-j).

Mount Hood

Mount Hood has erupted sporadically over the past 500,000 years and has experienced two major eruptive periods over the past 1,500 years (Gardner et al., 2010). The last major eruption occurred in the 1970s which triggered pyroclastic flows that rapidly melted significant quantities of snow and ice, resulting in lahars (mudflows). This hazard is closely associated with Mount Hood (Gardner et al., 2010). Frequent yet small landslides are also a common occurrence on the mountain.

Mount Jefferson

Mount Jefferson's most recent eruption occurred 15,000 years ago while its largest explosive eruption took place in the late Pleistocene (Ice Age) (Gardner et al., 2010). Despite this long period of inactivity, Mount Jefferson cannot be categorized as extinct with evidence suggesting that it is capable of large explosive eruptions. The next eruption will devastate downstream areas tens of miles away and downwind areas hundreds of miles away. The largest concern for Mount Jefferson is the possibility of lahars (mudflows) flowing into reservoirs, namely, Detroit Lake and Lake Billy

Impacts on People

Volcanoes are not expected to have major impacts on people within the City of Portland. Because the mountains draw people for recreation, there can be risks to Portlanders who visit a volcano. Pyroclastic blasts, lahars, and tephra cause the most volcanic fatalities—mostly to community members who live nearby, but deaths also include tourists, volcanologists, and members of the media (Brown et al., 2017). Mount St. Helens was the most destructive volcano in U.S. history; due to its proximity to nearby communities, it killed 57 people. Now, research and monitoring has allowed scientists to forecast eruptions and provide warning times (USGS, n.d.-p).

Impacts on Physical Infrastructure and Environment

Lahars (mudflows) pose a risk to transportation routes and unreinforced/unmaintained infrastructure located within their inundation zones or the path of their flow. These structures include roads, bridges, and the Union Pacific Railway. The high velocity of lahar flows allows them to carry large masses of debris that threaten vulnerable structures. Their tendency to run into water channels also threatens to contaminate drinking-water wells and wastewater treatment plants (PBEM, 2016b).

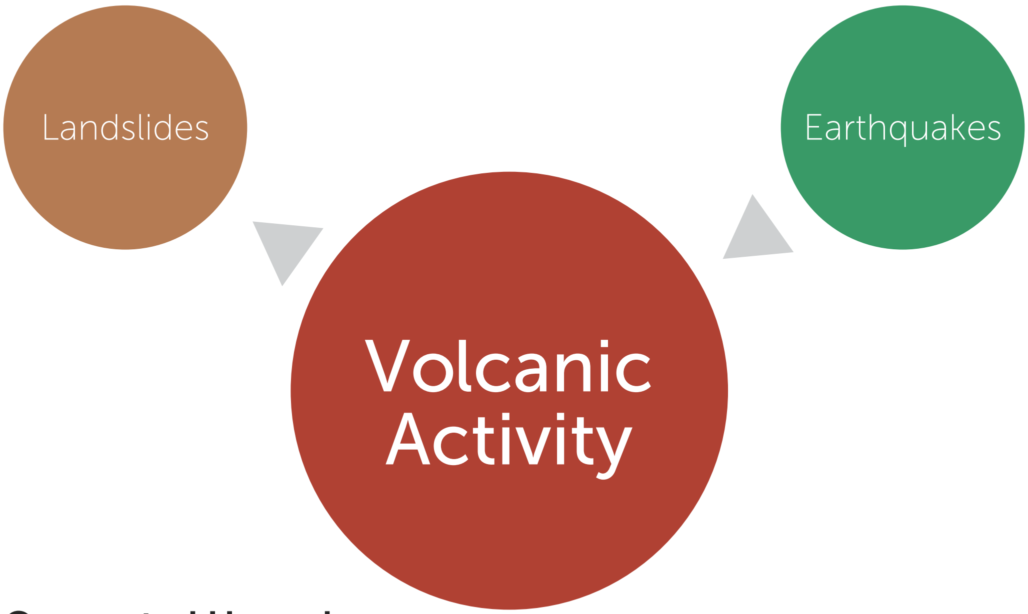
Tephra is a threat to all transportation facilities. The accumulation of rock fragments promotes hazardous driving conditions by decreasing visibility on all transportation routes, thus impeding the evacuation and response processes. For instance, after the eruption of Mount St. Helens, 900,000 tons of ash and tephra were removed from highway lanes in Washington State (USGS, 1997). Machinery and equipment used to remove debris are also vulnerable to tephra accumulation. In addition, ashfall contaminates water facilities (USGS, 1997).

Economic Impact

Volcanic eruptions can disrupt the interconnected flow of commerce and human activity, even without injury or loss of life. Ashfall reduces visibility, hindering automobile traffic flow which leads to the slowdown of corporate and independent businesses. Outside of the urban environment, ashfall also slows agricultural production as the particles tend to damage machinery and equipment. Shipping may also be impacted which can be detrimental to the city's imports and exports. In addition, the removal of ash utilizes a significant amount of city government resources and manpower. Oftentimes, the impacts on the tourism industry are the most concerning effects during volcanic activity. The eruption of Mount St. Helens devastated the recreation and tourism industry of the surrounding natural environment. Tourists avoided the Pacific Northwest, and many conventions, events, and social gatherings were postponed to different locations or canceled altogether. However, low tourism in Washington State did not last, as Mount St. Helens' volcanic activity began to interest tourists again (USGS, 1997).

Estimated Recovery Period

Depending on the severity and duration of volcanic activity, the recovery period can take five to 10 years. Recovery requires a long-term planning process which takes place in multiple phases that build upon each other. The recovery period should prioritize immediate and near-term needs while considering generational planning (Hawaii County, n.d.).



Connected Hazards

Landslides: Lahars are concrete-like mudflows caused by the rapid melting of snow and ice during eruptions, debris avalanches, flooding from crater lakes, and rain-eroded volcanic ash deposits (USGS, n.d.-c). Lahars travel downstream and down hills and occur concurrently with volcanic eruptions. Landslides can also occur when hydrothermal processes weaken volcanoes' slopes, causing rock formations to fall and break. Local communities that reside in populated, downstream valleys are most vulnerable to these secondary hazards. The May 18, 1980, eruption of Mount St. Helens produced a landslide that reached speeds of 100 to 180 mph and climbed over a 1300 ft ridge located 3 mi from the vent (USGS, n.d.-o).

Earthquakes: Volcanic activity can cause two types of earthquakes, according to the Pacific Northwest Seismic Network (PNSN, n.d.-b):

- Volcanic-tectonic earthquakes happen where weak parts of the crust are strained by the sheer mass of the volcano. They can also be caused by pressure changes within the volcano when magma erupts.
- Volcanic long-period earthquakes result from vibrations generated by the moving magma and other materials inside the volcano. These types of earthquakes are often precursors to volcanic eruption. For example, nearby communities were able to evacuate before the 1980 Mount St. Helens eruption because of the warnings indicated by such earthquakes.

More rarely, earthquakes can cause volcanic eruptions. According to USGS, "a few large regional earthquakes (greater than magnitude 6) are considered to be related to a subsequent eruption or to some type of unrest at a nearby volcano" (USGS, n.d.-a). Earthquakes cause eruptions only when the volcano is already poised to erupt, meaning that it holds enough "eruptible" magma and there is significant pressure where the magma is stored.

Wind Storms

What are Windstorms?

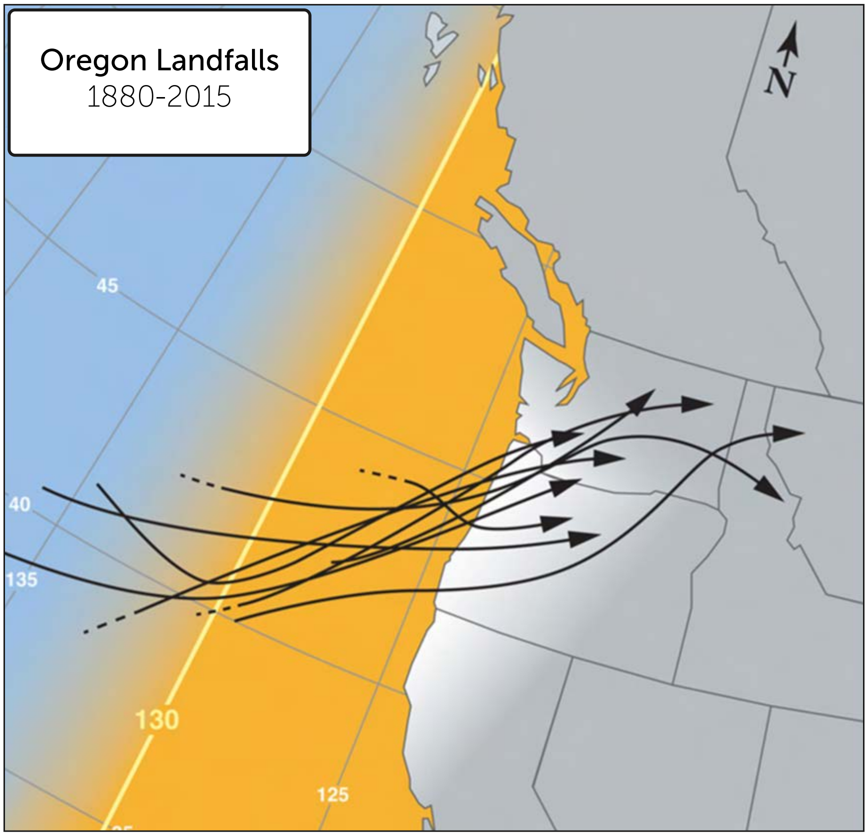
Windstorms are periods of strong winds, usually at speeds more than 34 MPH (Pielke, n.d.), that can cause damage to natural and built infrastructure. Strong winds can occur in the City of Portland during thunderstorms, light precipitation, or even in dry conditions. Hurricanes and tornadoes can also be classified as windstorms. While tornadoes are unlikely to occur in Portland, hurricane-force winds have been known to reach the city.

Winds are caused by air pressure fluctuations in the atmosphere, particularly the tension between high- and low-pressure pockets. When pressure is high in one area, air is forced into a lower-pressure region. Meteorologists call this the "pressure gradient force".

Windstorms can involve several different wind patterns, and sometimes multiple types at the same time. Wind types most likely to affect Portland (as defined by NOAA's National Severe Storms Laboratory (NSSL)) include:

- Straight-line winds are winds not associated with rotation (i.e., not a tornado). This is the most common and damaging wind pattern in Portland.
- Downdrafts are small-scale columns of air that rapidly sink toward the ground. They are most common during thunderstorms.
- Downbursts are localized wind events that occur when a strong downdraft reaches the ground and splays out – much like faucet water when it hits the bottom of a sink. There are two types of downburst: a macroburst is a downburst that spreads larger than 2.5 mi (4 km) horizontally, while a microburst is a downburst that spreads less than 2.5 mi (4 km) horizontally. Microbursts typically last only 5-10 minutes, but their windspeeds can exceed 100 mph (NSSL, n.d.-a).
- A Gust Front is the leading edge of rain-cooled air that clashes with warmer thunderstorm inflow. Gust fronts are characterized by a wind shift, temperature drop, and gusty winds in advance of a thunderstorm (NSSL, n.d.-a).
- Mid-Latitude Cyclones are large-scale low-pressure systems that form along Earth's mid-latitudes (NESDIS, 2018). They are a less common but highly destructive type of windstorm that can impact Portland with hurricane-force winds. Mid-latitude cyclones happen when cold (high-pressure) air from the north meets warm (low-pressure) air from the south; the pressure systems bend together, forming a cyclone.

Figure 3.56 Extra-tropical cyclones originating off the Oregon Coast (Read, 2016)



Characteristics of Windstorms in Portland

Wind typically reaches Portland from off the coast. Southwesterly winds are associated with strong storms moving in from the Pacific Ocean. Though less frequent, the most severe winds come from the South, parallel to mountain ranges. According to the Oregon Natural Hazard Mitigation Plan, "the damaging effects of windstorms may extend for distances of 100 to 300 miles from the center of storm activity" (NHMP, 2020).

Portland is relatively protected from severe winds by the coastal and Cascade Mountain ranges. However, windstorms that do reach Portland will be felt throughout the city, especially those resulting from Southerly winds. East Portland can experience more impacts from wind due to the area's proximity to the Columbia River Gorge. This is primarily due to pressure differences, or gradients, between Portland (lower) and the Gorge (higher). Winds from the East are compressed and funneled through the Gorge, reaching Portland at its exit (Tomlinson, 2019).

Windstorms can last minutes, hours, or even days. The severity of a windstorm can be understood by:

- Measuring the atmospheric pressure gradient. A pressure gradient is how much air pressure changes over a given distance (NWS, n.d.-d). The greater the difference in pressure between two areas, the stronger winds are likely to be, as high-pressure air moves quickly into lower-pressure areas. The distance between the high-pressure and low-pressure areas also influences how quickly air accelerates between them (i.e., wind speed) (USGS, n.d.-i). Meteorologists analyze pressure gradient readings and pressure system movement to forecast windstorms.
- Measuring wind speed. Wind speed is typically characterized along two different metrics: sustained wind and peak gust. Sustained wind is the average wind speed over a two-minute period, while a peak gust is the highest instantaneous wind speed observed or recorded during a windstorm. A gust is a rapid increase in wind speed lasting only around 3-5 seconds.
- Using the Beaufort Wind Scale. This scale measures wind severity according to visible environmental impacts, without the use of instruments. For example, a gust at force six would be considered a "strong breeze" that sways large tree branches or forms whitecap waves in the sea.

Table 3.17 The Beaufort Wind Scale (NWS, 2013a)

Force	Speed	Description	Conditions
0	0-1	Calm	Calm; smoke rises vertically.
1	1-3	Light Air	Direction of wind shown by smoke drift, but not by wind vanes.
2	4-7	Light Breeze	Wind felt on face; leaves rustle; ordinary vanes moved by wind.
3	8-12	Gentle Breeze	Leaves and small twigs in constant motion; wind extends light flag.
4	13-18	Moderate	Raises dust and loose paper; small branches are moved.
5	19-24	Fresh Breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	25-31	Strong Breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	32-38	Near Gale	Whole trees in motion; inconvenience felt when walking against the wind.
8	39-46	Gale	Breaks twigs off trees; generally impedes progress.
9	47-54	Severe Gale	Slight structural damage occurs (chimney-pots and slates removed)
10	55-63	Storm	Seldom experienced inland; trees uprooted; considerable structural damage occurs.
11	64-72	Violent Storm	Very rarely experienced; accompanied by wide-spread damage.
12	72-83	Hurricane	Violent destruction.

Other factors that can inform forecasts and indicate the severity of a windstorm include dry air, moist air, strength of the updraft, and storm motion (NSSL, n.d.-a). Observable impacts like fallen trees or damaged power lines can indicate how severe a windstorm was in retrospect – especially since these secondary hazards typically present the most risk.

Predicting Windstorms in Portland

The National Weather Service can issue three different alerts depending on the expected severity of a windstorm:

- Wind Advisory: Sustained winds of 30 mph for one hour and/or frequent gusts of at least 45 mph are occurring or expected within the next 36 hours. These winds will make it difficult to drive high profile vehicles. Small, unsecured objects may be blown around by these winds.
- High Wind Watch: Sustained winds of 40 mph for one hour and/or frequent gusts of at least 58 mph are expected within the next 12 to 48 hours. Winds will make driving difficult, especially for high profile vehicles. These winds may damage trees, power lines and small structures.
- High Wind Warning: Sustained winds of 40 mph for one hour and/or frequent gusts of at least 58 mph are occurring or expected within the next 36 hours. Winds will make driving very difficult, especially for high profile vehicles. Winds this strong may damage trees, power lines and small structures (NWS, n.d.-h).

The Oregon Natural Hazards Mitigation Plan ranks Multnomah County (where Portland is located) as "high" for the probability that it would be impacted by a windstorm (NHMP, 2020). All of the City of Portland is subject to high winds from thunderstorms and other severe weather events. According to FEMA, the City of Portland is located in Wind Zone I, where wind speeds can reach up to 130 mph. The city is also located in a special wind region along the west coast from Washington to Oregon. The 100-year storm in Portland is considered to be one-minute average winds of 80 mph, a 50-year storm is 72 mph, and a 25-year storm is 65 mph in this region.

There is no consensus as to whether climate change will impact the weather systems coming off of the Pacific Ocean that cause extreme winds, but wind can combine with other climatic factors to create dangerous situations. For example, since Portland is expected to have hotter drier summers, windstorms in fall may cause greater risk when there is higher fire risk.

Impacts of Windstorms in Portland

Past Events

To understand the potential impact of windstorms in Portland, we considered four past events to show how such events developed. The most recent example also demonstrates how windstorms combined with other factors can become even more dangerous.

September 2020 Fire and Wind:

To consider how dangerous wind can be when coupled with expected impacts of climate change in Portland, we looked to the 2020 historic fire and smoke events that impacted the city and surrounding area. A strong easterly wind hit Portland on September 9. This windstorm arrived during 'shoulder season' and rain had not yet come to the Portland region. The state had also experienced a drier-than-average summer. The late arrival of rain and the dry hot summer are predicted impacts of climate change. When a strong windstorm hit during these extremely dry conditions it fueled wildfires to create the most significant smoke event in Portland in recorded history. In Portland the dry, hot, smoky atmosphere lasted nine days. These conditions impacted the City's economy and its public transportation system, interrupted critical services such as childcare, and forced people to remain inside their homes for days. While the physical damage from wind was not beyond the usual windstorm, the compounding factors of wind, heat and wildfire created a dangerous situation for many. Especially at risk were those who lived and worked outside, relied on public transportation, children, elderly, and individuals with respiratory conditions. Portlanders needed access to clean indoor air and in the midst of the COVID-19 pandemic emergency responders had to weigh the risks of bringing people together in clean air shelters. Those with the means scrambled to find good air filters and stay home; those without means risked their health.

Figure 3.57. 2006 Windstorm Aftermath (Read, 2016)

February 3rd-4th, 2006
A cyclone moved in from the coast and brought strong winds through most of northwest Oregon. Portland Airport reported winds of 24 mph and gusts up to 44 mph. Many residents experienced power outages due to fallen trees.

November 13-15, 1981
Two cyclone-related windstorms hit the Pacific Northwest in quick succession in the worst event since the Columbus Day Storm (see below). The strongest winds in Oregon were on Nov. 14, with 85-mph gusts on the Morrison Bridge. Hundreds of thousands lost power and 12 people died throughout Oregon and Washington (OregonLive, 2019).

October 12, 1962

The "Columbus Day Storm" was the most severe windstorm ever recorded in the Portland area, considered the equivalent of a Category IV hurricane in terms of wind speeds (NHMP, 2020). Winds from tropical typhoon Freda arrived in the Pacific Northwest via the Pacific coast. 38 people were injured and there was extensive timber loss, as well as extensive damage to buildings and livestock – estimated at more than 200 million dollars throughout the affected region. Wind gusts reached 116 mph in Downtown Portland, and many in Northwest Oregon were left without power for days or weeks (Read, 2015).

Impacts on People

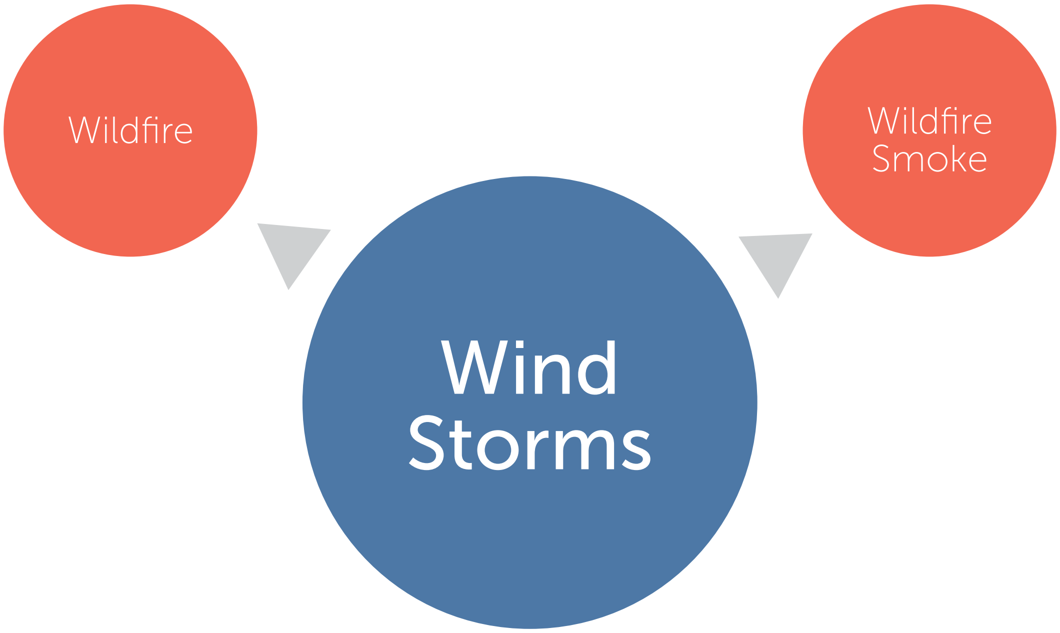
Debris carried by extreme winds and trees felled by gusty conditions can contribute directly to loss of life and indirectly to the failure of buildings and other structures that offer protection. Utility lines brought down by thunderstorms have also been known to cause fires, which start in dry roadside vegetation and downed electricity lines can cause lethal shock.

Impacts on Physical Infrastructure and Environment

As illustrated above, critical infrastructure most impacted by windstorms are utility lines and transportation routes.

Economic Impacts

This can cause economic impacts from the cost of debris removal and repair and in disruption to the jobs and daily life in the city of Portland that generates economic activity.



Connected Hazards

Wildfire and Wildfire Smoke: Winds add energy to fires, making them burn hotter and move faster.

Community Voices in Natural Hazard Mitigation Planning


Neighborhood Emergency Teams (NETs) Program, City of Portland

Introduction

A primary goal for updating the Mitigation Action Plan was to address the needs and priorities of frontline communities. This goal is intended to build on the equity and community work completed for the 2016 MAP and to build on community-based work that the Portland Bureau of Emergency Management (PBEM) has engaged in over the past five years. This part of the plan is intended to provide a voice to communities who are often left out of natural hazard planning yet are impacted the most by the hazards described in the plan and the projects and policies included in the MAP.

Engaging these community members and identifying their priorities was impacted by recent events and the state of Portland during the update project: the COVID-19 pandemic, the racial justice and police reform movements, and other natural hazards that impacted our community during the planning process. Although the effects of COVID-19 were felt throughout Portland, its health and economic consequences disproportionately impacted frontline communities. Communities of color and low-income populations were more at risk of getting sick and dying from COVID-19, as well as losing their jobs or housing as a result of the pandemic. These communities and the organizations that support them were traumatized by police killings that made the national news and engaged in a historical racial justice movement during this time. Simultaneously, they were responding to unprecedented wildfire smoke, winter storms and heat disasters during our planning period.

This context presented challenges to connecting directly with community organizations and groups, but also presented an opportunity to understand the real challenges and priorities for building community resilience. Likewise, while the context presented challenges for building trust and relationships in frontline communities—especially communities of color—it presented an opportunity for us to build on relationships that developed as a result of direct aid provided by the City of Portland during these crises. Our outreach approach took into account these challenges and opportunities and was focused on three areas of work:

- Reviewing and summarizing what we have already heard from frontline communities about how their priorities and needs related to building resilience to natural hazards.
- Collaborating with City employees to develop community priorities based on the relationships and work with community-based organizations that were already taking place during this period.
- Outreach to the community at community-gathering places outside over the summer when COVID-19 cases were lower, and some economic stabilization had taken place.

Summary of Previous Feedback

PBEM has furthered engagement with frontline and underserved communities—undertaking many outreach efforts related to emergency preparedness, hazard mitigation, disaster response, continuity of operations planning for businesses and non-governmental organizations (NGOs), and overall community resilience. Our first step in including the voices of these communities in our plan was to look to the work that had already been done since 2016 and derive relevant experiences and priorities from these efforts. This approach also responds to a key piece of feedback we have received from community: that new plans should respond to feedback that has already been provided, rather than asking the same questions in a new context. For this purpose we reviewed the following reports:

2016 Natural Hazard Mitigation Plan (NHMP) Public Survey: The public survey was distributed to the Portland area to obtain community input during the development of the Natural Hazard Mitigation Plan. The survey was launched on February 1, 2016 to inform development of mitigation projects and programs, plan content, and outreach strategies. To achieve its equity objectives, the survey sought to reach a broad cross-section of the Portland population, particularly communities that are often left out of the planning process. It was primarily distributed through online platforms in English, Spanish, Chinese, Russian, Ukrainian, and Vietnamese translations and included questions pertaining to disaster preparedness and risk reduction.

Black Barbershop Surveys: In April 2018, PBEM surveyed two different barber shops that serve the Black community with the goal of improving community outreach and preparedness. The survey, which was given to 75 community members, consisted of ten questions pertaining to community strengths, household emergency concerns, preferred communication sources, and barriers to disaster preparedness.

APANO Chinese Focus Group on Disaster Resilience: The Asian Pacific American Network of Oregon (APANO) conducted a focus group interview in August 2018 with 12 Chinese immigrants to measure and improve their knowledge on disaster preparedness and emergencies. The focus group was conducted entirely in Chinese to accommodate participants, all of whom identified as Cantonese-speaking women with limited English-language proficiency. Participants shared their personal experiences with disasters, such as earthquakes and flash floods, and pinpointed areas government entities should focus on to improve disaster response.

Latino Network – Communities of Color Insights Report: Latino Network, an education and capacity-building organization for Latinx youth and families, conducted focus group sessions on emergency and disaster preparedness with Latinx adults and youth on August 29, 2018 and September 12, 2018. The group sessions used educational resources such as chart papers, discussion themes, and images to measure the community's experiences with emergency and disaster preparedness. This mixed-method approach helped the City determine the community's culturally-specific needs while maintaining a sense of comfort throughout the discussion.

Voz Workers' Rights Education Project – Disaster Resilience Workshop: Staff and interns from Portland Voz, an organization dedicated to leadership and economic development of day laborers in Oregon, conducted an emergency preparedness and disaster resilience workshop with 10 Spanish speaking day laborers on May 15, 2019. As part of the Voz Workers' Rights Education Project, this event asked participants about their knowledge and lived experiences with disaster preparedness and were given culturally specific resources created with input from local CBOs.

Joint Volunteer Information Center (JVIC) Progress Report: The Joint Volunteer Information Center was established in March 2020 to provide direct support to over 80 community-based organizations (CBOs) through a community advocate model. After identifying personal hygiene items and cleaning supplies as essential resources that are lacking in frontline communities, JVIC advocates and CBOs established a distribution process for these supplies. In December 2020, the City conducted 30-minute focus group interviews via Zoom or phone call with JVIC community-based organizations to collect feedback on the project and pinpoint areas of the distribution process that could be improved.

A review of these efforts provided a few key takeaways for the 2021 Mitigation Action Plan Update:

- Assess Community Specific Needs: Participants showed interest in learning about emergencies and disaster preparedness, but to adequately meet the needs of frontline communities, the city must cater engagement and information to the community. This requires assessing community values, priorities, and existing or missing resources, and adopting a flexible disaster response strategy. Listening to and incorporating communities' lived experiences into the mitigation strategy is another critical part of this process.
- Strengthen Existing Community Partnerships: Partnerships such as JVIC supported communities by creating a zero-entry barrier for city services and resources and encouraging trust-building opportunities. Efforts should continue to nurture collaborations with CBOs and increase their capacities, as they are an essential component to achieving community resilience.
- Bridge the Language Divide: Several non-English speaking communities expressed interest in disaster preparedness education but felt a disconnect with city agencies due to lack of multilingual communications. Building trust and confidence within immigrant communities should include language accessible resources and education opportunities as well as culturally specific government responses to natural hazards.

Additional information on PBEM's past outreach efforts as well as in-depth descriptions of key takeaways for the 2021 Mitigation Action Plan can be found in the Appendix (Page 46).

2021 Building on Current Engagements

In March 2020, the City of Portland established the Joint Volunteer Information Center (JVIC), a partnership with 80 community-based organizations (CBOs), to provide material support to communities during the COVID-19 pandemic. This partnership helped build the City's capacity to serve frontline and underserved communities and provided an opportunity for learning about how the City can best serve these communities through our mitigation work. Focus group discussions were conducted with community based organizations (CBOs) in December 2020 and JVIC community advocates were interviewed via Zoom or telephone in early spring and summer 2021 to gain better insight on how the City could best serve frontline communities before, during and after disasters. This work provided key takeaways for the 2021 Mitigation Action Plan Update:

- **Maintaining the trust** of participating organizations and **building on these relationships**—either through the JVIC or another similarly focused engagement—can help us prepare communities for disasters and encourage community-based mitigation.
- Maintaining **a low-barrier to entry opportunity for engaging with the City** is important for reaching the communities we are most concerned about. The JVIC is a low-barrier to entry partnership, meaning that it eliminates various factors that prevent CBOs from accessing these resources and establishing an effective distribution model. Sidestepping the bureaucratic process is a critical advantage of the JVIC model and empowers organizations to serve their community members in direct ways and act as sources of safety and health resources.
- **A collaborative approach to community engagement** can reduce outreach exhaustion for community based organizations that is critical for working with community on mitigation efforts. The JVIC model also exemplifies the efficacy and adaptability of working across bureaus (outside of traditional silos in the City). The JVIC created a single-point of entry and opportunity for bureaus to work together with the community is an essential part of successful collaborations with the City.
- These interviews also allowed community advocates to provide **specific recommendations for mitigation projects**. Community advocates often noted the **need for mitigation and resilience planning to address endemic issues of race and poverty that intensify the impacts of natural hazards** on the communities they serve.

Several of the above findings do not translate to the type of strategies that fit within a Mitigation Action Strategy because they address systemic issues that go beyond disaster preparedness and hazard mitigation. However, they do emphasize the circumstances needed to build community resilience and maintain ongoing community feedback on our mitigation work. These recommendations should be pursued in conjunction with the Mitigation Action Strategy. Maintaining a JVIC-like program will be an essential component of incorporating equity and the needs of frontline communities into any resilience work the City does in the future, as it can provide a trusting forum for authentic community engagement.

Direct Outreach to Community

Portland Parks Outreach Summer 2021

In order to reach the community directly while keeping to COVID-19 protocols, the MAP Community Engagement Team collaborated with Portland Parks and Recreation to collect surveys outside at existing parks events. We distributed surveys from July 20, 2021 to August 9, 2021 at five East Portland parks: Gateway Discovery Park, Montavilla Park, Luuwit View Park, Wilkes City Park, and Essex Park. We selected parks in the East Portland area with the intent to collect surveys from a more diverse group of respondents and coincided outreach events with Portland Parks' Free Lunch and Play events to ensure that there would be enough participants.

The survey consisted of five questions pertaining to natural hazard prioritization, community safety planning, disaster preparedness and its barriers, and demographic information. The first question asked respondents to choose two locations they would go to if they could not return home, during a natural disaster. Most respondents reported that they would go to another person's home, followed by a hospital or clinic, neighborhood school, or a place of worship. Other common responses that people or families wrote in included: library, community center, local park, or a chain store or restaurant they frequented.


Community Engagement Team at Essex Park, Amy Lubitow

The second question asked participants to rank natural hazards from 1 to 5, with 1 being the most concerning. Earthquakes, Wildfires/Smoke, and Extreme Heat received the most 1s and 2s which is in line with Portland's record-breaking summer temperatures. Additionally, drought and winter storms were regarded as mid-range concerns for most survey participants while volcanoes and landslides were top concerns among children.

The third question asked participants which emergency supplies they had at home. More than 90% of our respondents reported having shelf-stable food, a flashlight or lantern, and hand sanitizer. Around 84% of respondents also reported having a basic first aid kit and some bottled water at home (though we did not confirm whether they had the recommended volume for their household size). 65% of those we surveyed also reported having extra blankets, a tent or a tarp, and a safety knife at home. People were least likely to have a battery or hand-crank radio (36%) or body warmers (33%) .

After noting which emergency supplies they had on hand, the last question asked participants to reflect on barriers to disaster preparedness. The most common responses were a lack of knowledge of what is needed (36%), limited financial resources to buy supplies (31%), and insufficient storage space (25%). Many individuals and families felt unprepared for a natural hazard.

The effort to engage and connect with 102 East Portland individuals or families demonstrates that people are aware of, and concerned about, natural hazards, but lack some information and material resources in order to be better prepared. Overall, this direct in-person community engagement was mostly well-received and suggests that additional investments in in-person outreach and education may be important aspects of natural hazard mitigation and resiliency efforts.

Future Work for Including Community in Natural Hazard Mitigation

Implementing recommendations from previous outreach work is necessary for building community resilience and strengthening Portland's natural hazard mitigation efforts. Frontline communities are eager to learn about disaster preparedness, but the City must adequately assess communities' priorities and resource gaps to determine what is needed. Doing so will show communities that they are being listened to and increase community-based resilience. Drawing from people's lived experiences through direct outreach is another way to inform city agencies on how to best assist underserved populations. Government preparedness, mit-

Outreach at Discovery Gate Park, Amy Lubitow igation and response work should include multilingual communication channels for immigrant populations. Chinese and Latinx participants expressed little confidence in government response due to the lack of language-accessible information and low fluency among city employees. By integrating more culturally-specific and translated resources, City agencies could increase public confidence in their abilities. Investing time and resources into these relationships increases trust in the City which is essential to creating resilient communities.

Continuing to invest and grow the JVIC model, or a similar program, is also essential to natural hazard mitigation efforts in Portland. Significant time, energy and resources have helped to establish a community engagement model that is embedded in the community in real and meaningful ways. If the JVIC lapses due to lack of city effort and intentionality, it we will lose this collaborative coalition that is building community resilience and bridging city-community emergency management. As natural hazards become more frequent in the Pacific Northwest, the JVIC model offers an expedient and effective approach to get information, resources and services into the hands of those most impacted by disasters.

Maintaining such a network was the main priority for future work but the CBO and JVIC advocates also suggested work that could build community resilience overall. This included an economic recovery program focused on frontline communities and City investments in long-term relationship building. An integrated economic recovery program that centers community needs could be a first step in developing a resiliency plan created by, and for, frontline communities. A centralized, consistent approach to community outreach and a relationship-management system could further the capacity of CBOs to track community interactions and engagements, ultimately improving communication and reducing outreach fatigue.

Lastly, the Portland Parks outreach events highlighted hazard concerns and barriers to disaster preparedness which can inform the city on how best to serve communities and determine which investments to prioritize. The survey and in-person outreach provided a few takeaways for the 2021 Mitigation Action Plan Update:

- Earthquakes, Wildfires/Smoke, and Extreme heat were participants' top concerns, an expected outcome during Portland's hottest summer on record. Volcanoes were a popular choice among young children, possibly indicating a gap in their understanding of natural disasters. This suggests that disaster planning and preparedness should begin to incorporate family-friendly education.
- Outreach efforts underscored the importance of increasing natural hazard education and community support, as many Portland residents reported that they did not feel ready for an emergency. Participants noted that they did not know what emergency supplies they needed to prepare for a disaster. The costs to buy supplies and finding a place to store them were another set of challenges.
- City agencies have the opportunity to provide multilingual and accessible disaster information to Portland residents. Participants, for example, appreciated PBEM's "Weekly Steps for Emergency Preparedness" handout and a guide to the city's BEECN (Basic Earthquake Emergency Communication Node) locations. A more thorough distribution of disaster information is advantageous to building resilience.

Mitigation Action Strategy

Introduction

The Mitigation Action Strategy is the heart of the MAP. It brings together the findings of the risk assessment and community engagement teams with the expertise of the Steering Committee and stakeholders to describe the mitigation work the City will take on over the next five years. The Mitigation Action Strategy includes projects within the FEMA-defined categories of mitigation work: Local Plans and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, and Education and Awareness Programs.

All parts of the MAP Update and planning process were guided by the vision, mission, and goals established by the Steering Committee. These guiding principles were especially important to deciding what should go into the Mitigation Action Strategy.

Vision

"Portland is a prosperous, healthy, equitable and resilient city where everyone has access to opportunity and is engaged in shaping decisions that affect their lives" (BPS, 2020).

Mission

To equitably reduce risk and the adverse impacts of natural hazards by building community resilience through collaborative, cost-effective actions and strategies.

Goals

- Protect life and reduce injuries.
- Engage and build capacity for the whole community.
- Minimize public and private property damage.
- Protect, restore, and sustain natural systems.
- Minimize the disruption of essential infrastructure and services.
- Integrate mitigation strategies into existing plans and programs.
- Prioritize multi-objective actions that can further sustainability and equity goals during ordinary times.
- Build on collaborations and lessons learned from resilience work that has occurred since 2016.
- Incorporate community voices and reflect the priorities of frontline and underserved communities.

Developing the Strategy

The Mitigation Action Strategy was developed by the Steering Committee, with input from key stakeholders. Steering Committee members were responsible for gathering feedback from colleagues, City leaders, and collaborators outside the City regarding proposed projects. These stakeholders often included leaders and supervisors who are responsible for individual bureau budgets and strategic priorities.

The first step to developing the Mitigation Action Strategy was a complete review of the actions in the 2016 MAP. The Planning Team collected status reports for each action and presented their findings to the Steering Committee. This review provided valuable insights for improving the mitigation action strategy in the 2021 update. We made two key observations:

Too many incomplete projects: Out of 163 projects reviewed, 17 were completed, and 43 were in progress. Uncompleted projects had often stalled due to political reasons (either lack of leadership within the City or lack of support from the community), lack of resources, or shifting priorities.

Need for greater coordination: The 2016 Mitigation Action Strategy arranged projects according to individual bureaus, rather than taking a cross-bureau or citywide collaborative approach, so that multiple bureaus listed repetitive projects , and few collaborative projects were suggested.

Our approach in the 2021 MAP was to create a more coordinated strategy that is both aspirational and realistic, (realistic in that it reflects the current social, political, and funding contexts). To revise the Mitigation Action Strategy, the Steering Committee and reporting contacts for the 2016 plan: identified which projects from the 2016 plan should carry over into the 2021 plan; grouped related projects together; and noted if a project is already captured in an existing city plan.

Once the review of the 2016 Mitigation Action Strategy was complete, the Steering Committee developed strategies that aligned with the MAP's goals, responded to the risk assessments, and included priorities that arose from our community engagement.

The Planning Team put together tools for the Steering Committee to use in developing new projects for the plan, and hosted a workshop to implement them. These included an equity tool that was first used in the 2016 MAP and a guided set of questions to ask about each project (included in the appendix). The Planning Team hosted a "MAP Strategy workshop" with the Steering Committee and additional stakeholders in May 2021. At the workshop, the Planning Team presented the tools and workshop participants practiced using them by developing one really good idea in a small group and then developing as many project ideas as they could in a set amount of time. Notes from this workshop and a full list of participants is included in the appendix. Steering Committee members then worked independently to develop the best projects for the Mitigation Action Strategy, iterating on the work at the workshop and relying on the tools developed by the Planning Team. They met with their supervisors and colleagues to collect additional ideas and vet a list of projects that they brought back to the Steering Committee and Planning Team.

After a draft list of projects was compiled, the Planning Team assembled and condensed the project list into a cohesive strategy. Projects were prioritized based on a scheme that reflected the MAP's overarching goals along with lessons learned from the 2016 MAP. The Planning Team devised a "good to great rating" system, which is depicted in the Figure 5.1 Projects selected for the plan were assigned a score of 1,2 or 3.

Figure 5.1 Good to Great Rating

SCORE

1

ALL ACTIONS MUST

- Reduce risk and adverse impacts of one of the hazards described in our plan
- Fit into one of the FEMA defined mitigation action categories
- Consider equity

2

GOOD ACTIONS

- Respond to multiple hazards
- Reduce risk and impacts for frontline and underserved communities
- Include an implementation plan
- Reflect existing plans and programs

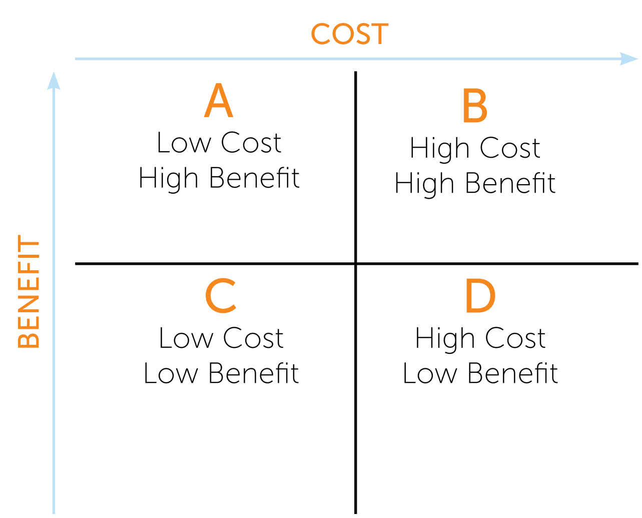
3

GREAT ACTIONS MUST

- Have immediate benefits for the community
- Foster collaboration, and include a plan for working collaboratively to address interdependencies and co-ordination
- Include an engagement point for underserved and frontline communities in implementation via process, decision making, workforce development, contracting etc.
- Respond to all hazards

The Steering Committee also completed a cost benefit analysis of each of the projects in the plan. Members of the Steering Committee were qualified to complete a planning level cost benefit analysis for each activity or could coordinate with stakeholders who have the best available information due to their professional roles. To categorize each project, they assigned it a letter score using the tool shown in Figure 5.2. This additional criteria was used in prioritizing the MAP strategy.

Figure 5.2. Cost-Benefit Analysis tool



Additional notes were made for each project to assist the evaluation process moving forward. These notes included the reporting contact and project details about the type of project. Finally, the MAP Planning Team put the individual projects together into a cohesive strategy, which is described below--prioritized first by the "good to great" rating and then categorically. The categories used to develop project ideas and listed in the MAP strategy are FEMA defined categories listed below:

Local Plans and Regulations

Local plans and regulations can further our mitigation goals by influencing the way that land and buildings are developed. Planning can be the first step in initiating an area of mitigation work and may often conclude with new regulations. These projects should be completed with consideration for the equity and sustainability impacts, opportunities for community engagement; and include an implementation plan that details cost-benefit analysis and opportunities for collaboration to further our "ordinary times" goals.

Structure and Infrastructure

Structure and infrastructure projects are the human-made tangible pieces of mitigation work. This describes the set of projects we will do to modify or construct structures that can reduce the impact of hazards. Providing safe infrastructure that protects people and the environment from natural hazards is an essential part of furthering our sustainability and equity goals. While these projects are discrete, they are often captured as actions within other City plans.

A special note about floodplain management activities: The MAP serves as a Natural Hazard Mitigation Plan and helps the City of Portland meet Community Rating System requirements. Because of this floodplain management activities were considered using a different set of categories which were then mapped to the categories above. These categories and how they were mapped into the categories described above are:

Preventative Activities: Which are mostly included in the "Local Plans and Regulations" because they deal with policies related to land and building development

Property Protection: which include programs to support property owners in the floodplain and are mostly included in the "Local Plans and Regulations" and a few "structure and infrastructure" projects

Natural Resource Protection: which are all included in "Natural Systems Protection"

Emergency Services: Which deal with measures taken during an emergency and are represented in "Local Plans and Regulations" as communications and other planning activities

Structural Projects: which are all included in "Structure and infrastructure" projects

Public Information: Which are all included in "Education and Awareness Programs" activities

Natural Systems Protections

Protecting natural systems can involve preservation and restoration activities that will help reduce our risk to natural hazards. As examples: sediment and erosion control can help mitigate impacts of landslides and winter storms, forest management can help reduce our vulnerability to wildfire, and wetland restoration can help mitigate the severity of floods. Like other types of projects, these projects should be implemented to further sustainability, equity and collaboration goals, and can provide opportunities to further equity in implementation (for example, providing workforce development opportunities).

Education and Awareness Programs

Education and awareness programs engage stakeholders within and outside of government about how to mitigate natural hazards. These types of projects are often ongoing. At the most basic level, this means educating our residents about the natural hazard risks in Portland and can include activities like providing information to property owners about how to landscape and maintain their property to reduce natural hazard risks like flooding and fire. Our work with community during the MAP planning process indicated how essential these programs are, and how important it is to deliver outreach using community-oriented strategies.

Mitigation Action Strategy Projects

Following is a list of projects that make up the Mitigation Action Strategy. The following list was developed, analyzed and prioritized using the process described above. The list recorded in this plan represents projects that were analyzed in full as of November 11,2021. Additional projects that have been added to the Strategy and can be viewed in an accompanying spreadsheet named "Mitigation Action Strategy 2021". Some projects are still being analyzed for priortization and the spreadsheet will be updated when those details are complete. The spreadsheet also includes additional project details that will be used for plan maintenance, project tracking, and integration with other City resilience work. This includes: reporting contacts, the project time frame, and notes.

Mitigation Actions

Top Actions

The following actions were given a "3" rating on the good-to-great scale. These actions are prioritized because they best respond to multiple MAP goals. Those actions which have both a "3" rating and an "A" cost-benefit rating--meaning they provide high benefit at low cost--are the highest priority actions in the plan.

#	Project				
BES-7	Partner with watershed councils, soil and water conservation districts, and other groups to provide stormwater management education, flood risk awareness, and community stewardship opportunities along rivers and streams.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BES	Flooding or Dam Failure	Extreme Heat and Landslides	Education and Awareness	A
PBEM-1	Develop a curriculum and templates plans to assist local businesses in preparing for disasters; promote business continuity planning for local businesses; encourage or require City vendors to develop business continuity plans.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PBEM	Multihazard		Education and Awareness	A
PBEM-8	Support the Neighborhood Emergency Team program by: providing essential supplies and storage space for NETs; providing access to culturally appropriate trainings; supporting neighborhood-level resilience planning. Prioritize neighborhoods that are have been underserved by government in the past.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PBEM	Multihazard		Education and Awareness	A
PBEM-5	Audit how existing disaster planning and plans respond to people with disabilities and make a plan to systematically improve service to people with disabilities; update all PBEM response plans and guidelines; provide training to other bureau emergency managers on disaster response for people with disabilities.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PBEM	Multihazard		Local Plans and Regulations	A

#	Project				
BDS-1	BDAP+: Update our building damage assessment plan to streamline assessment and permitting after a natural disaster. The update should include a prioritztion of buildings that reflects our equity goals, a plan for qualifying new and volunteer damage evaluators and communication and outreach to hard to reach communities.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BDS	Earthquake	Flooding	Local Plans and Regulations, Education and Awareness	A
PBEM-10	Work with affordable housing providers to monitor indoor temperatures at buildings where residents face risks from extreme heat; inform all housing providers when problems are detected in high-risk buildings. Develop and share templated action plan for when protective action is needed. Engage public health and university research partners to ensure remote sensor data is reliable and action plan reflects public health best practices.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PBEM	Heat	Smoke	Local Plans and Regulations; Structure and Infrastructure Projects	A
BES-23	Support efforts to plant more trees in the right of way, on private property and in City-owned natural areas, with a focus on areas that have been historically underserved such as East Portland.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BES, PPR, PBOT	Extreme Heat	Flooding or Dam Failure, Landslides	Natural Systems Protection	A
BPS-9	Stormwater: Develop new regulatory and incentive tools to increase the use of green building technologies and innovative stormwater management techniques (e.g., ecoroofs, green walls, trees on private property, impervious surface standards), renewable energy and energy efficiency in both new development and renovations. Adopt impervious surface limits in areas of Portland that are subject to landslide hazards and where there are stormwater management constraints.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BPS	Landslides and Flooding	Extreme Heat	Structure and Infrastructure Projects	A
BES-20	Implement BES Resiliency Master Plan recommendations.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BES	Multihazard		Local Plans and Regulations	B
PBEM-6	Develop a plan to supply fuel for essential City operations during earthquake response and early recovery; collaborate with other agencies and critical service providers. Consider solar plus storage as a generator alternative				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PBEM	Earthquake		Local Plans and Regulations	B

#	Project
BPS-16	Critical Energy Infrastructure hub. Work with industry, the community and other bureaus and agencies to develop a plan to transition away from fossil fuels. Identify what will be needed to support Portland region and the state with this transition and how the area can be safe and resilient to seismic threats during the transition.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BPS	Multi-hazard		Local Plans and Regulations, structure and infrastructure.	B

#	Project
BPS-15	Built environment Work with the community and other bureaus to integrate climate resiliency into built environment planning and code development across City and in high climate risk areas (e.g., urban heat islands, floodplains, landslide and wildfire risk areas)

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BPS	Multi-hazard		Local Plans and Regulations, structure and infrastructure	B

#	Project
BES-6	Continue installing green infrastructure and adjust design standards and operations and maintenance to increase resiliency to drought, heat, and winter storms.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Drought	Extreme Heat and Winter Storms	Structure and Infrastructure Projects	B

#	Project
PBEM-12	Implement a relationship-management system to ensure the City maintains consistent and coherent communication with community-based organizations that are active in disasters; provide consistent communication with these organizations about natural hazards, including in blue skies; acknowledge strong relationships of trust between government and CBOs as social infrastructure for hazard risk reduction.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
PBEM	Multihazard	Structure and Infrastructure projects	3	A

Tier 2 Actions

The following actions were given a “2” rating on the good-to-great scale. These are actions that respond to most of the MAP goals. Those actions which have both a “2” rating below and an “A” cost benefit rating--meaning they provide high benefit at low cost are the highest priority actions in this tier.

#	Project
BDS-5	**Conduct public education and outreach to owners of private property in high landslide hazard areas.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BDS	Landslides	Earthquake	Education and Awareness Programs	A

#	Project
PBEM-4	Continue to support the Public Alerts program for emergency communications to the community

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
PBEM	Multihazard		Education and Awareness Programs	A

#	Project				
BES-1	Perform air quality and temperature risk assessment for field staff, then develop monitoring strategy; establish baselines and use them to inform emergency response plans and future mitigation actions.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BES	Extreme Heat	Wildfires and Smoke	Local Plans and Regulations	A
BPS-11	Hazards within the environmental overlay zones: Update the Natural Resource Inventory background maps to reflect best available science regarding the location and extent of natural hazard related risks and update the environmental overlay zone code to include regulations that respond to the risks.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BPS	Landslides and Flooding	Wildfire	Local Plans and Regulations	A
BPS-2	Assess and Restart Garbage and Recycling Collection Services. Develop continuity of operations plans to restart garbage and recycling collection services to residence and businesses post-disaster. Implement requirements for garbage and recycling service providers to prepare and maintain emergency operations and continuity of operations plans.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BPS	Multihazard		Local Plans and Regulations	A
BPS-6	Wildfire mitigation actions: Develop recommended policies, regulations and/or landscape options for areas at risk from wildfires. Prioritize areas for action that have limited infrastructure to support emergency response.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BPS	Wildfire		Local Plans and Regulations	A
BPS-8	Floodplain Resilience Project: Update floodplain regulations to implement the flood-related goals and policies in the 2035 Comprehensive Plan and comply with the FEMA National Flood Insurance Program Biological Opinion. In this process, use best available science and mapping, including climate change scenarios, to inform City and County land use, transportation, and other infrastructure planning.				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BPS	Flooding		Local Plans and Regulations	A
PBEM-2	Earthquake Early Warning Implementation Plan Develop a Shake Alert implementation plan for the City of Portland; work with agency partners to plan for other key infrastructure such as the airport, public transit, and industry; systematically advance the projects identified in the plan(s).				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PBEM	Earthquake		Local Plans and Regulations	A
PBEM-7	Create a plan for the additional needs registry and how to identify, help prepare, and respond to individuals with disabilities for each hazard				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PBEM	Multihazard		Local Plans and Regulations	A

#	Project				
PPR-4	Conduct systematic assessments of the fire safety and ecological health of Portland's large, publicly owned, wildland tracts to ensure informed land management decisions.				
	Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
	PPR	Wildfire		Local Plans and Regulations	A
PWB-10	Implement the Portland Water Bureau (PWB) transportation system management plan for emergency and fire access in Bull Run Watershed with the USFS.				
	Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
	PBEM, PBOT, Counties, PWB	Wildfire	Dam Failure	Local Plans and Regulations	A
PWB-17	Partner with Multnomah County, Metro, Portland Public Schools (PPS), adjacent school districts, and Portland Parks and Recreation (PP&R) to develop a sheltering plan for city responders and their families.				
	Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
	PBEM, Mult-Co, Metro, PPS, PP&R	All Hazards		Local Plans and Regulations	A
PWB-18	Work with regional partners to develop a plan for emergency water distribution, including planning for availability, capacity, contracting and delivery of portable water tankers, treatment and distribution plants or bottled drinking water. Assist in regional implementation efforts to acquire, maintain and deploy equipment to support this plan.				
	Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
	Portland Water Bureau	All Hazards	Extreme Heat, Drought	Local Plans and Regulations	A
PWB-19	Incorporate seismic mitigation plans in to PWB emergency operations and response plans.				
	Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
	Portland Water Bureau	Earthquakes	All Hazards	Local Plans and Regulations	A
PWB-20	Coordinate with Commissioner's Office and Office of Government Relations (OGR) to elevate seismic retrofit funding for water infrastructure to a high priority on the City's legislative agenda. This action needs high-level support from City Council and Office of Government Relations (OGR).				
	Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
	Portland Water Bureau	Earthquake		Local Plans and Regulations	A
PWB-21	All Hazards Mitigation: Encourage Bureau staff via multiple methods to complete personal, family and work preparedness plans.				
	Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
	Portland Water Bureau	Earthquake		Local Plans and Regulations	A

PBEM-9	Disaster Debris Removal. Update the Disaster Debris Management Plan in order to develop a citywide plan for debris removal (trees, buildings, cars) post disaster and protect city operations during a disaster. Develop agreements and contracts with service providers and partner jurisdictions to prioritize local collection service providers, then assess needs and ensure rapid mobilization of out-of-region resources during emergency response operations.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
PBEM	Multihazard		Local Plans and Regulations	A

PF&R-7	Implement strategies from the Community Wildfire Protection Plan

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Fire	Wildfire		Local Plans and Regulations	A

BES-18	Continue to partner with United States Geological Survey to maintain and improve river and stream gages in the Portland metropolitan area, which are essential to flood risk monitoring and mitigation planning.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	All Hazards	Extreme Heat, Drought	Local Plans and Regulations	A

PWB-18	Work with regional partners to develop a plan for emergency water distribution, including planning for availability, capacity, contracting and delivery of portable water tankers, treatment and distribution plants or bottled drinking water. Assist in regional implementation efforts to acquire, maintain and deploy equipment to support this plan.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure	Drought	Natural Systems Protection	A

BES-21	Actively manage invasive species and pests in City-owned natural areas to reduce wildfire risk and improve habitat quality.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Wildfires and Smoke	Landslides	Natural Systems Protection	A

PWB-9	Develop a plan for maintaining access to the watershed via Bull Run watershed bridges after an earthquake.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	Earthquake		Natural Systems Protection, Structure and Infrastructure Projects	A

BES-19	Work with US Army Corps of Engineers and other partners to update flood risk models for the Lower Willamette River in downtown Portland and increase accuracy of flood risk maps.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure		Structure and Infrastructure Projects	A

BES-3	Update pump station and facility design standards to incorporate resiliency considerations.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Multihazard		Structure and Infrastructure Projects	A

BES-4	**Assess flood risk at BES facilities along waterways such as pump stations, and develop plans for facility flood response.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure	Earthquake	Structure and Infrastructure Projects	A

BES-8	**Perform seismic risk assessments and resiliency planning for City buildings where essential services are performed, or at facilities that could serve as back-up or continuity locations for essential work.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Earthquake		Structure and Infrastructure Projects	A

CB-1	**Integrated natural systems and property protection in landslide areas using green infrastructure, design standards and education**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Cross-bureau	Landslides		Structure and Infrastructure Projects	A

PPR-3	**Consistent with PP&R management practices and standard operating procedures, identify funding for risk reduction in natural areas with high wildfire danger, including public and private properties.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
PPR	Wildfire		Structure and Infrastructure Projects, Natural Systems Protection	A

PWB-11	**Establish cooperative agreements with local power suppliers to prioritize and provide emergency repairs and continuity of service to the Bureau facilities and Columbia South Shore Well Field during power outages.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	All Hazards	Wildfire, Extreme Heat, Winter Storms	Structure and Infrastructure Projects	A

PWB-12	**Develop Levee Failure Flooding Mitigation Plan. Review findings from levee studies and flood plain mapping, collaborate with Multnomah County Drainage District and Port of Portland to determine flooding impacts to water system and well field from levee failure, quantify risks, and identify potential mitigation strategies; review FEMA updated flood-plain mapping on Columbia and Willamette Rivers for impacts to Portland Water Bureau (PWB) facilities.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	Flood		Structure and Infrastructure Projects	A

PWB-13	**Make seismic improvements to Columbia South Shore well field and Groundwater Pump Station; Install backup electric transformers at Groundwater Pump Station to reduce vulnerability to power outages.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating

	Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
	Portland Water Bureau	All Hazards		Structure and Infrastructure Projects	A
PWB-15	**All Hazards Mitigation - Ensure Adequate Water Treatment Supplies via Hypochlorite Generation: Investigate hypochlorite generation at ground water pump station to reduce or eliminate the need for out of area deliveries.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	All Hazards		Structure and Infrastructure Projects	A
PWB-2	**Develop a plan for using remote sensors and/or controls at critical water distribution system locations. Controls may be used to: monitor Bull Run Dams for early detection of earthquake or movement, rapidly isolate damaged portions of the water conveyance system including river crossings, minimize water loss from storage, including at Vernon 270, Washington Park 229 and Mt. Tabor 270, and control valves where distribution system is tied to backbone.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	Earthquake	Flooding, Landslides	Structure and Infrastructure Projects	A
PWB-22	**Staging Locations for Emergency Repairs: Develop and establish a West-side emergency operations and staging facility for field crews. Develop and establish staging plan for stockpiling water system repair materials in strategic locations.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	All Hazards		Structure and Infrastructure Projects	A
PWB-5	**Mitigate wildfire in the Bull Run Watershed through natural systems protection and forest management in particular reducing risk of fire from tree fall.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	Severe Weather	Winter Storms, Extreme Heat, Drought	Structure and Infrastructure Projects, Local Plans and Regulations, Natural Systems Protection	A
PWB-8	**Plan for climate change impacts in the Bull Run watershed that may increase the likelihood of certain natural hazards**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	Wildfire		Structure and Infrastructure Projects, Local Plans and Regulations, Natural Systems Protection	A
BES-22	**Reduce local flood risk in MS4 basins that are outside the combined sewer area.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	BES	Flooding or Dam Failure		Structure and Infrastructure Projects	A
PWB-23	**Train PWB Emergency Responders Respond Effectively to Disasters: Continue to conduct ongoing emergency response training for all Portland Water Bureau (PWB) employees.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	All Hazards		Education and Awareness Programs	B

PWB-26	Train PWB responders to understand and follow protocols for Federal Emergency Management Agency (FEMA) reporting. Establish and document PWB reporting standards for both temporary protective measures and permanent repairs in compliance with Federal Emergency Management Agency (FEMA) guidelines. Expediting funding or reimbursement provides the means to make repairs to the water system, increasing the timeline for completion.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure		Structure and Infrastructure Projects	A

PWB-23	Train PWB Emergency Responders Respond Effectively to Disasters: Continue to conduct ongoing emergency response training for all Portland Water Bureau (PWB) employees.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	All Hazards		Education and Awareness Programs	B

PWB-26	Establish Process to Follow FEMA Guidelines for Documenting Response Efforts to Disasters, to Effectively Secure FEMA Funding and Request FEMA Grants: Train PWB responders to understand and follow protocols for Federal Emergency Management Agency (FEMA) reporting. Establish and document PWB reporting standards for both temporary protective measures and permanent repairs in compliance with Federal Emergency Management Agency (FEMA) guidelines. Expediting funding or reimbursement provides the means to make repairs to the water system, increasing the timeline for completion.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	All Hazards		Education and Awareness Programs	B

BPS-4	Work with the community and other bureaus and agencies to implement the 2015 Climate Action Plan and Climate Change Preparedness Strategy Implementation and the Climate Declaration.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BPS	Multihazard		Local Plans and Regulations	B

BPS-10	Update floodplain data and maps that inform land use decisions and infrastructure projects to include potential climate change scenarios

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BPS	Flooding		Local Plans and Regulations	B

BPS-14	Work with the community and other bureaus and agencies to develop a plan for Forest Park and adjacent areas to address wildfire and landslide issues while also considering recreation and wildlife habitat needs. While this immediate area may not include a high percentage of vulnerable populations, a catastrophic wildfire would be devastating to a much broader area. The products/implementation actions would likely include regulations, capital improvement projects, educational programs, etc

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BPS	Multi-hazard		Local Plans and Regulations, education and awareness, structure and infrastructure, natural systems protection	B

CB-2	**Develop a plan for an westside operations center that will support more efficient severe weather response and ensure access to emergency resources in the case of a catastrophic incident that damages Willamette River bridges.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Cross-bureau	Multihazard		Local Plans and Regulations	B

PBEM-11	**Work with industry and elected leaders to accomplish seismic retrofits of tanks, pipelines, and soil in the CEI hub. Ensure that potential costs for fuel clean-up and remediation after a seismic event or other significant spill are addressed by owner-operators and not by the public.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
PBEM	Multihazard		Local Plans and Regulations; Structure and Infrastructure Projects	B

PBOT-1	**Implement the PBOT resilience strategy**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
PBOT	Multihazard		Local Plans and Regulations	B

PWB-25	**Establish relationships with out-of-state utilities for future Emergency Management Assistance Compact (EMAC) agreements.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	All Hazards		Local Plans and Regulations	B

BES-10	**Continue acquiring floodplain properties. Where appropriate, remove structures, place open space deed restrictions, and restore natural floodplain functions.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure	Winter storms	Natural Systems Protection	B

BES-11	**Design and construct a minimum of two floodplain or wetland restoration projects along Johnson Creek that mitigate flood risk, restore habitat, and improve water quality. [Cedar Crossing, Springwater Wetlands, West Lents, Brunkow, Oxbow]**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure	Extreme Heat and Drought	Natural Systems Protection	B

BES-12	**Design one near shore restoration project along the Willamette River in Portland that provides flood storage, bank stabilization, and improved habitat.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure	Extreme Heat	Natural Systems Protection	B

BPS-12	Pre- and Post-disaster Floodplain Land Acquisition Program – Identify ongoing funding to expand the Johnson Creek Willing Seller Program and/or the Watershed Land Acquisition Program to purchase of priority floodplain properties in the city. Develop and implement a post-disaster land acquisition strategy for properties that are subject to high flood risk and establish a mechanism for ongoing funding for this program.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BPS	Flooding		Natural Systems Protection	B

BES-14	Perform repairs, replacement and add new capacity in combined sewer sub basins with significant risk for basement sewer backups and localized flooding. Reduce sewer backup risk for a minimum of 1,000 properties, and street flooding risk at minimum of 100 locations.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure	Winter Storms	Structure and Infrastructure Projects	B

BES-16	Design and build stormwater improvements along SW Capitol Hwy and local side streets to address drainage and conveyance deficiencies and recurring nuisance flooding.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure	Winter Storms	Structure and Infrastructure Projects	B

BES-2	Rebuild, rehab, or add a minimum of two wastewater/stormwater pump stations to increase capacity and be more resilient during heavy rain, flood and seismic events. Consider including redundant power supply and BEECN capabilities.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Earthquake	Flooding or Dam Failure. Winter Storms	Structure and Infrastructure Projects	B

BES-9	Assess and mitigate flood risk at Columbia Boulevard Wastewater Treatment Plant to protect employees, infrastructure, and the environment.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BES	Flooding or Dam Failure		Structure and Infrastructure Projects	B

BPS-13	Seismic upgrades to Central City Buildings: develop seismic requirements for Central City development that uses public funds and develop a plan for seismic upgrades in Old Town/China town that reflect equity considerations and allow for incremental improvements

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BPS	Earthquake		Structure and Infrastructure Projects	B

BPS-3	Neighborhood scale energy resilience: Develop neighborhood scale energy resilience through solar+battery systems. Work with the community and other bureaus and agencies to prioritize facilities that are essential to the City or the community, and prioritize installations in neighborhoods that serve communities with the greatest risks.

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BPS	Multihazard		Structure and Infrastructure Projects	B

CB-3	**Support projects located within the City of Portland in the Multnomah County Drainage District 1, PEN 1 and PEN 2 capital improvement projects towards flood control and emergency preparedness**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Cross-bureau	Flooding or Dam Failure	Earthquake	Structure and Infrastructure Projects	B
PBEM-3	**Provide a/c units to low-income Portlanders at great risk of hyperthermia; prioritize people who live in the hottest part of the City.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PBEM	Extreme Heat		Structure and Infrastructure Projects	B
PBOT-2	**Implement mitigation projects on bridges according to PBOT seismic assessment and bridge inventory**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PBOT	Earthquake		Structure and Infrastructure Projects	B
PPR-5	**Seismically retrofit or upgrade Parks & Recreation facilities, prioritizing unreinforced masonry (URM) buildings.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	PPR	Earthquake		Structure and Infrastructure Projects	B
PWB-1	**Harden Portland Water Bureau infrastructure as described in the Seismic Implementation Plan (2018) including: pipes, dams, storage tanks, pump stations, groundwater well field, and access roads.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	Earthquake	Landslides	Structure and Infrastructure Projects	B
PWB-24	**Mitigate Against Flood Damage: Purchase additional vacuum excavator(s) to facilitate access to water system for maintenance and repairs.**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	All Hazards	Flooding	Structure and Infrastructure Projects	B
PWB-28	**Incorporate landslide hazard reduction techniques in to water infrastructure projects, and mitigate landslide hazards for conduits within the Bull Run Watershed through natural systems protection and infrastructure investments**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	Landslide	Earthquakes	Structure and Infrastructure Projects	B
PWB-3	**Plan, design and construct new underground river crossings (burying water pipes) to reduce earthquake damage to pipes: Willamette River - 2 crossings, St. Johns River, Sandy River (Conduit 3)**				
	Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
	Portland Water Bureau	Earthquake		Structure and Infrastructure Projects	B

PWB-7	Mitigate Against Stormwater Runoff and Stream flow Effects in the Watershed through culvert improvements			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Portland Water Bureau	Flood		Structure and Infrastructure Projects	B

BPS-7	Education: Build Resiliency and Mitigation Education into BPS public events such as "fix it fairs" and outreach for long-range planning projects			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
BPS	Multihazard		Education and Awareness Programs	C

BDS-2	2008 Erosion and Sediment Control Manual Update: Update the manual so that it reflects recommendations from an EPA audit around "simple sites" and sites under construction.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
BDS	Flooding	Landslides	Local Plans and Regulations	C

BES-15	Expand secondary treatment capacity at Columbia Boulevard Wastewater Treatment Plant for NPDES compliance and to increase operational resiliency during heavy rainfall and improve seismic resiliency.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
BES	Winter Storms		Structure and Infrastructure Projects	D

BES-17	Replace air handler units at the Portland BES Water Pollution Control Lab that are past their service life and have failed in recent winter storms and extreme heat events.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
BES	Extreme Heat	Wildfires and Smoke	Structure and Infrastructure Projects	D

Tier 1 Actions

The following actions were given a "1" rating on the good-to-great scale. These are actions the meet the most basic MAP goals . Those actions which have both a "1" rating below and an "A" cost benefit rating--meaning they provide high benefit at low cost are the highest priority actions in this tier.

BDS-4 — **Floodplain Resilience Project Updating Title 24 – Chapter 24.50, Flood Hazard Areas: changes will increase floodplain function by increasing the ratio of required excavation for fill placed below the base flood elevation, and reduce the risk of flood losses and to protect human life and reduce injury through the non-conversion agreement which limits the uses of spaces below the flood protection elevation.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BDS	Flooding		Local Plans and Regulations	A

PWB-16 — **Develop recommendations and processes to balance the needs between fire flow requirements and water quality requirements.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	Wildfire	All Hazards	Local Plans and Regulations	A

BPS-1 — **Disaster Debris Removal. Develop a citywide plan for debris removal (trees, buildings, cars) post disaster. Develop agreements and contracts with service providers and partner jurisdictions to prioritize local collection service providers, then assess needs and ensure rapid mobilization of out-of-region resources during emergency response operations.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
BPS	Multihazard		Structure and Infrastructure Projects	A

PPR-1 — **Consider natural hazards on PP&R-managed property when planning for future development.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
PPR	Multihazard		Structure and Infrastructure Projects	A

PWB-36 — **Mitigate Against Earthquakes - Add Advanced Earthquake Sensors and Monitoring Capability: To improve the dependability of seismic instrumentation at Bull Run Dam 2, upgrade the three old strong motion accelerometers (SMA's) that require on-site data downloading, with modern SMA's connected to PWB's SCADA system.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	All Hazards	Earthquake	Structure and Infrastructure Projects	A

PWB-37 — **Develop Credentialing Process and Official Badges: for City staff to identify themselves to access their facilities when roads are closed during disasters. Ensure Police and Fire (or others such as PBOT and ODOT) personnel recognize official credentials to grant access.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	All Hazards		Structure and Infrastructure Projects	A

PWB-6	Move electrical power lines underground to prevent related fire ignitions (in coordination and cooperation with Portland General Electric and Clackamas County) and continue to manage vegetation along powerline corridors (BPA and PGE) to reduce the risk of fire ignitions and to reduce weather-related outages that impair water system operation."			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Portland Water Bureau	All Hazards	Wildfire, Power Outages	Structure and Infrastructure Projects	A

BPS-5	River Plan/North Reach – Work with the community and other bureaus and agencies to update the guiding plans, policies and regulations for the Willamette River North Reach to reduce exposure to natural hazards. This area is at risk of flooding, wildfires, liquefaction in the event of a earthquake. While this planning area is mostly industrial, the neighborhoods of Linnton and St Johns front the river and are surrounded on at least two sides by industry.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
BPS	Multihazard		Local Plans and Regulations	B

PF&R-6	Adopt the national "Fire Danger Rating System" and install the signs at key points in the City.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Fire	Fire		Local Plans and Regulations	B

PWB-4	Partner with University of Washington and PBEM to participate in ShakeAlert Early Warning System implementation			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
City, PBEM, EMSC	Earthquake		Local Plans and Regulations	B

BES-13	Include seismic resilience design in at least two large diameter pipeline projects. (Sullivan trunk, Stark trunk, Tanner trunk)			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
BES	Earthquake		Structure and Infrastructure Projects	B

PPR-2	Mitigate wildfire danger on PP&R-managed property			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
PPR	Wildfire		Structure and Infrastructure Projects	B

PWB-27	Harden water delivery system to reduce seismic impacts including: Trestles Carrying Conduits 2 and 3, Groundwater transmission main, conduits from Head works to Powell Butte, seismic improvements at Head works, seismic improvements at Lusted Hill treatment facility, and monitoring Bull Run Dams 1 and 2			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Portland Water Bureau	All Hazards	Earthquakes	Structure and Infrastructure Projects	B

PWB-35	Mitigate Against Dam Failure in the Bull Run and Subsequent Flooding Impacts: For Bull Run Dams 1 and 2, update hydrologic/hydraulic studies using current computer modeling applications to develop more accurate probable maximum flood inflow hydrographs and dam break downstream flood routing, and inundation mapping for the Emergency Action Plan.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Portland Water Bureau	Flooding		Structure and Infrastructure Projects	B

BDS-3	Amend Chapter 24.85 (Seismic Regulations) to adopt new seismic upgrade triggers and limit the requirements for seismic upgrades for conversions of single dwelling homes to multi-dwelling homes.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
BDS	Earthquake		Local Plans and Regulations	C

BDS-6	Investigate the effect of climate change on landslide risk			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
BDS	Landslides		Local Plans and Regulations	C

PWB-14	Increase Groundwater and Other Well Storage Capacity: Investigate well treatment options to increase existing well capacity.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Portland Water Bureau	All Hazards	All Hazards	Structure and Infrastructure Projects	C

PWB-29	Mitigate Against Potential Dam Failure and Flooding through scour protection of Bull Run Dam 1 flood overtopping abutment scour protection			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Portland Water Bureau	Flooding		Structure and Infrastructure Projects	C

PWB-30	Mitigate damage to concrete reservoir: Perform assessment and condition review via ground-penetrating radar survey of concrete liner at Mt. Tabor Reservoir 6.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Portland Water Bureau	Flooding		Structure and Infrastructure Projects	C

PWB-31	Mitigate Against Dam Failure in the Bull Run: Replace Bull Run Dam 2 Spillway Subdrain System Pipe to reduce likelihood of dam failure			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Portland Water Bureau	Flooding		Structure and Infrastructure Projects	C

PWB-32	Mitigate Against Dam Failure in the Bull Run - Scour repair of Bull Run Dam 2 spillway plunge pool: Erosion is undercutting the spillway toe; the cavity should be filled with concrete to support the spillway toe foundation and prevent further erosion.			
Lead Office	**Primary Hazard**	**Secondary Hazard**	**Mitigation Type**	**Cost Benefit Rating**
Portland Water Bureau	Flooding		Structure and Infrastructure Projects	C

PWB-33	**Mitigate Against Dam Failure and Flooding: Replace the Bull Run Dam 1 spillway gates: A recent structural analysis by HDR Engineering determined that the existing Dam 1 spillway gates would be overstressed under expected seismic loading. (Another recent study completed by West-Yost for Planning determined that it would be more cost-effective to replace the gates instead of repainting them, without accounting for proposed structural modifications to meet earthquake standards.)**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	Flooding		Structure and Infrastructure Projects	C

PWB-34	**Mitigate Against Dam Failure - Bull Run Dam 1 Abutments Scour Protection: A current Bull Run Dam 1 Overtopping Scour Analysis by HDR Engineering has determined that expected overtopping flows during the probable maximum flood could scour a zone of softer rock in the downstream abutments. The consultant probably will recommend some type of modifications to protect these potential scour areas.**

Lead Office	Primary Hazard	Secondary Hazard	Mitigation Type	Cost Benefit Rating
Portland Water Bureau	Flooding		Structure and Infrastructure Projects	C

Related and Referenced Plans

The Mitigation Action Strategy represents just one type of resilience work being done in the City of Portland. It is a framework for the mitigation work that still needs to be done which is also, at times, recorded in other city plans and documents. The strategy builds on and refers to these other plans. The following is a list of related and referenced plans.

Resiliency Master Plan (BES)

The Resiliency Master Plan is the Bureau of Environmental Services' plan for resilience related to earthquakes and climate change. It prioritizes improvements to wastewater and stormwater systems to reduce risk of infrastructure failure and increase the ability of services to withstand natural disasters. The Master Plan provides near-term actions and recommends long-term policies, investments, and programs which strengthen BES's critical system components and infrastructure. The purpose of this document is to convey future programs and policies that will help the city meet seismic and climate change resilience standards by 2063 (Reference, date). The Mitigation Action Plan refers to the BES Resiliency Master Plan as a critical part of the MAP strategy that falls within the Bureau of Environmental Services in their mission to manage Portland's wastewater and stormwater infrastructure to protect public health and the environment.

Resiliency Strategy (PBOT)

The Portland Bureau of Transportation is currently developing a resiliency strategy for transportation infrastructure such as roads and bridges. In collaboration with the Regional Disaster Preparedness Organization, PBOT will also incorporate Regional Emergency Transportation Routes (RETRs) into the strategy as priority routes critical for rapid damage assessment, debris-clearance, and life-saving response actions. The document will also highlight modifications to these emergency routes and other improvements to physical and social infrastructure. The Mitigation Action Plan refers to the PBOT resilience strategy as a critical part of the MAP strategy focused on transportation projects that can reduce the negative impacts of natural hazards.

RIPE Report (City/ISS)

Published in June 2018, the RIPE Report identifies vulnerabilities within the City of Portland's critical infrastructure systems and offers steps to building a multi-bureau disaster resilience and recovery framework. City staff from six bureaus as well as partners from PSU's Institute for Sustainable Solutions used major earthquake and 500-year flood scenarios to identify critical infrastructure, assess interdependencies, and measure infrastructure recovery periods.

The RIPE report represents some significant learning related to disaster mitigation and recovery that has taken place since the 2016 MAP was completed. The report also stresses that major disasters can have cascading impacts on infrastructure systems, but by focusing on the intermediate and long-term recovery phases, rather than emergency response, the City may mitigate these effects. This involves building community support networks, creating permanent housing solutions, and implementing economic revitalization strategies. The 2021 MAP update includes projects recommended in the RIPE report including developing a collaborative governance strategy for resilience and recovery and piloting a resilient island concept based on community-based critical infrastructure.

Earthquake Response Plan (PBEM)

The Earthquake Response Plan (2012), developed by the Portland Bureau of Emergency Management, is a disaster framework that will guide Portland City government, regional partners, and private entities during a large magnitude earthquake. In conjunction with the City's Basic Emergency Operations Plan (BEOP), it delineates critical response and recovery steps after a Cascadia Subduction zone earthquake. The Earthquake Response Plan notes that Portland's infrastructure systems were constructed prior to understanding the Pacific Northwest's seismic risk and describes susceptible transportation, water, sewer, and telecommunications assets. Due to these limitations, it is assumed that the City's response capabilities will be overwhelmed and multiple bureaus will require additional resources and support from external/private entities. This plan focuses on response, but the risk analysis overlaps with the Mitigation Action Plan. The Earthquake Response Plan will be updated this year and will be informed by the Mitigation Action Plan update.

2020-2024 Portland Water Bureau Strategic Plan (PWB)

The PWB Strategic Plan is a five-year risk management plan that addresses climate-related challenges to Portland's existing water system and regional emergency preparedness and resilience. In addition to highlighting areas of improvement, the Strategic Plan prioritizes building collaborative citywide partnerships and frequent reevaluation of strategic risks. The 2021 MAP points to the plan as a tool for emergency management and climate change mitigation strategies for protecting our water supply.

Water System Seismic Study (PWB)

The Water System Seismic Study (2017), led by the Portland Water Bureau, includes seismic risk assessment of PWB's water system and an infrastructure mitigation plan to achieve the Oregon Resilience Plan's (ORP) water recovery goals. The seismic study was crucial for assessing pipeline and facility performance, modeling the city's backbone water systems, producing emergency plans, and developing earthquake mitigation measures. The 2021 MAP refers to the implementation plan for this study and supports related mitigation projects, such as seismic retrofits, developing utility maps, and infrastructure evaluations, into future actions while simultaneously incorporating long-term resilience goals and objectives.

Water System Supply Master Plan (PWB)

The Water System Supply Master Plan (2020) is an update to the previous Infrastructure Master Plan and will ensure that Portland's access to fresh, clean water is maintained for years to come. This Water Bureau-led effort considers future scenarios pertaining to climate change, ultimately guiding the city's decision-making process for long-term water supply management. The SSMP will also identify improvement projects and possible changes to existing conservation programs. Several actions in the 2021 MAP update will support the SSMP.

Water Management and Conservation Plan (PWB)

The Portland Water Bureau developed a 2020 update to the Water Management and Conservation Plan. Their update accompanies the System Supply Master Plan as critical addition to respond to the expected impacts of climate change. PWB conducted water supply analyses to determine climate change impacts on Bull run storage and inform upcoming improvements to its water treatment processes. The WMCP's 2025 conservation benchmarks will guide the selection of 2021 MAP actions in order to curtail Portland's climate-related challenges.

Earthquake Ready Burnside Bridge Feasibility Study Report (Multnomah County)

The Burnside Bridge is a regional lifeline route across the Willamette River. Multnomah County's Feasibility Study Report evaluates the Burnside Bridge during a Cascadia Subduction

Zone earthquake and provides development alternatives such as maintenance, replacement, and enhanced retrofit crossing options. The study began in fall 2016 in which 100 Willamette River crossing options were analyzed through a multi-step screening process, resulting in four alternatives being recommended for evaluation. The 2021 MAP includes actions focused on bridge retrofitting and replacement and selection of alternative emergency transportations routes to support findings in the Feasibility Study.

Damage Assessment Plan (PBEM)

As part of PBEM's Basic Emergency Operations Plan, the Damage Assessment Plan (2014) provides a collaborative framework that will help city bureaus assess damages to infrastructure, public property, and private property after a disaster. The goal is to create a citywide damage assessment process that will inform future disaster declarations, response and recovery actions, and acquire funding for short and long-term needs. It also aims to build an organizational structure that promotes cross-bureau and stakeholder participation. The Damage Assessment Plan update is headed by the Bureau of Development Services (BDS) and focuses on rapid assessment of buildings within the City of Portland following a disaster. The Damage Assessment Plan update is expected to be a 24 month long project and will be informed by the 2021 MAP.

Corporate Seismic Risk Assessment Study (Port of Portland)

The Corporate Seismic Risk Assessment Study (2015) outlines the seismic evaluation of valuable assets at, and adjacent to, the Port of Portland. These assets include airfields, buildings, utilities, piers, levees, and highway structures. The study looked at 18 key Port facilities to understand potential impacts of a Cascadia Subduction Zone earthquake and the economic impacts of taking on seismic resilience projects. The study also presents potential mitigation strategies with estimated implementation costs. Asset performance levels and mitigation measures identified in these assessments will guide the selection of implementation actions that pertain to seismic resilience in the 2021 MAP update. In addition, the Port of Portland is conducting a cost-benefit analysis that supports the development of a seismically resilient runway (Port of Portland, 2015).

Regional Recovery Framework (RDPO)

The Regional Disaster Preparedness Organization developed a Regional Recovery Framework (2019) to coordinate city agencies and partners across the region in recovering from a natural hazard. Careful consideration is given to section 5, Recovery Support Functions (RSFs), which is an operational structure that provides resources and promotes coordination and collaboration between seven functional areas. The regional recovery framework can help us prioritize actions in the MAP strategy which are important regionally and provide a guide for collaboration and coordination with other jurisdictions.

Oregon Resilience Plan (OR Emergency Management)

The Oregon Resilience Plan (2013) is a policy guide for government agencies and includes recommendations that will protect communities, businesses, and infrastructure systems during and after a Cascadia earthquake and tsunami. The Oregon Seismic Safety Policy Advisory Committee (OSSPAC) led the development of the plan and formed eight task groups consisting of technical experts from government, university, and private sector as well as the general public. Each group determined the likely impacts of a magnitude 9.0 Cascadia earthquake and tsunami, set restoration time frames for critical facilities, and recommended improvements to current practices and policies that will meet their 50 year resilience targets. The Oregon Resilience Plan considers long term resilience actions that are more drawn out than typical government planning efforts. Local plans such as the 2021 MAP update can refer to the Oregon Resilience Plan as a policy guide for multi-generational planning and developing community-specific resilience measures in preparation for unpredictable natural disaster situations (OSSPAC, 2013)..

Disaster Debris Management Plan (PBEM)

As part of PBEM's Basic Emergency Operations Plan (BEOP), the Disaster Debris Management Plan (2014) supports a regional planning effort and aims to establish an organizational structure to coordinate debris removal and protect city operations in the event of a natural disaster. The plan also models debris volumes which helps determine the needs and capabilities of debris management. Disaster debris management was noted as an area that lacked significant planning efforts and was under-resourced in the 2016 MAP. An updated regional disaster debris plan is a critical part of the 2021 MAP strategy.

Climate Action Plan (BPS)

The Bureau of Planning and Sustainability published the 2015 Climate Action Plan to address climate change in the City of Portland and Multnomah County using innovative and equitable means. It describes climate change as an inevitable and serious threat to communities in Portland, particularly for low-income, non-white populations, and although Portland and Multnomah County lead the nation in carbon emission reductions, a more ambitious response is needed. As we begin to feel the impacts of climate change; climate mitigation and adaptation are becoming increasingly linked with disaster mitigation work. These areas of work also overlap in our focus on protecting frontline and underserved communities. The 2021 MAP builds on work that the Bureau of Planning and Sustainability has done to center frontline communities and identify important climate mitigation and adaptation strategies.

Community Wildfire Protection Plan (Multnomah County)

The Community Wildfire Protection Plan (2011) is a mitigation plan that identifies risks to citizens, the environment, and critical infrastructure and prioritizes strategies that make wildfire events less damaging in Multnomah County. The CWPP intends to increase wildfire awareness through community involvement and education, and integrate emergency operations and vegetation management projects to create more resilient communities. As of July 2021, Multnomah County is updating the CWPP which is expected to be completed in early 2022. This update comes at a time when recent smoke and fire events devastated surrounding communities, urging a re-evaluation of priorities and strengthening of collaborative partnerships. Because wildfires present a great threat to the City the MAP will point to the CWPP as a source for wildfire protection strategies.

Floodplain Resilience Project

The Floodplain Resilience Project is a Bureau of Planning and Sustainability-led effort that aims to mitigate the effects of future flooding and floodplain degradation. Per FEMA guidelines, the project will also implement rules for new developments along water channels and increase protections for local wildlife. The Willamette River and other 100-year flood areas will be prioritized. Currently, the project is under development at the stakeholder outreach phase with City Council decisions to be made in Spring 2022.

Portland THIRA Update (RDPO)

The Portland Threat and Hazard Identification and Risk Assessment is a risk assessment process that helps identify potential risks and establish regional level goals, objectives, and priorities. The THIRA update is led by the Regional Disaster Preparedness Organization, a citywide resilience partnership, and is responsible for determining critical capabilities, assets, and resources in the Portland Metropolitan Region. The 2021 MAP can refer to the THIRA update as an important tool for disaster preparedness and resilience planning.

Plan Maintenance Strategy

Introduction

The MAP is a living document that should be updated as new information becomes available and circumstances in our region change. Additionally, the MAP Planning Team recommends a "real time evaluation" approach that allows the City of Portland to evaluate how well the plan is moving us toward our resilience goals on an ongoing basis instead of at the end of the planning cycle (five years).

The 2016 MAP laid out a plan for collecting annual status reports on all items in the MAP strategy, and convening a MAP Working Group to meet bi annually and review progress. The Steering Committee felt that there was a significant opportunity to improve on this aspect of the 2016 plan. In particular, they felt that the plan maintenance strategy should respond to the following goals:

- Allow for feedback on MAP Actions that are ongoing and connected to other resilience planning efforts. Marking strategies as simply completed, in progress, stalled, or incomplete, does not provide information on the progress on mitigation work that takes place over a longer time frame. Likewise, the MAP strategy refers to several related resilience planning efforts; the interim goals for these plans may not be captured in the status reports. A more qualitative and descriptive reporting program is necessary to understand the progress being made.
- Provide concrete feedback on how the MAP strategy is furthering equity goals.
- Incorporate lessons learned from natural hazard responses that happen during the five year period.

Real Time Evaluation

A real time evaluation program for the MAP will utilize existing organizational infrastructure and resources to evaluate how well we are reaching our goals on an ongoing basis and allow for regular updates. This effort will be a collaboration between Portland Bureau of Emergency Management (PBEM) staff and the cross-bureau Disaster Resilience and Recovery Action Group (DRRAG). The steering committee included some members from City bureaus and other jurisdictions whose input was essential to the planning process, but who do not have primary responsibility for the MAP strategy. All other members of the Steering Committee are either part of DRRAG or in a couple instances have bureau representation as part of that group. DRRAG can act as an advisory body that is well versed in the MAP and is already part of the City's organizational structure. The plan will be reviewed and revised at regular intervals twice/year. The data used to keep the plan updated will be collected during these interim check-ins but also collected after a natural hazard event has taken place. The data used to evaluate and update the plan will be:

- After action reports from PBEM. Currently, PBEM leads a "hotwash" discussion of the strengths and weaknesses of response after every incident that leads to an activation of the City Emergency Coordination Center. The after-action reports that result from each hotwash will be included as part of the bi-annual plan review.
- Survey 1 will focus on qualitative feedback about the overall progress towards the plan goals. The survey will be sent to the 2021 MAP Steering Committee with additional stakeholders added as appropriate.
- Survey 2 will ask for specific feedback about the status of action items in the MAP strategy in the same format that was used in the 2016 plan. It will be sent to the "responsible party" identified for each action in the plan.

DRRAG will make recommendations for any changes based on presentations of the survey data and DRRAG participant expertise. These recommended changes will be shared with the community via the Portland Bureau of Emergency Management volunteer network. PBEM sends out a regular newsletter, a summary of these changes and an opportunity for comment will be included in the newsletter. The same information will also be posted to the 2021 Mitigation Action Plan website.

Plan Maintenance Strategy and Schedule

Timing	Plan Maintenance Activities
May 2022	Develop and disseminate Survey 1--qualitative survey Analyze survey results Compile time-relevant "after action" reports
June 2022	Present survey results and "after action" reports to DRRAG DRRAG develops feedback and recommendations
December 2022	Disseminate Survey 2--status reports Analyze survey results Compile time-relevant "after action" reports
January 2023	Present survey results and "after action" reports to DRRAG DRRAG develops feedback and recommendations Recommended changes are posted on the MAP website and shared in the PBEM newsletter along with a form to collect community feedback. Update plan based on recommendations from two survey engagements and community feedback.
May 2023	Develop and disseminate Survey 1--qualitative survey Analyze survey results Compile time-relevant "after action" reports
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Timing	Plan Maintenance Activities
December 2024	Disseminate Survey 2--status reports Analyze survey results Compile time-relevant "after action" reports
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May 2025	Develop and disseminate Survey 1--qualitative survey Analyze survey results Compile time-relevant "after action" reports
June 2025	Present survey results and "after action" reports to DRRAG DRRAG develops feedback and recommendations Record recommendations as a starting place for the five year update of the plan
December 2025	Disseminate Survey 2--status reports Analyze survey results Compile time-relevant "after action" reports
January 2026	Present survey results and "after action" reports to DRRAG DRRAG develops feedback and recommendations Produce a report of recommendations as a starting place for the five year update of the plan

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