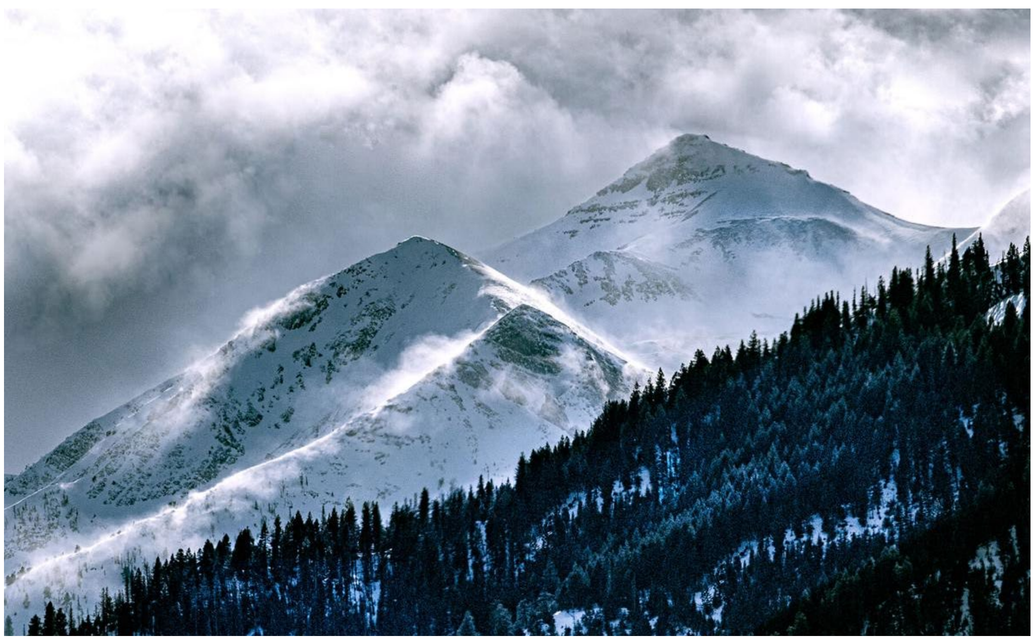

Volume II: Hazard Annexes

Photo Credits: Top photo - Ellen Morris Bishop for the Wallowa Chieftain, Smoke from Hurricane Creek Fire, 2014
Bottom photo - Ellen Morris Bishop for the Wallowa County Chieftain, February 5, 2021

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INTRODUCTION

The following Natural Hazard Annexes provide additional detail not previously provided in the 2014 *Northeast Oregon Natural Hazard Mitigation Plan* (*2014 NHMP*) on natural hazards addressed by that plan. New sections have been added to provide background on the newly identified natural hazards identified by the Wallowa County NHMP update Steering Committee. These are Poor Air Quality; Insect Pests, Noxious Weeds, and Invasive Species; and Dam Failure. The natural hazards of Extreme Temperature and Severe Weather from the *2014 NHMP* were further divided calling out both Extreme Heat and Extreme Cold as well as clarifying the types of Severe Storms (both winter snowstorms and summer thunderstorms) and Windstorms experienced in Wallowa County. These are treated together in this update.

Annexes follow for Wildfire; Poor Air Quality; Severe Weather (including Extreme Cold, Extreme Heat, Windstorms and Severe Storms); Drought; Insect Pests, Noxious Weeds and Invasive Species; Landslide; Earthquake; Flood (with a section on Dam Failure), and Volcanic Event comprising Volume II. They are ordered roughly in descending order of importance as ranked by the Steering Committee during the Hazard Vulnerability Assessment process. The order of the Annexes was also influenced by the fact that natural hazards are interrelated. Some natural hazards may exacerbate the effects of other separate natural hazards, such as Drought impacting the severity of Insect Pest outbreaks. These factors as well as the impacts of future climate conditions on the severity and the nature of these natural hazards are addressed in the Annexes.

The Wallowa County NHMP Steering Committee (SC) considered at their initial meeting in February 2021 the types of natural hazards faced by residents and resources in the county. Several revisions were made to the named natural hazards to be addressed in this plan as outlined above. Subsequently, the SC dedicated two meetings to the evaluation of these natural hazards in the completing the Hazard Vulnerability Assessment by the OEM Methodology for assessing Risk. The methodology used for this exercise required the group to consider each of four factors for each natural hazard. These include History, Probability, Vulnerability and Maximum Threat. Table 1 below shows the Hazard Vulnerability Assessment results. More information about the Steering Committee's process and considerations can be found in XXX in Volume I. More information about the OEM Methodology can be found in Volume III, Appendix D.

Of highest concern is Wildfire. Among the first large fires in the particularly early "fire season" of 2021, more than 7,610 acres burned in the Joseph Creek fire in Wallowa, a fire started by lightning on June 4, 2021. Severe weather such as Extreme Cold and Windstorms also ranked among the highest risk natural hazard events in Wallowa County. Newly identified hazards of Poor Air Quality (a function of the topography and regional air movement patterns) and Insect Pests, Noxious Weeds and Invasive Species ranked among the high-risk natural hazards faced by the county. Landslides and Debris Flows is also considered a high-risk natural hazard. Drought, Earthquake and Dam Failure are natural hazards that pose a moderate risk to residents and natural resources in Wallowa County. Although the History and future Probability of both Earthquake and Dam Failure events were considered low, the Maximum Threat and Vulnerability to these hazards was ranked highly. Flood and Extreme Heat are of much lower concern, while Volcanic Events are of concern only to the extent that poor air quality could occur in Wallowa County according to the assessment of the

Wallow County NHMP update Steering Committee. For this reason, Volcanic Events was not ranked on its own, but was considered under Poor Air Quality. Severe Storms (both winter snowstorms and summer thunderstorms) are common and expected to continue in frequency, however, residents are for the most part prepared for them. The principal concern expressed by the Steering Committee members about the threat posed by Severe Storms was the possibility of power outages or blocked roads causing emergency access issues.

Table 1. Wallowa County Hazard Vulnerability Assessment

HAZARD	HISTORY			PROBABILITY			VULNERABILITY			MAX THREAT			RISK
	WF = 2		Subtotal	WF = 7		Subtotal	WF = 5		Subtotal	WF = 10		Subtotal	SCORE
Wildfire	2 x	**10**	20	7 x	**10**	70	5 x	**10**	50	10 x	**10**	100	**240**
Poor Air Quality	2 x	**10**	20	7 x	**9**	63	5 x	**10**	50	10 x	**10**	100	**233**
Windstorms	2 x	**9**	18	7 x	**10**	70	5 x	**7**	35	10 x	**10**	100	**223**
Extreme Cold	2 x	**4**	8	7 x	**9**	63	5 x	**5**	25	10 x	**10**	100	**196**
Insect Pests, Noxious Weeds and Invasive Species	2 x	**10**	20	7 x	**10**	70	5 x	**9**	45	10 x	**6**	60	**195**
Landslides/Debris Flows	2 x	**8**	16	7 x	**6**	42	5 x	**7**	35	10 x	**10**	100	**193**
Severe Storms (Winter snow and summer thunderstorms with hail)	2 x	**8**	16	7 x	**7**	49	5 x	**4**	20	10 x	**10**	100	**185**
Drought	2 x	**10**	20	7 x	**7**	49	5 x	**9**	45	10 x	**6**	60	**174**
Earthquakes	2 x	**1**	2	7 x	**3**	21	5 x	**10**	50	10 x	**10**	100	**173**
Dam Failure	2 x	**1**	2	7 x	**2**	14	5 x	**10**	50	10 x	**10**	100	**166**
Extreme Heat	2 x	**1**	2	7 x	**8**	56	5 x	**6**	30	10 x	**6**	60	**148**
Floods	2 x	**8**	16	7 x	**7**	49	5 x	**6**	30	10 x	**5**	50	**145**

Source: Wallowa County NHMP update Steering Committee, during meetings on April 26 and May 24, 2021.

Federal Disaster and Emergency Declarations

Looking at the past events that have occurred in the region can also provide a general sense of the hazards that have caused significant damage. Where trends emerge, disaster declarations can help inform hazard mitigation project priorities.

President Dwight D. Eisenhower approved the first federal disaster declaration in May 1953 following a tornado in Georgia. Since then, federally declared disasters have been approved within every state because of natural hazard related events. As of June 2021, FEMA has declared a total of 137 disasters in Oregon, 96 for fire, 16 for flood, 17 for severe storms and one for drought.[1]

The Governor of Oregon has issued Executive Orders (EO) making Determinations of States of Emergency in Wallowa County twice (EO 20-01, EO 19-04) due to severe winter storms including High Winds, Flooding and Landslides. The Governor has made Determinations of a State of Drought Emergency twice, in 2021 and 2009 (EO 21-13, EO 03-09). In 2015, EO 15-15 invoked the Emergency Conflagration Act for the Grizzly Bear Complex fire in Wallowa County.

Federal Disaster Declarations in which Wallowa County was a Declared County are listed below.

Table 2. FEMA Major Disaster, Emergency and Fire Management Declarations for NE Oregon

Declaration Number	Declaration Date	Incident(s) Period	Incident(s)	Individual Assistance	Public Assistance Categories	Designated NE Counties
DR-4519	04/03/20	**02/05/20 to 02/09/20**	**Severe Storms, Flooding, Landslides, and Mudslides**	Umatilla	A, B, C, D, E, F, G	Umatilla, Union and **Wallowa**
DR-1510	2/19/04	**12/26/03 to 01/14/04**	**Severe Winter Storm**	None	A, B, C, D, E, F, G	Baker, Grant, Union, and **Wallowa**
DR-1160	1/23/97	**12/25/96 to 01/06/97**	**Severe Winter Storms/Flooding**	**Wallowa**	A, B, C, D, E, F, G	Baker, Grant, **Wallowa**
DR-1099	02/09/96	**02/04/96 to 02/21/96**	**Severe Storms/Flooding**	Union	A, B, C, D, E, F, G	Union and **Wallowa**
EM-3039	04/29/77	**4/20/77**	**Drought**	None	A, B	Baker, Grant, Union, and **Wallowa**
DR-413	01/25/74	**1/25/74**	**Severe Storms, Snow Melt, Flooding**	**Wallowa**	A, B, C, D, E, F, G	**Wallowa**
DR-184	12/24/64	**12/24/64**	**Heavy Rains, Flooding**	Baker, Grant, Union and **Wallowa**	A, B, C, D, E, F, G	Baker, Grant, Union, and **Wallowa**

Source: Declared Disasters | FEMA.gov consulted July 2021

[1] https://www.fema.gov/disaster/declarations

WILDFIRE HAZARD ANNEX

Causes and Characteristics of Wildfire

The majority of wildfires primarily occur in Eastern and Southern Oregon. Fire is an essential part of Oregon's ecosystem, but it is also a serious threat to life and property particularly in the state's growing rural communities. Wildfire is defined as an uncontrollable burning of forest, brush, or rangeland. Fire has always been a part of high desert ecosystems and can have both beneficial and devastating effects.[2]

Wildfires threaten valued forest and agricultural lands and individual home sites. State or federal firefighters provide the only formal wildfire suppression service in some areas, and they do not protect structures as a matter of policy. As a result, many rural dwellings have no form of fire protection. Once a fire has started, homes and development in wildland settings complicate firefighting activities and stretch available human and equipment resources. The loss of property and life, however, can be minimized through cooperation, preparedness, and mitigation activities.

Wallowa County has five fire districts/departments, providing structural fire protection primarily in and around the four incorporated towns including Wallowa Lake Community. The two rural fire departments (Wallowa and Wallowa Lake) and three city fire departments (Enterprise, Lostine and Joseph) are supported by agencies primarily responsible for wildland fire protection which include the U.S. Forest Service and the Oregon Department of Forestry. City fire protection agencies are responsible for structure protection within their protection areas. Rural departments provide not only structural protection, but also assist with wildland fire protections as well. For example, the Wallowa Rural fire department provides structural protection across a 62-mile area but assists Oregon Department of Forestry (ODF) with wildland fire protections over an additional 150 square mile area.[3]

Mutual Aid Agreements exist among the fire authorities for mutual aid and support in the event of a wildfire incident; however, each fire authority operates under regulations that dictate their area of responsibility and specify limitations. State and federal wildland firefighters can provide wildfire suppression service on non-state and non-federal areas through formal agreements.

Roughly 58% percent of Wallowa County is public land managed by the U.S. Forest Service and 39% is privately owned. The remaining 3% of the acres is the Nature Conservancy, Bureau of Land Management, and State of Oregon. Federal land managers include the United States Forest Service and the Bureau of Land Management. The Oregon Department of Forestry provides technical forest

[2]Fire Ecology, Pacific Biodiversity Institute http://www.pacificbio.org/initiatives/fire/fire_ecology.html and Evaluating the ecological benefits of wildfire by integrating fire and ecosystem simulation models, USDA, Treesearch, https://www.fs.usda.gov/treesearch/pubs/34994

[3] Wallowa County Wildfire Protection Plan, 2017

stewardship assistance and fire protection patrol for state and many private forest lands throughout Wallowa County. [4]

Public land management and protection by the Forest Service occurs at higher elevations of mountainous areas and in deep canyons surrounding the private lands. Privately owned land totaling 777,607 acres, includes all of Wallowa Valley, Promise, Troy area and Imnaha River Corridor. These private lands are under ODF protection agreements, including the Nature Conservancy. The BLM lands speckle the landscape and are under a mutual aid agreement for fire protection with the Forest Service, Wallowa-Whitman National Forest.[5]

The 2017 *Wallowa County Community Wildfire Protection Plan* (*2017 CWPP*) addresses the concerns of the National Fire Plan and embraces the 2014 National Cohesive Wildfire Strategy's three goals of fire response, fire-adapted communities, and restoring and maintaining local landscapes. The *2017 CWPP* emphasizes that a high degree of coordination between federal, state, and local agencies, as well as with citizens directly, is necessary for maximal prevention and management of wildfire.

All references to wildfire risk and mitigation in the *2021 Wallowa County NHMP* are based on the 2017 *CWPP* as the primary source of wildfire information and mitigation actions for the county. The *2021 Wallowa County NHMP* also draws on the *2020 Oregon State NHMP* and ongoing updates to statewide analysis of wildfire risk and mitigation strategies.

Community Wildfire Protection Plan[6]

The Healthy Forests Restoration Act of 2003 (HFRA) provides the impetus for wildfire risk assessment and planning at the county and community level. The HFRA refers to this level of planning as Community Wildfire Protection Plans (CWPP). The minimum requirements for a CWPP as described in the HFRA are:

- Collaboration: A CWPP must be collaboratively developed by local and state government representatives, in consultation with federal agencies and other interested parties. Prioritized Fuel Reduction: A CWPP must identify and prioritize areas for hazardous fuel reduction treatments and recommend the types and methods of treatment that will protect one or more at-risk communities and essential infrastructure.
- Treatment of Structural Ignitability: A CWPP must recommend measures that homeowners and communities can take to reduce the ignitability of structures throughout the area addressed by the plan.

The CWPP allows a community to evaluate its current situation with regards to wildfire risk and plan ways to reduce risk for protection of human welfare and other important economic, social or ecological values. The CWPP may address issues such as community wildfire risk, structure flammability, hazardous fuels and non-fuels mitigation, community preparedness, and emergency procedures. The CWPP should be tailored to meet the needs of the community.

[4] Wallowa County Wildfire Protection Plan, 2017
[5] Ibid.
[6] This section excerpts the 2017 Wallowa County Wildfire Protection Plan

The 2017 *Wallowa County CWPP* (*2017 CWPP*) provides detailed information on the vulnerability and history of wildfire in the county and identifies mitigation actions the county can implement to reduce the impact of wildfire. The plan contains 32 mitigation actions divided into three categories (Wildfire Response – 15 Mitigation Actions, Fire Adapted Communities – 10 Mitigation Actions, and Restore and Maintain Landscapes – 7 Mitigation Actions)

Among the concepts utilized in the *2017 CWPP* are that of the Wildland Urban Interface (WUI) and Communities at Risk (CAR) to identify higher areas of risk for wildfire.

Wildland Urban Interface (WUI) areas are where the human developed areas meet the undeveloped areas. The 2006 Wallowa County CWPP was revised in 2017 from twenty-two separate WUI communities to two larger WUI Zones that encompass the "middle ground" referenced in the Cohesive Wildfire Strategy, areas between communities and the more distant wildlands.[7]

The 2017 revision recognizes the need, based on "middle ground" landscape treatment concepts, to reassess the concepts behind WUI areas as well as their size and number of WUI areas.
If the population in Wallowa County grows, development in the WUI may increase. Concern is warranted when development patterns increase the threat of wildfire to life and property. Of the nearly 1.7 million total homes in Oregon, over 603,000 or 36%, are in the WUI. Nearly 3,700 sq. mi. or 2.4 million acres are considered WUI areas in Oregon.[8]

The total area of Wallowa County is a little over 2 million acres. The northern WUI Zone is 223,222 acres (11% of the county). The northern WUI Zone has no structural protection districts - it is serviced 100 percent through wildland protection by the Forest Service and ODF.

The southern WUI Zone encompasses 273,530 acres (14% of the county). Thirty percent (142,742 acres) of the southern WUI Zone acres fall under city or rural structure protection (Figure 1). In 2016 the decision was made to have 100% of Wallowa County under full wildland fire protection.

The *2017 CWPP* steering committee found that previous individual WUIs were rated against each other, resulting in competition for funding between wildland urban interfaces. This new approach recognizes that although some communities may be of higher risk and need, it does not eliminate opportunities for landowners in moderate or low risk areas to initiate or continue to promote risk reduction measures. It also allows for specific attributes that contribute to fire risk to share funding with other communities with similar mitigation needs.

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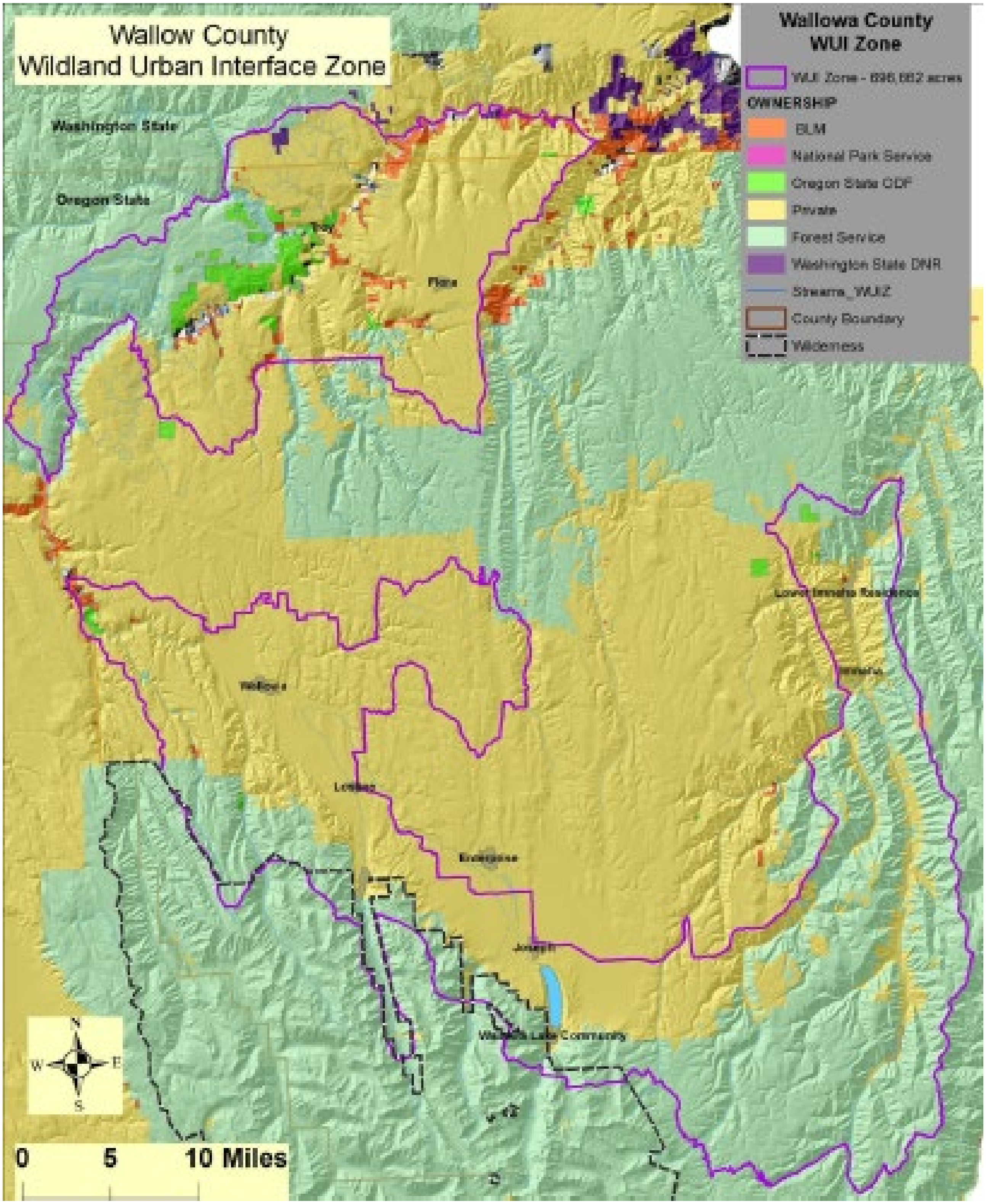
[7] Cohesive Wildfire Strategy, April 2014. The National Strategy: The Final Phase in the Development of the National Cohesive Wildland Fire Management Strategy. A collaborative effort by Federal, State, Local, Tribal Governments, non-government partners, and public stakeholders.

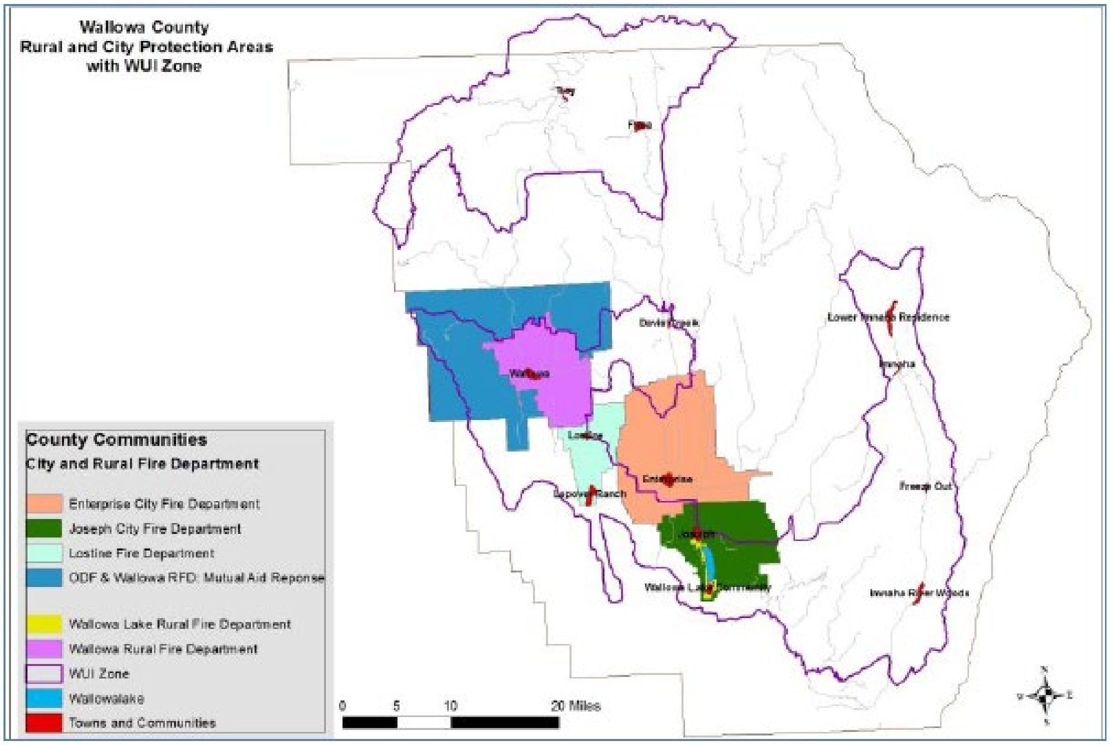
[8] Oregon Wildfire Risk Explorer, December 2019.

Figure 1. Wallowa County WUI Zone



Source: 2017 Wallowa County Community Wildfire Protection Plan

Figure 2. Rural and City Protection Areas with WUI Zones



Source: 2017 Wallowa County Wildfire Protection Plan

The Communities-At-Risk scoring system was developed by the American Association of State Foresters[9] and the Oregon Department of Forestry.[10] The CAR methodology for wildfire hazard assessment considers a range of rating factors. These include the likelihood of fire, topographic hazard, total fuel hazard, overall fire protection capability, weather factor, and values at risk. A Community-At-Risk (CAR) is defined as a group of homes or other structures with basic infrastructure (such as shared transportation routes) and services within or near federal land. A Wildland-Urban Interface (WUI) area surrounds a community-at-risk, including that community's infrastructure or water source, and may extend 1 ½ miles or more beyond that community.

In Wallowa County the *2017 CWPP* provides for a comprehensive approach to wildfire hazard mitigation planning. The CAR assessment provides a wildfire risk ranking of relative comparison for each community (Table 3), and the expanded area of the WUI Zones allow managers to take a holistic approach in wildfire risk mitigation at a landscape level (Figure 2).

[9] Field Guidance: Identifying and Prioritizing Communities at Risk. National Association of State Foresters. June 27, 2003.

[10] Concept for Identifying and Assessment of Communities at Risk in Oregon. Draft prepared by Jim Wolf, Fire Behavior Analyst, Oregon Department of Forestry. July 19, 2004.

Table 3. Communities At Risk (CAR) scores for Wallowa County communities

Communities At Risk	Wildland Fire Potential					Fire Protection and Structure Vulnerability								
	Fire Occurrence	Flame Lengths	Rate of Fire Spread	Probability of Canopy Fire	Fire Threat Index	Potential for increase threat to life of public and FF **	Structure Protected verse non-protected **	Wildland Development Area	Values Impacted	Level of Community Preparedness	Suppression Difficulty	Fire Effects Index		Final Fire Risk Index Rating
Alder Slope	L	H	M	H	H	M	M	M	H	M	H	H		H
Allen Canyon / Bear Creek	M	H	H	H	H	H	H	M	E	M	H	H		E
Davis Creek	M	M	M	H	H	H	E	M	H	H	L	E		H
Divide / Prairie Creek	M	H	M	H	H	H	E	M	H	M	M	M		H
Dry Creek	L	M	M	L	L	M	H	M	M	M	L	L		L
Enterprise	L	L	L	L	L	L	M	H	E	L	L	E		M
Flora / Lost Prairie	H	M	M	L	M	H	E	M	M	M	M	H		M
Hurricane Creek /Ent. Watershed	M	M	L	L	L	M	H	H	E	M	L	E		M
Imnaha Corridor	M	H	H	H	E	E	E	M	E	M	E	H		E
Joseph	H	L	L	L	L	L	M	E	E	L	L	E		H

Communities At Risk Issues	Wildland Fire Potential					Fire Protection and Fire Structure Vulnerability								
	Fire Occurrence	Flame Length	Rate of Fire Spread	Probability of Canopy Fire	Fire Threat Index	Potential for increase threat to life of public and FF **	Structure Protection verse non –protected **	Wildland Development Areas	Values Impacted	Level of community Preparedness	Suppression Difficulty	Fire Effects Index	Fire Effects - CWPP	Final Fire Risk Index Rating
Lostine Canyon	H	E	H	E	E	E	H	M	E	M	E	H		E
Power Meadows	L	L	L	M	L	L	E	L	M	H	L	L		L
Promise	M	M	M	L	L	M	E	M	M	H	M	M		M
Troy, Bartlett – Eden Bench	H	H	H	M	M	E	E	M	M	M	H	M		M
Wallow Lake – Ski Run	H	E	M	E	E	E	H	H	E	H	H	H		E
Wallowa - Lostine	L	M	M	L	L	L	M	M	E	L	L	E		L

Source: 2017 Wallowa County Wildfire Protection Plan.

The impact on communities from wildfire can be huge. Reporting by the Oregonian stated that in 2017, more than 1.1 million acres were scorched by wildfire in Oregon and Washington. 2018 was even worse, with 1.3 million acres of forest and fields going up in flame. That represents an area close to the size of Delaware up in smoke each year. Fighting wildfires cost Oregon and Washington more than a $1 billion in 2017 and 2018 combined, according to the Northwest Interagency Coordination Center.[11] Although the fire season in 2019 was less destructive, just over 200,000 acres were scorched across both states, a nearly 84 percent drop from the two previous years, the 2020 fire season once again witnessed devastating wildfires in and near urban areas in western Oregon.

Wildfire can be divided into four categories: interface fires, wildland fires, firestorms, and prescribed fires.[12] These descriptions are provided for a brief but comprehensive understanding of wildfire.

Interface Fires

An interface fire occurs where wildland and developed areas come together with both vegetation and structural development combining to provide fuel. The wildland/urban interface (sometimes abbreviated to WUI or called rural interface in small communities or outlying areas) can be divided into categories.

- The **classic wildland-urban interface** exists where well-defined urban and suburban development presses up against open expanses of wildland areas.
- The **mixed wildland-urban interface** is more typical of the problems in areas of exurban or rural development: isolated homes, subdivisions, resorts and small communities situated predominantly in wildland settings.
- The **occluded wildland-urban interface** where islands of wildland vegetation exist within a largely urbanized area.[13]

Wildland Fires

A wildland fire's main fuel source is natural vegetation. Often referred to as forest or rangeland fires, these fires occur in national forests and parks, private timberland, and on public and private rangeland. A wildland fire can become an interface fire if it encroaches on developed areas.

Firestorms and Mega-Fires

A firestorm is a very intense and destructive fire usually accompanied by high winds; it may be a large fire that is difficult to impossible to control. [14] Firestorms are events of such extreme intensity

[11]Portland Oregonian, Oregonlive.com https://www.oregonlive.com/environment/2019/10/summer-2019-the-oregon-wildfire-season-that-wasnt.html

[12] Federal Emergency Management Agency, *Multi-hazard, Identification and Risk Assessment Report*, 1997, Washington, D.C., https://www.fema.gov/media-library/assets/documents/7251.

[13] Ibid.

[14] Definition of firestorm, Merriam-Webster Dictionary, https://www.merriam-webster.com/dictionary/firestorm and Cambridge Dictionary, https://dictionary.cambridge.org/us/dictionary/english/firestorm.

that effective suppression is virtually impossible. Firestorms often occur during dry, windy weather and generally burn until conditions change, or the available fuel is consumed.

In 1987, widespread dry lightning in late August ignited fires throughout northern California and southwest Oregon. Two of these were over 10,000 acres, and according to the Oregon Department of Forestry, this series of events fits the definition of a firestorm. Resources were brought in from other states and Canada to fight them.[15] Another term used is mega-fire which is a fire that is more than 100,000 acres in size.

Prescribed Fires

Prescribed fires are intentionally set or are select natural fires that are allowed to burn for beneficial purposes. Before humans suppressed forest fires, small, low intensity fires cleaned the underbrush and fallen plant material from the forest floor while allowing the larger plants and trees to live through the blaze. These fires were only a few inches to two feet tall and burned slowly. Forest managers now realize that a hundred years of prevention has contributed to the unnatural buildup of plant material that can flare up into tall, fast moving wildfires. These can be impossible to control and can leave a homeowner little time to react.

Conditions Contributing to Wildfires

Ignition of a wildfire may occur naturally from lightning or from human causes such as debris burns, arson, careless smoking, recreational activities, equipment, or an industrial accident. Once started, four main conditions affect the fire's behavior: fuel, topography, weather, and development.

Fuel

Fuel is the material that feeds a fire. Fuel is classified by volume and type. Forested lands provide a larger fuel source to wildfires than other vegetated lands due to the presence of large amounts of timber and other dense vegetation in these areas. Grasslands are included in the rangeland areas. Grasslands, which naturally cover much of the region, are highly susceptible to wildfire. According to BLM staff, there are an increasing number of invasive grasses in the grasslands; these invasive grasses are more susceptible to burn. The variability of the fire likelihood is great, as the factors of soil moisture, soil temperature, and amount of and nature of grass there varies. Vegetation such as agricultural lands and rangelands also provides fuel for wildfires.

Topography

Topography influences the movement of air and directs a fire's course. Slope and hillsides are key factors in fire behavior. Hillsides with steep topographic characteristics are often also desirable areas for residential development.

In this region, much of the topography is hilly or mountainous which can exacerbate wildfire hazards. These areas can cause a wildfire to spread rapidly and burn larger areas in a shorter period of time, especially if the fire starts at the bottom of a slope and migrates uphill as it burns. Wildfires tend to burn more slowly on flatter lying areas, but this does not mean these areas are exempt from

[15] Wolf, Jim, ODF, personal communication, May 8, 2001.

a rapidly spreading fire. Hazards that can affect these areas after the fire has been extinguished include landslides (debris flows), floods, and erosion.

Weather

Weather is the most variable factor affecting wildfire behavior. High-risk areas in Oregon share a hot, dry season in late summer and early fall with high temperatures and low humidity.

The natural ignition of wildfires is largely a function of weather and fuel; human caused fires add another dimension to the probability. Lightning strikes in areas of forest or rangeland combined with any type of vegetative fuel source will always remain as a source for wildfire. Thousands of lightning strikes occur each year throughout much of the region. Fortunately, not every lightning strike causes a wildfire, though they are a major contributor.

Development

The increase in residential development in interface areas has resulted in greater wildfire risk. Fire has historically been a natural wildland element and can sweep through vegetation that is adjacent to a combustible home. New residents in remote locations are often surprised to learn that in moving away from urban areas, they have left behind readily available fire services providing structural protection. Rural locations may be more difficult to access and or simply take more time for fire protection services to get there.

Future Climate Projections

The Oregon Climate Change Research Institute (OCCRI) of Oregon State University concludes in the Fifth Oregon Climate Assessment (January 2021) that "(w)ildfire dynamics are affected by climate change, past and contemporary land management and human activity, and expansion of non-native invasive grasses. From 1984 through 2018, annual area burned in Oregon increased considerably. Over the next 50 to 100 years, area burned, and fire frequency are projected to increase substantially, initially east of the crest of the Cascade Range and then in the western Cascade Range. Over the long term, depending on how vegetation and fire weather shift with climatic changes and fuel and fire management, fire severity also may increase".[16]

Following decades of fire suppression that coincided with a relatively cool and wet climate, the density and flammability of many low- to mid-elevation dry forests and woodlands in Oregon has increased. For example, fire suppression in low elevation, historically open ponderosa pine (*Pinus ponderosa*) forests led to dense fuels and establishment of shade-tolerant tree species, such as grand fir (*Abies grandis*) and white fir (*A. concolor*), throughout the tree canopy, connecting fuels vertically from the ground to the crown. As a result, the intensity and severity of fires in the last three to four decades has increased. Due to changes in climate and fire severity, some dry forests

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[16] Dalton, M., and E. Fleishman, editors. 2021. Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://oregonstate.app.box.com/s/7mynjzhda9vunbzqib6mn1dcpd6q5jka.

and woodlands at low to intermediate elevations in eastern Oregon may not be able to reestablish naturally and could transition to more-flammable shrublands or grasslands.[17]

Increases in fire severity also have been observed in arid shrubsteppe in central and eastern Oregon. In these ecosystems, the rapid expansion of non-native invasive grasses, such as cheatgrass (*Bromus tectorum*) and ventenata grass (*Ventenata dubia*), has increased fine-fuel biomass and spatial continuity of fuels Formerly sparse sagebrush ecosystems continue to be colonized by cheatgrass, which has resulted in increases in area burned of up to 200% since 1980. Expansion of cheatgrass leads to a positive feedback loop in which increases in fire frequency and extent facilitate further increases in the distribution and density of cheatgrass. Any ground disturbance, whether from livestock grazing, tree thinning, or fire, can facilitate the colonization and increase in abundance of cheatgrass.[18]

Over the last several decades, warmer and drier conditions during the summer months have contributed to an increase in fuel aridity and enabled more frequent large fires, an increase in the total area burned, and a longer fire season across the western United States, particularly in forested ecosystems. The lengthening of the fire season is largely due to declining mountain snowpack and earlier spring snowmelt.

History of Wildfire in Wallowa County

Densely forested Douglas fir forests and stands of ponderosa pine may be highly vulnerable to wildfire because of the extensive forested land in Wallowa County and the frequency of lightning strikes. Grasslands, which naturally cover much of the region, also are potentially flammable. Nevertheless, the ecosystems of most forests and wildlands depend upon fire to maintain functions.

The effects of fire on ecosystem resources can include damages, benefits, or some combination of both. The benefits can include, depending upon location and other circumstances, reduced fuel load, disposal of slash and thinned tree stands, increased forage plant production, and improved wildlife habitats, hydrological processes, and aesthetic environments. Despite the benefits, fire has historically been suppressed for years because of its effects on rangelands, grasslands, recreation areas, agricultural operations, and the significant threat to property and human life.

Knowing the fire history of a place is important to understand the fire environment of the area. Knowing where and why fires start is one of the first steps in prevention and mitigation efforts. Understanding the burn probability, the hazard to potential structures, the fire intensity and flame length, and the sub-watershed level for context, provides comprehensive information for decision-making about wildfire prevention and mitigation.

During the period from January 2014 through July 2021 a total of 204 fires were reported in the Wallowa Unit of the Oregon Department of Forestry.[19] The majority of those fires consumed less

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[17] Dalton, M., and E. Fleishman, editors. 2021. Fifth Oregon Climate Assessment citing Higuera et al. 2015, Haugo et al. 2019, Hessburg et al. 2015, Marlon et al. 2012, Davis et al. 2019, 2020; Rodman et al. 2020, Bradley et al. 2018, Williamson et al. 2020 Citations removed to ease readability.

[18] Ibid.

[19] ODF Fire List, https://apps.odf.oregon.gov/DIVISIONS/protection/fire_protection/fires/FIRESlist.asp consulted June 2020

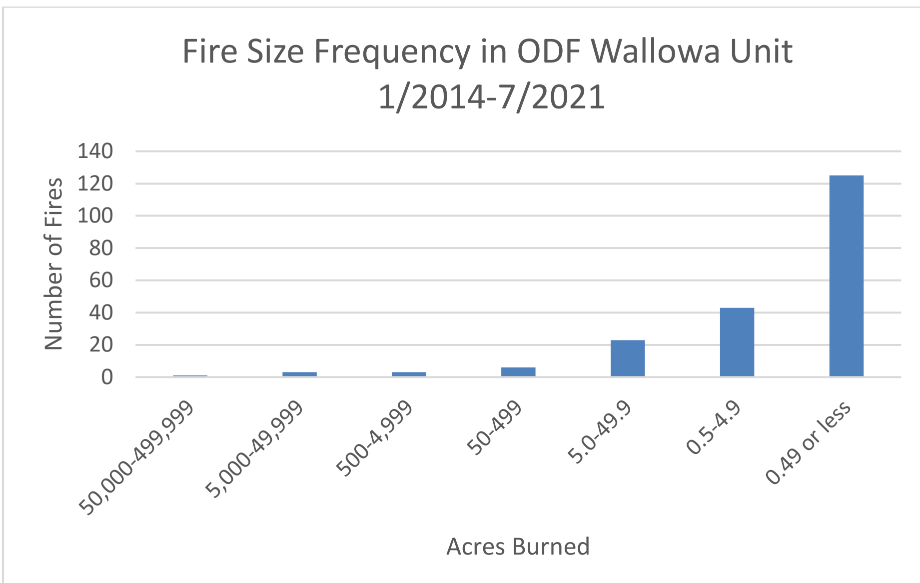
than half an acre of land. The largest fires were few in number but caused the greatest amount of damage as shown in Table 4 and Figure 3 below.

Table 4. Size distribution of fires in Wallowa County from 1/2014 through 7/2021

Number of fires	Acres burned
1	50,000-499,999
3	5,000-49,999
3	500-4,999
6	50-499
23	5-49
43	0.5-4.9
125	0.49 or less

Source: data from Oregon Department of Forestry Fire Database, consulted July 2021; Oregon Department of Forestry - FIRES List

Figure 3. Fire Incidents in Wallowa County 2014-2021



Source: data from Oregon Department of Forestry Fire Database, consulted July 2021, data graphed by author; Oregon Department of Forestry - FIRES List

Table 5 below provides the history of wildfires in Wallowa County from 1960 to 2021 (July) for fires of 1,000 acres and greater. The notable fires that have occurred in Wallowa County since 1960 include the Jim Creek/Eastside fire in Wallowa in 2000. In 2015, the Grizzly Bear Complex of fires was started by lightning in southeast Washington and destroyed two homes and dozens of other structures. The Governor declared an Executive Order (EO 15-15) for this fire. In 2021, the Elbow Creek and Joseph Canyon fires burned more than 21,000 acres.

Table 5. Wildfire History in Wallowa County (>1,000 acres) from 1968-2021 (through July)

Fire Year	Fire Name	Report Date	General Cause	ODF Acres	Total Acres	Oregon Conflagration Act Executive Orders
2021	Elbow Creek	7/15/21	Under investigation	14,551		
2021	Joseph Canyon	6/4/2021	Lightning	3,602	7,610	
2021	Dry Creek Fire	6/4/2021	Lightning		1,585	
2015	Grizzly Bear Complex	8/2015	Lightning		82,659	EO 15-15
2014	Somers	8/3/2014	Lightning	120	36,185	
2014	5 Mile	8/3/2014	Lightning	389	4,524	
2012	Cache Creek	8/20/2012	Lightning	3,925	73,500	
2011	Cactus Mountain	9/7/2011	Miscellaneous	138	8,350	
2009	Big Sheep Ridge	8/29/2009	Lightning	136	3,270	
2007	Battle Creek Complex	7/13/2007	Lightning	83	79,299	
2007	Cottonwood	7/14/2007	Lightning	2,117	8,100	
2007	Grizzly Ridge	7/14/2007	Lightning	565	6,474	
2006	Jim Creek	8/22/2006	Lightning	0.01	12,946	
2005	Haas/ Tryon Complex	8/8/2005	Lightning	764	42,700	
2005	Turner Creek	9/14/2005	Debris Burning	156	1,419	
2003	Lightning Creek Complex	8/20/2003	Lightning	316	16,028	
2001	Horse Creek	8/14/2001	Lightning	628	16,309	EO 01-20
2000	Jim Creek/Eastside	8/24/2000	Lightning	1,371	56,319	
2000	Deep Creek/Eastside	8/24/2000	Lightning	760	32,967	
2000	Thorn Creek/Eastside	8/24/2000	Lightning	370	4,035	EO 00-27
2000	Carrol Creek	8/24/2000	Lightning	232	3,197	
1994	Thomason Complex	8/28/1994	Lightning	698	4,588	
1989	89974761	7/27/1989	Lightning	1,033	1,033	
1988	Ward Canyon/Troy	8/23/1988	Equipment Use	7,572	7,572	
1988	Teepee Butte	8/25/1988	Lightning	5,791	5,791	
1986	Joseph Canyon #1	8/10/1986	Lightning	9,548	9,548	
1986	Rye Ridge	8/11/1986	Lightning	4,800	4,800	
1986	86974775	8/11/1986	Lightning	1,512	1,512	
1968	68974202	8/3/1968	Lightning	1,200	1,200	

Source: ODF Fire List and 2020 OR State NHMP, Oregon Department of Forestry - FIRES List

Other Executive Orders issued by the Governor of Oregon include Executive Order 00-27 for the Carrol Creek and the Thorn Fires, two of several fires that were burning near Enterprise in 2000. Carrol Creek is 10 miles east of Wallowa Lake. The Thorn Fire was 37 miles northeast of Enterprise. Executive Order 01-20 was issued for the Horse Creek Fire which was caused by lightning and was located north of Imnaha threatening the town of Imnaha and residences along the Imnaha River.

Members of the Wallowa County Steering Committee have lived experience with wildfire in Wallowa County both within work contexts and within lived experiences. One committee member conveyed her memories as a child of being airlifted by helicopter to evacuate wildfire threatening Imnaha due to the lack of safe land routes for evacuation.

Over the last several decades, warmer and drier conditions during summer have contributed to an increase in vegetation dryness and enabled more frequent large wildfires, an increase in the total area burned, and a longer wildfire season across the western United States. Fire danger is generally evaluated on the basis of daytime conditions. Historically, wildfires were less active overnight. However, nights have become hotter and drier, and the temperature and duration of wildfire is expected to increase as a result.[20]

[20] Future Climate Projections Wallowa County, Oregon, OCCRI, 2022

POOR AIR QUALITY HAZARD ANNEX

Causes and Characteristics

The hazard of Poor Air Quality has been named for inclusion in several recent NHMP updates as communities recognize the impacts of inversion layers trapping particulates in smoke from wood stoves, prescribed fire, wildfire, field burning, and leaf burning.

Geographic Causes

The nature of air movement or stagnation in a valley causes inversion layers to form. At the valley floor daytime temperatures heat the air. In the evening, air further up the slope of the mountains cools faster than the air lower down the slope. Because cool air is slightly heavier than warm air, the cool air sinks in to the valley which displaces the warm air above it to form a "lid". If the weather creates stagnant conditions this inversion "lid" may persist trapping air pollutant discharges to create poor air quality.

Air quality issues can occur widely across Wallowa County, affecting the unincorporated rural areas and the incorporated cities. There are many microclimates throughout the county which result in localized issues.

Seasonal Characteristics

In terms of weather, Vincent Papol of the National Weather Service in Pendleton describes conditions in Wallowa County in winter and summer as follows:

Winter: At times and mostly between November and February, Wallowa County can experience cold air settling across the lower levels of the atmosphere while warm air remains aloft. This pattern can create an inversion that may trap air particles near the surface for extended periods of time affecting air quality. When this occurs, the National Weather Service may issue an Air Stagnation Advisory.[21]

Summer: During the summer months and mainly from June through August, a high-pressure system will remain in place over the Pacific Northwest for an extended period of time. When this occurs, airflow will be reduced resulting in the accumulation of air particles over the lower levels of the atmosphere affecting the air quality. In addition, smoke from surrounding fires could impact Wallowa County and affect the air quality prompting Air Stagnation Advisories.[22]

[21] Vincent Papol, National Weather Service – Pendleton, personal communication with T. Sears, DLCD, 1/26/21

[22] Ibid.

Sources of Pollutants

Wildfires[23] tend to provide a wide ranging source of smoke that can blanket large areas and be detrimental to the health of people, animals, and plants. Wood burning stoves tend to be a more concentrated, point source type of pollution that decreases air quality. Field burning is an agricultural technique that can contribute to air quality issues. Diesel emissions, often from vehicles on roads, also contribute to lower air quality. If a volcano were to erupt, ashfall could inundate the areas sufficiently to impact transportation and cause widespread health concerns.

Regulatory Framework

Federal Regulations

The Clean Air Act of 1970 and the U.S. Environmental Protection Agency (EPA) established health-based National Ambient Air Quality Standards (NAAQS) for six air pollutants: carbon monoxide (CO), particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and lead (Pb). The areas that fail to meet the standards are designated “non-attainment” and are required to develop plans to come into compliance with the standards. Once compliance with the standard is achieved, a maintenance plan is developed to ensure that air quality will not be compromised in the future. Wallowa County is not an Air Quality Maintenance Area (AQMA).[24]

The Clean Air Act established two types of national air quality standards. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings. The Clean Air Act requires periodic review of the science upon which the standards are based and the standards themselves.[25]

Oregon Regulations

The Oregon Department of Environmental Quality (DEQ) is a regulatory agency with the responsibility to protect and enhance the quality of Oregon's environment. DEQ is responsible for providing accurate scientific data concerning the State of Oregon’s air quality “to ensure that the state meets the National Ambient Air Quality Standards (NAAQS) as required by the Federal Clean Air Act.” [26]

Air Quality Pollutants

Oregon DEQ operates the ambient monitoring network for the entire state with the exception of Lane County which is operated by the Lane Regional Air Protection Authority (LRAPA). These air quality monitoring networks measure ambient concentrations of the criteria pollutants - ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, lead. Air quality pollutants are monitored

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[23] See the Wildfire Hazard Annex for more information about wildfire impacts.

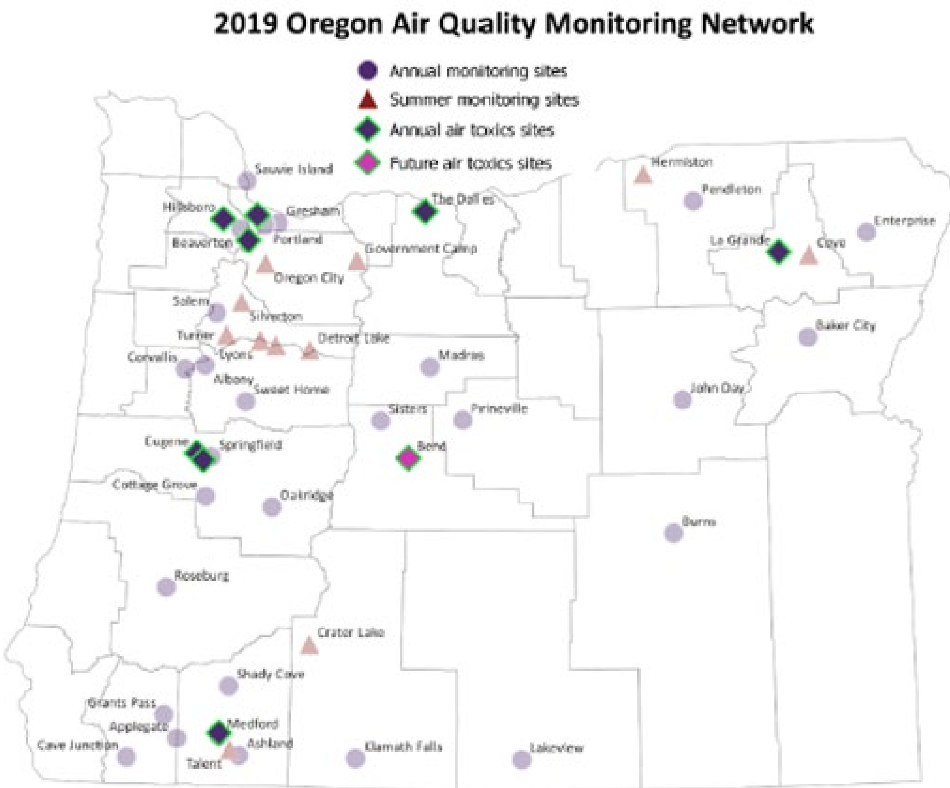
[24]Peter Brewer, DEQ, personal communication, 8/5/19.

[25]*Air Quality in Pendleton Documen*t, Greg Lacquement, personal communication, 2/4/21.

[26]DEQ, *Air quality home*, retrieved September 1, 2016 from http://www.oregon.gov/DEQ/aq/Pages/default.aspx.

at the locations shown on Figure 4.[27] There are monitors in Enterprise, Cove, La Grande, Hermiston, and Pendleton. Enterprise and Pendleton are annual monitoring sites and Hermiston and Cove are summer monitoring sites. The full range of air toxics is measured at the monitoring site in La Grande.

Figure 4. Oregon's 2020 Ambient Air Monitoring Network (ODEQ and LRAPA sites)



Source: DEQ, 2019 *Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan,* https://www.oregon.gov/deq/FilterDocs/AQmonitoringplan.pdf. Remains the same in the *2020 Plan*.

DEQ collects data on air quality pollutant trends for Ozone, $PM_{2.5}$, PM_{10}, carbon monoxide, sulfur dioxide, nitrogen dioxide, air toxics, and greenhouse gases. Each of these trends is described below.

Ozone

DEQ describes that

> "Ozone is a secondary pollutant formed when there are elevated levels of nitrogen dioxide (NO2) and volatile organic compounds (VOCs) that undergo chemical reactions in high temperatures, and sunlight. In Oregon, elevated ozone occurs in the summer and can be formed by human-caused pollution from fossil fuel combustion and also by naturally caused pollution from wildfire smoke, which contains NO_2 and. In 2017, most of the state experienced elevated ozone because the wildfire smoke introduced natural precursors on top of the human-caused

[27] DEQ, 2019 *Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan,* https://www.oregon.gov/deq/FilterDocs/AQmonitoringplan.pdf. Remains the same in the *2020 Plan*.

> emissions. With global warming we expect more fires in the Northwest and higher temperature days; this will result in more elevated ozone days."[28]

DEQ states that "data with wildfire contributions is included because it is very difficult to determine if the ozone would have exceeded the NAAQS without the smoke from wildfires."[29] DEQ notes that the wildfire smoke in 2017 contributed to the elevated ozone levels most likely caused Portland to violate the NAAQS. However, it is very difficult to determine what the ozone level would have been but for the wildfire smoke.

The *2020 Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan* describes the 10 Oregon DEQ and LRAPA monitoring sites for ozone. The closest one to Wallowa County is in Hermiston.

PM$_{2.5}$

Fine particulate matter ($PM_{2.5}$) is a concern due to smoke impacts from woodstoves, fireplaces and other wood burning appliances besides wildfire smoke in the summer. Other sources of $PM_{2.5}$ include open burning, prescribed burning, wildfires, smoke from industrial stacks, and some road dust from vehicle travel.

The *Future Climate Projects* report prepared by the Oregon Climate Change Research Institute for Umatilla County's NHMP update stated that with the increasing wildfires and $PM_{2.5}$ levels, there is a greater risk of wildfire smoke exposure through increasing frequency, length, and intensity of "smoke waves". "Smoke waves" are two or more consecutive days with high levels of $PM_{2.5}$ from wildfires.[30]

DEQ notes that it is useful to understand how much wildfire smoke contributed to particulate levels above the NAAQS standard, because this shows the effectiveness of local air quality improvement in communities with particulate reduction plans to promote such actions as wood stove efficiency programs.

There are harmful effects from breathing particles measuring less than 10 microns in diameter (PM_{10}). Most recent research indicates that even smaller particles, those measuring less than 2.5 microns in diameter ($PM_{2.5}$) may be responsible for the most significant health effects, like premature mortality, hospital admissions, and respiratory illness. These particles can be inhaled deeply into the lungs where they enter the bloodstream or can remain for years. The health effects of particulate matter vary with the size, concentration, and chemical composition of the particles."[31]

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[28] DEQ, *Oregon Air Quality Annual Report: 2017,* https://www.oregon.gov/deq/FilterDocs/2017aqannualreport.pdf.

[29] Ibid.

[30] OCCRI, *Future Climate Projections: Umatilla County,* October 2020, https://www.oregon.gov/lcd/CL/Documents/Umatilla_County_FutureClimateProjectionsReport_Oct2020.pdf

[31] *Air Quality in Pendleton Document*, Greg Lacquement, personal communication with T. Sears, DLCD, 2/4/21.

PM_{10}

The PM_{10} trend chart shows the values in the city with the highest concentration, the average, concentration, and the lowest concentration. All cities are well below the standard, but EPA requires DEQ to continue monitoring in PM_{10} maintenance areas and in cities over 500,000 people.[32]

Carbon Monoxide, Sulfur Dioxide, Nitrogen Dioxide

The carbon monoxide, sulfur dioxide, and nitrogen dioxide trends for cities in Oregon as compared to the federal standards are measured. These are not a hazard concern for Wallowa County.

Air Toxics

Oregon DEQ and LRAPA began sampling for air toxics in Oregon in 1999. This section of the *Oregon Air Quality Annual Report: 2017* describes data for the toxics of concern: benzene, acetaldehyde, arsenic, cadmium, lead, and manganese. These are not a hazard concern for Wallowa County at this time.

The information is for neighborhood monitoring only; it does not include monitoring next to industrial facilities. That information is presented in separate reports issued by the Oregon Health Authority, specific to the monitoring project and facility.[33]

Greenhouse Gases

Information about greenhouse gas emissions in Oregon are presented on DEQ's website at https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx. According to this page, "Oregon's sector-based inventory measures human-caused greenhouse gas emissions produced within Oregon by economic sector. It also includes the emissions associated with the electricity used in Oregon regardless of where that electricity is generated." [34] Figure 5 is excerpted from that report and shows Oregon's greenhouse gas emissions from 1990 through 2019 by sector. Emissions from transportation and electricity use are Oregon's largest sources of greenhouse gas emissions.

Identifying Poor Air Quality

Both specific measures of components of poor air quality and a general Air Quality Index are methods for determining the quality of the air.

Standards for air quality as determined by the US Environmental Protection Agency (EPA) have changed over time. In 1987 particulate matter was measured using the national PM_{10} levels as 24-hour concentrations and as average annual concentrations. The Clean Air Act, which was last amended in 1990, requires EPA to set National Ambient Air Quality Standards. In 1996 the impact of 2.5-micron particles was recognized and the national $PM_{2.5}$ 24-hour National Ambient Air Quality Standard (NAAQS)

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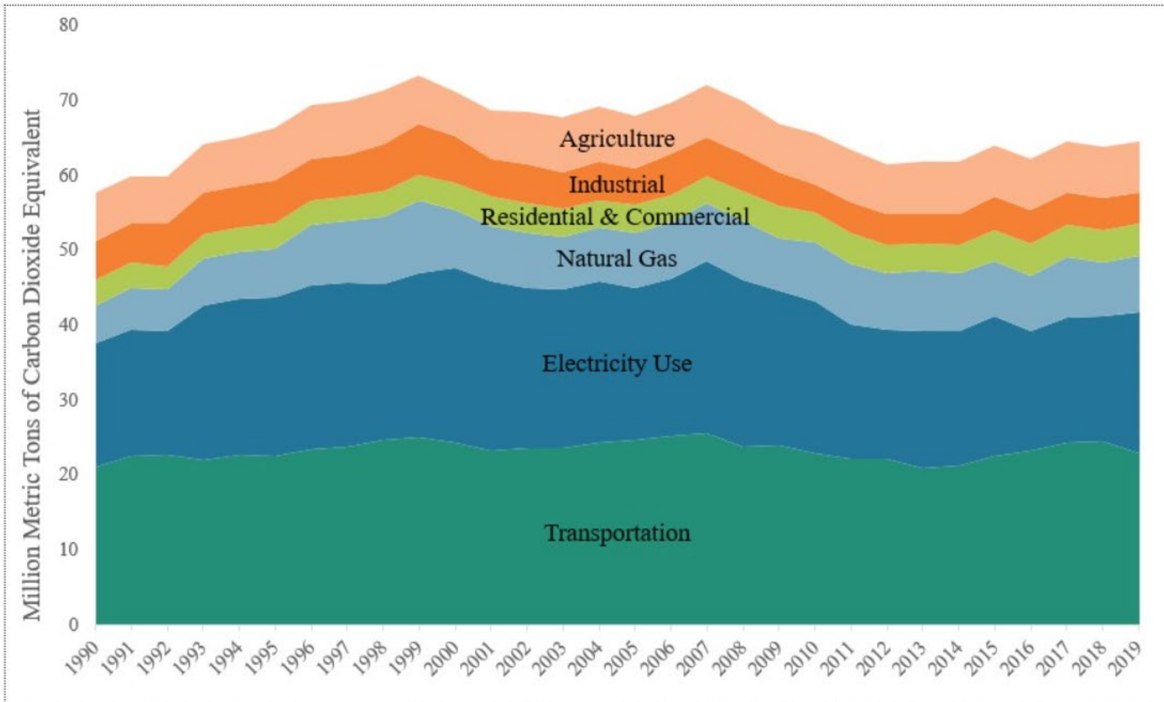
[32] DEQ, *Oregon Air Quality Annual Report: 2017,* https://www.oregon.gov/deq/FilterDocs/2017aqannualreport.pdf

[33] DEQ, *Oregon Air Quality Annual Report: 2017,* https://www.oregon.gov/deq/FilterDocs/2017aqannualreport.pdf

[34] DEQ, *Oregon Greenhouse Gas Sector-Based Inventory Data*, https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx, accessed 2/26/21

was established at 65 ug/m^3, and the annual average NAAQS set at 15 ug/m^3. In 2006 the national $PM_{2.5}$ 24-hour standard was reduced to 35 ug/m^3. In 2012 the national $PM_{2.5}$ annual average NAAQS was further reduced to 12 ug/m^3. The PM_{10} annual average was revoked.

Figure 5. Oregon Greenhouse Gas Emissions 1990-2019



Source: DEQ, Oregon Greenhouse Gas Sector-Based Inventory Data, https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx, accessed 2/26/21

The Air Quality Index is a daily index of air quality that reports how clean the air is and provides information on potential health risks. Oregon's index is based on three pollutants regulated by the federal Clean Air Act: ground-level ozone, particle pollution and nitrogen dioxide. The highest of the AQI values for the individual pollutants becomes the AQI value for that day. For example, if values are 90 for ozone and 88 for nitrogen dioxide, the AQI reported would be 90 for the pollutant ozone on that day. A rating of good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous are designated for the AQI providing a daily air quality rating (Table 6). EPA provides all states with the AQI equation for national uniformity. DEQ and Lane County Regional Air Protection Authority (LRAPA) report the AQI for cities in Oregon. The *Oregon Air Quality Annual Report* provides a review of the health levels over the past year.[35]

[35] DEQ, *Oregon Air Quality Annual Report: 2020*, https://www.oregon.gov/deq/FilterDocs/AQmonitoringplan.pdf

Table 6. Air Quality Index Ranges and Episode Stages

Air Quality Rating	Air Quality Index (AQI)	$PM_{2.5}$ 24-hour Average (µg/m³)	Ozone 8-hour Average (ppm)
GOOD	0 - 50	0.0 - 12.0	0.000 - 0.054
MODERATE	51 - 100	12.1 - 35.4	0.055 - 0.070
UNHEALTHY FOR SENSITIVE GROUPS	101 - 150	35.5 - 55.4	0.071 - 0.085
UNHEALTHY	151 - 200	55.5 - 150.4	0.086 - 0.105
VERY UNHEALTHY	201 - 300	150.5 - 250.4	0.106 - 0.200
HAZARDOUS	>300	>250.5	>0.200

Source: DEQ, *Oregon Air Quality Monitoring Annual Report: 2019,* https://www.oregon.gov/deq/FilterDocs/aqMonitorAnnualRep2019.pdf

For 2020, the air pollutants of greatest concern in Oregon were[36]:

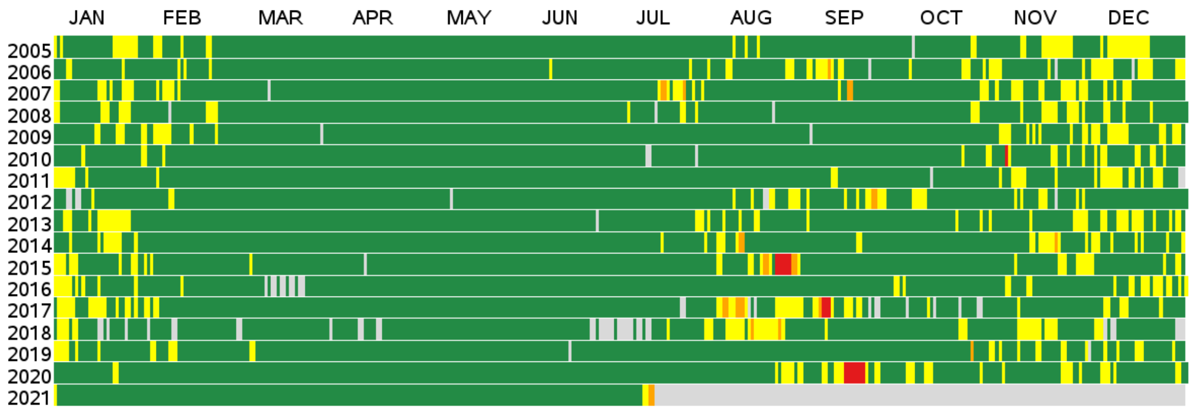
- Fine particulate matter (mostly from combustion sources) known as **$PM_{2.5}$** (2.5 micrometers and smaller diameter).
- **Air Toxics -** pollutants that cause or may cause cancer or other serious health effects.
- Ground-level **ozone**, a component of smog.
- **Greenhouse gas** (GHG) emissions and global climate change are also concerns in Oregon. Oregon state agencies track GHG emissions from a wide variety of products, services, utilities, and fuel providers. These emissions data are available on DEQ's web site under Air Quality/ AQ Programs / Greenhouse Gas Reporting Home. This is an overall issue across all of Oregon but more considered in the higher population density areas.

History of Air Quality in Wallowa County

The data available to track poor air quality conditions in Wallowa County have been limited to a single monitoring station. The EPA Air Quality monitoring station in Enterprise measures $PM_{2.5}$. Figure 6 below shows a pattern of periods of the year where the likelihood of high levels of particulate matter of this diameter (2.5 microns) have been present at that station.

[36] Peter Brewer, DEQ, personal communication, 3/11/21 and the *Oregon Air Quality Annual Report: 2017*, https://www.oregon.gov/deq/FilterDocs/2017aqannualreport.pdf.

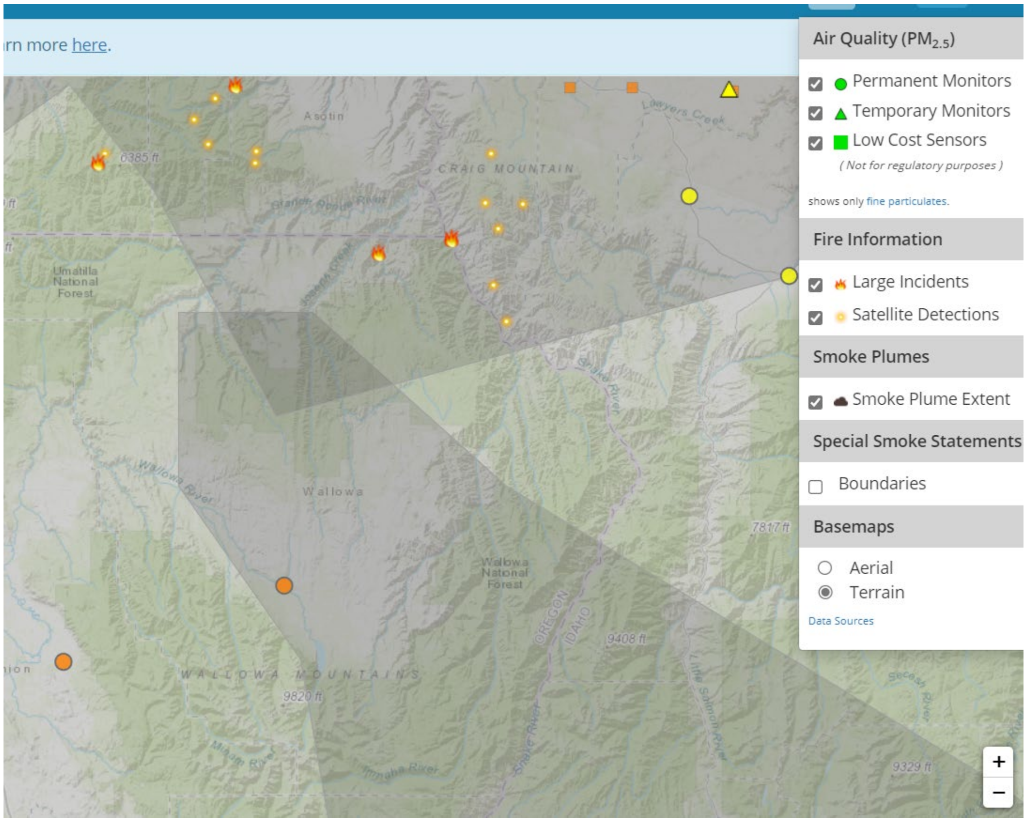
Figure 6. PM2.5 Daily AQI Values, 2005 to 2021, Wallowa County, OR



Source: [Air Data - Multiyear Tile Plot | US EPA](), consulted July 2021

The EPA maintains a real time Fire and Smoke monitoring map that map provide useful for NHMP plan holders to use in using the plan.[37] The mapping tool provide a snapshot on July 14, 2021 (Figure 7) of the most recent time period shown in Figure 6.

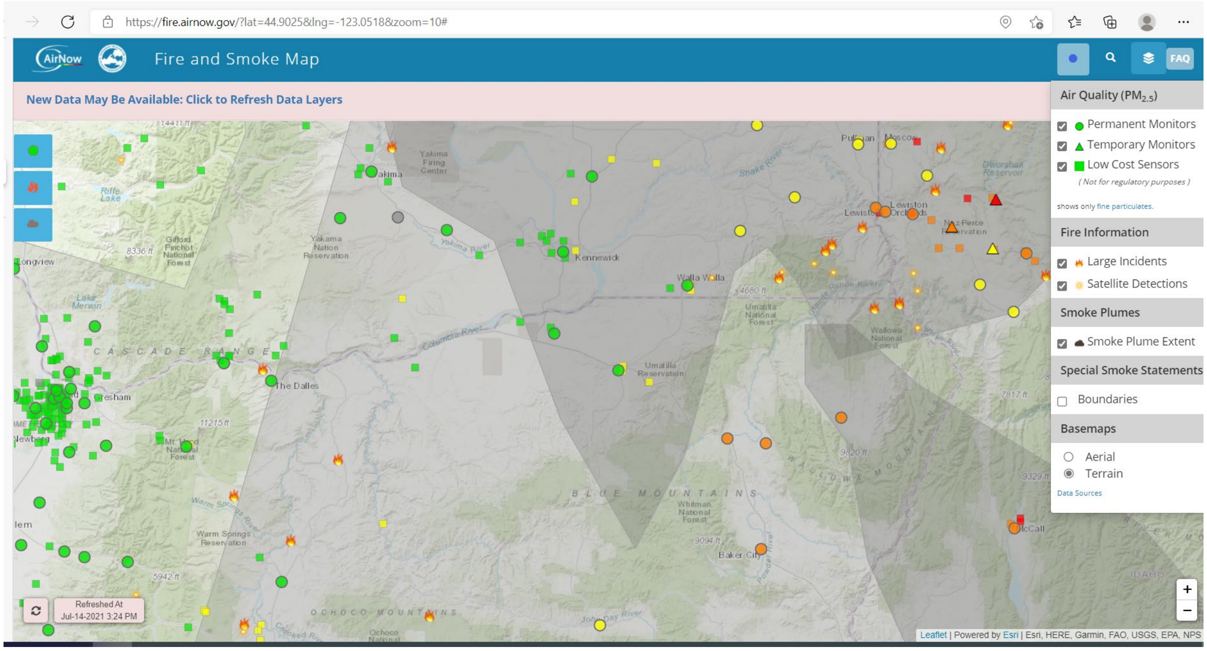
Figure 7. AirNow Fire and Smoke Map of Wallowa County on 7/14/2021



Source: [Fire and Smoke Map (airnow.gov)]()

[37] [Fire and Smoke Map (airnow.gov)]()

Figure 8. Air Quality Monitoring Station Types



Source: [Fire and Smoke Map (airnow.gov)]

A wider view of this tool shows the use of Low Cost Air Quality monitors not valid for regulatory purposes, but represented on the map in the interest of public health.

The county has developed and approved a Smoke Management Community Response Plan to address these issues. The management of smoke from prescribed burning may be aided by more air quality data collection to determine the when it reduces the quality of air in populated areas. Determination of the severity of the hazard of poor air quality and collecting data demonstrating the problem may provide support for mitigation actions aimed at managing prescribed burning to reduce the risk of high intensity wildfire and support for mitigation actions aimed at providing relief for vulnerable people during poor air quality conditions. The EPA Ambient Monitoring Technology Information Center (AMTIC) provides information on monitoring programs and methods, quality assurance and control procedures, and federal regulations.[38]

Future climate projections are for reduced outdoor air quality. Warmer temperatures may increase ground-level ozone concentrations, increases in the number and size of wildfires may increase concentrations of smoke and particulate matter, and increases in pollen abundance and the duration of pollen seasons may increase aeroallergens. Such poor air quality is expected to exacerbate allergy and asthma conditions and increase the incidence of respiratory and cardiovascular illnesses and death (Fann *et al.*, 2016).[39]

[38] Ambient Monitoring Technology Information Center (AMTIC) | US EPA

[39] Future Climate Projections Wallowa County, Oregon, OCCRI, 2022

SEVERE WEATHER HAZARD ANNEX

The purpose of this annex is to summarize four different severe weather hazards: Extreme Heat, Extreme Cold, Windstorm, and Winter Storm in terms of their causes and characteristics, to provide an historical inventory of severe weather events, and to identify vulnerabilities and issues to be addressed with respect to mitigation for these natural hazards.

Causes, Characteristics and Effects of Severe Weather

Extreme Heat

Northeast Oregon can also be a place of extreme temperatures events. From extreme cold spells to extreme heat waves, extreme temperatures events have the potential to inflict serious health damage. In extreme temperature environments the body must work harder to maintain a normal temperature, these conditions can induce health related illnesses, particularly among vulnerable peoples.[40]

The Wallowa County NHMP Steering Committee (SC) provided a preliminary benchmark to determine whether an Extreme Heat event has occurred. They identified an Extreme Heat event as four consecutive days during which the temperature reaches 100 °F or higher. They noted that although this is not a frequent occurrence, it is of concern due to the vulnerability of the population to such an event.

According to the Fifth Oregon Climate Assessment prepared by the Oregon Climate Change Research Institute (OCCRI) published in January 2021 with respect to "Extreme (H)eat (t)he frequency and magnitude of days that are warmer than 90°F is increasing across Oregon. During summer, relative increases in nighttime minimum temperatures have been greater than those in daytime maximum temperatures. The frequency, duration, and intensity of extreme heat events is expected to increase throughout the state during the twenty-first century."[41]

Extreme Cold

Extreme cold events can be defined similarly -- where conditions get so severe that health related illnesses occur.[42] The Wallowa County NHMP SC provided a similar preliminary benchmark to identify an Extreme Cold event. Unlike Extreme Heat, Extreme Cold is a more common occurrence in Wallowa County. The SC defined an Extreme Cold event as four consecutive days during which the temperature drops to 0 °F or below.

The effects of below freezing temperatures can pose hazards to crops and structures as well as people. Early and late season extreme cold can damage agricultural crops. Below freezing temperatures can lead to breaks in un-insulated water lines serving schools, businesses, and industry and individual homes. If these effects last more than several days, they can create significant economic impacts for the

[40] FEMA "Extreme Heat" http://www.ready.gov/heat
[41] Fifth Oregon Climate Assessment Report, OCCRI 2021 https://oregonstate.app.box.com/s/7mynjzhda9vunbzqib6mn1dcpd6q5jka
[42] Taylor, George H. and Chris Hannan. The Oregon Weather Book. Corvallis, OR: Oregon State University Press. 1999

communities affected as well for the surrounding region, and even outside of Oregon. In the rural areas of Oregon severe winter storms can isolate small communities, farms and ranches and create serious water problems for livestock operations.

Winter storms can have significant impacts to the local economy. Snow and ice can block access to neighboring towns thus interrupting the distribution of crops, provision of agricultural services, and access for emergency transports, and other The National Weather Service uses weather forecast models to predict oncoming windstorms, while monitoring storms with weather stations in protected valley locations throughout Oregon.[43] Table 7 below shows the wind speed probability intervals that structures 33 feet above the ground would expect to be exposed to within a 25, 50, and 100 year return period. Inter-mountain valley regions of Northeast Oregon are known for high winds.

Windstorms generally affect the region's buildings, utilities, tree-lined roads, transmission lines, residential parcels, and transportation systems along open areas such as grasslands and farmland. Windstorms can result in collapsed or damaged buildings, damaged or blocked roads and bridges, damaged traffic signals, streetlights, and parks, among others.

Table 7. Probability of Severe Wind Events by NHMP Region

	25-Year Event (4% annual probability)	50-Year Event (2% annual probability)	100-Year Event (1% annual probability)
Region 1: Oregon Coast	75 mph	80 mph	90 mph
Region 2: North Willamette Valley	65 mph	72 mph	80 mph
Region 3: Mid/Southern Willamette Valley	60 mph	68 mph	75 mph
Region 4: Southwest Oregon	60 mph	70 mph	80 mph
Region 5: Mid-Columbia	75 mph	80 mph	90 mph
Region 6: Central Oregon	60 mph	65 mph	75 mph
Region 7: Northeast Oregon	70 mph	80 mph	90 mph
Region 8: Southeast Oregon	55 mph	65 mph	75 mph

Source: Oregon Public Utilities Commission

Positive wind pressure is a direct and frontal assault on a structure, pushing walls, doors, and windows inward. Negative pressure also affects the sides and roof: passing currents create lift and suction forces that act to pull building components and surfaces outward. The effects of high-velocity winds are magnified in the upper levels of multi-story structures. As positive and negative forces impact and

[43] "Some of the Area's Windstorms." National Weather Service, Portland http://www.wrh.noaa.gov/pqr/paststorms/wind.php

remove the building protective envelope (doors, windows, and walls), internal pressures rise and result in roof or leeward building component failures and considerable structural damage.

Debris carried along by extreme winds can directly contribute to loss of life and indirectly to the failure of protective building envelope components. Upon impact, wind-driven debris can rupture a building, allowing more significant positive and internal pressures. When severe windstorms strike a community, downed trees, power lines, and damaged property are major hindrances to response and recovery.

Roads blocked by fallen trees during a windstorm may have severe consequences to people who need access to emergency services. Emergency response operations can be complicated when roads are blocked or when power supplies are interrupted. Windstorms can cause flying debris which can also damage utility lines. Overhead power lines can be damaged even in relatively minor windstorm events. Industry and commerce can suffer losses from interruptions in electric service and from extended road closures. They can also sustain direct losses to buildings, personnel, and other vital equipment. There are direct consequences to the local economy resulting from windstorms related to both physical damages and interrupted services. Table 8 provides detail on the damage that may be caused by wind from 25 miles per hour (mph) to wind speeds over 155 mph.

Table 8. Effects of Wind Speed

Wind Speed (mph)	Wind Effects
25-31	Large branches will be in motion.
32-38	Whole trees in motion; inconvenience felt walking against the wind.
39-54	Twigs and small branches may break off trees; wind generally impedes progress when walking; high profile vehicles such as trucks and motor homes may be difficult to control.
55-74	Potential damage to TV antennae; may push over shallow rooted trees, especially if the soil is saturated.
75-95	Potential for minimal structural damge, particularly to unanchored mobile homes; power lines, and signs; and tree branches may be blown down.
96-110	Moderate structural damage to walls, roofs, and windows; large signs and tree branches blown down; moving vehicles pushed off roads.
111-130	Extensive structural damage to walls, roofs, and windows; trees blow down; mobile homes may be destroyed.
131-155	Extreme damage to structures and roofs; trees uprooted or snapped.
Greater than 155	Catastrophic damage; structures destroyed.

Source: Washington County, Office of Consolidated Emergency Management, Wind Effects

Tornadoes are most common in the Midwest and are more infrequent and generally small west of the Rockies. Nonetheless, Oregon and other western states have experienced tornadoes on occasion, many of which have produced significant damage and occasionally injury or death. Oregon's tornadoes can be formed in association with large Pacific storms arriving from the west. Most of them, however, are caused by intense local thunderstorms. These storms also produce lightning, hail, and heavy rain, and are more common during the warm season from April to October.[44] Northeast Oregon's relatively low population may cause many tornadoes to go unreported.[45] One example of this is a tornado that had virtually no eyewitnesses -- formed in June 11, 1968 in Wallowa County and destroyed about 1,800 acres of timber and damaged another 1,200 acres.[46]

Severe Storms

Severe winter storms can consist of rain, freezing rain, ice, snow, cold temperatures, and wind. Severe summer thunderstorms may consist of heavy rain, wind and hail. The magnitude or severity of severe storms is determined by a number of meteorological factors including the amount and extent of rain, snow or ice; air temperature; wind speed; and event duration.

Winter storms occur over eastern Oregon regularly during December through February.[47] Wallowa County is known for cold, snowy winters. This is advantageous in at least one respect: in general, the region is prepared, and those visiting the region during the winter usually come prepared. However, there are occasions when preparation cannot meet the challenge.

Drifting, blowing snow has often brought highway traffic to a standstill. Many severe winter storm deaths occur as a result of traffic accidents on icy roads, heart attacks while shoveling snow, and hypothermia from prolonged exposure to the cold. The temporary loss of home heating can be particularly hard on the elderly, young children, and other vulnerable individuals. Also, windy, icy conditions have often closed mountain passes and canyons to certain classes of truck traffic. In these situations, travelers must seek accommodations, sometimes in communities where lodging is very limited.

Local residents also experience problems. During the winter, heating, food, and the care of livestock and farm animals are everyday concerns. Severe winter storms can isolate small communities, farms and ranches and create serious problems for open range cattle operations. During a winter snowstorm emergency access to farms and ranches can be extremely difficult and present a serious challenge to local emergency managers.[48]

Property at risk due to flooding and landslides may also be at risk if there is a rapid, heavy snowmelt. Additionally, ice, wind and snow can affect the stability of trees, power and telephone lines and TV and radio antennas. Down trees and limbs can become major hazards for houses, cars, utilities and other property. Such damage in turn can become major obstacles to providing critical emergency response, police, fire and other disaster recovery services.

Like snow, ice storms are comprised of cold temperatures and moisture, but subtle changes can result in varying types of ice formation, including freezing rain, sleet, and hail. Freezing rain can be the most damaging of ice formations. While sleet and hail can create hazards for motorists when it accumulates, freezing rain can cause the most dangerous conditions within a community. Ice buildup can bring down trees, communication towers, and wires creating hazards for property owners, motorists, and

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[44] Taylor, George H., Holly Bohman, and Luke Foster. August 1996. A History of Tornadoes in Oregon.Oregon Climate Service. Corvallis, OR: Oregon State University. http://www.ocs.orst.edu/pub_ftp/reports/book/tornado.html

[45] Taylor, George; Hatton Raymond Oregon Weather Book 1999

[46] Ibid.

[47] Oregon State Natural Hazards Mitigation Plan "Winter Storms Chapter". 2020

[48] Ibid.

pedestrians alike. With respect to power lines, the older lines have wider spans between poles, and when ice accumulates on them, they are heavily weighed down. When the ice melts, the lines snap up and wrap around other overhead lines, causing a short and significant structural damage. The most common freezing rain occurs near the Columbia Gorge, but it also poses a hazard to Northeast Oregon.[49]

Summer storms occur generally between June and September. These storms are often accompanied by high winds and hail. This is also the time of the year when tornadoes can develop over the inter-mountain areas of Northeastern Oregon. Severe summer storm hail can damage agricultural crops and cause damage to structures and vehicles.

History of Severe Weather in Northeast Oregon

Severe weather incidents have historically been a threat to Wallowa County. Table 9 below lists the most significant severe weather storms to impact Wallowa County.

Table 9. Partial History of Significant Severe Weather Events

Date	Location	Remarks
December 22, 1861	Statewide in OR, Pacific Northwest	**Winter Storm**: storm produced 1–3 feet of snow throughout Oregon; in NE Oregon temperatures ranged from 0°F to -30°F. Over 10,000 cattle starved in eastern Oregon
December 1892	Northern Counties, Oregon	**Winter Storm**: 15–30 inches of snow fell throughout the northern counties
August 5-11, 1898	Eastern Oregon	**Extreme Heat**: record breaking heat east of the Cascades; Pendleton reached 119°F
April 1931	NE Oregon	**Windstorm:** unofficial wind speeds reported at 78 mph. Damage to fruit orchards and timber
February 1933	Statewide	**Cold Spell:** coldest February to date for eastern Oregon. Seneca reached -54°F, an all-time record for Oregon
January 9-18, 1950	Statewide	**Winter Storm**: Heaviest snowfalls on record for January especially from the 9th through the 18th; ice; extreme low temperatures; property damage throughout state
November 10-11, 1951	Statewide	**Windstorm:** widespread damage, transmission and utility lines, wind speeds 40-60 mph, gust 75-80 mph
December 4, 1951	Statewide	**Windstorm:** wind speed up to 60 mph in Willamette Valley
December 21-23, 1955	Statewide	**Windstorm:** wind speeds 55-65 mph, with 69 mph gusts. Considerable damage to buildings and utility lines
August 14, 1956	Wallowa County	**Windstorm:** Thunder and Hail 1.5-inch diameter recorded
January 25-31, 1957	Statewide	**Cold Spell:** Low temperature of -43°F in Seneca
November 3, 1958	Statewide	**Windstorm:** wind speeds up to 51 mph, with 71 mph gusts. Major highways blocked by fallen trees
March 1-2, 1960	Statewide	**Winter Storm**: heavy snow throughout the state; many automobile accidents; two fatalities
October 12, 1962	Almost all of Oregon	**Windstorm:** Oregon's most famous and most destructive windstorm, the Columbus Day Storm. Total damage estimated at $170 million
July 7, 1963	Wallowa County	**Hail:** 1" in diameter recorded
June 11, 1968	Wallowa County	**Tornado:** Category 7 damage – possibly the strongest tornado to strike the Northwest; $25 million in damages reported; 1.75 " of hail reported

[49] Taylor, George H. and Chris Hannan. The Oregon Weather Book. Corvallis, OR: Oregon State University Press. 1999

Date	Location	Remarks
January 25-30, 1969	Statewide	**Winter Storm**: heavy snow throughout state; $3-4 million in property damage
June 23, 1969	Wallowa County	**Tornado:** $25,000 in damages reported
July, August 1971	Eastern Oregon	**Extreme Heat:** temperatures were high in Eastern Oregon for four consecutive weeks. Ontario had 32 consecutive days of 100°F or more
January 9-11, 1980	Statewide	**Winter Storm**: series of storms, extreme winds across state; many injuries and power outages. One death in Baker along with 5 others across the state.
November 13-15, 1981	Pacific Northwest	**Winter Storm:** Two storms back-to-back
February 1985	Statewide	**Winter Storm**: 2 feet of snow in northeast mountains; downed power lines; fatalities reported
January 7, 1986	Northeast Oregon	**Windstorm:** Elgin High School gymnasium received damage; sustained winds of 80-90 mph in La Grande
February 1986	Northeast mountains, Oregon	**Winter Storm**: heavy snow; school closures; traffic accidents; broken power lines; 6 to 12" of snow in the basins and valleys of northeastern Oregon
June 17, 1987	Wallowa County	**Hail:** 1" in diameter reported
June 26, 1988	Wallowa County	Windstorm
December 26, 1988 – January 22, 1989	Northeast Oregon	**Winter Storm**: Summerville was perhaps the most affected with three blizzards in a 4-week period; 15-foot drifts; wind over 60 mph
February 1-8, 1989	Statewide	**Winter Storm/Cold Spell:** Heavy snow and cold temperatures throughout the state
February 11-16, 1990	Statewide	**Winter Storm**: heavy snow throughout state
December 1990	Wallowa County	**Windstorm:** Wind damage to City of Joseph Elementary School and post office.
January 6-7, 1991	Eastern Oregon	**Winter Storm**: the higher lands of eastern Oregon accumulated between 1 and 6 inches of new snow
March 1991	NE Oregon	**Windstorm:** severe windstorm
December 12, 1991	NE Oregon	**Windstorm:** severe windstorm
July 22, 1992	Wallowa County	Tornado
December 1992	Northeastern mountains	**Windstorm:** severe windstorm
December 1993	NE Oregon	**Windstorm:** high winds ranged between 70 to 80 mph with gusts of up to 103 mph. No significant damage was reported
January 1994	Northeast mountains, Oregon	**Winter Storm**: heavy snow throughout region
May 15, 1994	Eastern Oregon	**Windstorm:** severe windstorm, blowing dust; winds 55 to 65 mph; particularly damaging in Baker County
December 12, 1995	Statewide	**Windstorm:** strongest windstorm since November 1981; DR-1107
January 1998	Northeast Oregon	**Winter Storm**: heavy snow throughout region
July 2, 1998	Minam, Wallowa County	**Hail:** 0.75" in diameter reported
Winter 1998-99	Statewide	**Winter Storm:** one of the snowiest winters in Oregon history (snowfall at Crater Lake: 586 inches)
June 1999	Wallowa and Imnaha	**Thunderstorm/Hail/Windstorm:** Dime-sized hail (0.75") fell in Imnaha on June 18th. Strong winds from a thunderstorm knocked down several trees in Wallowa on June 24th. Hail also fell with this storm.
December 14, 2000	Wallowa County	**Windstorm:** High winds during the evening blew down trees and brought widespread power outages to portions of the Grande Ronde Valley and

Date	Location	Remarks
		Wallowa County. In Wallowa County, several trees were downed on Highway 3 in Minam Canyon. A wind gust of 52 mph was recorded by a spotter in Joseph at 6:30 pm.
January 11, 2001	Wallowa County	**Heavy Snow:** Heavy snow fell overnight and throughout the morning in the Wallowa Valley. Joseph, at an elevation of 4100 feet, received 7 inches. Another location just west of Lostine at an elevation of 3400 feet recorded 9 inches.
May 24, 2001	Enterprise and Imnaha	**Lightning:** Lightning struck a 75-foot radio antenna and short-circuited many electronic devices such as faxes, computers and phones, which were located next to the tower. One business owner estimated total losses of over $25,000. Lightning strikes cut power to 800 customers in the nearby towns of Wallowa Lake and Joseph. **Thunderstorm:** Winds from a severe thunderstorm estimated at 70 mph felled several trees just north of Imnaha. Several other locations near town also lost trees and large branches. An estimated 0.8 inches of rain fell in 30 minutes just north of Imnaha.
January 3, 2002	Wallowa County	**Heavy Snow:** Heavy snow fell overnight in Wallowa County. Joseph, at 4085 feet reported 8 inches of snow. Enterprise, at 3800 feet, reported between 7 and 8 inches of snow.
March 24, 2002	Wallowa County	**Heavy Snow:** 11 inches near Imnaha. Trees down and power outages which affected 300 people.
December 28, 2002	Central and Eastern Oregon	**Heavy Snow:** A winter storm brought heavy snow to all of central and eastern Oregon, resulting in numerous minor motor vehicle accidents. Two flights were cancelled out of Redmond due to the heavy snow. Pendleton saw the most snow from this storm since a storm which dumped 16 inches in 1994. Snow amounts from the storm included: Wallowa County: Wallowa 11 inches, Joseph 8 inches
June 2003	Baker and Wallowa Counties	**Windstorm:** 65 mph winds in Baker City caused property damage and power outages; $1,000 in property damage in Wallowa County
December 28, 2003 – January 9, 2004	Statewide	**Heavy Snow**: Federal Disaster Declaration DR-1510. Grant, Union, and **Wallowa Counties** declared in Region 7. Eleven inches of snow fell in **Wallowa** and eight (8") inches in **Joseph.** Two feet of snow in the Blue Mountains in eastern Oregon. The eastbound lanes of I-84 closed at Ladd Canyon east of La Grande. 60 mph wind gusts in Union County created whiteout conditions, prompting the closure of I-84 between La Grande and Baker City. There were two (2) fatalities.
May 20, 2004	Enterprise, Wallowa County	**Funnel cloud** sited by a trained spotter.
September 1, 2004	Imnaha and Enterprise, Wallowa County	**Thunderstorm**: High winds from a thunderstorm knocked down large trees near the confluence of north/south forks of the Imnaha River. Hail (3/4") reported in Imnaha and Enterprise
November 1, 2005	Joseph, Wallowa County	**Windstorm**: High winds blew down approximately eight trees and a stop sign in the Joseph area. Several power poles were snapped under the force of the wind two miles east of Joseph on the Imnaha highway. Power outages were also reported due to the wind, including Joseph High School. In Enterprise, two-inch diameter tree limbs were snapped due to high winds. An automated weather station in Joseph recorded a peak wind of 58 MPH.
February 16, 2006	Joseph, Wallowa County	**Heavy Snow:** Snowfall of 12-14 inches in Joseph.

Date	Location	Remarks
May 19 and 21, 2006	Roberts Butte and Paradise, Wallowa County	**Hail:** Quarter size hail reported.
June 4, 2006	Enterprise, Wallowa County	**Thunderstorm:** Large tree fell in storm blocking the road to Freezeout Trail.
July 21, 2006	Wallowa County	**Extreme Heat:** Daily maximum temperatures between 100 and 113 degrees were observed at lower elevations, with temperatures 90 to 100 degrees at elevations up to 4000 feet. Several people were treated for heat related illness.
August 8, 2006	Flora	**Hail**: 3/5" inch hail reported by the general public
August 16, 2006	Lostine	**Lightning:** Lightning started a barn fire which was quickly extinguished by neighbors and the Lostine Volunteer Fire Department.
August 21, 2006	Enterprise	**Tornado:** Brief land spout tornado observed moving north by several golfers at Alpine Meadows Golf Course northwest of Enterprise. Tornado hit trees and broke off branches up to 2 inches in diameter.
November 12-15, 2006	Wallowa County	**High Wind:** A strong low pressure system moving across northern Washington brought high winds and damage.
November 12, 2007	Wallowa County	**Windstorm**: A deep low pressure area moving across British Columbia combined with very strong upper-level winds produced damaging surface winds across northeast Oregon. The winds were most devastating near Wallowa Lake where dozens of trees were downed and crashed into buildings and vehicles. $500,000 in damages resulted from the windstorm in Wallowa Lake State Park and it was temporarily closed as a result of the damage. A wind gust to 111 mph was measured at Sheep Ridge, near Enterprise at an elevation of 7000 feet.
November 18, 2007	Wallowa County	**Heavy Snow:** A moist southwest flow aloft combined with cold air at the surface brought heavy snow to northcentral and northeast Oregon. Snowfall amounts in inches in Wallowa County included **Flora** (4"), 7 miles south of **Lostine** (5.5").
Jan. 2–Feb. 9, 2008	Northern Blue Mountains including Wallowa County	**Heavy Snow**: Heavy snow and freezing rain across eastern Oregon; 5–13 inches of snow. Snowfall of 5-12 inches was reported north of **Wallowa** and in **Joseph** on January 26th.
May 26, 2008	Wallowa Lake, Joseph and Enterprise	**Funnel Cloud**: Several people observed and photographed funnel clouds near Joseph, Enterprise, and Wallowa Lake.
August 15, 2008	Wallowa County	**Excessive Heat:** Multiple days of at least 100° temperatures. Wallowa recorded temperatures of 102°F and 103°F
March 7, 2009	Eagle Cap Wilderness	**Avalanche:** A 50-year-old Enterprise, Oregon man died in an avalanche while backcountry skiing in the Eagle Cap Wilderness. Two other people were rescued. The quarter mile long slap avalanche occurred about 1 pm. Heavy snow had fallen in the area earlier in the week.
May 6, 2009	Wallowa	**Tornado:** An upper level trough combined with an approaching cold front and daytime heating produced severe thunderstorms. A brief tornado was observed near Wallowa in Wallowa County also near Adams in Umatilla County. Eyewitnesses saw the cover being ripped off the sewer ponds and rotating debris being blown into the air across the Wallowa River.
May 18, 2009	Flora	**Hail:** Daytime heating combined with an unstable air mass produced a severe thunderstorm over Wallowa County. Hail .8" in diameter was reported in Flora.

Date	Location	Remarks
August 29, 2009	Enterprise, Lostine and Wallowa	**Thunderstorm/Hail:** An upper level low pressure area over the Columbia Basin combined with daytime heating produced late afternoon and evening severe thunderstorms with heavy rainfall across northeast Oregon
October 3, 2009	Wallowa County	**Heavy Snow:** An unseasonably cold and strong upper level low pressure system produced early season heavy snowfall across portions of central and northeast Oregon. Snowfall amounts in inches included 1 mile south southeast of Joseph (4”), Enterprise (6”), 6 miles east of Joseph (11”).
November 17, 2009	Wallowa County	**High Wind:** A powerful low pressure area from the Pacific and strong upper level winds brought damaging downslope winds to the southern Grande Ronde Valley and the Joseph area. Wind gusts included 88 mph 3 miles north of Joseph, which caused long term power outages.
May 5, 2010	Wallowa County	**Heavy Snow:** A deep and cold upper level low pressure area dropped south southeast from British Columbia and brought a heavy late season snowfall to Wallowa County. Snowfall amounts included Joseph (7”), 6 miles south of Joseph (12”), 6 miles south of Lostine (12”), and 3 miles south of Joseph (8”).
June 28-29, 2010	Lostine, Roberts Butte, Joseph, and Enterprise	**Thunderstorm/Hail**: An upper level trough combined with a moist unstable atmosphere to produce severe thunderstorms across Union and Wallowa Counties during the late afternoons of these days.
August 5, 2010	Imnaha	**Thunderstorm/Hail**: 1.75” hail reported in Imnaha as part of a thunderstorm.
November 16, 2010	Northeastern Oregon	**High Wind:** A cold front combined with a strong jet stream aloft and tight surface pressure gradient produced high winds across central and northeast Oregon. Damage was reported in Condon, Enterprise, La Grande, Imbler, Elgin, Summerville, Camp Sherman**,** Lostine and three miles south southeast of Joseph.
December 27, 2010	Northeastern Oregon	Over a 48-hour period, the mountains above 4000 feet received over 2 feet of snow. Reported snowfall amounts included **Flora** (7.5”), 13 miles northeast of **Lostine** (5”), and 6 miles northwest of **Flora** (12”). The heavy wet snow caused some tree damage and power outages.
February 19, 2011	Wallowa County	**Heavy Snow**: Upper-level low pressure systems rotating through a broad upper-level trough brought heavy snowfall to Deschutes and Wallowa counties. Snowfall amounts reported included 1.5 miles west southwest of Bend (10”), 2.3 miles west southwest of Bend (8”), Joseph (13”) and 20 miles south of **Imnaha** (6”).
June 22, 2011	Joseph, Troy	**Thunderstorm/Hail:** An unstable atmosphere ahead of an upper-level trough produced severe thunderstorms during the late afternoon and early evening. Large hail was reported in Troy.
January 17, 2012	Northern Oregon	**Winter Storm:** Modified arctic air moved into the region followed by a series of moderate to strong upper-level storm systems riding on a moist subtropical jet stream. The result was widespread heavy snow and local high winds. Snowfall amounts for January 17-18 in inches include Lostine (5”) and 1 mile southeast of Flora (15”).
March 20, 2012	Blue Mountains	**Heavy Snow:** A moist southwest flow ahead of an upper-level low pressure brought heavy snowfall to the areas just east of the Cascade Mountains and to the Blue Mountains. Snowfall of 8” was reported in Flora.
April 4, 2012	Northern Blue Mountains	**Heavy Snow:** A large upper-level low pressure system near the Pacific Coast brought considerable moisture from the south which produced heavy snowfall over northeast Oregon. Snowfall amounts reported

Date	Location	Remarks
		included Enterprise (5”), 5 miles east of Joseph (5”), Joseph (6.5”). An unstable atmosphere in the afternoon produced showers and localized hail.
July 17, 2012	Flora, Wallowa County	**Thunderstorm/Hail:** In Flora it was reported that wind gusts up to 40 mph preceded the hail.
November 19, 2012	Wallowa County	**Windstorm:** A strong upper-level jet and tight surface pressure gradients aided in high winds of approximately 68 knots. Other reports of wind damage include County wide power outage in Wallowa, a large tree came down on Bear Creek Road and took down several power poles.
January 28, 2013	Northern Blue Mountains	**Heavy Snow**: Heavy snow was reported across the Blue Mountains, the John Day Highlands, and the John Day Basin. Wallowa County was not as badly hit as other areas. Snowfall of 5” reported near **Joseph.**
May 9, 2013	Lostine	**Tornado:** A very weak EF0* tornado briefly touched down 4 miles northeast of Lostine on Thursday May 9th. The track was 0.1 miles and had a width of 10 yards. The COOP observer noted as the source for this report sent in pictures and a brief video of the short-lived tornado.
August 22, 2013	Roberts Butte	**Thunderstorm:** A severe thunderstorms knocked down several trees along a state highway in Wallowa County.
December 8, 2013	Wallowa County	**Extreme cold:** A strong Arctic front pushed in from Canada and brought very cold temperatures and dangerous wind chills to the area.
December 20, 2013	Wallowa County	**Winter Storm:** A complex weather system moved across the area, with high predictable waters associated. The system would start off as snow before changing over to rain several hours later.
January 11, 2104	Northern Blue Mountains	**High Wind:** Strong winds moved into the interior Pacific Northwest over the January 10-12th weekend. Several reports of high wind gusts and damage were recorded with these winds. In **Wallowa,** a roof peeled off of a house was reported on our social media. Wind gusts of 59 mph were reported north of **Joseph** among other places.
November 13, 2014	Wallowa County	**Winter Storm**: A warm front from the south collided with an arctic air mass from the north and produced significant winter weather across most of central and northeast Oregon. Although no snowfall totals are reported for Wallowa County locations, Cove received 7” of snowfall.
December 10-11, 2014	Northern Blue and Wallowa Mountains	**Windstorm:** A deep strong low-pressure system off the coast provided strong southerly flow to the forecast area. With a strong upper-level jet and associated strong low level jet running perpendicular to the mountain terrain, and a strong surface low that set up over the Washington Basin would tighten the gradients along the Blue Mountain Foothills. A few gusts ranging from (68-75 mph) near **Joseph**. A gust of (60) across the Grand Ronde Valley in Ladd and Pyles Canyon.
December 24- 29, 2014 through January 4, 2015	Northern Blue Mountains	**Winter Storm:** A series of four pacific winter storms moved across the interior pacific northwest providing significant accumulations to several areas ranging from 7”-14” over the course of these storms. The January 4, 2015, storm provided the heaviest snowfall over **Wallowa County**, with a trained spotter reporting 7 inches near Wallowa.
February 5, 2015	Enterprise, Wallowa County	**Windstorm:** A low pressure system off the Pacific provided a moist southerly flow to the forecast area. Strong southerly winds associated with the warm front would mix down to the surface across several areas in central and northeast Oregon. As a result, strong wind gusts and several reports of damage occurred. In Joseph wind gusts of 86 mph were recorded. A 55ft crank up ham radio tower was lost in the wind

Date	Location	Remarks
		event. A tree fell on a house in Enterprise and there were power outages in Wallowa County.
Dec. 6-23, 2015	Statewide storm events	**Heavy Snow:** Federal Disaster Declaration DR-4258. Clatsop, Columbia, Multnomah, Clackamas, Washington, Tillamook, Yamhill, Polk, Lincoln, Linn, Lane, Douglas, Coos, and Curry Counties declared. Several pacific storm systems moved across the region over the Dec 12-13 weekend. Another series of storms moved across Oregon on Dec 16-17 and Dec 21-23. Each storm system brought several inches of snow to the mountain areas. A narrow but long-lived band of precipitation moved across Wallowa County the morning of December 19th. Several reports of moderate snow occurred over the **Joseph and Enterprise** areas. Snowfall amounts in inches ranged from 5 to 6 inches, with northern **Wallowa County** receiving reports of up to 9 inches just outside of **Flora**. On December 21st heavy snow fell over portions of central Washington and Oregon due to a cold front. Snowfall amounts are as followed: 14" recorded at the Milk Shakes SnoTel in Wallowa County.
May 5, 2016	Wallowa	**Thunderstorm/Hail:** A few strong to severe thunderstorms moved across northeast Oregon on May 5th. Although some wind gusts were around 40 mph, the main threat was heavy rain and hail. Hail sizes in inches reported as followed: (1.25) 10 miles W of Cove, (1.00) 3 miles SE of La Grande, (1.00) 13 miles E of Elgin, (0.75) in Imbler, (0.75) in Summerville.
July 12, 2016	Roberts Butte	**Tornado**: A thunderstorm produced a brief EF0* tornado in rural Wallowa County. No other severe weather reports were received with this storm.
July 19, 2016	Lostine, Imnaha, Wallowa County	**Thunderstorm/Hail**: A thunderstorm produced wind damage 8 miles north northwest of Imnaha and moved through Wallowa County on July 19th. 12 large trees were downed along Fence Line Rd. Also 1 inch hail was still seen 15 hours after the storm had passed, indicating hail was likely a lot larger during the storm. The hail destroyed a canvas tent and damaged a horse trailer and fire tower. Penny size (0.75) was also reported in Lostine on this day.
October 14, 2016	Joseph, Wallowa County	**Thunderstorm/Windstorm:** Early in the morning on Oct 14th a fast-moving squall developed and produced brief but strong wind gusts across a few locations in northeast Oregon. Wind gust reports varied from 60 mph in the Joseph area to 78 mph 4 miles NW of Cayuse.
December 4, 2016	Wallowa County	**Winter Storm:** Heavy snow was expected and occurred the Blue Mountains of Oregon and Washington. Snow fell east the Blues over Wallowa County as well.
December 14, 2016	Wallowa County	**Winter Storm:** A Pacific system brought heavy snow to the Washington Cascade east slopes, the Blue Mountains, Wallowa County and the Grande Ronde Valley.
December 27, 2016	Wallowa County	**Winter Storm:** A Pacific system brought heavy snow to the Washington Cascade east slopes, the Blue Mountains, Wallowa County and the Grande Ronde Valley.
January 17, 2017	Northern Blue Mountains	**Ice Storm:** A major winter storm brought significant snow and ice to the region. Also, the Grande Ronde valley experienced high winds and blizzard conditions.
October 12, 2017	Northern Blue Mountains	**Heavy Snow**: A Pacific storm system lowered snow levels to between 3500 and 4500 feet. This was followed by a second system that produced significant early season snow in the Blue Mountains. Measured heavy snow accumulation of 6 inches overnight, 1 mile southeast of **Flora.**

Date	Location	Remarks
November 26, 2017	Wallowa Valley	**Windstorm:** Locally high wind gusts occurred near the south end of the Wallowa valley in Wallowa County due to a low-pressure system moving through southeast Washington state.
December 24, 2017	Wallowa County	**Heavy Snow:** A Pacific system spread snow across much of southeast Washington and northeast Oregon on Christmas Eve and early Christmas Day.
January 11, 2018	Northern Blue Mountains	**Heavy Snow:** A Pacific system brought rain and snow the region during the second week of January. Snow levels were relatively high for this time of year, with snow accumulating above 3800 feet in the Blue Mountains. Ten inches of snow was reported 9 miles SW of Ski Bluewood in NW Wallow County.
Feb. 14-23, 2018	Northern Blue Mountains	**Heavy Snow/High Wind**: A cold front moved south from Washington through eastern Oregon February 13th and 14th. This front caused widespread snow across the area. Persist upslope flow into the Northern Blue Mountains of Oregon resulted in additional accumulations. On February 17th, a Pacific storm system moved across the region causing strong winds over a good portion of the area from late morning into the evening. A pair of disturbances brought snow to the region late Friday February 23rd and on Saturday February 24th. The most significant snow fall occurred in the northern Blue Mountains.
March 1-2, 2018	Wallowa County	**Heavy Snow**: A Pacific storm system brought snow to the region on the first two days of March 2018.
March 17, 2018		**Heavy Snow**: Snow fall was heavy above 4500 feet in the Northern Blue Mountains of Northeast Oregon 17th of March 2018. This snowfall was due to moisture wrapping around from the east on the north side of an upper low.
May 25, 2018	Imnaha	**Thunderstorm/Hail**: Thunderstorms developed late morning and continued well into the evening. The storms produced locally heavy rain and some flooding. Also, some hail occurred with the storms. The hail was mainly small but did reach to 1 inch in diameter.
February 3-4, 2019	Northern Blue Mountains	**Heavy Snow**: A pair of storm systems brought significant snow to all elevations on the 3rd and 4th of February. Wraparound moisture from the first system brought 8 to 12 inches of snow to the Blue Mountains as well as the Grande Ronde and **Wallowa Valleys**. Initial precipitation with the second system combined with lingering wraparound moisture brought between 4 and 7 inches to all elevations on the 4th of February. Numerous accidents were reported due to slippery conditions. Interstate 84 for closed for several hours between Baker City and Pendleton during the day on the 4th to clear multiple accidents.
February 10-12, 2019	Northern Blue Mountains	**Heavy Snow**: A winter storm brought heavy snowfall to the Columbia River Gorge, Northern Blue Mountains and the Blue Mountains, 10 to 13 inches in the Northern Blue Mountains, 8 to 20 inches in the Grande Ronde Valley and 4 to 9 inches in **Wallowa County** were reported.
February 19, 2019	Northern Blue Mountains	**Heavy Snow**: A winter storm brought heavy snow to the Blue Mountains and adjacent valleys. Storm total accumulations in the northern Blue Mountains ranged from 6 to 14 inches with 4 to 6 inches in the Grande Ronde Valley and 3 to 6 inches in **Wallowa County**. Interstate 84 between Pendleton and La Grande was closed for several hours due to heavy snow and near zero visibility.
February 23, 2019	Northern Blue Mountains	**Winter Storm**: Persistent troughing off the coast of the Pacific Northwest focused a stream of mid-level moisture over the Inland Northwest resulting in a long duration snow event between the 22nd and 27th of

Date	Location	Remarks
		February. Snowfall rates were in excess of 1 inch per hour in some places. Storm total snowfall amounts were measured at: 40 inches in Sisters, 33 inches in Bend, 30 inches in Redmond, 26 inches in Meacham, 22 inches in Prineville, 21 inches in Elgin, 16 inches in Mitchell, 14 inches in **Lostine** and La Grande, 12 inches in Pendleton and Joseph and 10 inches in John Day. In Bend a few roofs collapsed under the weight of the snow.
January 10-11, 2020	Northern Blue Mountains	**Heavy Snow** was reported over the mountains and High Valleys with 6 to 12 inches of accumulation reported in many locations. Six inches of snow reported SE of **Flora** and 7.5 inches reported WNW of **Joseph**.
February 4-5, 2020	Wallowa County	**Winter Storm/Flooding**: Winter storm with copious moisture dumped 1 to locally 2+ feet of snow over the eastern mountains and valleys February 4th and 5th. This was the precursor to significant flooding that occurred later in the week when the snow melted due a warm-up and heavy rains. Snowfall in Wallowa amounted to 8" and in Joseph 6" was reported. **DR-4519**
March 31, 2020	Wallowa County	**Heavy Snow**: An early spring winter storm produced heavy snow over Wallowa County dropping up to a foot of snow in some areas.
May 31, 2020	Joseph, Wallowa County	**Thunderstorm/Hail**: A major severe weather event occurred over central and northeast Oregon and southeast Washington. A powerful upper-level storm system moved across the area during the afternoon and evening helping to trigger severe thunderstorms. Nickle to quarter size hail covering the ground in Joseph.
November 17, 2020	Wallowa County	**High Wind:** A trained spotter measured a wind gust of 79 mph 3 miles north of Joseph, OR. Two irrigation pivots turned over. Trees and power lines in Joseph were reported down.
December 30, 2020	Northern Blue Mountains	**Heavy Snow:** A warm and cold front passage followed by a deep Pacific low moving across the region starting during the day on Dec. 29th through Dec. 31st produced heavy snow along the Blue Mountains and resulted in accumulations of more than 10 inches being reported in this area.
February 14-15, 2021	Northern Blue Mountains	**Heavy Snow:** A cold front and upper-level trough in northwest flow aloft resulted in another round of light to moderate snowfall
February 25, 2021	Wallowa County	**Heavy Snow**: A shortwave trough coupled with surface cold front produced an initial surge in snowfall across the region with breezy to gusty winds developing behind the frontal passage.

Source: NOAA Storm Event database consulted July 2021 for all events in Wallowa County Storm Events Database | National Centers for Environmental Information (noaa.gov). Some entries have been combined to minimize length.

*EF0 means a zero on the Enhanced Fujita scale (EF-Scale) that rates the strength of tornadoes in the United States and Canada based on the damage they cause. en.wikipedia.org

DROUGHT HAZARD ANNEX

Drought is a natural hazard with significant social, economic, and ecological impacts. Persistent drought is common in the Northwest and Oregon is among the more drought-prone states. Over the last 20 years, the incidence, extent, and severity of drought has increased in both the western United States in general and the Northwest in particular compared with the twentieth century. These droughts have had numerous adverse impacts on agriculture, water availability, recreation, ecosystems, and wildfire risk. The likelihood of continued increases in drought severity and duration in the twenty-first century raises questions about how best to prepare for and mitigate the impacts of drought and how to better understand drought and its causes. [50]

The simplest conceptual definition of drought is "insufficient water to meet needs" (Redmond 2002). Drought broadly may be defined as a sustained imbalance of moisture supply and demand at the surface relative to long-term average conditions. Precipitation supplies moisture, whereas evapotranspiration creates a moisture demand. Drought severity depends on the magnitude and duration of moisture deficiency and the size of the affected area.[51]

Droughts are not just a summer-time phenomenon; winter droughts can have a profound impact on agriculture. Below average snowfall in higher elevations has a far-reaching effect, especially in terms of hydro-electric power, irrigation, recreational opportunities, and a variety of industrial uses.

Drought can affect all segments of a jurisdiction's population, particularly those employed in water-dependent activities such as ranching, agriculture, hydroelectric generation, and recreation. Aquifer capacity may be a notable concern under drought conditions. Domestic water-users within the cities may be subject to stringent conservation measures such as water rationing and could be faced with significant increases in electricity rates.

Seasonal irrigation water from mountain snowpacks tails off towards the end of August. It is common to find water systems imposing some type of water rationing during dry years. Location of reservoirs helps mitigate the impact of a drought -- water availability is not always correlated to the amount of precipitation.

Facilities affected by drought conditions include communications facilities, hospitals, and correctional facilities that are subject to power failures. Storage systems for potable water, sewage treatment facilities, water storage for firefighting, and hydroelectric generating plants may be vulnerable to drought. Low water also means reduced hydroelectric production especially as the habitat benefits of water compete with other beneficial uses.

There also are environmental consequences. A prolonged drought in forests promotes an increase of insect pests, which in turn, damage trees already weakened by a lack of water. A moisture-

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[50] Fifth Oregon Climate Assessment, 2021, OCAR5.pdf | Powered by Box

[51] Ibid.

deficient forest constitutes a significant fire hazard (see the Wildfire summary). While drought may limit the growth of fuel for wildfires, it does provide ideal conditions for wildfires to occur. Drought significantly increases the probability for lightning-caused wildfires to occur and provides ideal conditions for the rapid spread of wildfire. In addition, drought and water scarcity add another dimension of stress to species listed pursuant to the Endangered Species Act (ESA) of 1973.[52]

Characteristics and Causes of Drought

Drought occurs in virtually every climatic zone, but its characteristics vary significantly from one region to another.[53] Drought is a temporary condition – it is seen in an interval of time, generally months or years, when moisture is consistently below normal. It differs from aridity, which is restricted to low rainfall regions and is a permanent feature of climate. [54]

In the most general sense, drought is defined as a deficiency of precipitation over an extended period of time (usually a season or more), resulting in a water shortage. In the early 1980s, researchers with the National Drought Mitigation Center (NDMC) and the National Center for Atmospheric Research located more than 150 published definitions of drought. In order to simplify analysis, the NDMC now provides four different ways in which drought can be defined based on the impacts of the drought. They are as follows: meteorological, agricultural, hydrological, and socioeconomic. The first three approaches deal with ways to measure drought as a physical phenomenon. The last deals with drought in terms of supply and demand, tracking the effects of water shortfall as it ripples through socioeconomic systems. Figure 9 below illustrates the interrelationship of these types of drought.

Meteorological Droughts

Meteorological droughts are defined in terms of the departure from a normal precipitation pattern and the duration of the event. These are region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. This drought type may relate specific precipitation departures to average amounts on a monthly, seasonal, or yearly basis.

Agricultural Droughts

Agricultural drought links various characteristics of meteorological or hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced groundwater or reservoir levels. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. A good definition of agricultural drought accounts for the variable susceptibility of crops during different stages of crop development, from emergence to maturity.

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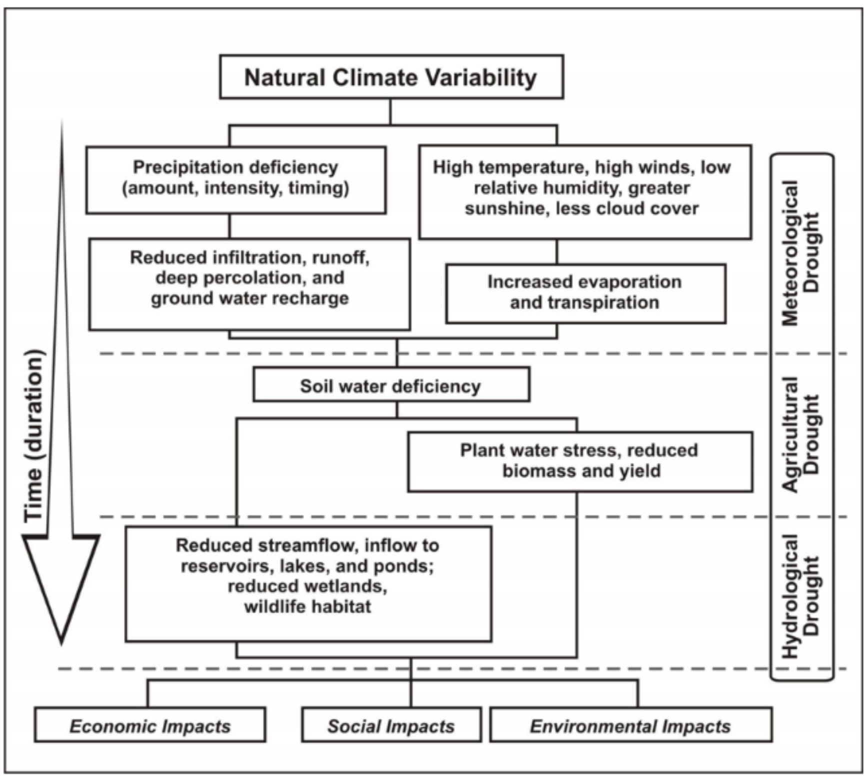
[52] Northeast Oregon Multi-Jurisdictional Natural Hazard Mitigation Plan (2014)
[53] National Drought Mitigation Center. 2007. What is Drought? https://drought.unl.edu/Education/DroughtBasics.aspx , accessed June 2020.
[54] National Drought Mitigation Center, *Types of Drought,* https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx, accessed April, 2020.

Hydrological Droughts

Hydrological droughts refer to deficiencies in surface water and sub-surface water supplies. It is measured as stream flow, and as lake, reservoir, and ground water levels. Hydrological measurements are not the earliest indicators of drought. When precipitation is reduced or deficient over an extended period of time, the shortage will be reflected in declining surface and sub-surface water levels.

Hydrological droughts are usually out of phase with the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, streamflow, and groundwater and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors. Also, water in hydrologic storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes (e.g., flood control, irrigation, recreation, navigation, hydropower, and wildlife habitat), further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought and conflicts between water users increase significantly.

Figure 9. Types of Drought and Impacts



Sequence of drought occurrence and impacts for commonly accepted drought types. All droughts originate from a deficiency of precipitation or meteorological drought but other types of drought and impacts cascade from this deficiency. (Source: NDMC)

Source: National Drought Mitigation Center [Home | National Drought Mitigation Center (unl.edu)]

Socioeconomic Droughts

Socioeconomic definitions of drought associate the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. It differs from the other three types of drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts. The supply of many economic goods, such as water, forage, food grains, fish, and hydroelectric power, depends on weather. Because of the natural variability of climate, water supply is ample in some years but unable to meet human and environmental needs in other years. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

In most instances, the demand for economic goods is increasing as a result of increasing population and per capita consumption. Supply may also increase because of improved production efficiency, technology, or the construction of reservoirs that increase surface water storage capacity. If both supply and demand are increasing, the critical factor is the relative rate of change. Is demand increasing more rapidly than supply? If so, vulnerability and the incidence of drought may increase in the future as supply and demand trends converge.

In addition to these primary drought designations, three other drought designations—ecological, flash, and snow—were proposed more recently to reflect more-specific drivers and impacts of drought. Ecological drought is defined as "[a]n episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems". Like agricultural drought, ecological drought usually is caused by meteorological and hydrological drought. Vegetation and soil types affect likelihood of ecological drought.[55]

Flash drought refers to relatively short periods of warm surface temperatures, low relative humidity and precipitation deficits, and rapidly declining soil moisture. These droughts tend to develop and intensify rapidly within a few weeks and may be generated or magnified by prolonged heat waves.[56]

Snow droughts are defined when snowpack—or snow water equivalent (SWE)—is below average for a given point in the water year, traditionally 1 April. Years with low SWE on 1 April often are followed by summers with low river and stream flows. The low flows sometimes lead to or exacerbate water supply deficiencies, especially in snowmelt-dominated basins. Although the idea of snow drought has existed for many years, it was further developed in Oregon and the Northwest following the 2015 water year, in which below-average snowpack counterintuitively corresponded with above-average precipitation. This type of snow drought is classified as warm snow drought. Dry snow drought is classified on the basis of below-average snowpack and precipitation.[57]

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[55] Fifth Oregon Climate Assessment, 2021, OCAR5.pdf | Powered by Box
[56] Ibid.
[57] Ibid.

Identifying Drought

Oregon Revised Statute (ORS) Chapter 536 identifies authorities available during a drought. "To trigger specific actions from the Water Resources Commission and the Governor, a "severe and continuing drought" must exist or be likely to exist. Oregon relies upon two inter-agency groups to evaluate water supply conditions, and to help assess and communicate potential drought-related impacts, the Water Supply Availability Committee and the Drought Readiness Council.

The Water Supply Availability Committee (WSAC) is a technical committee chaired by the Water Resources Department. The WSAC provides the scientific foundation that decision-makers need to identify and respond appropriately to drought. The Committee consists of state and federal science and emergency preparedness agencies.

The WSAC meets early and often throughout the year to evaluate the potential for drought conditions. If drought development is likely, monthly meetings occur shortly after release of NRCS Water Supply Outlook reports for that year (second week of the month beginning as early as January) to assess conditions. The following are indicators used by the WSAC for evaluating drought conditions:

- Snowpack
- Precipitation
- Temperature anomalies
- Long range temperature outlook
- Long range precipitation outlook
- Current stream flows and behavior
- Spring and summer streamflow forecasts
- Ocean surface temperature anomalies (El Nino, La Nina)
- Storage in key reservoirs
- Soil and fuel moisture conditions
- NRCS Surface Water Supply Index.[58]

The second inter-agency group, the Drought Readiness Council, is co-chaired by the Oregon Water Resources Department and Oregon Office of Emergency Management, and reviews local requests for assistance and makes recommendations to the Governor regarding the need for state drought declarations. The Council consists of state agencies with natural resources management, public health, or emergency management expertise.

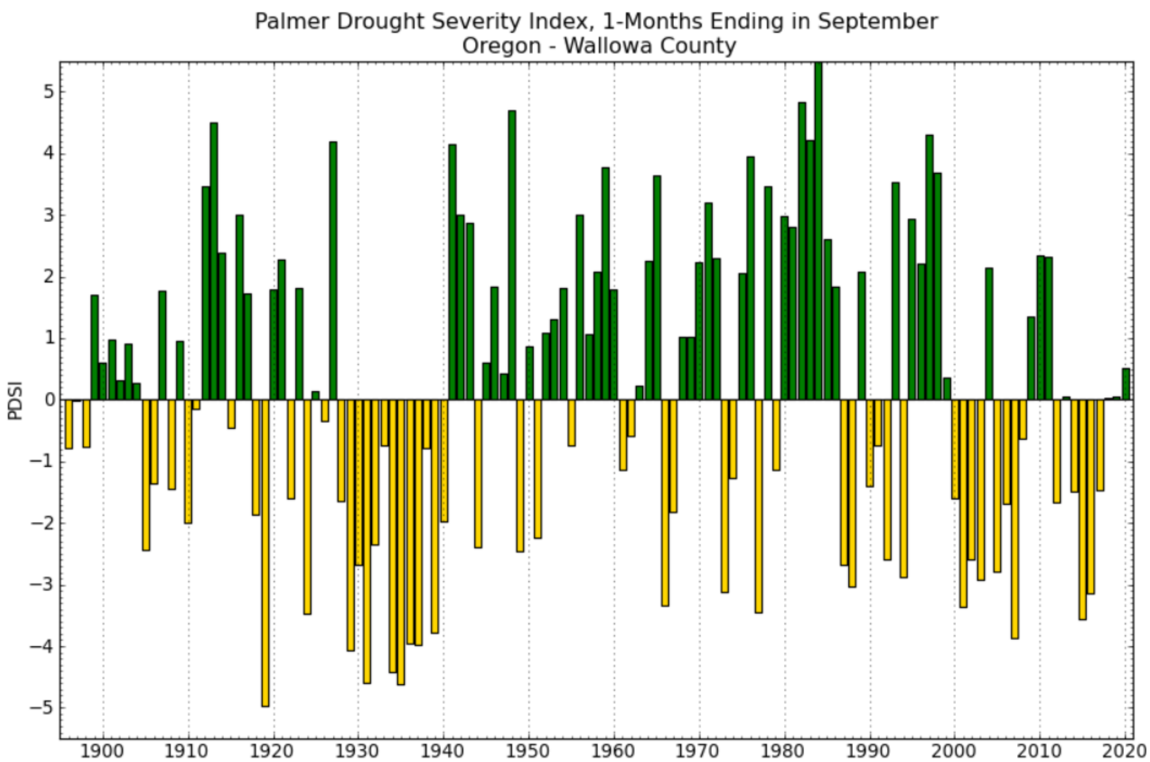
The Drought Monitor is the current primary tool used to identify and categorize drought conditions in Oregon (https://droughtmonitor.unl.edu/).

[58] State of Oregon, *Emergency Operations Plan*, *Incident Annex for Drought*, April 2016, https://www.oregon.gov/oem/Documents/2015_OR_EOP_IA_01_drought.pdf.

An example of a tool used to estimate drought conditions is the Water Supply Outlook Report (WSOR) produced by the Natural Resource Conservation Service (NRCS).[59] The Water Supply Outlook is a report containing forecasts of runoff and snowmelt runoff. It also contains a summary of current snowpack, precipitation, river flow volumes, reservoir storage and soil moisture, and data for these is published in the Maps and Data Summaries section. Runoff from the mountains is important for the major rivers in the province where reservoirs store water supplies for irrigation, hydroelectricity, community, and municipal purposes. Up to date WSOR are available for Oregon.

Quantifying drought requires an objective criterion for defining the beginning and end of a drought period. The Palmer Drought Severity Index is most effective in determining long-term drought — e.g. several months — and is not as good with short-term forecasts, e.g. a matter of weeks.

Figure 10. Oregon Counties Palmer Drought Severity Index for September 2020



Source: West Wide Drought Tracker, Oregon – PDSI, https://wrcc.dri.edu/wwdt/index.php?region=or

Most federal agencies use the Palmer Drought Severity Index (PDSI). The index incorporates precipitation, runoff, evaporation, and soil moisture as variables. However, the PDSI does not incorporate snowpack as a variable. Therefore, it is does not provide a very accurate indication of drought conditions in Oregon and the Pacific Northwest, although it can be very useful because of its a long-term historical record of wet and dry conditions. The PDSI uses a zero (0) as normal, and drought is shown in terms of negative numbers; for example, negative two (-2.00) is moderate

[59] Natural Resource Conservation Service, Water Supply Outlook reports https://www.wcc.nrcs.usda.gov/state_outlook_reports.htm

drought, negative three (-3.00) is severe drought, and negative four (-4.00) is extreme drought.[60] See Figure 10.

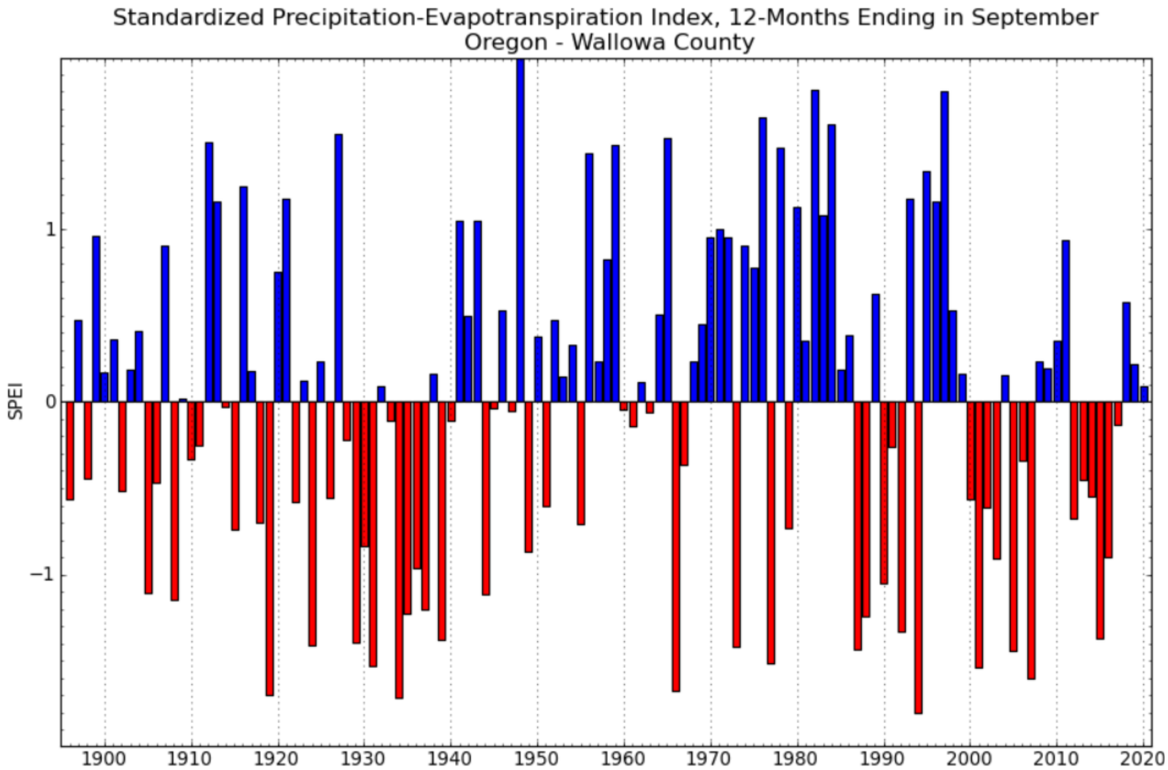
The Standardized Precipitation Evapotranspiration Index (SPEI) is another method for analyzing drought conditions. It is an extension of the widely used Standardized Precipitation Index (SPI) and is designed to take into account both precipitation and potential evapotranspiration in determining drought.

The dimensionless Standardized Precipitation-Evapotranspiration Index (SPEI) is a key quantitative metric for assessing the occurrence and severity of meteorological and hydrological drought. The SPEI compares the net water balance between precipitation and potential evapotranspiration between a recent period of time and a historical period.[61]

The SPEI allows for comparison of drought severity in different locations and times and for identification of different drought types, including consideration of the role of temperature in drought assessment. The 12-month SPEI is a reliable predictor of annual streamflow in the Northwest and water levels in lakes and reservoirs.[62] The SPEI employs a Drought Severity Scale where 0 represents normal and drought is represented by negative numbers (-1 to -1.49 = moderate drought; -1.5 to -1.99 = severe drought; -2.0 or less = extreme drought).

[60] https://climatedataguide.ucar.edu/climate-data/palmer-drought-severity-index-pdsi
[61] Fifth Oregon Climate Assessment, 2021; OCAR5.pdf | Powered by Box
[62] Ibid.

Figure 11. Standardized Precipitation-Evapotranspiration Index (SPEI) 1896-2020



Source: West Wide Drought Tracker https://wrcc.dri.edu/wwdt/time/

Based on the SPEI drought index, among the 125 years for which the index was calculated, Wallowa County experienced moderate drought in 15 of those 125 years (2015, 2005, 1992, 1990, 1988, 1987, 1973, 1944, 1939, 1937, 1935, 1929, 1924, 1908, and, 1905) and severe drought in 8 of those 125 years (1919, 1934, 1967, 1994 and 2007 among them).

For further comparison of these methods for drought prediction, please consult the National Center for Atmospheric Research.[63]

History of Drought in Wallowa County and Oregon

On a statewide basis some Oregon droughts were especially significant during the period of 1928 to 1994. The period from 1928 to 1941 was a prolonged drought that caused major problems for agriculture. The only area spared was the northern coast, which received abundant rains in 1930-33. The three Tillamook burns (1933, 1939, and 1945) were the most significant results of this very dry period.

[63] https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-evapotranspiration-index-spei

During 1959-1962 stream flows were low throughout Eastern Oregon, but areas west of the Cascades had few problems. The peak year of the drought was 1992, when a drought emergency was declared for all of Oregon. Forests throughout the state suffered from a lack of moisture. Fires were common and insect pests, which attacked the trees, flourished.

State declaration of drought conditions were made in northeastern counties during 2001, 2002, 2003, 2005, 2007 and 2013. Table 10 on the following page displays all the statewide, eastern Oregon, and northeast Oregon droughts since 1904. Droughts in Wallowa County are indicated with bold lettering.

During the 2005 drought the Governor issued declarations for eight counties, all east of the Cascades, and the USDA issued three drought declarations, overlapping two of the Governor's. State declarations were made for Wallowa, Baker, Crook, Gilliam, Hood River, Klamath, Morrow, Sherman, and Umatilla counties. Federal declarations were made in Coos, Klamath, and Umatilla counties. Wheeler County made a county declaration. The USDA declarations provided access to emergency loans for crop losses.

Table 10. History of Drought in Wallowa County and Northeast Oregon

Year	Location	Description
1904-1905	Statewide	A statewide drought period of about 18 months
1917-1931	Statewide	A very dry period punctuated by brief wet spells in 1920-21 and 1927
1928-1941	Statewide	A significant drought affected all of Oregon from 1928 to 1941. The prolonged statewide drought created significant problems for the agricultural industry. Punctuated by a three-year intense drought period from 1938-1941.
1938-1939	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
1959-1964	Eastern Oregon	Stream flows were low throughout eastern Oregon
1976-1981	Statewide	Low stream flows prevailed in Western Oregon during the period from 1976-1981, but the worst year, by far, was 1976-1977, the single driest year of the century.
1977	Central and eastern Oregon	FEMA Major Disaster Emergency Management Declaration EM-3039, April 29, 1977. A severe drought for northeast Oregon
1985-1994	Statewide	A dry period lasting from 1985 to 1994 cased significant problems statewide. The peak year was 1992, when the state declared a drought emergency. Malheur Lake declined in area over a six-year period from 175-000 acres to 400 acres (this was following abnormally large snow accumulations in the years preceding the drought period which increased the size of the lake.)
1994	Regions 4–8	in 1994, Governor's drought declaration covered 11 counties located within regions 4, 5, 6, 7, and 8
1999	**Wallowa**, Baker, Grant, and Union	Wallowa, Baker, Grant, and Union Counties were declared disaster areas by the Department of Agriculture due to drought. Approximately one-third of the wheat crop in those areas was lost due to weather.
2001	Baker, Union and **Wallowa**	Baker, Union and Wallowa Counties were issued declarations of local drought emergencies.
2002	southern and eastern Oregon	2001 drought declarations remain in effect for all counties, including Region 7's **Wallowa,** Baker, and Union Counties; Governor adds Grant County in 2002, along with five additional counties, bringing statewide total to 23 counties under a drought emergency.
2003	southern and eastern Oregon	Governor issues new declarations for **Wallowa** (EO 03-09), Baker, and Union Counties, which are in effect through December 2003
2004	Region 5-8	Baker County receives Governor-declared drought emergency in June 2004 along with three other counties in neighboring regions
2005	Regions 5–7	**Wallowa** and Baker Counties receive a Governor's drought declaration (EO-05-06); 13 counties affected statewide
2007	Regions 6-8	Grant, Baker, and Union Counties received a Governor drought declaration; three other counties affected in neighboring regions
2013	Regions 5-8	Baker County receives a drought declaration, as well as four other counties in neighboring regions
2014	Regions 4, 6-8	Grant and Baker Counties receive drought declarations; including eight other counties across other regions

2015	statewide	36 Oregon Counties across the state receive federal drought declarations, including 25 under Governor's drought declaration.
2018	Regions 1, 4-8	Baker and Grant Counties receive Governor's drought declaration, including 9 other counties in 5 other regions
2020	Region 7	Baker County received a determination of a State of Drought Emergency due to unusually low water supplies and hot, dry conditions.

Source: 2014 Northeast Oregon Natural Hazard Mitigation Plan update; 2020 Oregon State Natural Hazard Mitigation Plan

INSECT PESTS, NOXIOUS WEEDS, AND INVASIVE SPECIES HAZARD ANNEX

Planning for mitigation of this hazard focuses importance on the agricultural, grazing and timber resources of Wallowa County. Pasture resources are at risk from the slow, but steady spread of non-native invasive grasses. These grasses in turn render the landscape more susceptible to wildfire.[64] Timber resources are at risk due to increased activity of bark beetles, defoliating insects and sap-sucking insects.

Insects Pests, Noxious Weeds, and Invasive Species now pose a natural hazard in and of themselves. The natural resource base of the economy in Wallowa County dictates the consideration of this natural hazard and measures that can serve to mitigate the increased damage being sustained annually.

Characteristics: Type, Location and Extent

During the Steering Committee's review of risks that pose a potential impact the people, economy and built and natural environments of the communities in Wallowa County, threats to pasture resources and to timber resources posed by Insect Pests, Noxious Weeds and Invasive Species was identified as a separate and distinct natural hazard. Although the impact of these species is exacerbated by drought stress and extreme heat, the impact of insect pests on timber species in turn exacerbates the risk of wildfire. The ranchers of the Wallowa Valley recognize the risk to pasture resources and animal health from the spread of noxious weeds. The following specific species are of concern in Wallowa County.

Insect Pests

The following species are pests of timber species in Wallowa County and may cause up to xxx damage.

Bark beetles

Douglas-fir beetle: Douglas-fir beetle (*Dendroctonus pseudotsugae*) is a bark beetle that preferentially infests >10" dbh downed trees and then moves to nearby standing trees that are stressed, injured or less vigorous. At normal population levels, mortality from this pest is scattered on the landscape and often present in stands weakened by root disease, fire or wind damage. Population outbreaks typically follow storm events that cause blowdown, or defoliation from Douglas-fir tussock moth or western spruce budworm outbreaks.[65]

Fir engraver: The fir engraver beetle (*Scolytus ventralis*) is a bark beetle that is a significant pest of mature and pole-sized true fir. Although this insect is considered a secondary pest it can be a major contributor to mortality, particularly for drought-stressed true fir. Outbreaks of this pest

[64] Fifth Oregon Climate Assessment Report, OCCRI 2021, OCAR5.pdf | Powered by Box

[65] Douglas-fir-beetle.pdf (oregon.gov)

in Oregon are often associated with drought events. In addition to drought, other stressors such as root disease, defoliator outbreaks and stand disturbance from logging and other activity also contribute to increased susceptibility to beetle attacks. Non-lethal attacks from fir engraver (strip or patch kills) can cause physical defects in wood and introduce staining fungi.[66]

Mountain Pine beetle (Whitebark, Lodgepole, ponderosa, and white pine): Mountain pine beetle (*Dendroctonus ponderosae*) is the most destructive forest pest in the west and has contributed to more tree mortality than any other bark beetle in Oregon. Between 2007 and 2016 the average number of acres containing pine mortality from mountain pine beetle was estimated at 380,000 acres per year. Older, unmanaged (over-grown) stands of pine are most susceptible to this pest. These dense, "dog-hair" stands of lodgepole pine that have long been unmanaged and untouched by fire are often ground zero for mountain pine beetle outbreaks. At endemic levels, beetles will selectively attack stressed or weakened trees but during outbreaks, healthy trees and less preferred pine hosts may also be attacked.[67]

Defoliators

Douglas-fir tussock moth: The Douglas-fir tussock moth (DFTM; *Orgyia pseudotsugata*) is a major defoliator of Douglas-fir and true firs in the western United States. Tussock moths occur in most forests in Oregon, but episodes of severe defoliation have been mostly restricted to the Blue Mountains of northeastern Oregon as well as Klamath and Lake counties. Trees growing along exposed ridges or on less productive sites are most at risk for attack. Defoliation by this insect can cause top kill, reduce radial growth and result in up to 40% tree mortality. Outbreaks typically subside within 1-2 years. Several agencies in Oregon annually survey for DFTM population spikes via pheromone-baited traps.[68]

Larch casebearer/Hypodermella*:* Larch casebearer (*Coleophora laricella*) is an established, exotic defoliator that attacks western larch. Native and introduced natural enemies play an important role in controlling this pest. Damage from larch casebearer, which is heaviest at the top of the crown, may be confused with that from two fungal diseases in larch, which are heaviest at the base.[69]

Sapsuckers

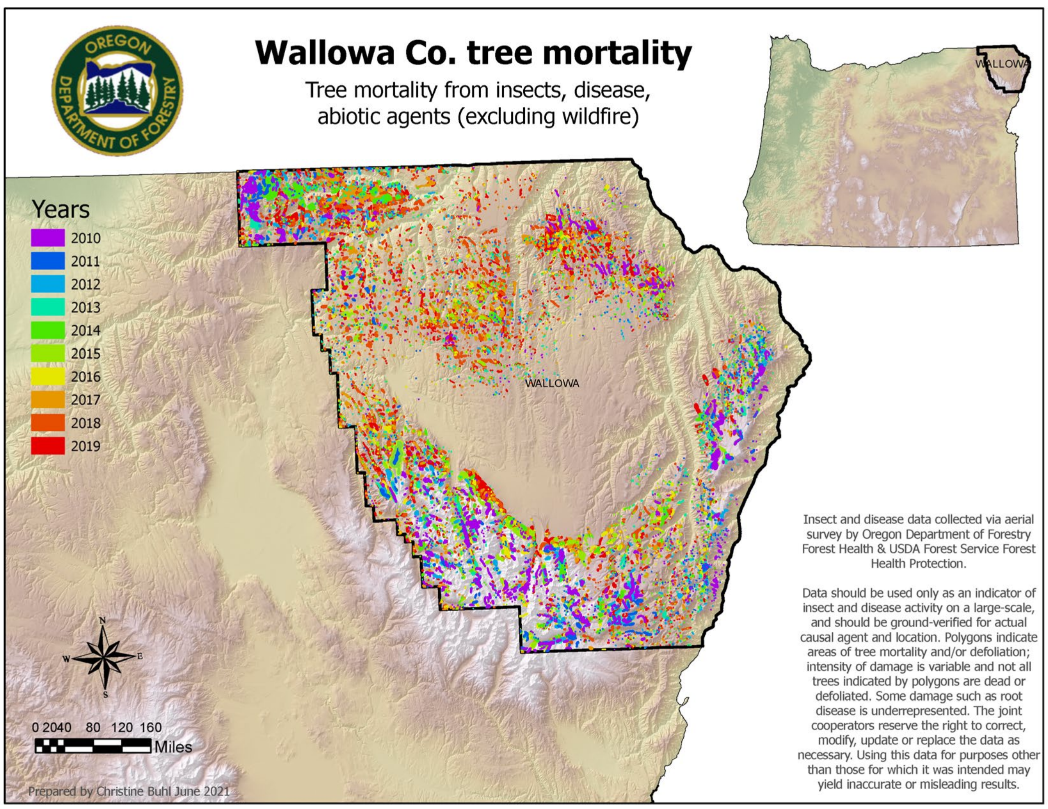
Balsam woolly adelgid*:* Adelgids are sap-sucking insects similar to aphids, but they feed only on conifers. Feeding by these insects can result in growths called galls. Adelgids cause mainly cosmetic damage, although chronic infestations can reduce tree growth, alter form, or result in mortality. Two major adelgids in Oregon are the established exotic, Balsam woolly adelgid (BWA; *Adelges piceae*), and the native Cooley spruce gall (CSG; *Adelges coolyi)*. BWA is a major

[66] FirEngraverBeetle.pdf (oregon.gov)
[67] MountainPineBeetle.pdf (oregon.gov)
[68] douglas-fir-tussock-moth.pdf (oregon.gov)
[69] LC_2017.pdf (oregon.gov)

pest in the Willamette Valley and Cascades where it has contributed to the long-term decline of several fir species.[70]

The extent and severity of Insect Pests of timber species is monitored by both the Oregon Department of Forestry (ODF) and the US Department of Agriculture through the US Forest Service (USFS). ODF conducts aerial surveys annually to collect information on tree mortality due to insect pest infestations (Figures 14 & 15). Over the past decade, detailed data on severity and species has been collected. Drought stress influences insect pest infestation, Christine Buhl, the Oregon State Forest Entomologist, confirmed by email. Dr. Buhl noted that it has only been in the last few years that aerial surveyors had the ability to mark trees as "drought" on survey narratives. She noted that drought is one of the most common primary stressors on a large scale. Secondary smaller scale stressors may be root disease, or mechanical damage caused by fire or storm damage. While stand mortality may be attributed to an insect pest in the aerial survey data in order to stay consistent with historical reporting, she notes that management techniques must address drought to be successful.[71]

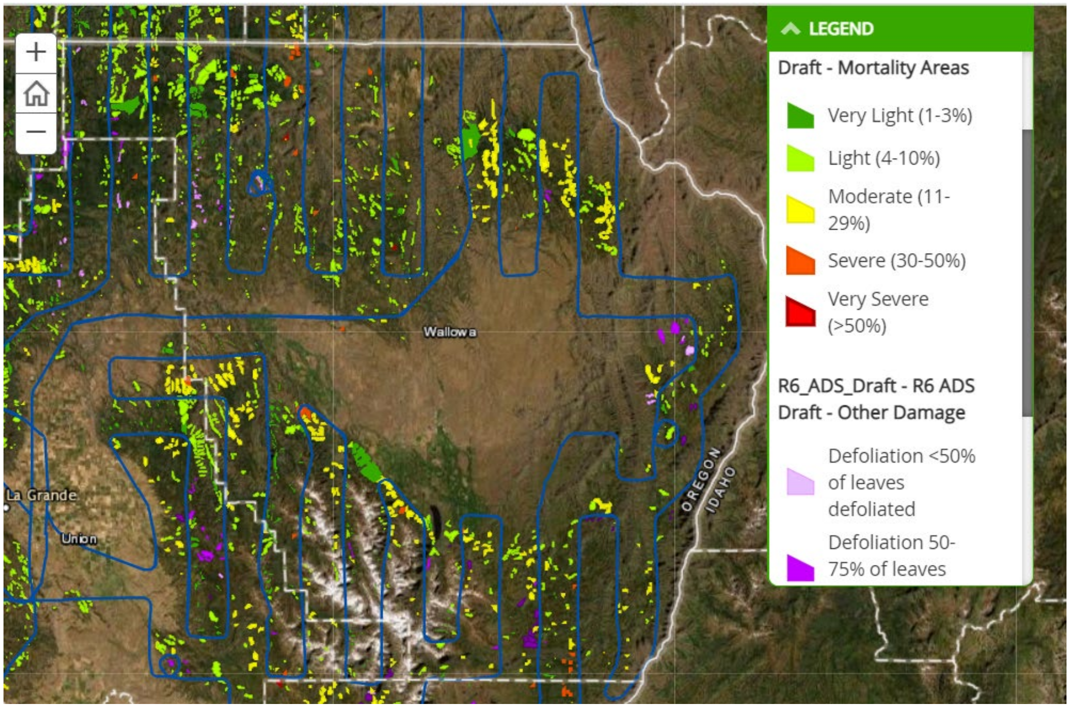
Figure 12. Forest Tree Mortality 2010-2019



Source: State Forest Entomologist, Christine Buhl, personal communication with K. Daniel, DLCD, June 2021.

[70] Adelgids_2017.pdf (oregon.gov)
[71] Personal communication, Dr. Christine Buhl, State Forest Entomologist,with K. Daniel, DLCD, June 2021

Figure 13. Aerial survey data on degree of tree mortality



Source: USFS Forest Mortality areas and aerial detection survey flight paths

With respect to management considerations, the guild, or group, of the insect pest determines appropriate management directions. For example, management for bark beetles should be directed toward planting species that can tolerate future climate trends in the target microclimate, increasing water availability and opening up stands so that attractive volatiles flow through. For defoliators, management should be directed toward diversifying species and avoiding too much Douglas Fir and true fir in dry spots. For balsam woolly adelgid, management should be directed toward sanitation due to the exotic nature of the balsam wooly adelgid and also managing by intermixing non-fir species which are not susceptible to this pest. Management for larch casebearer should be focused on intermixing species, avoiding open grown larch and improving resilience to tolerate defoliation.[72]

Noxious Weeds

Effectively managing threats from invasive weeds requires coordinated strategies on a local and regional scale. Wallowa County has been facing the challenge of invasive weeds since 1921 when it formed the Wallowa County Weed Control District. The *Wallowa County Integrated Weed Management Plan* forms the basis for mitigation of aspect of this natural hazard. This integrated weed management plan operates within the context of the *Wallowa County Nez Perce Salmon*

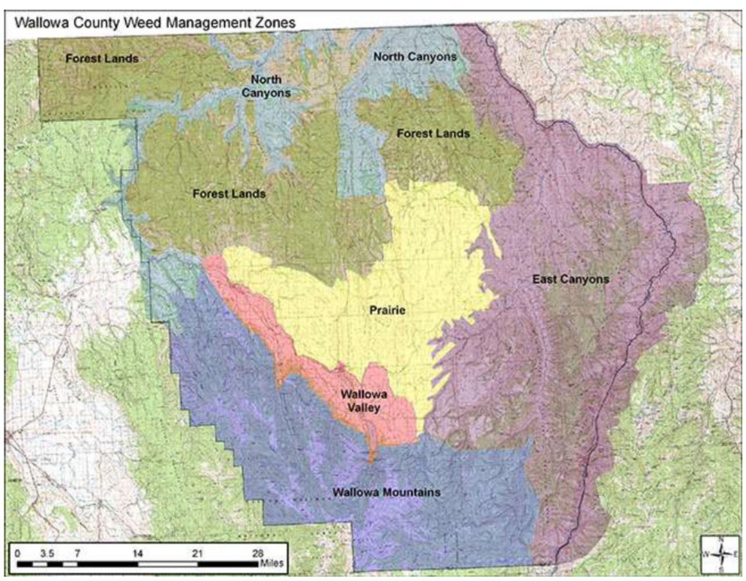
[72] Personal communication, Dr. Christine Buhl, State Forest Entomologist, paraphrased by K. Daniel, DLCD, June 2021

Habitat Recovery Plan, Oregon State Law and *Oregon's Comprehensive Guide for the Protection of Oregon's Resources* (2001). [73]

The Wallowa County Weed Board is a volunteer body that represents a cross section of local citizens. It actively provides professional and technical recommendations to the Wallowa County Board of Commissioners and works cooperatively with the Vegetation Manager and the Public Works Director. The Vegetation Department is the primary entity responsible for implementing the *Integrated Weed Management Plan* in the Weed Control District in accordance with county weed policies, and for enforcing noxious weed laws. Other partners to the Vegetation Manager and the Weed Board include local, federal, and state land management agencies, local service districts, tribal governments, non-profit organizations, Cooperative Weed Management Areas (CWMAs), and interested citizens. [74]

The *Wallowa County Integrated Weed Management Plan* prioritizes noxious weed species for treatment using a risk assessment based on the competitive nature of specific weeds, and their occurrence in Management Zones delineated by bio-physical and topographical attributes. The Management Zones include the Wallowa Mountains, North Canyons, East Canyons (defined by the Grande Ronde River and the Imnaha/Snake Rivers respectively), Wallowa Valley, and Forest Lands that are distributed amongst the other zones (see Map 1). This prioritization process provides a baseline for decision making by land managers in the Weed Control District.

Figure 14. Wallowa County Weed Management Zones



Map 1. *Wallowa County Weed Control District. Weed district boundary is the county line. Colored areas represent management zones.*

Source: Wallowa County Integrated Weed Management Plan, August 2013

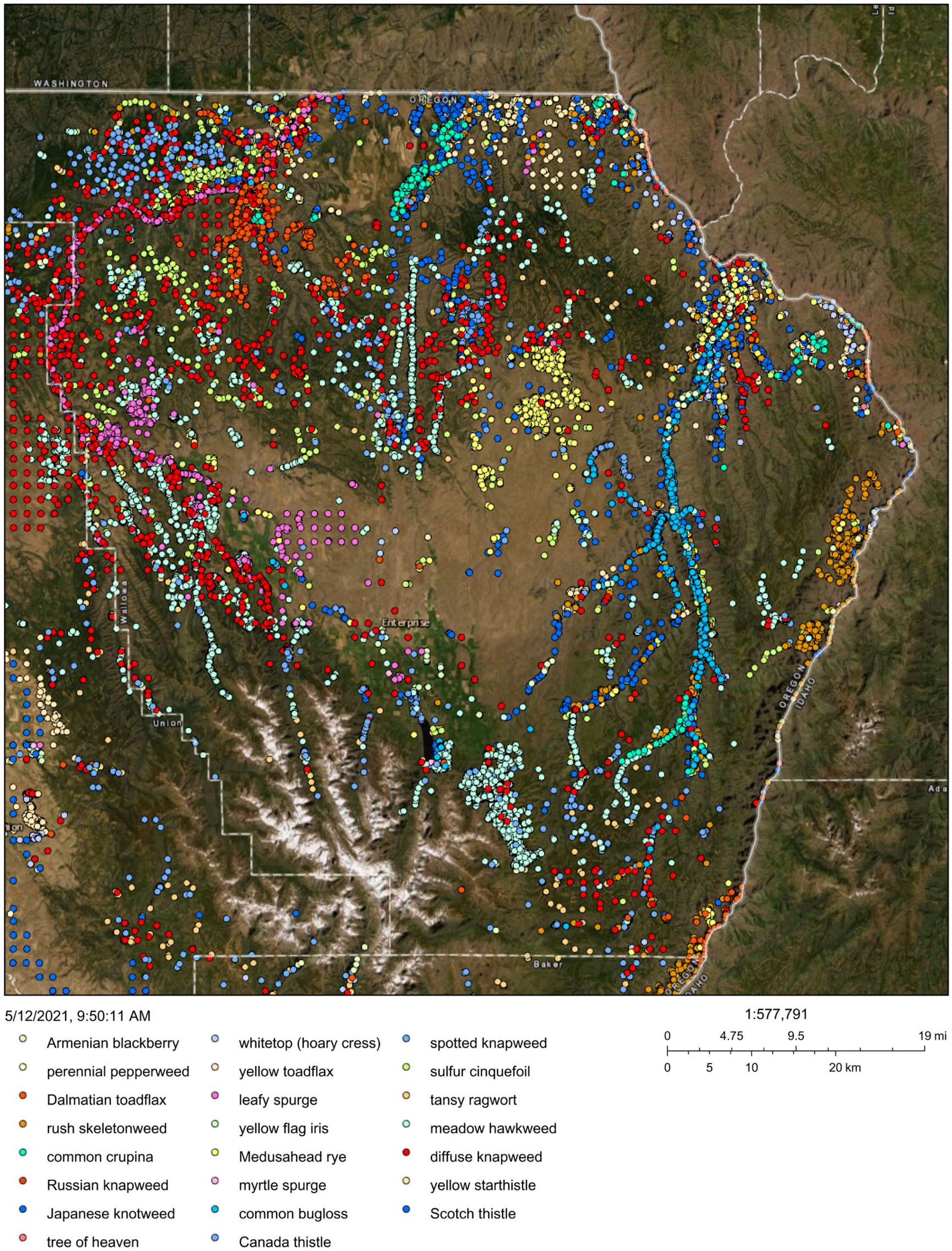
[73] *Wallowa County Integrated Weed Management Plan*, Wallowa County Commissioners, August 2013
[74] Ibid.

Since the formation of the Weed Control District, which encompasses the entire county, local government has adopted several weed control ordinances including hay quarantine, a weed-free forage inspection program, and an enforcement policy. In 2012, a five-year serial tax for the control of noxious weeds was approved by local voters ($0.19/$1,000 of assessed property value) generating approximately $112,000.00 annually for five years. The Wallowa Integrated Weed Management Plan provides information about annual action plans for the primary partners in the weed district, and supplementary information to help partners in the prioritization and implementation of weed control projects.

Noxious weeds currently rated as the top priority today include common bugloss, leafy spurge, meadow hawkweed, knapweeds, dalmatian toadflax, sulfur cinquefoil, rush skeletonweed, and yellow starthistle. Common bugloss and whitetop have established a competitive presence in the Imnaha River watershed, and rush skeletonweed is being detected in increasing numbers in the North and East Canyons. Yellow starthistle continues to spread across canyon lands, and a dalmatian toadflax invasion is being battled in the north canyons and ridge tops. Knapweeds, especially spotted, are increasing over thousands of acres, and leafy spurge is spreading along the Wallowa and Grande Ronde Rivers, and adjacent agricultural lands.

The Oregon Department of Agriculture has developed a geospatial mapping tool that displays a collection of spatial information on the distribution of noxious weeds listed by the Oregon Department of Agriculture. The map below was provided by Christine Buhl and shows the distribution of noxious weed species throughout Wallowa County.

Figure 15. Noxious Weed Locations in Wallowa County



Source: ODA Noxious Weed Control Program, ODA WeedMapper consulted May 2021

Invasive Species

Invasive species are animals, plants, and microorganisms that are not native to Oregon and once here can reproduce so vigorously that they replace our native species. They pose a threat to key sectors of Oregon's economy that depend upon natural resources and native ecosystems.[75] Several of the Noxious Weeds that threaten rangeland in Wallowa County and one of the Insect Pests that affects timber species in the county are considered Invasive Species.

The Oregon Invasive Species Council published a new handbook on this problem that highlights the issues surrounding the annual grass Medusahead, and the Turkish Thistle, both invasive plant species that threaten rangeland. The report also highlights the virus that causes Hoof and Mouth Disease in cattle and, the Balsam Wooly Adelgid that is a threat to the sub-alpine fir.

History of Insect Pests, Noxious Weeds and Invasive Species

Insect pests of timber species have been present for many decades. An historic review of insect and disease infestations in the Blue Mountains is provided by Boyd Wickman, 1992 publishing in a USFS general technical report. "A science perspective of forest health in the Blue Mountains is summarized by using both historical and biological information. Many of the current pest problems are related to human activities that have occurred over the last 90 years. The almost complete loss of periodic low-intensity fires since 1900 plus extensive logging of pine have resulted in many thousands of acres of fir occupying pine sites. These fir forests are highly susceptible to pests and to catastrophic forest fires. Some long-term management strategies are now needed to alleviate the problems. Research recommendations also are suggested as part of the long-term solution."

With respect to Noxious Weeds, these species have been a concern in Wallowa County since the 1920's. Wallowa County formed a Weed Control District on July 26, 1921, when the primary weeds of concern were Jim Hill mustard (*Sisymbrium altissimum* L.), Canada thistle (*Cirsium arvense*), and devil weed (*Thlaspi arvense L*.). Now, more than ninety years later, the weed list has expanded over 10-fold.[76]

Currently the Weed Control District operates under Oregon Regulatory Statute (ORS) 569.350. The Weed Control District boundary is the county line. The management objective of the Weed Control District is: To promote healthy and diverse ecological communities by using early detection and integrated weed management techniques, including restoration and rehabilitation, to eradicate new infestations and contain and/or reduce existing populations.[77]

The weed district supports the responsible use of natural resources by the local community. Stock growers, loggers, farmers, and other resource managers are invaluable allies in finding and controlling noxious weeds and in creating healthy plant communities that are more resistant to noxious weeds. However, it is also recognized that any disturbance from resource use can provide a niche and a vector for noxious weeds. Therefore, all landowners and managers in the district are

[75] Oregon Invasive Species Council Oregon Invasive Species Council
[76] Wallowa County Integrated Weed Management Plan, August 2013
[77] Ibid.

encouraged to consider the risk created by disturbance and the potential for noxious weed invasion and manage accordingly.[78]

Community Hazard Issues and Damage Susceptibility

Issues faced by the community with respect to outbreaks of infestations of timber insect pests and control of noxious weeds that threaten rangelands have been a community concern for decades. Organizations and partnerships have been established to address these concerns both within the forestry industry and within the ranching industry. The community is quite susceptible to damage from outbreaks of this natural hazard and as a result, there are plans in place to mitigate damage from them.

The Oregon Department of Forestry (ODF) maintains a Forest Health program that helps maintain and improve the health of Oregon's private and state-owned forests. Forest health professionals conduct aerial and ground surveys to monitor forest insects and tree diseases. They provide technical advice and training in the use of integrated pest management principles to help professional foresters and landowners meet their management goals and objectives. ODF's Unit Forester in Wallowa County serves as the connection point to ODF for private forest owners with respect to forest insect pests and their control.

The county has a program supported by OWEB for control of noxious weeds. The Wallowa County Integrated Weed Management Plan (IWMP) provides a written strategy to inform, and guide weed management activities over time for the Wallowa County Weed Control District. Oregon Watershed Enhancement Board (OWEB) supports this work with grant funding. This plan provides a framework for coordinating countywide noxious weed management within a regional context. Land managers with federal and state agencies, county and tribal governments, private landowners, and community groups may use it as a guide for prioritization of projects through risk assessments of real or potential threats by a specific weed, or to a specific site. This dynamic process is built into the system by allowing for five-year goal setting and the annual additions of work plans.

The Wallowa County Commissioners adopted the Wallowa County Integrated Weed Management Plan in August 2013, almost ten years ago. Wallowa Resources was a partner in that plan and continues to amplify the work of Wallowa County through the Wallowa Canyonlands Partnership (WCP), a cross-jurisdictional pilot program for controlling noxious weeds across fence lines. The WCP has coordinated over 17,500 acres of noxious weed mitigation. The Forest Service as well as the Nature Conservancy were also partners in that 2013 plan.

[78] Wallowa County Integrated Weed Management Plan, August 2013

LANDSLIDE HAZARD ANNEX

Landslides are a chronic problem in our state, affecting both infrastructure and private property. Approximately 13,048 documented landslides have occurred in Oregon in the last 150 years. The combination of geology, precipitation, topography, and seismic activity makes portions of Oregon especially prone to landslides.[79]

Landslides are a geologic hazard in almost every state in America. Nationally, landslides cause 25 to 50 deaths each year.[80] In Oregon, economic losses due to landslides for a typical year are estimated to be over $10 million.[81] In years with heavy storms, such as in 1996, losses can be an order of magnitude higher and exceed $100 million.[82]

While not all landslides result in private property damage, many landslides impact transportation corridors, fuel and energy conduits, and communication facilities. They can also pose a serious threat to human life. Increasing population in Oregon and the resultant growth in home ownership has caused the siting of more development in or near landslide areas. Often these areas are highly desirable owing to their location along the coast, rivers, and on hillsides.

Characteristics and Causes of Landslides

Landslides are fairly common, naturally occurring events in various parts of Oregon. In simplest terms, a landslide is any detached mass of soil, rock, or debris that falls, slides or flows down a slope or a stream channel. Landslides are classified according to the type and rate of movement and the type of materials that are transported.

In a landslide two forces are at work: 1) the driving forces that cause the material to move down slope, and 2) the friction forces and strength of materials that act to retard the movement and stabilize the slope. When the driving forces exceed the resisting forces, a landslide occurs.

All landslides can be classified into one of the following six types of movements: (1) slides, (2) flows, (3) spreads, (4) topples, (5) falls, or (6) complex. Most slope failures are complex combinations of these six distinct types, but the generalized groupings provide a useful means for framing discussion of the type of hazard and potential mitigation actions. Movement type should be combined with

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[79] Sears, Lahav, Burns and McCarley. 2019. Preparing for Landslide Hazards: A Land Use Guide for Oregon Communities https://www.oregon.gov/lcd/Publications/Landslide_Hazards_Land_Use_Guide_2019.pdf

[80] Mileti, Dennis. 1999. Disasters by Design: A Reassessment of Natural Hazards in the United States. Washington D.C.: Joseph Henry Press.

[81] Wang, Yumei, Renee D. Summers, R. Jon Hofmeister, and Oregon Department of Geology and Mineral Industries. 2002. "Open-File Report O-02-05: Landslide Loss Estimation Pilot Project in Oregon."

[82] Ibid.

other landslide characteristics such as type of material, rate of movement, depth of failure, and water content to understand more fully the landslide behavior.[83]

In addition, landslides may be broken down into the following two categories: (1) rapidly moving; and (2) slow moving. Rapidly moving landslides are typically “off-site” (debris flows and earth flows) and present the greatest risk to human life, and persons living in or traveling through areas prone to rapidly moving landslides are at increased risk of serious injury. Rapidly moving landslides have also caused most of the recent landslide-related injuries and deaths in Oregon. Slow moving landslides tend to be “on-site” (slumps, earthflows, and block slides) and can cause significant property damage, but are less likely to result in serious human injuries.

Landslides vary greatly in the volumes of rock and soil involved, the length, width, and depth of the area affected, frequency of occurrence, and speed of movement. Some characteristics that determine the type of landslide are slope of the hillside, moisture content, and the nature of the underlying materials.

One type of landslide that is commonly life threatening is channelized debris flow, sometimes referred to as a rapidly moving landslide or RML. They are more prevalent and impactful than most people recognize. Channelized debris flows normally initiate on a steep slope, move into a steep channel (or drainage), increase in volume by incorporating channel materials, and then deposit material, usually at the mouth of the channel on existing fans. Debris flows can be mobilized by other types of landslides that occur on slopes near a channel. Debris flows can also initiate within channels from accelerated erosion during heavy rainfall or snowmelt. These debris flows move fast enough that they are difficult to outrun[84].

Debris flows or mudflows are a hybrid possessing some characteristics of landslide and some characteristics of flooding. As water runs downhill through burned areas, it can create major erosion and pick up large amounts of ash, rocks, boulders, and burned trees, generating a debris flow (also commonly termed “mudflow”). Fast-moving, highly destructive debris flows are one of the most dangerous post-fire hazards since they occur with little warning. High rainfall rates are the trigger for debris flows, rather than the total amount of rain. Their mass and speed make them particularly destructive. Debris flows can strip vegetation, block drainages, damage structures, and endanger human life. The force of the rushing water and debris can threaten life and property miles away from the burned area. Survivors of debris flows describe sounds of cracking, breaking, roaring, or a freight train.[85]

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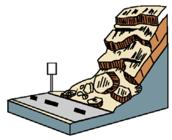
[83] U.S. Transportation Research Board Special Report 247, Landslides: Investigation and Mitigation,Turner & Schuster, 1996

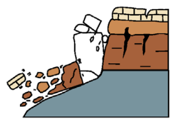
[84] Preparing for Landslide Hazards: A Land Use Guide for Oregon Communities (October 2019)

[85] Oregon Post-Wildfire Flood Playbook, 2018, USACE Silver Jackets

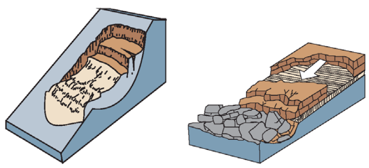
Figure 16. Types of Common Landslides in Oregon



Falls are near-vertical, rapid movements of masses of materials, such as rocks or boulders. The rock debris sometimes accumulates as talus at the base of a cliff.

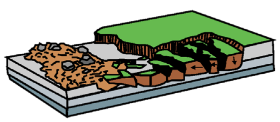


Topples are distinguished by forward rotation about some pivotal point, below or low in the mass.

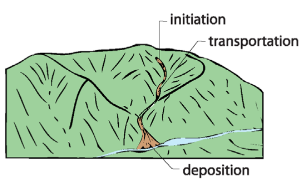


Slides are downslope movement of soil or rock on a surface of rupture (failure plane or shear-zone).

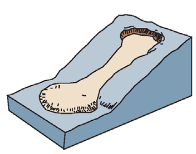
- **Rotational** slides move along a surface of rupture that is curved and concave.
- **Translational** slides displace along a planar or undulating surface of rupture, sliding out over the original ground surface.



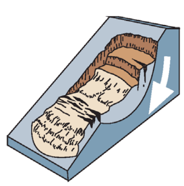
Spreads are commonly triggered by earthquakes, which can cause liquefaction of an underlying layer and extension and subsidence of commonly cohesive materials overlying liquefied layers.



Channelized Debris Flows commonly start on a steep, concave slope as a small slide or earth flow into a channel. As this mixture of landslide debris and water flows down the channel, it pick ups more debris, water, and speed, and deposits in a fan at the outlet of the channel.



Earth Flows commonly have a characteristic "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head.



Complex landslides are combinations of two or more types. A common complex landslide is a slump-earth flow, which usually exhibit slump features in the upper region and earth flow features near the toe.

Source: Preparing for Landslide Hazards: A Land Use Guide for Oregon Communities (October 2019)

Conditions Affecting Landslides

Natural conditions and human activities can both play a role in causing landslides. Certain geologic formations are more susceptible to landslides than others. Locations with steep slopes are at the greatest risk of slides. However, the incidence of landslides and their impact on people and property can be accelerated by development. Developers who are uninformed about geologic conditions and processes may create conditions that can increase the risk of or even trigger landslides.

The following are principal factors that affect or increase the likelihood of landslides:

- Natural conditions and processes including the geology of the site, rainfall, wave and water action, seismic tremors and earthquakes and volcanic activity.
- Excavation and grading on sloping ground for homes, roads and other structures. Improper excavation practices, sometimes aggravated by drainage issues, can reduce the stability of otherwise stable slopes.
- Drainage and groundwater alterations that are natural or human-caused can trigger landslides. Human activities that may cause slides include broken or leaking water or sewer lines, water retention facilities, irrigation and stream alterations, ineffective storm water management and excess runoff due to increased impervious surfaces.
- High rainfall accumulation in a short period of time increases the probability of landslides. An extreme winter storm can produce inches of rainfall in a 24 hour period; if the storm occurs well into the winter season, when the ground is already saturated, the hydraulic overload effect is heightened.
- Change or removal of vegetation on very steep slopes due to timber harvesting, land clearing and wildfire.

Although landslides are propelled by gravity, they can be triggered by other natural geologic events or human activity. Volcanic eruptions and earthquakes can initiate earth movement on a grand scale. Although earthquakes can initiate debris flows, the major causes of landslides in the northwest are continuous rains that saturate soils. Landslides can also be the direct consequence of human activity. Seemingly insignificant modifications of surface flow and drainage may induce landslides. In an urban setting, improper drainage is most often the factor when a landslide occurs.

Many unstable, landslide prone areas can be recognized. Tip-offs include scarps, tilted, and bent (“gun-stocked”) trees, wetlands and standing water, irregular and hummocky ground topography, and over steepened slopes with a thick soil cover. The technology of spotting landslides by use of aerial photography and new laser-based terrain mapping called lidar is helping DOGAMI develop much more accurate and detailed maps of areas with existing landslides, and they are now able to create landslide susceptibility maps, that is, maps that that show where staff geologists estimate that different types of landslides may occur in the future.

In general, areas at risk to landslides have steep slopes (25 percent or greater,) or a history of nearby landslides. In otherwise gently sloped areas, landslides can occur along steep river and creek banks, and along ocean bluff faces. At natural slopes under 30 percent, most landslide hazards are related to excavation and drainage practices, or the reactivation of preexisting landslide hazards.[86]

[86]Interagency Hazard Mitigation Team.2012 - Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management

Allowing development on or adjacent to existing landslides or known landslide-prone areas raises the risk of future slides regardless of excavation and drainage practices. Homeowners and developers should understand that in many potential landslide settings there are no development practices that can completely assure slope stability from future slide events.

Building on fairly gentle slopes can still be subject to landslides that begin a long distance away from the development. Sites at greatest risk are those situated against the base of very steep slopes, in confined stream channels (small canyons), and on fans (rises) at the mouth of these confined channels. Home siting practices do not cause these landslides, but rather put residents and property at risk of landslide impacts. In these cases, the simplest way to avoid such potential effects is to locate development out of the impact area, or construct debris flow diversions for the structures that are at risk.

Certain forest practices can contribute to increased risk of landslides. Forest practices may alter the physical landscape and its vegetation, which can affect the stability of steep slopes. Physical alterations can include slope steepening, slope-water effects, and changes in soil strength. Of all forest management activities, roads have the greatest effects on slope stability, although changing road construction and maintenance practices are reducing the effects of forest roads on landslides.

The severity or extent of landslides is typically a function of geology and the landslide triggering mechanism. Rainfall initiated landslides tend to be smaller, and earthquake induced landslides may be very large. Even small slides can cause property damage, result in injuries, or take lives. Natural conditions and human activities can both play a role in causing landslides. The incidence of landslides and their impact on people and property can be accelerated by development.[87]

Slopes that have failed in the past often remain in a weakened state, and many of these areas tend to fail repeatedly over time. For example, a channel with a debris flow fan at its mouth indicates a history of debris flows in that channel. The formation of talus slopes indicates that numerous rock falls have occurred above the slope. Talus is "[a]n outward sloping and accumulated heap or mass of rock fragments of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep, rocky slope, and formed chiefly by gravitational falling, rolling, or sliding" (USGS).[88]

The tendency for failures to reoccur is true for all types of landslide movements and over periods much longer than human recorded history. Large landslide complexes may have moved dozens of times over thousands of years, with long periods of stability punctuated by episodes of movement. In some cases, areas that have previously failed have subtle topographic morphology now, making them difficult to identify. However, technological advances such as lidar have greatly helped in the process of identifying and mapping older landslides. Identifying and mapping both historical and

[87] DLCD, CPW, Planning for Natural Hazards: Oregon Technical Resource Guide, 1999
[88] Preparing for Landslide Hazards: A Land Use Guide for Oregon Communities 2019

ancient landslide areas – many of which will move again – is of great importance for mitigating the risk these natural hazards pose.[89]

Potential slope instability is not limited to past landslide sites. Areas near previous landslides and of similar geology and topography are also at higher risk for slope failure. This makes it even more important to locate previous landslides and study them. Mapping landslide locations can identify nearby or similar areas susceptible to slope instability. [90]

The staff from Oregon Department of Geology and Mineral Industries teamed up with staff from Oregon Department of Land Conservation and Development to develop an updated guide on land use issues for landslide hazards. This Landslide Guide both describes landslides and the methods used to map them more accurately using lidar (Light Detection and Ranging) methods, as well as the types of site specific reporting and the professionals qualified to produce them, mitigation planning topics and the implementation of mitigation actions including a guide to examples of landslide codes for local planners. This document is excerpted in this section and a reference to the full document is available through the following link:
https://www.oregon.gov/lcd/Publications/Landslide_Hazards_Land_Use_Guide_2019.pdf

History of Landslides in Wallowa County and Oregon

Most recently in the Columbia Gorge near Dodson, the winter storms of January 2021 resulted in a rapidly moving landslide that buried a car and driver under 15 feet of mud and debris.[91] Particularly noteworthy landslides accompanied storms in 1964, 1982, 1966, 1996, and 2005. Most of Oregon's landslide damage has been associated with severe winter storms where landslide losses can exceed $100 million in direct damage such as the February 1 1996 event. More winter storm induced landslides occurred in Oregon during November 1996. Intense rainfall on recently past logged land as well as previously unlogged areas triggered over 9,500 landslides and debris flows that resulted directly or indirectly in eight fatalities. Highways were closed and a number of homes were lost. Some of these slides were the reactivation of ancient and historically active landslides and some were new failures. The fatalities and losses resulting from the 1996 landslide events brought about the passage of Oregon Senate Bill 12, which set site development standards, authorized the mapping of areas subject to rapidly moving landslides and the development of model landslide (steep slope) ordinances. Annual average maintenance and repair costs for landslides in Oregon are over $10 million.[92]

In Wallowa County, DOGAMI's SLIDO database contains fifteen landslide, debris flow and rockfall records most of which occurred in the period between 1996 and 1997. Debris flows that carried 90,000 to 160,000 cubic feet of material blocked Gumboot Creek and damaged two miles of the Wallowa Mountain Road. A separate debris flow moved 300,000 cubic feet of material to leave

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[89] Preparing for Landslide Hazards: A Land Use Guide for Oregon Communities 2019

[90] Ibid.

[91] Authorities recover body of woman who went missing in gorge landslide | kgw.com

[92] Wang and Chaker, 2004. Geological Hazards Study for the Columbia River Transportation Corridor. Oregon Department of Geology and Mineral Industries Open File Report OFR 0-4-08

debris on the Upper Imnaha Road at Nine Point Creek. Three landslides that caused damage to the infrastructure of Highway 3 in the northern portion of Wallowa County in 1996 are also documented in the SLIDO dataset. Two other landslides were documented in the northwestern portion of the county on tributaries to the Grande Ronde (Bear Creek and Courtney Creek) both of which blocked and required repairs to roadways.

Historic landslide records also document a number of slide areas along Highway 82 just over the county line in Union County. Although these slides are not in Wallowa County, Highway 82 is a critical lifeline for access during emergencies. The database also documents three rockfall areas where five or more times per year material is deposited on or near the Joseph Wallowa Lake Highway near the northern end of the lake (Mile Posts 2.05, 2.24 and 2.43) according to Oregon Department of Transportation.

Preparing for Landslide Hazards: A Land Use Guide for Oregon

DOGAMI and DLCD prepared a comprehensive guide on landslide hazard reduction entitled *Preparing for Landslide Hazards: A Land Use Guide for Oregon* (referred to as the Landslide Guide) that addresses what landslides are and the nature of the risk that they pose to people and property along with specific details on the methodology for mapping landslide susceptibility. The Landslide Guide goes beyond the identification of the hazard and description of the risk to mitigation actions that local jurisdictions can to reduce risk from landslides. The Landslide Guide contents will be summarized here and will serve as a key reference to consult when considering mitigation of the risk of landslides in Oregon communities.

The Landslide Guide identifies planning tools and mitigation strategies to reduce landslide hazard risk. Improved mapping is the first step in better identifying areas where landslides have occurred in the past, a landslide inventory map, and susceptible to landslides. This improved mapping based on lidar (Light Detection and Ranging) technology has significantly improved DOGAMI's ability to identify and map landslide features. Lidar is a relatively new technology that allows mappers to see the earth's surface beneath vegetation and trees, as if the earth had been stripped bare. Lidar gives geologists the ability to identify and map landslide features that may have previously been unrecognized or overlooked. DOGAMI has published the landslide inventory maps in a database called SLIDO. Currently SLIDO is at release 4.2 and has been updated to contain 14,326 historic landslide points and 53,311 landslide polygons.[93]

Further analysis that combines geologic information with the landslide inventory can be used to develop landslide susceptibility maps. Once a landslide feature has been recognized and mapped using lidar, several attributes about the slide, such as type of movement and material, depth of failure, direction of movement, volume of material, and initial slope angle are recorded to aid in the creation of landslide susceptibility maps for the local area. The estimated depth of failure or landslide thickness is used to classify some of the landslides as shallow (less than 15 feet depth) or deep (greater than 15 feet depth). The deep and shallow susceptibility maps are produced using the

[93] Introduction - SLIDO - Statewide Landslide Information Database for Oregon (SLIDO) - Oregon Department of Geology and Mineral Industries (oregongeology.org)

landslide inventory data combined with models and highlight the relative risk of a landslide occurring at any given point within the mapped area. These susceptibility maps work in conjunction with landslide inventory maps to provide jurisdictional staff, community leaders, and residents information necessary to reduce the risk of landslides impacting people, property, and the environment.

The Landslide Guide answers questions local planners and property owners may have regarding the type of professionals who are qualified to perform engineering geologic reports or geotechnical engineering reports. Engineering geologic reports and geotechnical engineering reports refer to different but related services performed by geoprofessionals with different professional certifications. Engineering geologic reports focus on how the earth (e.g., landforms, water table, soil, and bedrock) and earth processes (e.g., landslides and earthquakes) impact structures or potential structures and describe the degree of risk, while geotechnical engineering reports focus on the design of building products (e.g., structures, retaining walls, pavements) that can withstand or mitigate for subsurface and geologic conditions.

The primary purpose of the Landslide Guide is to provide a range of tools and strategies for using the information provided by landslide inventory and susceptibility maps and the information in geotechnical engineering or engineering geologic reports.

The Landslide Guide addresses how landslide hazard can be incorporated into comprehensive plans. In Oregon the required components of a comprehensive plan are an inventory of existing conditions; goals and objectives; plan policies; and implementation measures and ordinances. The inventory of existing conditions provides the basis and justification for plan policies. The plan policies provide general guidance in review of land use proposals. The implementing measures and ordinances provide the specific standards and criteria against which development proposals are reviewed. The Cities of Medford, Astoria and Portland provide examples of incorporation of landslide hazard mapping into comprehensive planning.

The Landslide Guide goes further to address the implementation of comprehensive plans through zoning codes. Zoning for natural hazards is often accomplished through zoning overlays, with other related maps, and with corresponding text in the zoning code. A better understanding of the causes and characteristics of landslides, as well as recognizing the locations, types, and extents of landslides leads to more effective plans, policies, and implementing measures. Identifying hazard areas and evaluating proposed development in these areas reduces risk and better protects a community. Zoning ordinances can be a powerful tool for protecting community and private assets against landslides and other hazards.

Finally, the Landslide Guide reviews the codes of thirty-four Oregon communities with respect to landslide hazard and summarizes what makes a strong regulatory framework for reducing hazards from landslide. The Landslide Guide summarizes key ways that communities can reduce risk from landslide as follows:

• **Identify the hazard** – Know what the hazard is, where it is located, what causes it, what are its characteristics, when and where has it occurred historically, and when and where might it happen again.

• **Assess the vulnerabilities** – Inventory and analyze the existing and planned property and populations exposed to a hazard, and estimate how they will be affected by the hazard.

• **Assess the level of risk** – Risk is the expression of the potential magnitude of a disaster's impact. A natural hazards risk assessment involves *Landslide Hazards Land Use Guide for Oregon Communities* characterizing the natural hazards, assessing the vulnerabilities, and describing the risk either quantitatively or qualitatively or both.

• **Avoid the hazard** – Stay away from the hazard area if possible.

• **Reduce the level of risk** - Minimize development, reduce density, and implement mitigation measures. Manage the water on the site. Coordinate land use planning efforts with other planning efforts such as emergency operations plans, transportation plans, economic development plans, stormwater management plans, and so forth.

• **Evaluate development in landslide-prone areas** – Use technical information such as maps and reports, including site specific studies as well as broader scale information.

• **Require geotechnical investigations** – When development is proposed for locations that have landslide hazards, require site specific reports by a certified engineering geologist engineer (geotechnical assessment) or a certified engineering geologist and a geotechnical engineer (geotechnical report).

• **Adopt land use policies and enact regulations** – Regulatory tools such as overlay zones, incentive zoning, grading and erosion control provisions, stormwater management, restrictions on the types of uses and development in landslide-prone areas, size and weight of structures, management of vegetation, and other means can reduce risk of landslides. Incentive zoning requires developers to exceed limitations imposed upon them by regulations, in exchange for specific concessions. For example, if the developer avoids building on a landslide-prone area of the property then they could build on another portion of the land at a higher density than is allowed by the zoning.

• **Consider non-regulatory strategies** – Sharing information, incentives, and purchasing high hazard lands to keep them as open space are examples of strategies that can reduce risk.

• **Provide public outreach and education** – Information about the landslide hazards should be available to all inhabitants of the jurisdiction. Post it on the website, have handouts, and raise awareness of the hazard with the public at large.

EARTHQUAKE HAZARD ANNEX

Causes and Characteristics of Earthquake

Earthquakes occur in Oregon every day; every few years an earthquake is large enough for people to feel; and every few decades there is an earthquake that causes damage. Each year, the Pacific Northwest Seismic Network locates more than 1,000 earthquakes greater than magnitude 1.0 in Washington and Oregon. Of these, approximately two dozen are large enough to feel. These noticeable events offer a subtle reminder that the Pacific Northwest is an earthquake-prone region.

Seismic hazards pose a real and serious threat to many communities in Oregon, including Northeast Oregon, requiring local governments, planners, and engineers to consider their community's safety. Currently, no reliable scientific means exists to predict earthquakes. Identifying seismic-prone locations, adopting strong policies and implementing measures, and using other mitigation techniques are essential to reducing risk from seismic hazards in Northeast Oregon.[94]

Oregon and the Pacific Northwest in general are susceptible to earthquakes from three sources: 1) shallow crustal fault – slippage events within the North American Plate; 2) deep intra-plate events within the subducting Juan de Fuca Plate; and 3) the off-shore Cascadian Subduction Zone.[95] The geographic position of the Northeastern region of Oregon makes it susceptible to earthquakes from two sources: (a) shallow crustal events within the North America Plate, and (b) volcanic-earthquakes.[96]

Northeast Oregon contains high mountains and broad inter-mountain valleys. Although there is abundant evidence of crustal faulting, seismic activity is low when compared with other areas of the state. There are a few identified faults in the region that have been active in the last 20,000 years. The region has been shaken historically by crustal earthquakes and prehistorically by subduction zone earthquakes centered outside the area. All considered, there is good reason to believe that the most devastating future earthquakes would probably originate along shallow crustal faults in the region.

A series of faults are located on the eastern edge of the Wallowa range to the west of the Wallowa Valley cities of Joseph, Enterprise, Lostine and Wallowa. Talus colluvium from ancient landslides is located adjacent to these faults.

Earthquake activity occurs in the vicinity of Hells Canyon, an area with a complex geologic history. Several significant earthquakes that have occurred in Northeastern Oregon include the 1913 Hells Canyon event, earthquakes in 1927 and 1942 in Pine Valley, the 1965 John Day earthquake (M4.4),

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[94]Interagency Hazard Mitigation Team. 2012. Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management

[95] Planning for Natural Hazards: Oregon Technical Resource Guide, Community Planning Workshop, (July 2000), p. 8-8.

[96] 2020 Oregon State Natural Hazard Plan update DRAFT Oregon Natural Hazards Mitigation Plan

and the 1965 and 1966 Halfway earthquakes (M4.3 and 4.2).[97] A brief description of the history of earthquakes in Oregon and Northeastern Oregon follows further down in this section along with a focus specifically on the history of earthquakes in Wallowa County.

Identifying Earthquake Hazards

The Oregon Department of Geology and Mineral Industries (DOGAMI), in partnership with other state and federal agencies, has undertaken a rigorous program in Oregon to identify seismic hazards, including active fault identification, bedrock shaking, tsunami inundation zones, ground motion amplification, liquefaction, and earthquake induced landslides.

The extent of the damage to structures and injury and death to people will depend upon the type of earthquake, proximity to the epicenter and the magnitude and duration of the event.

Types of Earthquakes

Crustal Fault Earthquakes

These are the most common earthquakes and occur at relatively shallow depths of 6-12 miles below the surface.[98] When crustal faults slip, they can produce earthquakes of magnitudes up to 7.0. Although most crustal fault earthquakes are smaller than 4.0 and generally create little or no damage, some of them can cause extensive damage. Earthquakes related to volcanic activity can also affect the region.

Deep Intraplate Earthquakes

Occurring at depths from 18 to 60 miles below the earth's surface in the subducting oceanic crust, deep intraplate earthquakes can reach magnitude 7.5.[99] This type of earthquake is more common in the Puget Sound; in Oregon these earthquakes occur at lower rates, and none have occurred at a damaging magnitude.[100] The February 28, 2001 earthquake in Washington State was a deep intraplate earthquake. It produced a rolling motion that was felt from Vancouver, British Columbia to Coos Bay, Oregon and east to Salt Lake City, Utah.[101]

Subduction Zone Earthquakes

The Pacific Northwest is located at a convergent continental plate boundary, where the Juan de Fuca and North American tectonic plates meet. The two plates are converging at a rate of about 1.5 inches per year.[102] This boundary is called the Cascadia Subduction Zone (CSZ, see Figure EQ-1). It extends from British Columbia to northern California. Earthquakes are caused by the abrupt release of this slowly accumulated stress.

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[97] University of Washington. List of Magnitude 4.0 or Larger Earthquakes in Washington and Oregon 1872-2002; and Wong and Bott, November 1995. A look Back at Oregon's Earthquake History, 1841-1994, *Oregon Geology.*

[98] Madin, Ian P. and Zhenming Wang, Relative Earthquake Hazard Maps Report, DOGAMI, 1999.

[99] Planning for Natural Hazards: Oregon Technical Resource Guide, Community Planning Workshop, (July 2000), p. 8-8.

[100] Interagency Hazard Mitigation Team. 2012. Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management

[101] Hill, Richard. "Geo Watch Warning Quake Shook Portland 40 Years Ago." The Oregonian. October 30, 2002.

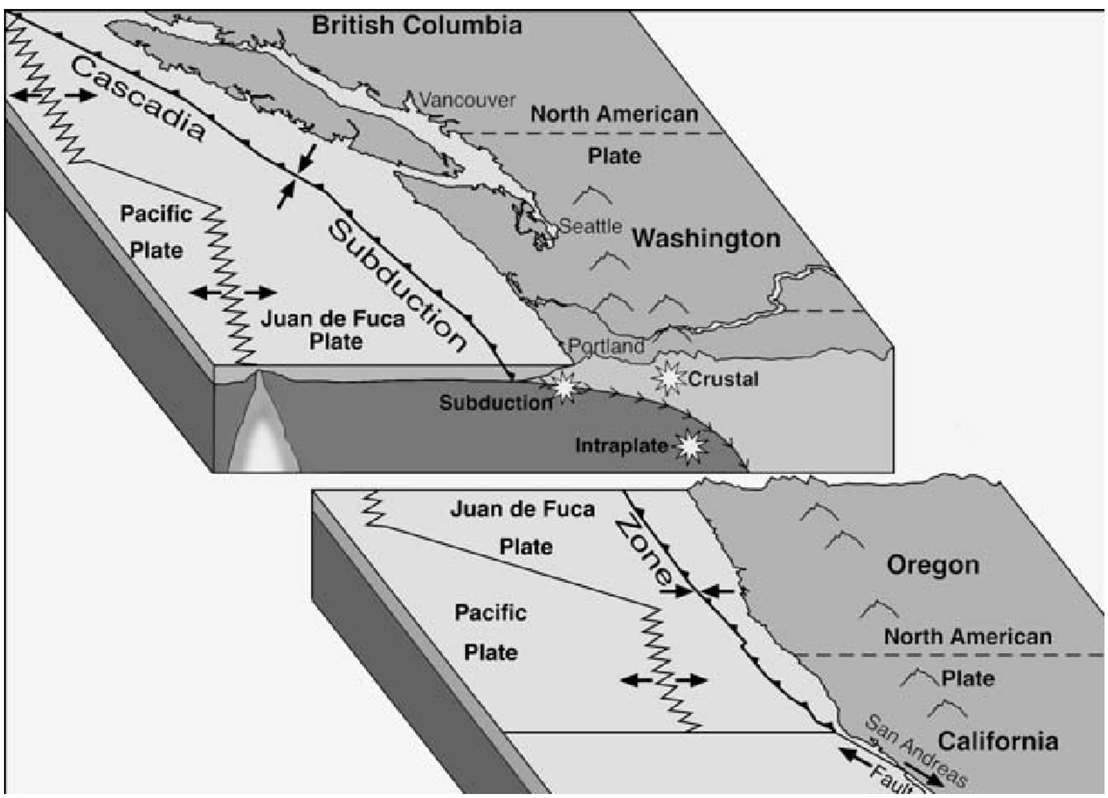
[102] Interagency Hazard Mitigation Team. 2012. Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management

Although there have been no large, recorded earthquakes along the offshore Cascadia Subduction Zone, similar subduction zones worldwide do produce "great" earthquakes with magnitudes of 8 or larger. They occur because the oceanic crust "sticks" as it is being pushed beneath the continent, rather than sliding smoothly. Over hundreds of years, large stresses build which are released suddenly in great earthquakes. Such earthquakes typically have a minute or more of strong ground shaking and are quickly followed by numerous large aftershocks.

Subduction zones like the Cascadia Subduction Zone have produced earthquakes with magnitudes of 8.0 or larger. Historic subduction zone earthquakes include the 1960 Chile earthquake (magnitude 9.5), the 1964 southern Alaska earthquakes (magnitude 9.2), the 2004 Indian Ocean earthquake (magnitude 9.0) and the 2011 Tohoku earthquake (magnitude 9.0).

Geologic evidence shows that the Cascadia Subduction Zone has also generated great earthquakes, and that the most recent one was about 300 years ago. Large earthquakes also occur at the southern end of the Cascadia Subduction Zone (in northern California near the Oregon border) where it meets the San Andreas Fault system.

Figure 17. Cascadia Subduction Zone



Source: Shoreland Solutions. Chronic Coastal Natural Hazards Model Overlay Zone. Salem, OR: Oregon Department of Land Conservation and Development (1998) Technical Guide-3.

While all three types of earthquakes have the potential to cause major damage, subduction zone earthquakes pose the greatest danger. A major CSZ event could generate an earthquake with a magnitude of 9.0 or greater resulting in devastating damage and loss of life. Such earthquakes may cause great damage to the coastal area of Oregon as well as inland areas in western Oregon. Northeast Oregon is unlikely to be directly affected by a subduction zone earthquake; however, the county could be affected as populations of refugees flee eastward, and as streams of commerce are interrupted. It is estimated that shaking from a large subduction zone earthquake could last up to five minutes.[103]

Characteristics of Earthquakes

> *"Due to the amount of faulting in the area, [the 1999 Klamath Falls earthquake] is just business as usual for such a geologically active region. Historic evidence, combined with geologic evidence for large numbers of earthquakes in the prehistoric past, suggest that one or more earthquakes capable of damage (magnitude 4 – 6) hit south-central Oregon every few decades, so it pays to be prepared."*
>
> James Roddey, DOGAMI

Ground Shaking

Ground shaking is the motion felt on the earth's surface caused by seismic waves generated by the earthquake. Ground shaking is the primary cause of earthquake damage. The strength of ground shaking depends on the magnitude of the earthquake, the type of fault that is slipping, and distance from the epicenter (where the earthquake originates). Buildings on poorly consolidated and thick soils will typically see more damage than buildings on consolidated soils and bedrock.

Ground Shaking Amplification

Ground shaking amplification refers to the soils and soft sedimentary rocks near the surface that can modify ground shaking from an earthquake. Such factors can increase or decrease the amplification (i.e., strength) as well as the frequency of the shaking. The thickness of the geologic materials and their physical properties determine how much amplification will occur. Ground motion amplification increases the risk for buildings and structures built on soft and unconsolidated soils.

Surface Faulting

Surface faulting are planes or surfaces in Earth materials along which failure occurs. Such faults can be found deep within the earth or on the surface. Earthquakes occurring from deep lying faults usually create only ground shaking.

Liquefaction and Subsidence

Liquefaction occurs when ground shaking causes wet, granular soils to change from a solid state into a liquid state. This results in the loss of soil strength and the soil's ability to support weight. When the ground can no longer support buildings and structures (subsidence), buildings and their occupants are at risk.

The severity of an earthquake is dependent upon a number of factors including: 1) the distance from the earthquake's source (or epicenter); 2) the ability of the soil and rock to conduct the earthquake's seismic energy; 3) the degree (i.e., angle) of slope materials; 4) the composition of slope materials; 5) the magnitude of the earthquake; and 6) the type of earthquake.

Earthquake-Induced Landslides and Rockfalls

Earthquake-induced landslides are secondary hazards that occur from ground shaking and can destroy roads, buildings, utilities and critical facilities necessary to recovery efforts after an

[103]Planning for Natural Hazards: Oregon Technical Resource Guide, Community Planning Workshop, (July 2000), p. 8-9.

earthquake. These areas often have a higher risk of landslides and rockfalls triggered by earthquakes.

The severity of an earthquake is dependent upon a number of factors including: 1) the distance from the earthquake's source (or epicenter); 2) the ability of the soil and rock to conduct the earthquake's seismic energy; 3) the degree (i.e., angle) of slope materials; 4) the composition of slope materials; 5) the magnitude of the earthquake; and 6) the type of earthquake.

History of Earthquakes: Pacific Northwest and Northeast Oregon

All of Oregon west of the Cascades is at risk from the three earthquake types and associated hazards. East of the Cascades the earthquake hazard is predominately of the crustal type. The amount of earthquake damage at any place will depend on its distance from the epicenter, local soil conditions, and types of construction. Due to Oregon's relatively short written history and the infrequent occurrence of severe earthquakes, few Oregon earthquakes have been recorded in writing. Moreover, in the past century, there have been no reported damage or injuries in the Northeast Region due to earthquakes. However, several significant earthquake events have occurred in southeastern Washington in the past 150 years. Details concerning these events are highlighted below.

Image of damage from the 2001 Nisqually earthquake near Seattle

The Pacific Northwest has experienced major earthquakes in 1949 (magnitude 7.1), 1962 (magnitude 5.2), and 2001 (magnitude 6.8). Table 11 shows the location of selected Pacific Northwest earthquakes.

Northeast Oregon has been shaken by crustal and intraplate earthquakes centered on the area in the past. Historically there have been few earthquakes in Northeast Oregon, and even fewer earthquakes that have caused structural damage to buildings. In the last 42 years, the region around Northeast Oregon has been affected by several earthquakes of estimated magnitudes of three and greater. Table 12 lists the location of earthquakes magnitude 4.0 or greater that have occurred in Northeastern Oregon since 1900. This data relies on the Pacific Northwest Seismic Networks database.

The Pacific Northwest Seismic Network (PNSN) website has a tool to search for recent (https://pnsn.org/earthquakes/recent) and historic earthquakes that have been recorded in the PNSN reporting area. Historical listing of earthquakes in Wallowa County was developed with this tool.

History of Earthquakes: Wallowa County

Wallowa County experienced one earthquake greater than magnitude 3.0 in during the update period. On November 3, 2014, a 3.1 magnitude earthquake was recorded east of Joseph. Prior to that date, earthquakes of magnitude 3.0 or greater have been recorded in Wallowa County in 2002, 1999, and 1984. The strongest was a magnitude 4.0 quake January 30, 1984, with an epicenter located east of Imnaha in the Hells Canyon National Recreation Area.

Table 11. Earthquake History in Pacific Northwest

Date	Location	Magnitude	Comments
Approximate years: 1400 BCE, 1050, BCE 600 BCE 400, 750, 900	Offshore, Cascadia subduction zone	Probably 8.0-9.0	Researchers Brian Atwater and Eileen Hemphill-Haley have dated earthquakes and tsunamis at Willapa Bay, Washington; these are the midpoints of the age ranges for these six events.
January 26, 1700	Offshore, Cascadia Subduction zone	Approximately 9.0	Generated a tsunami that struck Oregon, Washington and Japan; destroyed Native American villages along the coast.
November 23, 1873	Oregon/California border, near Brookings	6.8	Felt as far away as Portland and San Francisco; may have been an intraplate event because of lack of aftershocks.
March, 1893	Umatilla	VI-VII (Modified Mercalli Intensity)	Damage unknown
July 15, 1936	Milton-Freewater	6.4	Two foreshocks and many aftershocks felt; $100,000 damage (in 1936 dollars).
April 13, 1949	Olympia, Washington	7.1	Eight deaths and $25 million damage (in 1949 dollars); cracked plaster, other minor damage in northwest Oregon.
January, 1951	Hermiston	V (Modified Mercalli Intensity)	Damage unknown
November 5, 1962	Portland/Vancouver	5.5	Shaking lasted up to 30 seconds; chimneys cracked, windows broke, furniture moved.
1968	Adel	5.1	Swarm lasted May through July, decreasing in intensity; increased flow at a hot spring was reported.
April 12, 1976	Near Maupin	4.8	Sounds described as distant thunder, sonic booms, and strong wind.
April 25, 1992	Cape Mendocino, California	7.0	Subduction earthquake at the triple-junction of the Cascadia subduction zone and the San Andreas and Mendocino faults.
March 25, 1993	Scotts Mill	5.6	On Mount Angel-Gates Creek fault; $30 million damage, including Molalla High School and Mount Angel church.
September 20, 1993	Klamath Falls	5.9 and 6.0	Two deaths, $10 million damage, including county courthouse; rockfalls induced by ground motion.

Source: Ivan Wong and Jacqueline D.J. Bolt, November 1995, A Look Back at Oregon's Earthquake History, 1841-1994, Oregon Geology, pp. 125-139 and Niewendorp, C.A., Neuhaus, M.E., 2003. Map of Selected Earthquakes for Oregon, 1841 through 2002. Oregon Department of Geology and Mineral Industries Open File Report 03-02

Table 12. Earthquakes Greater than 4.0 in Northeastern Oregon (1900 to 2013)

Date	Location	Magnitude	Comments
October, 1913	Hells Canyon	6.0	
April, 1927	Pine Valley-Cuddy Mountain	5.0	
June, 1942	Pine Valley-Cuddy Mountain	5.0	Minor Damage
August 1, 1965	John Day	4.4	
November, 1965	Halfway	4.3	
December, 1966	Halfway	4.2	

Source: University of Washington. List of Magnitude 4.0 or Larger Earthquakes in Washington and Oregon 1872-2002; and Wong and Bott, November 1995. A look Back at Oregon's Earthquake History, 1841-1994, *Oregon Geology.*

Table 13 lists earthquake activity in Wallowa County and vicinity with magnitudes of 3.0 or greater.

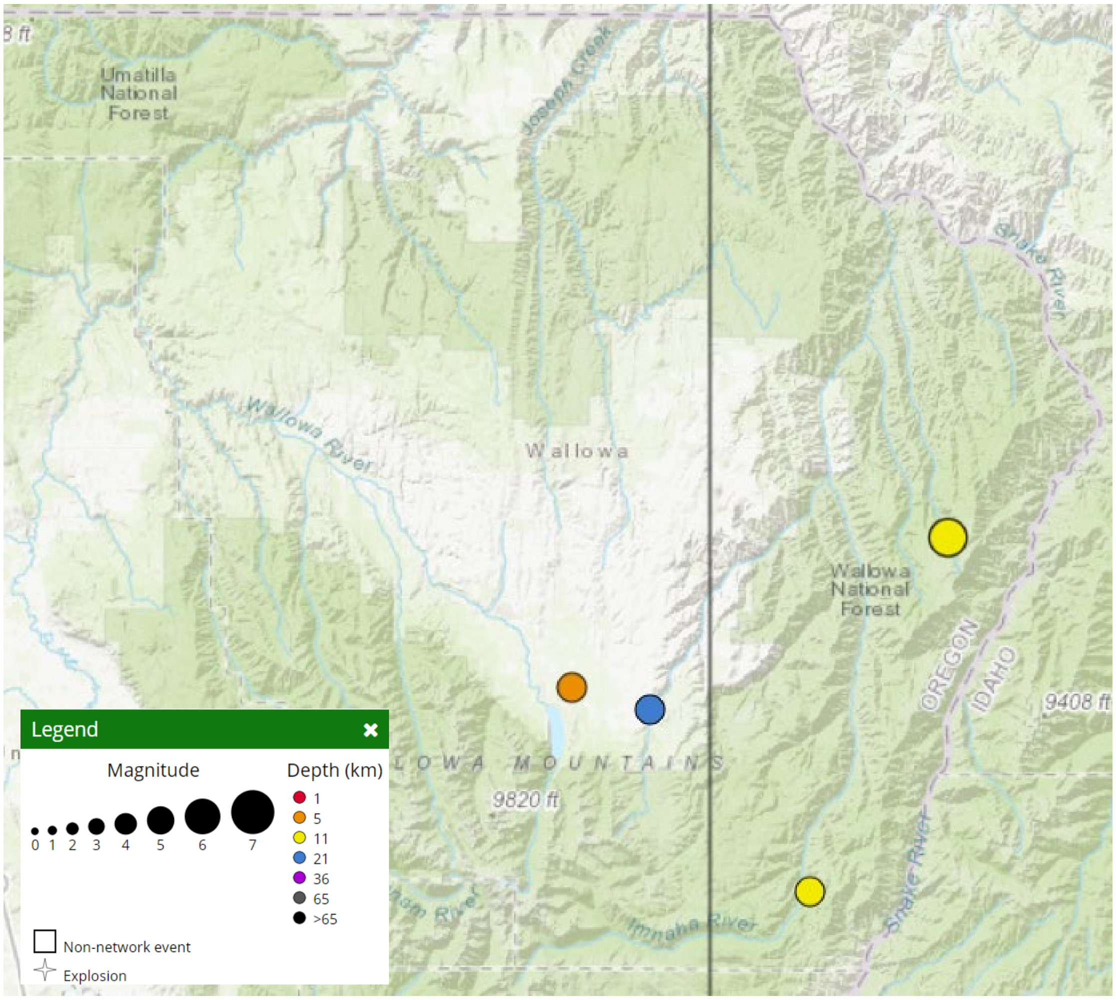
The reporting area for PNSN is shown in an interactive map on the organization's website (https://pnsn.org/earthquakes/recent). DLCD Natural Hazards Planner, Katherine Daniel, performed a search, with the parameter of recorded earthquakes between magnitude 3 and 10 that have occurred from February 14, 1969 to August 30, 2021; the results identified 7 earthquakes, 4 of which were located in Wallowa County. The location, date and time, magnitude, depth, and other information related to each earthquake is provided in Table 13 and a map of the locations is provided in Figure 18.

Table 13. Earthquakes Greater than 3.0 in Wallowa County and vicinity (1969-2020)

Date	Magnitude	Location	Depth
January 30, 1984	4.0	SE of Imnaha (Lat, Long: 45.496, -116.673)	3.3 miles
July 21, 1998	3.1	Baker County (Lat., Long: 44.941, -117.129)	-0.5 miles
March 3, 1999	3.0	East of Joseph (Lat., Long.: 45.331, -117.0823)	11.2 miles
November 15, 2002	3.4	Hells Canyon in Baker County (Lat., Long: 45.072, -116.828)	5.7 miles
November 16, 2002	3.1	Southeast Wallowa County (Lat., Long: 45.155, -116.86)	5.7 miles
November 3, 2014	3.1	East of Joseph (Lat., Long: 45.351, -117.189)	1.7 miles
August 14, 2017	3.1	Baker County (Lat., Long: 45.045, -117.214)	5.2 miles

Source: Pacific Northwest Seismic Networks database search conducted August 2021, https://pnsn.org/

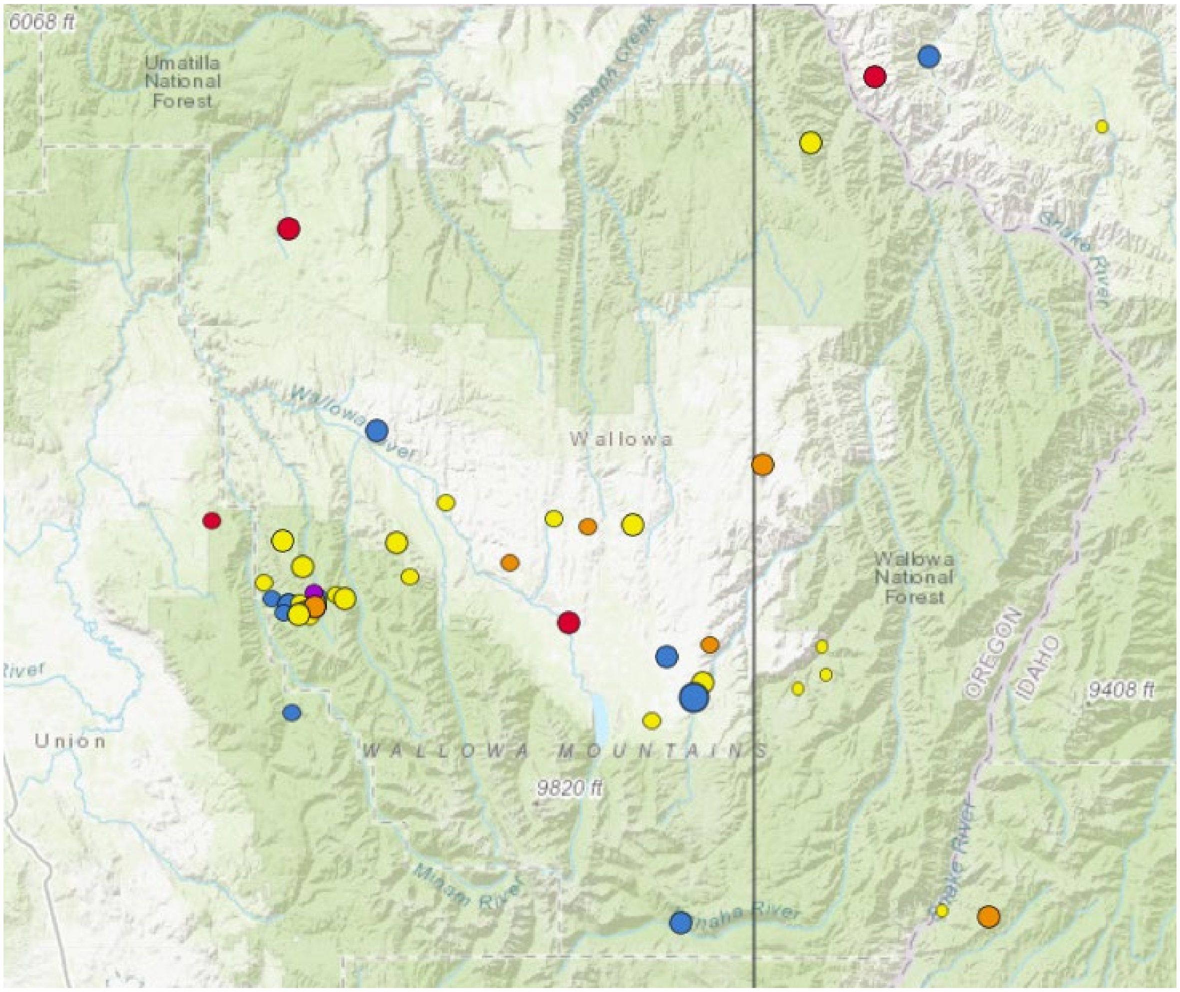
Figure 18. Location of Earthquakes greater than M3.0 in Wallowa County 1969-2021



Source: Pacific Northwest Seismic Networks database search conducted August 2021, https://pnsn.org/

Earthquakes of M3.0 or less occur much more frequently in Wallowa County. A similar search for these was performed by K. Daniel which resulted in a list of forty-one measurable earthquakes recorded since 1969 with half of these registering at less than M2.0. A map of these locations is below in Figure 19.

Figure 19. Location of Earthquakes less than M3.0 in Wallowa County 1969-2021



Source: Pacific Northwest Seismic Networks database search conducted August 2021, https://pnsn.org/

The 2020 State NHMP Risk Assessment for Region 7 concluded that the probability of damaging earthquakes varies widely across the state. In Region 7, the hazard is dominated by local faults and background seismicity. DOGAMI has developed a new probability ranking for Oregon counties that is based on the average probability of experiencing damaging shaking during the next 100 years. In this ranking Wallowa County is estimated to have a 10-20% chance of experiencing damaging shaking during the next 100 year.[104]

Earthquake Damage Susceptibility

Earthquake damage occurs because humans have built structures that cannot withstand severe shaking. Buildings, airports, schools, and lifelines (highways, phone lines, gas, water, etc.) suffer damage in earthquakes and can ultimately result in death or injury to humans.

[104] 2020 Oregon NHMP update, p. 1202-1203 DRAFT Oregon Natural Hazards Mitigation Plan

Death and Injury

Death and injury can occur both inside and outside of buildings due to falling equipment, furniture, debris, and structural materials. Likewise, downed power lines or broken water and gas lines endanger human life. Death and injury are highest in the afternoon when damage occurs to commercial and residential buildings and during the evening hours in residential settings.[105]

Building and Home Damage

Wood structures tend to withstand earthquakes better than structures made of brick or unreinforced masonry buildings.[106] Building construction and design play a vital role in the survival of a structure during earthquakes. Damage can be quite severe if structures are not designed with seismic reinforcements or if structures are located atop soils that liquefy or amplify shaking. Whole buildings can collapse or be displaced.

Bridge Damage

All bridges can sustain damage during earthquakes, leaving them unsafe for use. More rarely, some bridges have failed completely due to strong ground motion. Bridges are a vital transportation link – damage to them can make some areas inaccessible.

Because bridges vary in size, materials, siting, and design, earthquakes will affect each bridge differently. Bridges built before the mid 1970's often do not have proper seismic reinforcements. These bridges have a significantly higher risk of suffering structural damage during a moderate to large earthquake. Bridges built in the 1980's and after are more likely to have the structural components necessary to withstand a large earthquake.[107]

2001 Nisqually Earthquake

A 6.8 magnitude earthquake centered southwest of Seattle struck on February 28, 2001, followed by a mild aftershock the next morning, and caused more than $1 billion worth of damage. Despite this significant loss, the region escaped with relatively little damage for two reasons: the depth of the quake center and preparations by its residents. Washington initiated a retrofitting program in 1990 to strengthen bridges, while regional building codes mandated new structures withstand certain amounts of movement. Likewise, historic buildings have been voluntarily retrofitted with earthquake-protection reinforcements.

Source: "Luck and planning reduced Seattle quake damage", CNN Report, March 1, 2001

Damage to Lifelines

Lifelines are the connections between communities and critical services. They include water and gas lines, transportation systems, electricity, and communication networks. Ground shaking and amplification can cause pipes to break open, power lines to fall, roads and railways to crack or move, and radio or telephone communication to cease. Disruption to transportation makes it especially difficult to bring in supplies or services. All lifelines need to be usable after an earthquake to allow for rescue, recovery, and rebuilding efforts and to relay important information to the public.

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[105] Planning for Natural Hazards: Oregon Technical Resource Guide, Community Planning Workshop, and (July 2000).

[106] Wolfe, Myer, et al. Land Use Planning for Earthquake Hazard Mitigation: A Handbook for Planners, Special Publication 14, Natural Hazards Research and Applications Information Center.

[107] University of Washington website: www.geophys.washington.edu/SEIS/PNSN/INFO_GENERAL/faq.html#3.

Disruption of Critical Facilities

Critical facilities are police stations, fire stations, hospitals, and shelters. These are facilities that provide services to the community and need to be functional after an earthquake event. The earthquake effects outlined above can all cause emergency response to be disrupted after a significant event.[108]

Economic Loss: Equipment and Inventory Damage, Lost Income

Seismic activity can cause great loss to businesses, either a large-scale corporation or a small retail shop. Losses not only result in rebuilding cost, but fragile inventory and equipment can be destroyed. When a company is forced to stop production for just a day, business loss can be tremendous. Residents, businesses, and industry all suffer temporary loss of income when their source of finances are damaged or disrupted.

Fire

Downed power lines or broken gas mains can trigger fires. When fire stations suffer building or lifeline damage, quick response to quench fires is less likely.

Debris

After damage occurs to a variety of structures, much time is spent cleaning up brick, glass, wood, steel or concrete building elements, office and home contents, and other materials.

Existing Hazard Mitigation Activities

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake.[109]

Seismic Retrofitting

Business Oregon's Infrastructure Finance Authority supports the Seismic Rehabilitation Grant Program (SRGP). This program is a State of Oregon competitive grant program that provides funding for the seismic rehabilitation of critical public buildings, particularly public schools and emergency services facilities. Public K-12 school districts, community colleges, and education service districts are eligible for the grant program. For emergency services facilities, the emphasis is on first responder buildings. This includes hospital buildings with acute inpatient care facilities, fire stations, police stations, sheriff's offices, 9-1-1 centers, and Emergency Operations Centers (EOCs).

Individual Preparedness

At an individual level, preparedness for an earthquake is minimal as perception and awareness of earthquake hazards are low.[110] Strapping down heavy furniture, water heaters and expensive personal property as well as having earthquake insurance, is a step towards earthquake mitigation.

[108] Earthquake Damage in Oregon: Preliminary Estimates of Future Earthquake Losses.

[109] Planning for Natural Hazards: Oregon Technical Resource Guide, Community Planning Workshop, (July 2000), p. 8-20.

[110] Darienzo, Mark, Oregon Military Department – Office of Emergency Management, Personal Interview, (February 22, 2001).

Earthquake Awareness Month

Oregon Military Department – Office of Emergency Management coordinates activities such as earthquake drills like the Great Shake Out and encourages individuals to prepare for earthquakes by strapping down computers, heavy furniture and bookshelves in homes and offices.

School Education

Schools conduct earthquake drills regularly throughout Oregon and teach students how to respond when an earthquake event occurs.

Building Codes

The Oregon State Building Codes Division adopts statewide standards for building construction that are administered by the state, cities and counties throughout Oregon. The codes apply to new construction and to the alteration of, or addition to, existing structures. Within these standards are six levels of design and engineering specifications that are applied to areas according to the expected degree of ground motion and site conditions that a given area could experience during an earthquake. The Structural Code requires a site-specific seismic hazard report for projects including critical facilities such as hospitals, fire and police stations, emergency response facilities, and special occupancy structures, such as large schools and prisons.

The seismic hazard report required by the Structural Code for essential facilities and special occupancy structures considers factors such as the seismic zone, soil characteristics including amplification and liquefaction potential, any known faults, and potential landslides. The findings of the seismic hazard report must be considered in the design of the building. The Dwelling Code incorporates prescriptive requirements for foundation reinforcement and framing connections based on the applicable seismic zone for the area. The cost of these requirements is rarely more than a small percentage of the overall cost for a new building.

Requirements for existing buildings vary depending on the type and size of the alteration and whether there is a change in the use of the building that is considered more hazardous. Oregon State Building Codes recognize the difficulty of meeting new construction standards in existing buildings and allow some exception to the general seismic standards. Upgrading existing buildings to resist earthquake forces is more expensive than meeting code requirements for new construction. The state code only requires seismic upgrades when there is significant structural alteration to the building or where there is a change in use that puts building occupants and the community at greater risk.

Local building officials are responsible for enforcing these codes. Although there is no statewide building code for substandard structures, local communities have the option of adopting a local building code to mitigate hazards in existing buildings. Oregon Revised Statutes allow municipalities to create local programs to require seismic retrofitting of existing buildings within their communities. The building codes do not regulate public utilities or facilities constructed in public right-of-way, such as bridges.

FLOOD HAZARD ANNEX

Flooding results when rain and snowmelt create water flow that exceed the carrying capacity of rivers, streams, channels, ditches, and other watercourses. In Oregon, flooding is most common from October through April when storms from the Pacific Ocean bring intense rainfall. Most of Oregon's most destructive natural disasters have been floods.[111] Flooding can be aggravated when rain is accompanied by snowmelt and frozen ground; the spring cycle of melting snow is the most common source of flood in the region.

Causes and Characteristics of Flooding

Statewide the most damaging floods have occurred during the winter months, when warm rains from tropical latitudes melt mountain snowpacks. Somewhat lesser flooding has been associated with ice jams, normal spring run-off, and summer thunderstorms. Heavily vegetated stream banks, low stream gradients, and breeched dikes have contributed to past flooding at considerable economic cost. Northeast Oregon counties also have experienced flooding associated with low bridge clearances, over-topped irrigation ditches, and natural stream constrictions

The principal types of floods that occur in Wallowa County include:

Riverine Flooding

Riverine floods occur when water levels in rivers and streams overflow their banks. Most communities located along such water bodies have the potential to experience this type of flooding after spring rains, heavy thunderstorms or rapid runoff from snow melt. Riverine floods can be slow or fast-rising, but usually develop over a period of days. The danger of riverine flooding occurs mainly during the winter months, with the onset of persistent, heavy rainfall, and during the spring, with melting of snow. Figure 20 below shows the principal watersheds in Wallowa County draining to the Grande Ronde and the Snake Rivers.

Shallow Area Floods

These floods are a special type of riverine flooding. FEMA defines a shallow area flood hazard as an area that is inundated by a 100-year flood with a flood depth between one to three feet. Such areas are generally flooded by low velocity sheet flows of water.

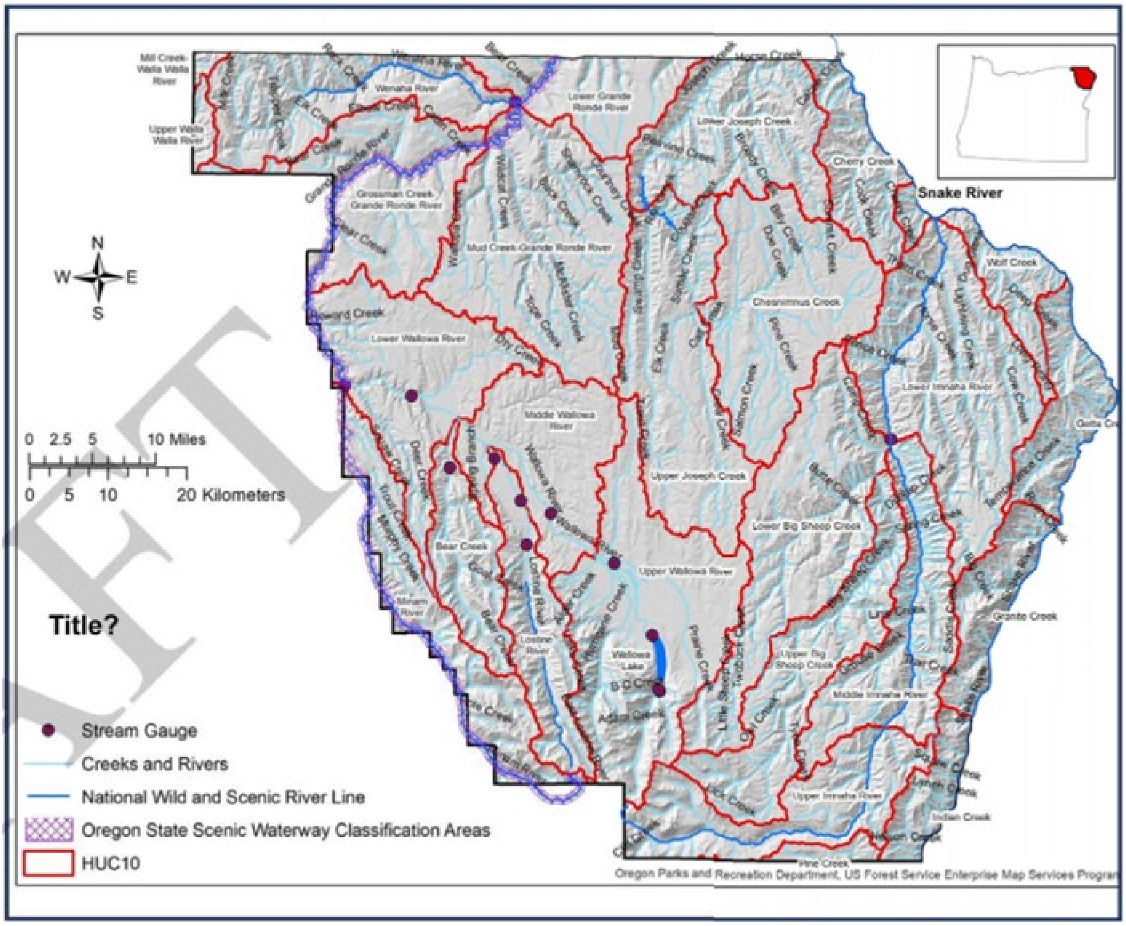
Snow-melt Flooding

Flooding throughout the region is most commonly linked to the spring cycle of melting snow. The weather pattern that produces these floods occurs during the winter months and has come to be associated with La Nina events, a three to seven year cycle of cool, wet weather. In brief, cool,

[111] Taylor, George H. and Chris Hannan. The Oregon Weather Book. Corvallis, OR: Oregon State University Press. 1999

moist weather conditions are followed by a system of warm, moist air from tropical latitudes. The intense warm air associated with this system quickly melts foothill and mountain snow. Above-freezing temperatures may occur well above pass levels (4,000-5,000 feet).

Figure 20. Wallowa County Watershed Boundaries



Source: Draft Natural Resource Management Plan, TBD

Flash Floods

Flash floods usually result from intense storms dropping large amounts of rain within a brief period. Flash floods usually occur in the summer during thunderstorm season, appear with little or no warning and can reach full peak in a few minutes. They are most common in the arid and semi-arid central and eastern areas of the state where there is steep topography, little vegetation and intense but short duration rainfall. Flash floods can occur in both urban and rural settings, often along smaller rivers and drainage ways. In flash flood situations, waters not only rise rapidly, but also generally move at high velocities and often carry large amounts of debris. In these instances, a flash flood may arrive as a fast-moving wall of debris, mud, water or ice. Such material can accumulate at a natural or man-made obstruction and restrict the flow of water. Water held back in such a manner can cause flooding both upstream and then later downstream if the obstruction is removed or breaks free.

Terms related to Flooding

Floodplain

A floodplain is land adjacent to a river, stream, lake, estuary, or other water body that is subject to flooding. These areas, if left undisturbed, act to store excess floodwater. The floodplain is made up of two areas: the flood fringe and the floodway:

Floodway

The floodway is the portion of the floodplain that is closer to the river or stream. For National Flood Insurance Program (NFIP) and regulatory purposes, floodways are defined as the channel of a river or stream, and the over-bank areas adjacent to the channel. Unlike floodplains, floodways do not reflect a recognizable geologic feature. The floodway carries the bulk of the floodwater downstream and is usually the area where water velocities and forces are the greatest. NFIP regulations require that the floodway be kept open and free from development or other structures, so that flood flows are not obstructed or diverted onto other properties. The NFIP floodway definition is "the channel of a river or other watercourse and adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot (See Figures FL-3 and FL-4)." Floodways are not mapped for all rivers and streams but are typically mapped in developed areas.

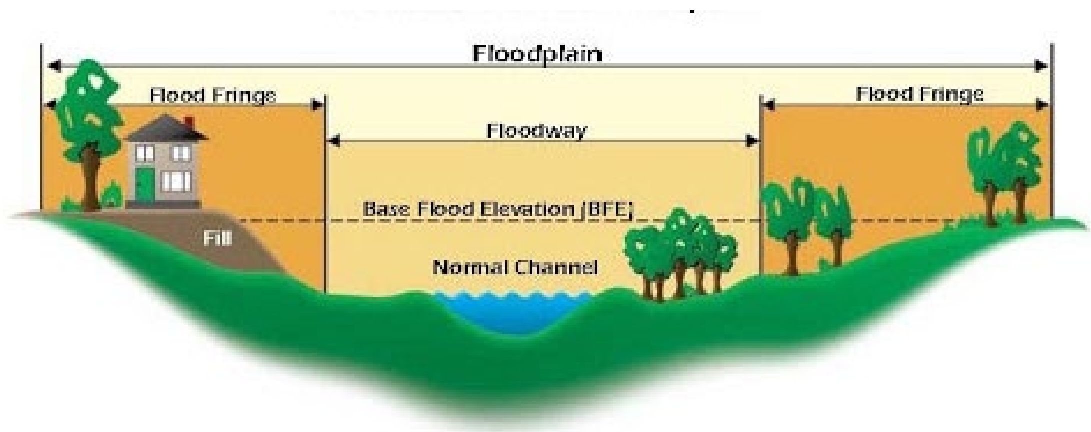
The Flood Fringe

The flood fringe refers to the outer portions of the floodplain, beginning at the edge of the floodway and continuing outward. This is the area where development is most likely to occur, and where precautions to protect life and property need to be taken (See Figure FL-3).

Base Flood Elevation

Base Flood Elevation (BFE) means the water surface elevation during the base flood in relation to a specified datum or benchmark. The Base Flood Elevation (BFE) is depicted on the FEMA Flood Insurance Rate Map (FIRM) to the nearest foot and in the Flood Insurance Study to the nearest 0.1 foot. The Base Flood Elevation is a baseline pulled together from historic weather data, local topography, and the best science available at the time. It's a reasonable standard to insure against, but it is not a guarantee that it will flood only 1 time every 100 years.

Figure 21. Characteristics of a Floodplain



Source: Oregon Department of Geology and Mineral Industries

Factors that Affect Flooding in Wallowa County

Precipitation

The northeast region's precipitation is well distributed year-round with annually low levels – approximately 16 inches per year. Mountainous regions may exceed 100 inches of precipitation per year, primarily in the form of snow. Locations surrounded by mountains receive barely 10 inches per year, a portion of which falls as snow. This is in sharp contrast to the 37 to 50 inches normally seen in other parts of the Pacific Northwest. Low levels of precipitation are due in part by the rain shadow effect caused by the Cascade Mountains. Summer precipitation is very low, increasing the risk of wildfire and requiring irrigation for crops.

There are large seasonal variations in temperature ranging from high temperatures of 80 to 90 °F from June to September to average highs of low teens in the winter months. In most winters, there are frequent and severe winter storms characterized by temperature, wind velocity, ground saturation, and snowpack. Winter storms can slow or halt traffic, damage power lines, and kill livestock.

Location of Development

When development is located in the floodplain, it may cause floodwaters to rise higher than before the development was located in the hazard areas. This is particularly true if the development is located within the floodway. When structures or fill are placed in the floodplain, water is displaced. Development raises the base-flood elevation by forcing the river to compensate for the flow space obstructed by the inserted structures. Over time, when structures or materials are added to the floodplain and no fill is removed to compensate, serious problems can arise.

Displacement of a few inches of water can mean the difference between no structural damage occurring in a given flood event and the inundation of many homes, businesses, and other facilities.

Careful attention must be paid to development that occurs within the floodplain and floodway of a river system to ensure that structures are prepared to withstand base flood events.

Wallowa County is approximately 3,153 square miles.[112]Approximately 60% of the land area is publicly owned, of which land is administered predominantly by the US Forest Service, but also by various other federal, state, and local agencies.[113] The Wallowa County Comprehensive Plan has recommendatory provisions for flood prone areas and claims that the "present flood plain maps are inadequate in detail to be used for zoning or other regulatory purposes."[114]

Surface Permeability

In urbanized areas, increased pavement leads to an increase in volume and velocity of runoff after a rainfall event, exacerbating potential flood hazards. Storm water systems collect and concentrate rainwater and then rapidly deliver it into the local waterway. Traditional storm water systems are a benefit to urban areas, by quickly removing captured rainwater. However, they can be detrimental to areas downstream because they cause increased stream flows due to the rapid influx of captured storm water into the waterway. It is very important to evaluate storm water systems in conjunction with development in the floodplain to prevent unnecessary flooding to downstream properties. Frozen ground and burn scars are other contributors to rapid runoff in the urban and rural environment.

The principal flooding sources in Wallowa County include the Wallowa River, Minam River, Lostine River, Imnaha River, Hurricane Creek and Prairie Creek.

Future Climate Conditions

In Oregon, observed precipitation is characterized by high year-to-year variability and future precipitation trends are expected to continue to be dominated by this large natural variability. On average, summers in Oregon are projected to become drier and other seasons to become wetter resulting in a slight increase in annual precipitation by the 2050's.

The Oregon Climate Change Research Institute's Fifth Oregon Climate Assessment, 2021 analyzed factors that are likely to affect flood magnitude in the future. One of these factors is that large precipitation events are expected to become more intense.[115] The primary reason for the increase in intensity is simply that warmer air can hold more water, so there may be more moisture in the air available to fall out as rain or snow in a warmer climate.

A second factor suggesting that flood magnitudes will increase is that rainfall-driven floods tend to have larger flood peaks than snowmelt-driven floods given the same amount of precipitation.

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112 Oregon Blue Book "Wallowa County" http://bluebook.state.or.us/local/counties/counties32.htm Accessed May 2013
113 Wallowa County Community Wildfire Protection "Wallowa County Profile and Fire History" Plan 2006
114 Wallowa County Comprehensive Plan "VII: Areas Subject to Natural Disasters and Hazards" 1995
115 Fifth Oregon Climate Assessment, 2021 citing Allen and Ingram 2002, Westra et al. 2014, Warner and Mass 2017

Therefore, as rising temperatures cause the proportion of precipitation falling as rain relative to snow to increase, flood magnitudes are projected to increase.[116]

A third factor is that total wet-season (November–April) precipitation is projected to increase in the Pacific Northwest. Greater precipitation, even after accounting for increases in evaporation, implies a higher likelihood of wetter soil and reduced depth to ground water—both of which are enabling conditions for flooding—prior to the arrival of heavy precipitation events.[117]

Projections for future changes in climate suggest that there is greater uncertainty in future projections of precipitation-related metrics than temperature-related metrics. Future streamflow magnitude and timing in the Pacific Northwest is projected to shift toward higher winter runoff, lower summer and fall runoff, and an earlier peak runoff, particularly in snow-dominated regions. These changes are expected to result from warmer temperatures causing precipitation to fall more as rain and less as snow, in turn causing snow to melt earlier in the spring; and in combination with increasing winter precipitation and decreasing summer precipitation.

Warming temperatures and increased winter precipitation are expected to increase flood risk for many basins in the Pacific Northwest, particularly mid-to low-elevation mixed rain-snow basins with near freezing winter temperatures. The greatest changes in peak streamflow magnitudes are projected to occur at intermediate elevations in the Cascade Range and the Blue Mountains.

Regulatory Framework for Flooding Hazard

Flood hazard in some areas of Wallowa County is identified through FEMA issued Flood Insurance Rate Maps (FIRMs), in conjunction with their Flood Insurance Studies (FIS). Flood records in areas without FIRMs are often not well documented, particularly in unincorporated areas because their floodplains are sparsely developed and risk to life and property are low. The Wallowa County's Flood Insurance Rate Maps (FIRMs), like much of eastern Oregon are not yet provided by FEMA in digital format. The FIS and the FIRM date from 1988.

Wallowa County and all of the cities within the county (Enterprise, Joseph, Lostine and Wallowa) all participate in the National Flood Insurance Program. Tables 14 and 15 below show that as of January 2021, Wallowa County, including the four cities of Enterprise, Joseph, Lostine and Wallowa, has 72 National Flood Insurance Program (NFIP) policies in force, 16 total paid claims and no repetitive loss buildings. The repetitive flood loss claims in Wallowa County and the City of Wallowa resulted in $17,497 in payments over 16 losses. The tables below display the number of policies by building type and show that most residential structures that have flood insurance policies are single-family homes and that there are ten non-residential structures with flood insurance policies.

The State NFIP Coordinator has worked to communicate with many cities and counties across the state of Oregon to provide assistance and training to Floodplain Coordinators. The City of Enterprise

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[116] Fifth Oregon Climate Assessment, 2021 citing Davenport et al. 2020, and Chegwidden et al. 2020

[117] Fifth Oregon Climate Assessment, 2021 citing Dalton et al. 2017, Easterling et al. 2017, Rupp et al. 2017, and Seager et al. 2014

[*]Community Assistance Visits and Community Assistance Contacts are two means for the FEMA National Flood Insurance Program to be the focus of discussion with a technical expert and local staff.

participated in a Community Assistance Visit* in 2011 which has not yet been completed. The City is working to update its floodplain management practices. Wallowa County and the cities of Wallowa, and Lostine have not received a Community Assistance Visit or Community Assistance Contact in the past 20 or 21 years. The county is not a member of the Community Rating System (CRS) and neither are any of the incorporated cities within Wallowa County.

Table 14. Wallowa County Flood Insurance Policy Detail

Jurisdiction	Current FIRM effective date	Policies	Pre-FIRM	Policies by Building Type			
				Single Family	2 to 4 Family	Other Residential	Non-Residential
Wallowa County	02/17/1988	27	16	25	-	-	2
Enterprise	02/17/1988	44	30	33	3	-	8
Joseph	02/17/1988	1	-	1	-	-	-
Lostine	02/17/1988	-	-	-	-	-	-
Wallowa	02/17/1988	0	-	-	-	-	-
Totals		72	46	59	3	-	10

Source: Information compiled by Department of Land Conservation and Development; FEMA Community Information System consulted January 2021.

Table 15. Wallowa County Flood Insurance Claim and Substantial Damage Detail

Jurisdiction	Insurance in Force	Total Paid Claims	Substantial Damage Claims	Repetitive Loss Buildings	Total Paid Amount	Last CAV	Last CAC
Wallowa County	$6,112,700	7	0	0	$15,788	11/04/1998	07/22/2005
Enterprise	$6,087,100	0	0	0		09/11/2011	07/22/2005
Joseph	$350,000	0	0	0	$0	11/04/1998	06/27/1991
Lostine	$0	0	0	0	$0	never	never
Wallowa	$0	9	0	0	$1,709	12/14/1999	08/28/1992
Totals	$12,549,800	16	0	0	$17,497		

Source: Information compiled by Department of Land Conservation and Development; FEMA Community Information System consulted January 2021.

History of Flooding in Wallowa County

Table 16 below shows the history of major flood events within Wallowa County. Staff at the Oregon Department of Land Conservation and Development (DLCD) compiled a list of all recorded floods in Oregon across 146 years of available data, as part of a 2020 update to the 2015 State NHMP table of flooding events. Data for this list had two sources: the Table 1 in the DLCD *Flood Technical Resource*

Guide (Andre and others, 2001)[118] which was used to record events that occurred prior to 2000 and the NOAA Storm Event Database [119] which captured events from 2000 to the present.

There are limitations to this listing in that information from the DLCD *Flood Technical Resource Guide*'s represents a list of 'Historic Flooding' which typically records only at most 12 events in a single region across a decade. In comparison, the NOAA database records storm-driven flooding events that result in damage, injury, loss of life or events that have unusual conditions that may generate media attention. This shows as many as 45 events occurring in one region within a decade. By compiling data from two different sources, neither of which have a quantitative metric for defining a flood, has resulted in a list that is inconsistent and likely incomplete, but represents our best attempt to catalogue these events. This table differs somewhat from the list of historic floods in the 2014 NHMP because this plan relates to only a portion of the area covered in the *2014 NHMP*.

Table 16. History of flooding in Wallowa County and Northeast Oregon

Date	Location	Description
1894	NE Oregon	Widespread flooding
1910	Powder River and Malheur River	Widespread flooding
1917	NE Oregon	Widespread flooding
1932	NE Oregon	Widespread flooding
1935	NE Oregon	Widespread flooding
May 1948	Columbia Basin/NE OR	Unusually large mountain snow melt produced widespread flooding
Dec 1955-Jan 1956	Snake and Columbia basins	Warm rain melted snow. Runoff on frozen ground.
Dec. 1964–Jan. 1965	Pacific Northwest	Widespread, very destructive flooding, warm rain, melted snow; runoff on frozen ground; record flood on many rivers
Jan 1974	Much of state	Warm rain/melted snow/runoff on frozen ground
Feb 1986	Entire State	Warm rain/ melted snow/ runoff on frozen ground
June 1986	**Wallowa** County	Severe thunderstorm/rain and hail/flash flooding
May 1991	Union and Baker Counties	Warm rain/ melted snow; considerable damage to cropland and highways. A number of bridges were destroyed
February 1996	Nearly statewide	Damages statewide totaled over $28 million, Numerous mudslides were triggered, disrupting transportation in mountainous areas of western Oregon and in the Northeast Mountains. In the

[118] https://oregonexplorer.info/data_files/OE_topic/hazards/documents/04_flood.pdf
[119] https://www.ncdc.noaa.gov/stormevents/

Date	Location	Description
		Northeast Mountains, the town of **Troy** was cut off from the outside world from mudslide and sinkhole damage to all the roads into the town.
January 1, 1997	**Imnaha**	This flood washed away one house, several parts of the Imnaha Road, numerous parts of the Loop Road (3900 road). People were without electricity and could not get to town for 2 weeks. Supplies were helicoptered in as well as with a pack string. One house in the River Woods was wiped out by a mudslide. Imnaha River at Imnaha - Maximum discharge, 20,200 feet^3/sec Jan. 1, 1997, gage height, 11.44 feet
May 1998	Eastern and Central OR	Persistent rains; widespread damage
May 22, 1998	**Imnaha**	3.10 inches of rain fell in a 25-hour period. Springs and streams flowing out of canyons flooded and left 1.0- to 1.5-foot-deep ruts in some roads.
July 10, 1998	**Joseph Airport**	Flash flooding along Hurricane Creek about four miles west of Joseph Airport washed out several roads and stranded some campers. The flash floods caused four mudslides. About 25 people were stranded when the largest slide went across the road and change the course of Hurricane Creek. The slide was estimated to be 150 feet wide and 4 feet deep. One of the mud slides pushed a Chevy Geo about 12 feet into the side of the owners' tent. No one was injured.
July 31, 1998	**Lostine**	Water overflowed banks of Hurricane Creek. Mudslides in Lostine Canyon covered a few places along the road.
June 2002	Baker and Malheur Counties	Slow-moving thunderstorms dropped very heavy rainfall over the Rye Valley area near the Baker-Malheur County line.
July 2004	Union	$5,000 in property damage
May 2008	Union and **Wallowa** Counties	Flooding along Catherine Creek and Grande Ronde River damaged roads in Union County causing $30,000 in damages; in Wallowa County the **Imnaha River crested above flood stage**
June 2010	Northeast OR	Flooding occurred on **Imnaha River, Wallowa River, Grande Ronde River** among other rivers in NE Oregon.

Date	Location	Description
Jan 2011	**Wallowa** and Grant Counties	Minor damage to homes in the **Troy area**; in Grant County, Mount Vernon and John Day sustained minor flooding
May 2011	Baker City, Grant County	Powder River near Baker City was source of minor flooding; Canyon City, John Day, Mount Vernon were flooded along the John Day River; Grant Union HS and several basements in Canyon City were flooded
April 2012	**Wallowa** County	Flooding along the **Imnaha River**
March 2014	**Wallowa**, Union and Grant Counties	Heavy rain fell across much of the northern Blue Mountains and **Wallowa County** throughout the first week of March.
May 2016	Baker County	A strong thunderstorm dumped up to a quarter of an inch of rain over a 15-minute period over terrain scorched by wild fire in August of 2015 causing flash flooding and debris flows.
March 2017	**Wallowa** County	An extended period of snow melt, combined with a period of heavy rain, caused an extended period of flooding along portions of the Grande Ronde River. The **Grande Ronde River at Troy** crested 1.5 ft above flood stage on 3/16/17 and 1.7 ft above flood stage again on 3/19/17.
May 2017	**Imnaha**	Increased snow melt caused minor flooding along portions of the Imnaha river on May 5th. The **Imnaha River at Imnaha** had minor flooding early on May 6th, due to snow melt. The river crested at the flood stage of 5.5 feet early on May 6th.
September 2017	Baker County	Thunderstorms producing heavy rain over the 2016 Rail Fire burned area on the Wallowa-Whitman National Forest resulted in flash flooding and debris flows.
May 2018	Grant and **Wallowa** Counties	Heavy rain from slow moving thunderstorms caused rockslides and water on roadways within an area that includes Mount Vernon, John Day, Canyon City, and Imnaha. Run off and landslides damaged Imnaha Highway (Hwy 350) between mile posts 14 and 20. The road was closed and clean up continued into at least the next day. Rainfall south of Imnaha was as much as 0.87 inches over a one-and-a-half-hour period leading up to the flood.

Date	Location	Description
June 2018	Baker County	Thunderstorms with heavy rainfall developed over southwest Baker County, Oregon on June 20th, leading to flash flooding and debris flow on the Rail and Cornet-Windy Ridge fires burn scar areas.
April 2019	Union, Grant, and **Wallowa** Counties	Snow water equivalents near 200% of normal in the Blue Mountains coupled with warm temperatures and near record rainfall totals for April produced significant river flooding across eastern Oregon.
Feb 2020	Umatilla, Union and **Wallowa** Counties	**DR-4519**; severe storms, flooding, landslides, and mudslides

Sources: DLCD "Flood Technical Resource Guide" (Andre and others, 2001) and National Climate Data Center Storm events Database http://www.ncdc.noaa.gov/stormevents

Dam Failure

The Oregon Water Resources Department (OWRD) is the state authority for dam safety with specific authorizing laws and implementing regulations. Oregon's dam safety laws were re-written by HB 2085 which passed through the legislature and was signed by Governor Brown in 2019. This law became operative on July 1, 2020.

OWRD coordinates on but does not directly regulate the safety of dams owned by the United States or most dams used to generate hydropower. OWRD is the Oregon Emergency Response System contact in the event of a major emergency involving a state-regulated dam, or any dam in the State if the regulating agency is unknown. The Program also coordinates with the National Weather Service and the Oregon Office of Emergency Management on severe flood potential that could affect dams and other infrastructure.

The OWRD has been striving to inspect the over 900 dams under its jurisdiction with recommendations sent to dam owners. At times, urgent dam safety notices are needed, and for uncooperative dam owners failure to maintain the dam may lead to an administrative hearing and formal order. The program meets the minimum FEMA standard for Emergency Action Plans and sometimes exceeds FEMA guidance for dam safety inspections on schedule and for condition classification.

Causes and Characteristics of Dam Failure

Oregon's statutory size threshold for dams to be regulated by OWRD is at least 10 feet high and storing at least 3 million gallons. An additional 12,000 or so dams that fall below that threshold have water right permits for storage from OWRD. As of December 2019, there were 945 state-regulated dams and another 252 federally regulated dams that met Oregon's statutory size threshold for regulation by OWRD. The largest dams are under federal ownership or regulation.

Under normal loading conditions dams are generally at very low risk of failure. Specific events are associated with most dam failures. Events that might cause dams to fail include:

- An extreme flood that exceeds spillway capacity and causes an earthen dam to fail;
- Extended high water levels in a dam that has no protection against internal erosion;
- Movement of the dam in an earthquake; and
- A large rapidly moving landslide impacting the dam or reservoir.

Landslides are a significant hazard in many parts of Oregon, and some dams are constructed on landslide deposits. Though not common, a large and rapidly moving landslide or debris flow may generate a wave that can overtop a dam, causing significant flooding, especially if it causes a dam to fail.

Wildfires may increase the risk of debris flows (though wildfire generated debris flows are typically on the smaller size scale). Wildfires and windstorms can also result in large woody debris that can block spillways, also a risk to dam integrity. Oregon will be evaluating both landslide and wildfire risks during its High Hazard Potential Dam grant funded risk assessments of dams currently eligible for the program.

Most of the largest dams, especially those owned or regulated by the Federal Government are designed to safely withstand these events and have been analyzed to show that they will.

However, there are a number of dams where observations, and sometimes analysis indicates a deficiency that may make those dams susceptible to one or more of the events. The majority of state regulated dams do not have a current risk assessment or analysis, and safe performance in these events is uncertain.

Failures of some dams can result in loss of life, damage to property, infrastructure, and the natural environment. The impacts of dam failures range from local impacts to the dam owner's property and waters below the dam to community destruction with mass fatalities. The 1889 Johnston Flood in Pennsylvania was caused by a dam failure and resulted in over 2000 lives lost. Oregon's first dam safety laws were developed in response to the St. Francis dam failure in California in 1928. That failure was attributed to unsafe design practice, and because of this about 500 persons perished. In modern times (2006) a dam owner filled in the spillway of a dam on the island of Kauai causing dam failure that killed 7 people. This dam had no recent dam safety inspections because the hazard rating was incorrect.

Where a dam's failure is expected to result in loss of life downstream of the dam, an Emergency Action Plan (EAP) must be developed. The EAP contains a map showing the area that would potentially be inundated by floodwaters from the failed dam. These dams are often monitored so that conditions that pose a potential for dam failure are identified to allow for emergency evacuations

Historic Significant Dam Failures Oregon has records of at least 55 dam failures in the State. Many of these failures had very little or no impacts on people, structures, or properties. Of these, four dam failures have occurred in northeast Oregon, all of which were in Baker County.

Dam Hazard Ratings Oregon's new dam safety laws were developed considering the joint Association of State Dam Safety Officials and FEMA's Model State Dam Safety Program. Oregon follows national guidance for assigning hazard ratings to dams and for the contents of Emergency Action Plans, which are now required for all dams rated as "high hazard." Each dam is rated according to the anticipated impacts of its potential failure. The state has adopted these definitions (ORS 540.443–491) for state-regulated dams:

- "High Hazard" means loss of life is expected if the dam fails.
- "Significant Hazard" means loss of life is not expected if the dam fails, but extensive damage to property or public infrastructure is.
- "Low Hazard" is assigned to all other state-regulated dams.
- "Emergency Action Plan" means a plan that assists a dam owner or operator, and local emergency management personnel, to perform actions to ensure human safety in the event of a potential or actual dam failure.

OWRD conducts hazard rating reviews as its limited resources permit. Correction of hazard ratings is a Program priority, and therefore hazard ratings can and do change. Ratings may change for a number of reasons. For example, a dam's original rating may not have been based on current inundation analysis methodologies, or new development may have changed potential downstream impacts. Since 2013, OWRD has formally reviewed the hazard ratings of over 25 state-regulated dams, resulting in the ratings of about 16 being elevated to high hazard status. Federal agencies conduct similar analyses to determine hazard ratings of federally regulated dams.

Dam Safety Issues in Wallowa

The Wallowa Lake Dam is the only state-regulated high hazard dam in Wallowa County. At its original construction the Dam was owned and operated by the Associated Ditch Companies, Inc. The ADC was comprised of five different ditches: Silver Lake, Farmers, Big Bend, Dobbin, and Creighton. In 2017 the farmers decided to restructure and form an Irrigation District, which is the current operation of Wallowa Lake Irrigation District[120]. It is currently assessed to be below accepted safety standards (in Poor or Unsatisfactory Condition). The population at risk was evaluated using the screening tool DSS-WISE. This analysis concluded that 1,131 people are at risk during the daytime and 1,334 people are at risk during the nighttime.

The Wallowa Lake Dam is located at the northern end of Wallowa Lake. The original curved section of the dam was constructed in 1919 on the natural outlet of Wallowa Lake. It was raised 3 feet the following year and raised an additional 5 feet in 1929. Since 1979 Dam safety inspections have occurred semi-annually. In 1996 the Wallowa Lake Dam was listed as High Hazard by Oregon Water Resources Department Dam Safety. This has forced the farmers to operate the Dam at a 72% capacity. Since this classification the local farmers have volunteered countless hours with the Wallowa Lake Irrigation District, the owner of the dam, to find ways to fund a rehabilitation project, which would bring us back to 100% capacity, as well as providing fish passage into the lake.[121]

[120] History | Wallowa Lake Irrigation District | Wallowa Lake Dam (wlid.org)
[121] Ibid.

Recent legislation has been passed allowing the release of $14 million in state funds for the $16 million refurbishment of the Wallowa Lake Dam. The four signatories to the agreement, the Nez Perce Tribe, the Wallowa Lake Irrigation District, the Oregon Department of Fish and Wildlife and the Confederated Tribes of the Umatilla Indian Reservation are in the process of making agreements on water storage and release. The details of fish passage design is complicated and has been tabled at this writing.[122]

The Hells Canyon Dam is the only federally regulated High Hazard dam in Wallowa County. It is one in the chain of three hydroelectric dams within the Snake River canyon that were constructed by the Army Corps of Engineers between 1959 and 1967. The Brownlee Dam opened in 1959 and the Oxbow Dam opened in 1961. The Hells Canyon Dam produces 2,015.3 GWh of electricity annually. All three dams lack passage for migrating salmon thereby blocking access to anadromous salmonids to a stretch of the Snake River basin up to Shoshone Falls in south central Idaho.

In 2003, Idaho Power filed an application with the Federal Energy Regulatory Commission (FERC) to relicense the three dams. The existing license expired in 2005, and the company is sought a new, 30-year license. Following legal challenges and complex negotiations an agreement was announced in December 2018 that Idaho Power would pay $20 million over 20 years to improve water quality in the Snake River below the Complex, conduct research, and boost the production of spring Chinook salmon at the company's Rapid River Hatchery from 3.2 million smolts per year to 4 million. In exchange, Oregon accepted that fish passage would not be required by the state Department of Environmental Quality. As a result, both states will issue water-quality certifications for the Complex, allowing the long relicensing effort to move forward. That will resolve the last administrative obstacle in the way of FERC issuing a new license with terms and conditions. [123]

[122] Wallowa Lake Dam agreement approved | Local News | wallowa.com
[123] Hells Canyon | Northwest Power and Conservation Council (nwcouncil.org)

VOLCANIC EVENT HAZARD ANNEX

Volcanoes are present in Washington, Oregon, and California where volcanic activity is generated by continental plates moving against each other (Cascadia Subduction Zone movement). Because the population of the Pacific Northwest is rapidly expanding, volcanoes of the Cascades Range are now considered some of the most dangerous in the United States.[124]

Volcanoes, however, provide benefits to humans living on or near them. They produce fertile soil, and provide valuable minerals, geothermal resources, and scenic beauty. Volcanic products are used as building or road-building materials, as abrasive and cleaning agents, and as raw materials for many chemical and industrial uses. Volcanic ash makes soil rich in mineral nutrients thus encouraging human settlement.[125]

Causes and Characteristics of Volcanic Eruption

Northeast Oregon and the Pacific Northwest, lie within the "ring of fire," an area of very active volcanic activity surrounding the Pacific Basin. Volcanic eruptions occur regularly along the ring of fire, in part because of the movement of the Earth's tectonic plates. The Earth's outermost shell, the lithosphere, is broken into a series of slabs known as tectonic plates. These plates are rigid, but they float on a hotter, softer layer in the Earth's mantle. As the plates move about on the layer beneath them, they spread apart, collide, or slide past each other. Volcanoes occur most frequently at the boundaries of these plates and volcanic eruptions occur when the hotter, molten materials, or magma, rise to the surface.

The primary threat to lives and property from active volcanoes is from violent eruptions that unleash tremendous blast forces, generate mud and debris flows, and produce flying debris and ash clouds. The immediate danger area in a volcanic eruption generally lies within a 20-mile radius of the blast site. The following section outlines the specific hazards posed by volcanoes.

Volcanoes are commonly conical hills or mountains built around a vent that connect with reservoirs of molten rock below the surface of the earth.[126] Some younger volcanoes may connect directly with reservoirs of molten rock, while most volcanoes connect to empty chambers. Unlike most mountains, which are pushed up from below, volcanoes are built up by an accumulation of their own eruptive products: lava or ash flows and airborne ash and dust. When pressure from gases or molten rock becomes strong enough to cause an upsurge, eruptions occur. Gases and rocks are pushed through the opening and spill over or fill the air with lava fragments. Figure 22 diagrams the basic features of a volcano.

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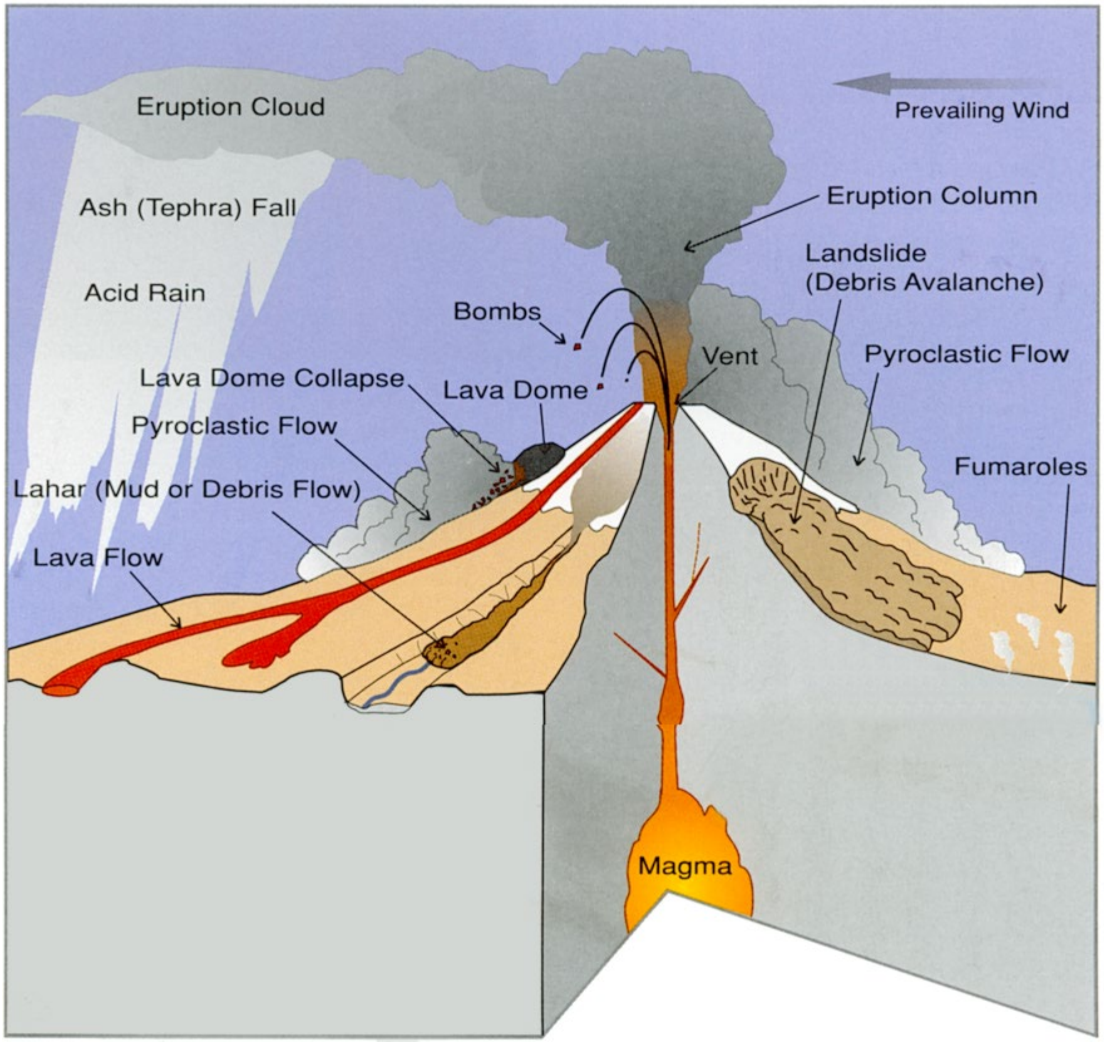
[124]Dzurisin, Dan, Peter H. Stauffer, and James W. Hendley II, Living With Volcanic Risk in the Cascades, USGS Fact Sheet 165-97, (2000).
[125] FEMA Library: Volcanoes at http://www.fema.gov/library/volcano.htm.
[126] Tilling, Robert I., Volcanoes, USGS General Interest Publication, (1985).

Figure 22. Volcanic Hazard from a Composite Type Volcano



Source: Walder et al, "Volcano Hazards in the Mount Jefferson Region," 1999; W.E. Scott, R.M. Iverson, S.P. Schilling, and B.J. Fischer, Volcano Hazards in the Three Sisters Region, Oregon: U.S. Geological Survey Open-File Report 99-437, 14p,200.

Ash / Tephra

Tephra consists of volcanic ash (sand-sized or finer particles of volcanic rock) and larger fragments. During explosive eruptions, tephra together with a mixture of hot volcanic gas are ejected rapidly into the air from volcanic vents. Larger fragments fall down near the volcanic vent while finer particles drift downwind as a large cloud. When ash particles fall to the ground, they can form a blanket-like deposit, with finer grains carried further away from the volcano. In general, the thickness of ash fall deposits decreases in the downwind direction. Tephra hazards include impact of falling fragments, suspension of abrasive fine particles in the air and water, and burial of structures, transportation routes and vegetation.

During an eruption that emits ash, the ash fall deposition is controlled by the prevailing wind direction.[127] The predominant wind pattern over the Cascades is from the west, and previous eruptions seen in the geologic record have resulted in most ash fall drifting to the east of the volcanoes.[128]

Earthquakes

Volcanic eruptions can be triggered by seismic activity or earthquakes can occur during or after a volcanic eruption. Earthquakes produced by stress changes are called volcano-tectonic earthquakes. These earthquakes, typically small to moderate in magnitude, occur as rock is moving to fill in spaces where magma is no longer present and can cause land to subside or produce large ground cracks.[129] In addition to being generated after an eruption and magma withdrawal, these earthquakes also occur as magma is intruding upward into a volcano, opening cracks and pressurizing systems.[130] Volcano-tectonic earthquakes do not indicate that the volcano will be erupting but can occur at any time and cause damage to manmade structures or provoke volcanic events.

Lava flows

Lava flows are streams of molten rock that erupt relatively non-explosively from a volcano and move down slope, causing extensive damage or total destruction by burning, crushing, or burying everything in their paths. Secondary effects can include forest fires, flooding, and permanent reconfiguration of stream channels.[131]

Pyroclastic flows and surges

Pyroclastic flows are avalanches of rock and gas at temperatures of 600 to 1500 degrees Fahrenheit. They typically sweep down the flanks of volcanoes at speeds of up to 150 miles per hour. Pyroclastic surges are a more dilute mixture of gas and rock. They can move even more rapidly than a pyroclastic flow and are more mobile. Both generally follow valleys, but surges sometimes have enough momentum to overtop hills or ridges in their paths. Because of their high speed, pyroclastic flows and surges are difficult or impossible to escape. If one occurs, evacuation orders should be issued as soon as possible for the hazardous areas. Objects and structures in the path of a pyroclastic flow are generally destroyed or swept away by the impact of debris or by accompanying hurricane-force winds. Wood and other combustible materials are commonly burned. People and animals may also be burned or killed by inhaling hot ash and gases. The deposit that results from pyroclastic flows is a combination of rock bombs and ash and is termed *ignimbrite.* These deposits may accumulate to hundreds of feet thick and can harden to resistant rock.[132]

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[127] Oregon State Natural Hazard Mitigation Plan. 2012." Volcanic Hazards Chapter,"
[128] Ibid.
[129] Riley, Colleen M., A Basic Guide to Volcanic Hazards, Michigan Technological University: http://www.geo.mtu.edu/volcanoes/hazards/primer.
[130] Scott, W. E., USGS Cascades Volcano Observatory, Personal Correspondence, (July 5, 2001).
[131] Oregon State Natural Hazard Mitigation Plan. 2012." Volcanic Hazards Chapter,"
[132] Ibid.

Lahars and debris flows

Lahar is an Indonesian term that describes a hot or cold mixture of water and rock fragments flowing down the slopes of a volcano or river valley.[133] Lahars typically begin when floods related to volcanism are produced by melting snow and ice during eruptions of ice-clad volcanoes like Mount Shasta, and by heavy rains that may accompany eruptions. Floods can also be generated by eruption-caused waves that could overtop dams or move down outlet streams from lakes.

Lahars react much like flash flood events in that a rapidly moving mass moves downstream, picking up more sediment and debris as it scours out a channel. This initial flow can also incorporate water from rivers, melting snow and ice. By eroding rock debris and incorporating additional water, lahars can easily grow to more than ten times their initial size. But as a lahar moves farther away from a volcano, it will eventually begin to lose its heavy load of sediment and decrease in size.[134]

Lahars often cause serious economic and environmental damage. The direct impact of a lahar's turbulent flow front or from the boulders and logs carried by the lahar can easily crush, abrade, or shear off at ground level just about anything in the path of a lahar. Even if not crushed or carried away by the force of a lahar, buildings and valuable land may become partially or completely buried by one or more cement-like layers of rock debris. By destroying bridges and key roads, lahars can also trap people in areas vulnerable to other hazardous volcanic activity, especially if the lahars leave deposits that are too deep, too soft, or too hot to cross.[135]

Volcanic Landslides (debris avalanches)

Landslides – or debris avalanches – are a rapid downhill movement of rocky material, snow, and (or) ice. Volcanic landslides range in size from small movements of loose debris on the surface of a volcano to massive collapses of the entire summit or sides of a volcano. Steep volcanoes are susceptible to landslides because they are built up partly of layers of loose volcanic rock fragments. Landslides on volcano slopes are triggered not only by eruptions, but also by heavy rainfall or large earthquakes that can cause materials to break free and move downhill.[136]

History of Volcanic Events in Northeast Oregon

Although there have been no recent volcanic events in the Northeast Oregon region, it is important to note the area is active and susceptible to eruptive events since the region is near the volcanic Cascades Range. Figure 23 displays volcanoes of the western United States.

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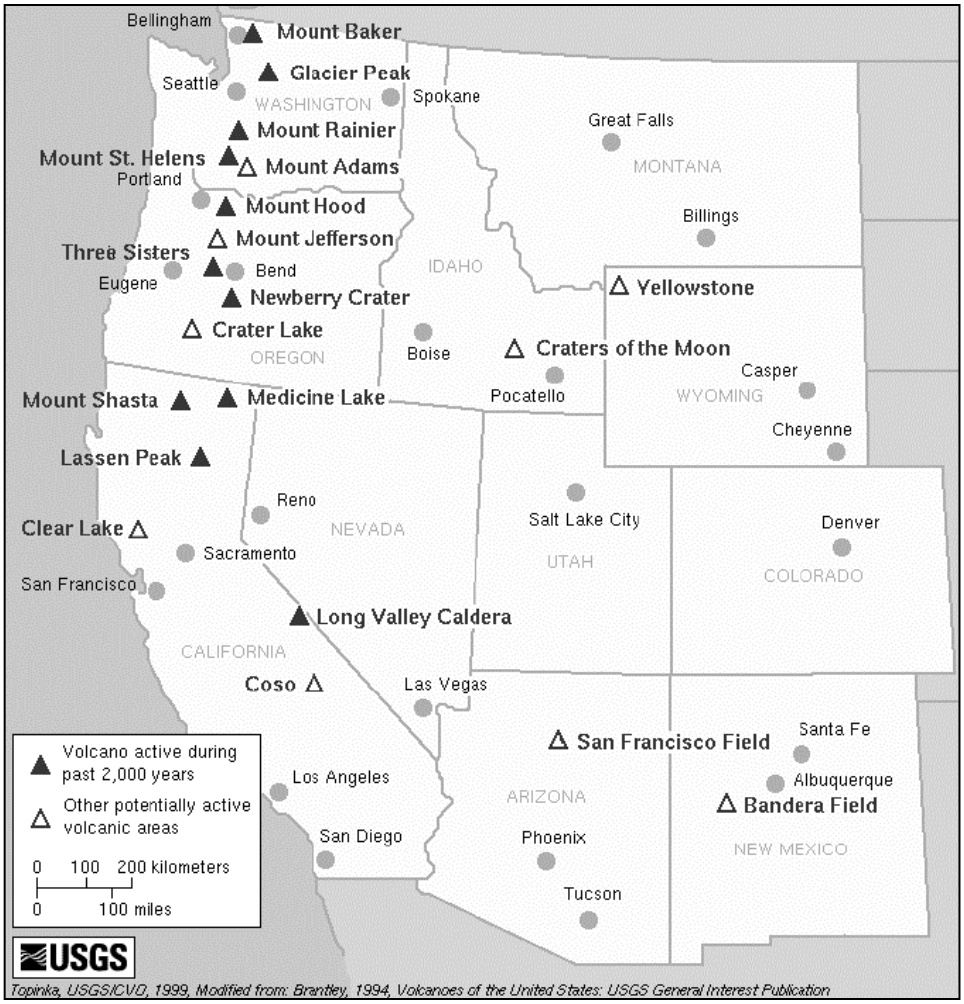
[133] USGS website: http://volcanoes.usgs.gov/Hazards/What/Lahars/lahars.html
[134] Ibid.
[135] Ibid.
[136] Wright and Pierson, Living With Volcanoes, USGS Volcano Hazards Program Circular 1973, (1992).

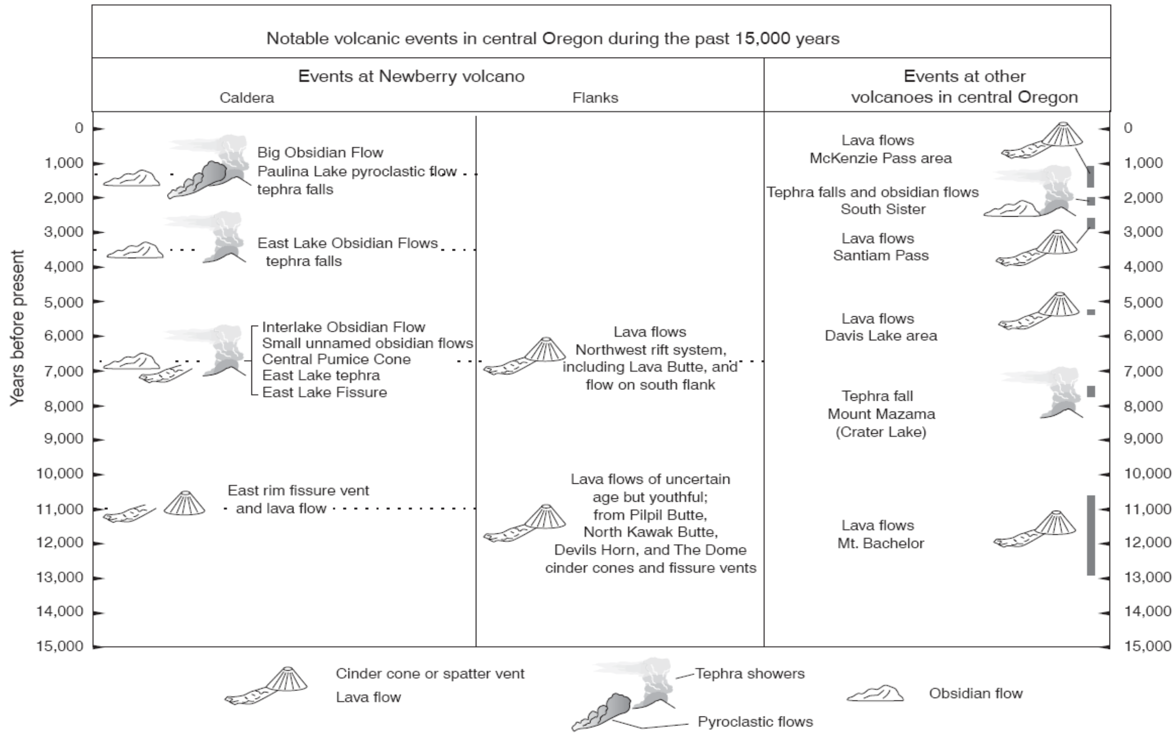
Figure 23. Potentially Active Volcanoes of the Western United States



Source: USGS. http://www.volcano.si.edu/reports/usgs/maps.cfm#usa

Volcanoes in the Cascade Range have been erupting for hundreds of thousands of years. Newberry Volcano, for example, has had many events in the last 15,000 years as shown in Figure 24 below. The Three Sisters region has also had some activity during this time while the last major eruptive activity at Mt. Mazama occurred approximately 7,700 years ago, forming Crater Lake in its wake. Some of the most recent events include Big Obsidian Flow at Newberry Volcano. All of the Cascade volcanoes are characterized by long periods of quiescence and intermittent activity. And these characteristics make predictions, recurrence intervals, or probability very difficult to ascertain.

Figure 24. Notable Volcanic Events in Central Oregon during the Past 15,000 Years



Source: D.R. Sherrod, L.G. Mastin, W.E. Scott, and S.P. Schilling, 1997, Volcano Hazards at Newberry Volcano, Oregon: U.S. Geological Survey Open-File Report 97-513

Mount St. Helen's Case Study

On May 18, 1980, following two months of earthquakes and minor eruptions and a century of dormancy, Mount St. Helens in Washington, exploded in one of the most devastating volcanic eruptions of the 20th century. Although less than 0.1 cubic mile of magma was erupted, 58 people died, and damage exceeded 1.2 billion dollars. Fortunately, most people in the area were able to evacuate safely before the eruption because the U.S. Geological Survey (USGS) and other scientists had alerted public officials to the danger. As early as 1975, USGS researchers had warned that Mount St. Helens might soon erupt. Coming more than 60 years after the last major eruption in the Cascades (Lassen Peak), the explosion of St. Helens was a spectacular reminder that the millions of residents of the Pacific Northwest share the region with live volcanoes.[137]

Identifying the Risk of Volcanic Events

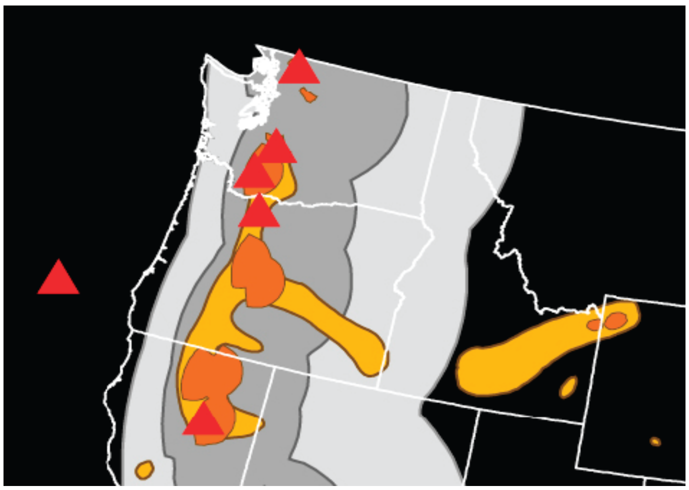
Communities that are closer to volcanoes may be at risk to the proximal hazards, as well as the distal hazards, such as lahars, lava flows, and ash fall. The communities that are farther away, such as those in the Wallowa Valley are only at risk from the distal hazards, (mainly ash fall). The image below shows the locations of some of the Cascade volcanoes (red triangles) with relative volcanic hazard zones. In Figure 25 below dark orange areas have a higher volcanic hazard; light-orange areas

[137] Dzurisin, Dan, Peter H. Stauffer, and James W. Hendley II, Living With Volcanic Risk in the Cascades, USGS Fact Sheet 165-97, (2000).

have a lower volcanic hazard. Dark-grey areas have a higher ash fall hazard; light-grey areas have a lower ash fall hazard.

Geologic hazard maps have been created for most of the volcanoes in the Cascade Range by the USGS Volcano Program at the Cascade Volcano Observatory in Vancouver, WA and are available at http://vulcan.wr.usgs.gov/Publications/hazards_reports.html.

Figure 25. National Volcanic Hazard Map



Note: The red triangles are volcano locations. Dark-orange areas have a higher volcanic hazard; light-orange areas have a lower volcanic hazard. Dark-gray areas have a higher ash fall hazard; light-gray areas have a lower ash fall hazard. Information is based on data during the past 10,000 years.

Source: Image modified from USGS Fact Sheet 2006-3014

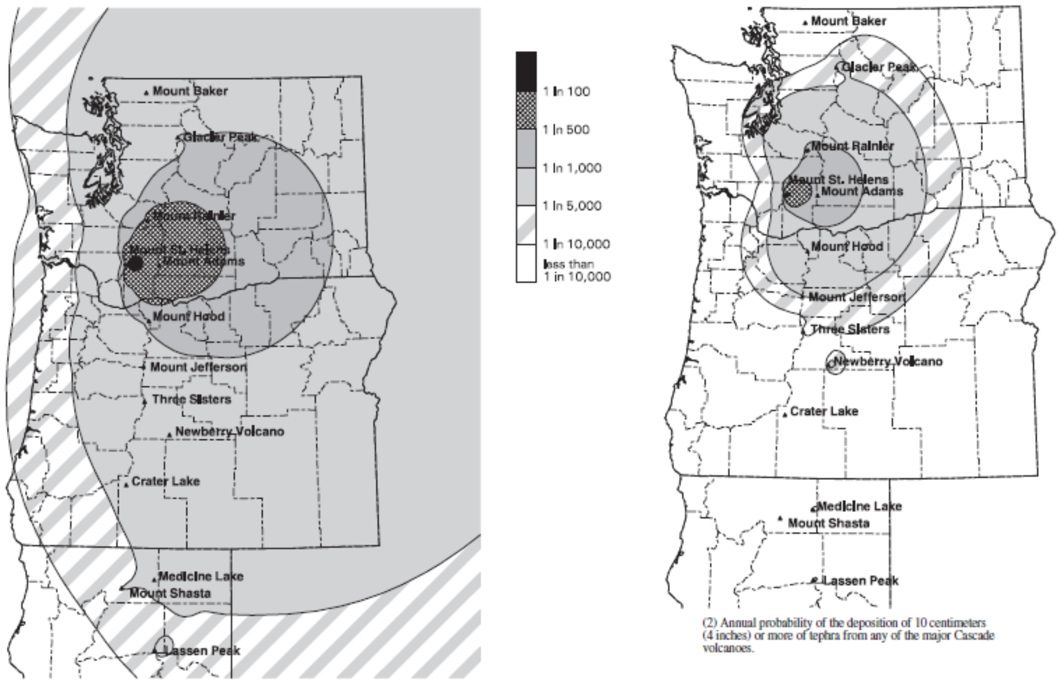
Scientists also use wind direction to predict areas that might be affected by volcanic ash; during an eruption that emits ash, the ash fall deposition is controlled by the prevailing wind direction. The predominant wind pattern over the Cascades originates from the west, and previous eruptions seen in the geologic record have resulted in most ash fall drifting to the east of the volcanoes. Figure 26 below depicts the potential and geographical extent of volcanic ash fall in excess of ten centimeters from a large eruption within the Cascade Range (Mt. St. Helens). The image on the left shows the annual probability of the deposition of one-centimeter or more of tephra; the figure on the right shows the annual probability of the deposition of ten-centimeters or more of tephra.

Volcanic eruptions can send ash airborne, spreading the ash for hundreds or even thousands of miles. An erupting volcano can also trigger flash floods, earthquakes, rockfalls, and mudflows. Volcanic ash can contaminate water supplies, cause electrical storms, and collapse roofs.[138]

Businesses and individuals can make plans to respond to volcano emergencies. Planning is prudent because once an emergency begins, public resources can often be overwhelmed, and citizens may need to provide for themselves and make informed decisions. Knowledge of volcano hazards can help citizens make a plan of action based on the relative safety of areas around home, school, and work.[139]

[138]Dzurisin, Dan, Peter H. Stauffer, and James W. Hendley II, Living With Volcanic Risk in the Cascades, USGS Fact Sheet 165-97, (2000).
[139]Scott, W.E. et al, Volcano Hazards in the Three Sisters Region, Oregon, USGS Open-File Report 99-437, (2001).

Figure 26. Regional Tephra-fall Maps



(1) Annual probability of the deposition of 1 centimeter (0.4 inches) or more of tephra from any of the major Cascade volcanoes.

(2) Annual probability of the deposition of 10 centimeters (4 inches) or more of tephra from any of the major Cascade volcanoes.

Source: USGS "Volcano Hazards in the Mount Jefferson Region, Oregon"

Building and Infrastructure Damage

Buildings and other property in the path of a flash flood, debris flow, or tephra fall can be damaged. Thick layers of ash can weaken roofs and cause collapse, especially if wet. Clouds of ash often cause electrical storms that start fires or damp ash can short-circuit electrical systems and disrupt radio communication.

Pollution and Visibility

Tephra fallout from an eruption column can blanket areas within a few miles of the vent with a thick layer of pumice. High-altitude winds may carry finer ash tens to hundreds of miles from the volcano, posing a hazard to flying aircraft, particularly those with jet engines. In an extreme situation, the airports would need to close to prevent the detrimental effect of fine ash on jet engines and for pilots to avoid total impaired visibility. Fine ash in water supplies will cause brief muddiness and chemical contamination.

Economic Impacts

Volcanic eruptions can disrupt the normal flow of commerce and daily human activity without causing severe physical harm or damage. Ash a few millimeters thick can halt traffic, possibly up to one week, and cause rapid wear of machinery, clog air filters, block drains and water intakes, and can kill or damage agriculture.

Transportation of goods between Northeast Oregon and nearby communities and trade centers could be deterred or halted. Subsequent airport closures can disrupt airline schedules for travelers. Ash can cause short circuits in electrical transformers, which in turn cause electrical blackouts. Volcanic activity can also force nearby recreation areas to close for safety precautions long before the activity ever culminates into an eruption.

Death and Injury

Inhalation of volcanic ash can cause respiratory discomfort, damage or result in death for sensitive individuals miles away from the cone of a volcano. Likewise, emitted volcanic gases such as fluorine and sulfur dioxide can kill vegetation for livestock or cause a burning discomfort in the lungs. Hazards to human life from debris flows are burial or impact by boulders and other debris.