Clackamas County Multi-Jurisdictional Hazard Mitigation Plan

Clackamas County and the Jurisdictions of: Canby, Estacada, Gladstone, Happy Valley, Johnson City, Lake Oswego, Milwaukie, Molalla, Oregon City, Sandy, West Linn, Wilsonville and Clackamas Fire District #1

Photo Credit: Gary Halvorson, Oregon State Archives

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Volume I: Basic Plan

Prepared for:

Clackamas County Disaster Management

Prepared by:

University of Oregon
Institute for Policy Research and Engagement
Oregon Partnership for Disaster Resilience

CLACKAMAS COUNTY

UNIVERSITY OF OREGON | School of Planning, Public Policy and Management | Institute for Policy Research and Engagement

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CLACKAMAS COUNTY

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Special thanks to Jay Wilson, Clackamas County Resilience Coordinator for his vision, passion, and positive outlook throughout the plan update process.

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The Clackamas County GIS department (Kelly Neumeier) updated the vulnerability analysis tables; this table was a vital component to the committee's review and update of the hazard analysis. The contributions from this department were essential in illustrating the extent and potential losses associated with the natural hazards affecting the community.

Additional Thanks:

To the Department of Geology and Mineral Industries for assistance with hazard data; the Department of Land Conservation and Development staff in the hazards for flood data, mapping and process support; to the Oregon Office of Emergency Management for grant administration and process support.

About the Institute for Policy Research and Engagement

The Institute for Policy Research and Engagement (IPRE), a research center affiliated with the School of Planning, Public Policy and Management at the University of Oregon, is an interdisciplinary organization that assists Oregon communities by providing planning and technical assistance to help solve local issues and improve the quality of life for Oregon residents. The role of the IPRE is to link the skills, expertise and innovation of higher education with the transportation, economic development and environmental needs of communities and regions in the State of Oregon, thereby providing service to Oregon and learning opportunities to the students involved.

About the Oregon Partnership for Disaster Resilience

The Oregon Partnership for Disaster Resilience (OPDR) is a coalition of public, private and professional organizations working collectively toward the mission of creating a disaster-resilient and sustainable state. Developed and coordinated by the Institute for Policy Research and Engagement at the University of Oregon, the OPDR employs a service-learning model to increase community capacity and enhance disaster safety and resilience statewide.

NHMP Template Disclaimer

This NHMP is based in part on a plan template developed by the Oregon Partnership for Disaster Resilience. The template is structured to address the requirements contained in 44 CFR 201.6; where language is applicable to communities throughout Oregon, OPDR encourages the use of standardized language. As part of this regional planning initiative, OPDR provided copies of the plan templates to communities for use in developing or updating their hazards mitigation plans. OPDR hereby authorizes the use of all content and language provided to Clackamas County in the plan template.

TABLE OF CONTENTS

Volume I: Basic Plan

Volume II: Jurisdictional Addenda

Volume III: Appendices

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PLAN SUMMARY

Clackamas County updated this Multi-Jurisdictional Natural Hazards Mitigation Plan (NHMP) to prepare for the long-term effects resulting from hazards. It is impossible to predict exactly when these hazards will occur, or the extent to which they will affect the community. However, with careful planning and collaboration among public agencies, private sector organizations and citizens within the community, it is possible to create a resilient community that will benefit from long-term recovery planning efforts.

FEMA defines mitigation as ". . . the effort to reduce loss of life and property by lessening the impact of disasters . . . through risk analysis, which results in information that provides a foundation for mitigation activities that reduce risk." Said another way, hazard mitigation is a method of permanently reducing or alleviating the losses of life, property and injuries resulting from hazards through long and short-term strategies. Example strategies include policy changes, such as updated ordinances, projects, such as seismic retrofits to critical facilities; and education and outreach to targeted audiences, such as non-English speaking residents or the elderly. Hazard mitigation is the responsibility of the "Whole Community." FEMA defines Whole Community as, "private and nonprofit sectors, including businesses, faith-based and disability organizations and the public, in conjunction with the participation of local, tribal, state, territorial and Federal governmental partners."

> *44 CFR 201.6 – The local mitigation plan is the representation of the jurisdiction's commitment to reduce risks from natural hazards, serving as a guide for decision makers as they commit resources to reducing the effects of natural hazards. . . .*

Why Develop this Mitigation Plan?

The Disaster Mitigation Act of 2000 (DMA2K) and the regulations contained in 44 CFR 201 require that jurisdictions maintain an approved NHMP in order to receive FEMA Hazard Mitigation Assistance (HMA) funds for mitigation projects. To that end, Clackamas County is involved in a broad range of hazard and emergency management planning activities. Local and federal approval of this NHMP ensures that the County and listed jurisdictions will (1) remain eligible for pre- and post-disaster mitigation project grants and (2) promote local mechanisms to accomplish risk reduction strategies.

> *44 CFR 201.6(a)(1) – A local government must have a mitigation plan approved pursuant to this section in order to receive HMGP project grants . . .*

What is Mitigation?

"Any sustained action taken to reduce or eliminate long-term risk to life and property from a hazard event."

- U.S. Federal Emergency Management Agency

Who Participated in Developing the Plan?

The Clackamas County NHMP is the result of a collaborative effort between the County, cities, special districts, citizens, public agencies, non-profit organizations, the private sector and regional organizations. County and City Hazard Mitigation Advisory Committees (HMACs) guided the NHMP development process.

For a list of specific County HMAC participants, refer to the acknowledgements section above. The update process included representatives from the following jurisdictions and agencies:

County Departments

- Application Services
- Disaster Management
- Public Health
- Public Works
- Transportation and Development
- Water Environment Services

Participating Cities

- City of Canby
- City of Estacada
- City of Gladstone
- City of Happy Valley
- City of Johnson City
- City of Milwaukie
- City of Molalla
- City of Lake Oswego
- City of Oregon City
- City of Sandy
- City of West Linn
- City of Wilsonville

Other

- Clackamas Soil and Water Conservation District
- Clackamas River Water Providers
- Clackamas Co. Fire District #1
- Oregon Department of Geology and Mineral Industries
- Oregon Department of Land Conservation and Development
- Oregon Office of Emergency Management
- United States Army Corps of Engineers

44 CFR 201.6(c)(1) – Documentation of the planning process used to develop the plan, including how it was prepared, who was involved in the process and how the public was involved.

The Clackamas County Resilience Coordinator convened the planning process and will take the lead in implementing, maintaining and updating the County NHMP. Each of the participating cities have also named a local convener who is responsible for implementing, maintaining and updating the Jurisdictional Addenda (see addenda for specific names and positions). Clackamas County is dedicated to directly involving the public in the continual review and update of the NHMP. The County achieves this through systematic engagement of a wide variety of active groups, organizations or committees, public and private infrastructure partners, watershed and neighborhood groups and numerous others. Although members of the HMAC represent the public to some extent, the public will continue to provide feedback about the NHMP throughout the implementation and maintenance period.

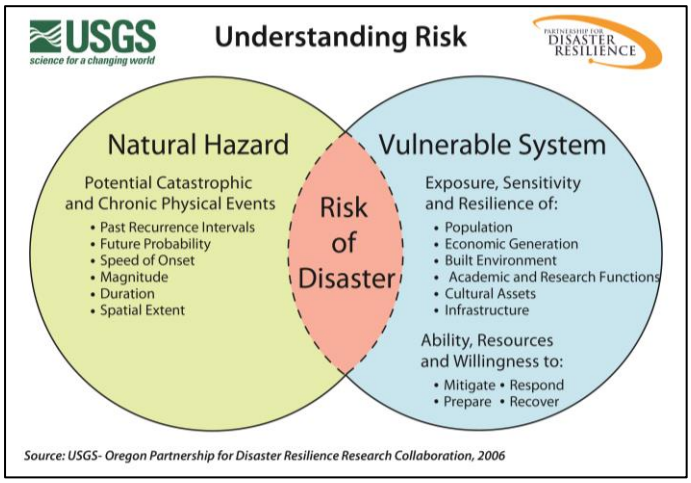
How Does this NHMP Reduce Risk?

> *44 CFR 201.6(c)(2) – A Risk Assessment that provides the factual basis for activities proposed in the strategy . . .*

The NHMP is intended to assist Clackamas County reduce the risk from hazards by identifying resources, information and strategies for risk reduction. It is also intended to guide and coordinate mitigation activities throughout the County. A risk assessment consists of three phases: hazard identification, vulnerability assessment and risk analysis, as illustrated in Figure PS-1.

By identifying and understanding the relationship between hazards, vulnerable systems and existing capacity, Clackamas County is better equipped to identify and implement actions aimed at reducing the overall risk to hazards.

Figure PS-1 Understanding Risk



What is Clackamas County's Overall Risk to Hazards?

Clackamas County reviewed and updated the risk assessment to evaluate the probability of each hazard as well as the vulnerability of the community to that hazard. Table PS-1 summarizes hazard probability and vulnerability as determined by the County HMAC (for more information see Volume I, Section 2).

Table PS-1 Hazard and Vulnerability Assessment Summary

Hazard	History	Vulnerability	Maximum Threat	Probability	Total Threat Score	Hazard Rank	Hazard Tiers
Earthquake - Cascadia	4	45	100	49	198	#1	*Top Tier*
Earthquake - Crustal	6	50	100	21	177	#2	
Wildfire	12	25	70	56	163	#3	
Winter Storm	10	30	70	49	159	#4	
Drought	10	15	50	56	131	#5	*Middle Tier*
Flood	16	20	30	56	122	#6	
Windstorm	14	15	50	42	121	#7	
Landslide	14	15	20	63	112	#8	*Bottom Tier*
Volcanic Event	2	35	50	14	101	#9	
Extreme Heat	2	20	40	14	76	#10	

Source: Clackamas County NHMP Hazard Mitigation Advisory Committee, 2018

What is the NHMP's Mission?

The mission of the Clackamas County NHMP is to:

Promote sound public policy designed to protect citizens, critical facilities, infrastructure, private property, and the environment from natural hazards.

This can be achieved by increasing public awareness, documenting the resources for risk reduction and loss-prevention, and identifying activities to guide the county towards building a safer, more sustainable community.

44 CFR 201.6(c)(3)(i) – A description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.

What are the NHMP Goals?

The plan goals describe the overall direction that the participating jurisdiction's agencies, organizations and citizens can take toward mitigating risk from all-hazards. The goals of the Clackamas County NHMP are organized under several broad categories. The goals are:

GOAL 1: PROTECT LIFE AND PROPERTY

- Implement activities that assist in protecting lives by making homes, businesses, infrastructure, critical facilities, and other property more resistant to natural hazards.
- Reduce losses and repetitive damages for chronic hazard events while promoting insurance coverage for catastrophic hazards.
- Improve hazard assessment information to make recommendations for discouraging new development and encouraging preventative measures for existing development in areas vulnerable to natural hazards.

GOAL 2: ENHANCE NATURAL SYSTEMS

- Balance watershed planning, natural resource management, and land use planning with natural hazards mitigation to protect life, property, and the environment.
- Preserve, rehabilitate, and enhance natural systems to serve natural hazard mitigation functions.

GOAL 3: AUGMENT EMERGENCY SERVICES

- Establish policy to ensure mitigation projects for critical facilities, services, and infrastructure.
- Strengthen emergency operations by increasing collaboration and coordination among public agencies, non-profit organizations, and business, and industry.
- Coordinate and integrate natural hazards mitigation activities, where appropriate, with emergency operations plans and procedures.

GOAL 4: ENCOURAGE PARTNERSHIPS FOR IMPLEMENTATION

- Strengthen communication and coordinate participation among and within public agencies, citizens, non-profit organizations, business, and industry to gain a vested interest in implementation.
- Encourage leadership within public and private sector organizations to prioritize and implement local, county, and regional hazard mitigation activities.

GOAL 5: PROMOTE PUBLIC AWARENESS

- Develop and implement education and outreach programs to increase public awareness of the risks associated with natural hazards.
- Provide information on tools, partnership opportunities, and funding resources to assist in implementing mitigation activities.

How are the Action Items Organized?

The action items are organized within an action matrix included within Section 3, Mitigation Strategy.

44 CFR 201.6(c)(3)(ii) – A section that identifies and analyzes a comprehensive range of specific mitigation actions . . .

Data collection, research and the public participation process resulted in the development of the action items. The Action Item Matrix portrays the plan framework and identifies linkages between the plan goals and actions. The matrix documents the title of each action along with, the coordinating organization, timeline and the NHMP goals addressed. City specific action items are included in Volume II, Jurisdictional Addenda.

Comprehensive Action Plan

Action items are detailed recommendations for activities that local departments, citizens, and others could engage in to reduce risk. The HMAC will prioritize the following actions to focus their attention, and resource availability, upon an achievable set of high leverage activities over the next five-years.

In addition to the actions listed below **Wildfire #1** (see Appendix A) is considered high priority. See the Clackamas County Community Wildfire Protection Plan for detailed information.

EDUCATION AND OUTREACH

- **Multi-Hazard (MH) #4.** Identify, improve, and sustain collaborative programs focusing on the real estate and insurance industries, public and private sector organizations, and individuals to avoid activity that increases risk to natural hazards
- **Multi-Hazard (MH) #7.** Strengthen emergency services preparedness and response by linking emergency services with natural hazard mitigation programs, and enhancing and implementing public education programs on a regional scale
- **Flood (FL) #1.** Identify opportunities to educate people within Clackamas County's public and private flood prone properties and identify feasible mitigation options
- Flood (FL) #8. Encourage purchase of flood insurance
- **Landslide (LS) #3.** Continue to limit activities in identified potential and historical landslide areas through regulation and public outreach
- **Wildfire (WF) #2.** Encourage private landowners to create and maintain defensible space around homes and other buildings.

GIS/MAPPING

- No action within this category was identified as a priority.

MAINTENANCE/PLANNING

- **Multi-Hazard (MH) #1.** Integrate the goals and action items from the Clackamas County Natural Hazard Mitigation Plan into existing regulatory documents and programs, where appropriate.
- **Multi-Hazard (MH) #2.** Identify and pursue funding opportunities to develop and implement local and county mitigation activities.
- **Severe Weather (SW) #3.** Monitor and implement programs to keep trees from threatening lives, property, and public infrastructure during windstorm events

CRITICAL INFRASTRUCTURE/ESSENTIAL FACILITIES

- **Multi-Hazard (MH) #6.** Update and Maintain inventories of at-risk buildings and infrastructure and prioritize mitigation projects
- **Multi-Hazard (MH) #11.** Perform pre-disaster assessments on County owned and/or operated buildings and facilities, potential shelter sites, and essential facilities.
- **Earthquake (EQ) #3.** Encourage seismic strength evaluations for existing critical facilities in the County to identify vulnerabilities for mitigation of schools and universities, public infrastructure, and critical facilities to meet current seismic standards

LAND USE/DEVELOPMENT

- **Multi-Hazard (MH) #9.** Enhance strategies for debris management.
- **Landslide (LS) #4.** Recommend construction and subdivision design that can be applied to steep slopes to reduce the potential adverse impacts from development.

How will the NHMP be implemented?

44 CFR 201.6(c)(3)(iii) – An action plan describing how the actions . . . will be prioritized, implemented and administered . . .

44 CFR 201.6(c)(4) – A plan maintenance process . . .

The implementation and maintenance section (Section 4) details the formal process that will ensure that the Clackamas County NHMP remains an active and relevant document. The Clackamas County Resilience Coordinator is the designated convener (NHMP Convener) and is responsible for overseeing the review and implementation processes (see jurisdictional addenda for city and special district conveners). The NHMP maintenance process includes a schedule for monitoring and evaluating the NHMP semi-annually and revising the NHMP every five years. This section also describes how the communities will integrate public participation throughout the implementation and maintenance process.

The accomplishment of the NHMP goals and actions depends upon regular HMAC participation and adequate support from County, city, and special district leadership. Comprehensive familiarity with this NHMP will result in the efficient and effective implementation of appropriate mitigation activities and a reduction in the risk and the potential for loss from future natural hazard events.

NHMP Adoption

Once the NHMP is locally reviewed and deemed complete the NHMP Convener (or their designee) submits it to the State Hazard Mitigation Officer at the Oregon Office of Emergency Management (OEM). OEM reviews the NHMP and submits it to FEMA Region X for pre-approval. This review will address the federal criteria outlined in 44 CFR Part 201.6. Once pre-approved by FEMA, the County, cities, and special districts may formally adopt it via resolution.

> *44 CFR 201.6(c)(5) – Documentation that the plan has been formally adopted by the governing body of the jurisdiction . . .*
>
> *44 CFR 201.6(d) – Plan review [process] . . .*

The Clackamas County NHMP Convener will be responsible for ensuring local adoption of the NHMP and providing the support necessary to ensure NHMP implementation. Once the resolution is executed at the local level and documentation is provided to FEMA, the NHMP will be formally approved by FEMA and the County, participating cities, and special districts will regain eligibility for Hazard Mitigation Assistance (HMA) grant programs

The HMACs for Clackamas County and participating cities each met to review the NHMP update process and their governing bodies adopted the NHMP as shown below:

County, City, and Special District Dates of Adoption and Approval

Clackamas County adopted the NHMP on **April 4, 2019**

FEMA Region X approved the Clackamas County NHMP on **April 12, 2019**. With approval of this NHMP, the entities listed above are now eligible to apply for the Robert T. Stafford Disaster Relief and Emergency Assistance Act's hazard mitigation project grants through **April 11, 2024**.

For the date of adoption for each participating City of special district see Volume II.

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Volume I:
Basic Plan

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SECTION I: INTRODUCTION

This section provides a general introduction to natural hazard mitigation planning in Clackamas County. In addition, it addresses the planning process requirements contained in 44 CFR 201.6(b) thereby meeting the planning process documentation requirement contained in 44 CFR 201.6(c)(1). The section concludes with a general description of how the NHMP is organized.

What is Natural Hazard Mitigation?

The Federal Emergency Management Agency (FEMA) defines mitigation as ". . . the effort to reduce loss of life and property by lessening the impact of disasters . . . through risk analysis, which results in information that provides a foundation for mitigation activities that reduce risk."[1] Said another way, natural hazard mitigation is a method of permanently reducing or alleviating the losses of life, property and injuries resulting from natural hazards through long and short-term strategies. Example strategies include policy changes, such as updated ordinances, projects, seismic retrofits to critical facilities and education and outreach to targeted audiences, such as Spanish speaking residents or the elderly. Natural hazard mitigation is the responsibility of the "Whole Community"; individuals, private businesses and industries, state and local governments and the federal government.

Engaging in mitigation activities provides jurisdictions (counties, cities, special districts, etc.) with many benefits, including reduced loss of life, property, essential services, critical facilities and economic hardship; reduced short-term and long-term recovery and reconstruction costs; increased cooperation and communication within the community through the planning process; and increased potential for state and federal funding for recovery and reconstruction projects.

Why Develop a Mitigation Plan?

Clackamas County updated this Multi-Jurisdictional Natural Hazard Mitigation Plan (NHMP) to reduce future loss of life and damage to property resulting from natural hazards. It is impossible to predict exactly when natural hazard events will occur, or the extent to which they will affect community assets. However, with careful planning and collaboration among public agencies, private sector organizations and citizens within the community, it is possible to minimize the losses that can result from natural hazards.

In addition to establishing a comprehensive community-level mitigation strategy, the Disaster Mitigation Act of 2000 (DMA2K) and the regulations contained in 44 CFR 201, require that jurisdictions maintain an approved NHMP to receive federal funds for mitigation projects. Local adoption and federal approval of this NHMP ensures that the County and listed cities will remain eligible for pre- and post-disaster mitigation project grants.

[1] FEMA, *What is Mitigation?* http://www.fema.gov/what-mitigation

What Federal Requirements Does This NHMP Address?

DMA2K is the latest federal legislation addressing mitigation planning. It reinforces the importance of mitigation planning and emphasizes planning for natural hazards before they occur. As such, this Act established the Pre-Disaster Mitigation (PDM) grant program and new requirements for the national post-disaster Hazard Mitigation Grant Program (HMGP). Section 322 of the Act specifically addresses mitigation planning at the state and local levels. State and local jurisdictions must have approved mitigation plans in place in order to qualify to receive post-disaster HMGP funds. Mitigation plans must demonstrate that State and local jurisdictions' proposed mitigation measures are based on a sound planning process that accounts for the risk to the individual and State and local jurisdictions' capabilities.

Chapter 44 Code of Federal Regulations (CFR), section 201.6, also requires a local government to have an approved NHMP in order to receive HMGP project grants.[2] Pursuant of Chapter 44 CFR, the NHMP planning processes shall include opportunity for the public to comment on the NHMP during review and the updated NHMP shall include documentation of the public planning process used to develop the NHMP.[3] The NHMP update must also contain a risk assessment, mitigation strategy and a NHMP maintenance process that has been formally adopted by the governing body of the jurisdiction.[4] Lastly, the NHMP must be submitted to the Oregon Office of Emergency Management (OEM) for initial review and then sent to FEMA for federal approval.[5] Additionally, a recent change in the way OEM administers the Emergency Management Performance Grant (EMPG), which helps fund local emergency management programs, also requires a FEMA-approved NHMP.

What is the Policy Framework for Natural Hazards Planning in Oregon?

Planning for natural hazards is an integral element of Oregon's statewide land use planning program, which began in 1973. All Oregon cities and counties have comprehensive plans and implementing ordinances that are required to comply with the statewide planning goals. The challenge faced by state and local governments is to keep this network of local plans coordinated in response to the changing conditions and needs of Oregon communities.

Statewide land use planning Goal 7: Areas Subject to Natural Hazards calls for local plans to include inventories, policies and ordinances to guide development in or away from hazard areas. Goal 7, along with other land use planning goals, has helped to reduce losses from natural hazards. Through risk identification and the recommendation of risk-reduction actions, this NHMP aligns with the goals of the jurisdiction's Comprehensive Plan and helps each jurisdiction meet the requirements of statewide land use planning Goal 7.

The primary responsibility for the development and implementation of risk reduction strategies and policies lies with local jurisdictions. However, additional resources exist at the state and federal levels. Some of the key agencies in this area include OEM, Oregon Building Codes Division (BCD), Oregon Department of Forestry (ODF), Oregon Department of

2 Code of Federal Regulations, Chapter 44. Section 201.6, subsection (a), 2015

3 ibid, subsection (b). 2015

4 ibid, subsection (c). 2015

5 ibid, subsection (d). 2015

Geology and Mineral Industries (DOGAMI) and the Department of Land Conservation and Development (DLCD).

How was the NHMP Developed?

The NHMP was developed by the Clackamas County NHMP Hazard Mitigation Advisory Committee (HMAC) and the HMACs for the participating jurisdictions (cities and special districts). The Clackamas County HMAC formally convened on two occasions to discuss and revise the NHMP. Each of the participating city HMACs met at least once formally. HMAC members contributed data and maps, reviewed and updated the community profile, risk assessment, action items, and implementation and maintenance plan.

An open public involvement process is essential to the development of an effective NHMP. To develop a comprehensive approach to reducing the effects of natural disasters, the planning process shall include opportunity for the public, neighboring communities, local and regional agencies, as well as, private and non-profit entities to comment on the NHMP during review.[6] Clackamas County provided an accessible project website for the public to provide feedback on the draft NHMP: https://www.clackamas.us/dm/naturalhazard.html. In addition, Clackamas County provided a press release on their website to encourage the public to offer feedback on the NHMP update. The County and city websites continue to be a focal point for distribution natural hazard information using hazard viewers, emergency alerts, hazard preparation and annual natural hazard progress reports. In addition, the County administered a survey (see Appendix G) that was used to inform the prioritization of action items.

How is the NHMP Organized?

Each volume of the NHMP provides specific information and resources to assist readers in understanding the hazard-specific issues facing county and city residents, businesses and the environment. Combined, the sections work in synergy to create a mitigation plan that furthers the community's mission to reduce or eliminate long-term risk to people and their property from hazards and their effects. This NHMP structure enables stakeholders to use the section(s) of interest to them.

Volume I: Basic Plan

Plan Summary

The NHMP summary provides an overview of the FEMA requirements, planning process and highlights the key elements of the risk assessment, mitigation strategy and implementation and maintenance strategy.

Section 1: Introduction

The Introduction briefly describes the countywide mitigation planning efforts and the methodology used to develop the NHMP.

[6] Code of Federal Regulations, Title 44. Section 201.6, subsection (b). 2015

Section 2: Hazard Identification and Risk Assessment

This section provides the factual basis for the mitigation strategies contained in Volume I, Section 3. (Additional information is included within Volume III, Appendix C, which contains an overall description of Clackamas County and the incorporated cities.) This section includes a brief description of community sensitivities and vulnerabilities. The Risk Assessment allows readers to gain an understanding of each jurisdiction's vulnerability and resilience to natural hazards.

A hazard summary is provided for each of the hazards addressed in the NHMP. The summary includes hazard history, location, extent, vulnerability, impacts and probability. This NHMP addresses the following hazards:

- Drought
- Earthquake
- Flood
- Landslide
- Severe Weather
  - Extreme Heat
  - Windstorm
  - Winter Storm
- Volcanic Event
- Wildfire

Additionally, this section provides information on each jurisdictions' participation in the National Flood Insurance Program (NFIP).

Section 3: Mitigation Strategy

This section documents the NHMP vision, mission, goals and actions (mitigation strategy) and describes the components that guide implementation of the identified actions. Actions are based on community sensitivity and resilience factors and the risk assessments in Volume I, Section 2 and Volume II.

Section 4: Plan Implementation and Maintenance

This section provides information on the implementation and maintenance of the NHMP. It describes the process for prioritizing projects and includes a suggested list of tasks for updating the NHMP, to be completed at the semi-annual and five-year review meetings.

Volume II: Jurisdictional Addenda

Volume II of the NHMP is reserved for any city or special district addenda developed through this multi-jurisdictional planning process. Each of the cities with a FEMA approved addendum went through an update to coincide with the county's update. As such, the five-year update cycle will be the same for all the cities and the county.

The NHMP includes addenda for the following cities:

- Canby;
- Estacada;
- Gladstone;
- Happy Valley;
- Johnson City;
- Lake Oswego;
- Milwaukie;
- Molalla;
- Oregon City;
- Sandy;
- West Linn; and
- Wilsonville.

In addition, the Clackamas Fire District #1 created an addendum during this update period.

Note 1: The City of Damascus disincorporated in 2016, as such there is not update for the City and the applicable information has been incorporated into the County portion of this NHMP.

Note 2: Additional special districts may opt to develop an addendum during future versions of the NHMP. See acknowledgements for a list of special districts that participated in the development of this NHMP.

Volume III: Appendices

The appendices are designed to provide the users of the Clackamas County NHMP with additional information to assist them in understanding the contents of the NHMP and provide them with potential resources to assist with NHMP implementation.

Appendix A: Action Item Forms

This appendix contains the detailed action item forms for each of the mitigation strategies identified in this NHMP.

Appendix B: Planning and Public Process

This appendix includes documentation of all the countywide public processes utilized to develop the NHMP. It includes invitation lists, agendas and sign-in sheets of HMAC meetings as well as any other public involvement methods.

Appendix C: Community Profile

The community profile describes the County from several perspectives to help define and understand the region's sensitivity and resilience to natural hazards. The information in this section represents a snapshot in time of the current sensitivity and resilience factors in the region when the NHMP was updated.

Appendix D: Natural Hazard and Base Maps

This appendix includes base and natural hazard maps that are cited throughout the NHMP, particularly within Volume I, Section 2 and Volume III, Appendix C. Additional maps for participating cities and special districts are provided in Volume II.

Appendix E: Economic Analysis of Natural Hazard Mitigation Projects

This appendix describes the FEMA requirements for benefit cost analysis in natural hazards mitigation, as well as various approaches for conducting economic analysis of proposed mitigation activities.

Appendix F: Grant Programs and Resources

This appendix lists state and federal resources and programs by hazard.

Appendix G: Community Survey

This appendix includes the survey instrument and results from the community survey administered by Clackamas County.

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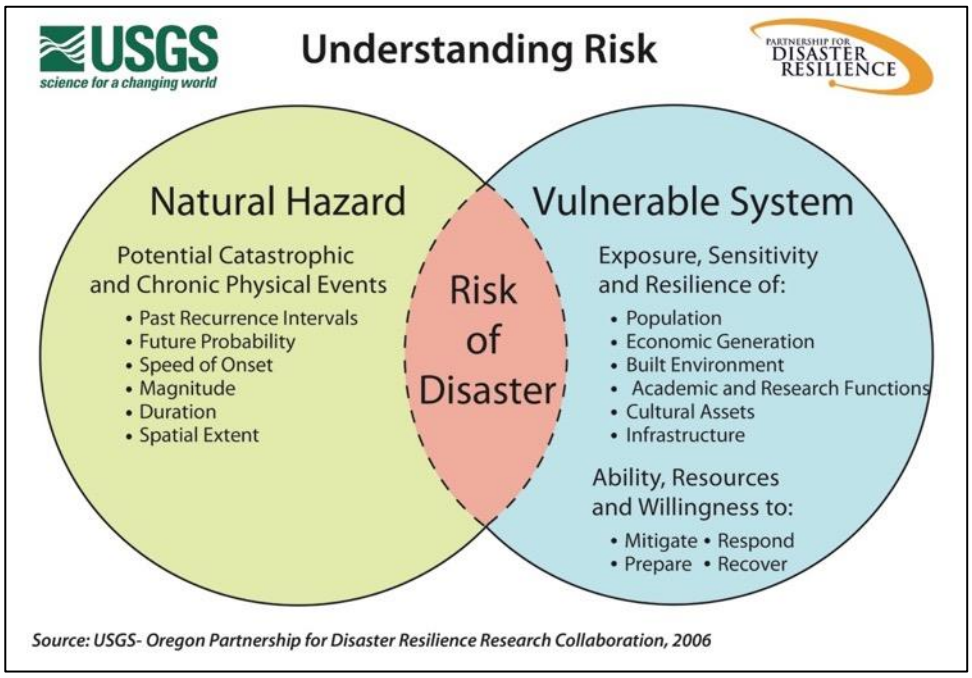
SECTION 2:
HAZARD IDENTIFICATION AND RISK ASSESSMENT

This section of the NHMP addresses 44 CFR 201.6(c)(2) - Risk Assessment. The Risk Assessment applies to Clackamas County and the city addenda included in the NHMP. We address city specific information where relevant. In addition, this section can assist with addressing Oregon Statewide Planning Goal 7 – Areas Subject to Natural Hazards.

We use the information presented in this section, along with community characteristics presented in Volume III, Appendix C to inform the risk reduction actions identified Volume I, Section 3. Figure 2-1 shows how we conceptualize risk in this NHMP. Ultimately, the goal of hazard mitigation is to reduce the area where hazards and vulnerable systems overlap.

Figure 2-1 Understanding Risk



Source: Oregon Partnership for Disaster Resilience.

What is a Risk Assessment?

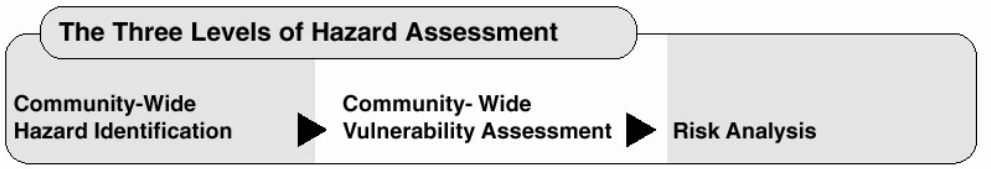
A risk assessment consists of three phases: hazard identification, vulnerability assessment and risk analysis.

- **Phase 1:** Identify hazards that can affect the jurisdiction. This includes an evaluation of potential hazard impacts – type, location, extent, etc.
- **Phase 2:** Identify important community assets and system vulnerabilities. Example vulnerabilities include people, businesses, homes, roads, historic places and drinking water sources.

- **Phase 3:** Evaluate the extent to which the identified hazards overlap with, or have an impact on, the important assets identified by the community.

The following figure illustrates the three-phase risk assessment process:

Figure 2-2 Three Phases of a Risk Assessment



Source: Planning for Natural Hazards: Oregon Technical Resource Guide, 1998

This three-phase approach to developing a risk assessment should be conducted sequentially because each phase builds upon data from prior phases. However, gathering data for a risk assessment need not occur sequentially.

Hazard Identification

Clackamas County identifies nine natural hazards that could have an impact on the County and participating cities. Table 2-1 lists the hazards identified in the County in comparison to the hazards identified in the Oregon NHMP for the Northern Willamette Valley/Portland Metro (Region 2), which includes Clackamas County.

Table 2-1 Clackamas County Hazard Identification

Clackamas County	State of Oregon NHMP Region 2: Northern Willamette Valley/ Portland Metro
Drought	Drought
Earthquake	Earthquake
Extreme Heat	N/A
Flood	Flood
Landslide	Landslide
Volcanic Event	Volcano
Wildfire	Wildfire
Windstorm	Windstorm
Winter Storm	Winter Storm

Source: Clackamas County NHMP Hazard Mitigation Advisory Committee (2018) and State of Oregon NHMP, Region 2: Northern Willamette Valley/Portland Metro (2015)

Probability and Vulnerability Summary

Table 2-2 presents the probability scores for each of the natural hazards present in Clackamas County for which descriptions are provided herein. Probability assesses the likelihood that a hazard event will take place in the future. Vulnerability assesses the extent to which people are susceptible to injury or other impacts resulting from a hazard as well as the exposure of the built environment or other community assets (social, environmental, economic, etc.) to hazards. The exposure of community assets to hazards is critical in the assessment of the degree of risk a community has to each hazard. Identifying the

populations, facilities and infrastructure at risk from various hazards can assist the County in prioritizing resources for mitigation and can assist in directing damage assessment efforts after a hazard event has occurred. The exposure of County assets to each hazard and potential implications are explained in each hazard section.

Vulnerability includes the percentage of population and property likely to be affected under an "average" occurrence of the hazard. Clackamas County evaluated the best available vulnerability data to develop the vulnerability scores presented below.

Table 2-2 Probability and Vulnerability Assessment Summary

Hazard	Probability	Vulnerability
Drought	**High**	Low
Earthquake - Cascadia	Moderate	**High**
Earthquake - Crustal	Low	**High**
Extreme Heat	Low	Moderate
Flood	**High**	Moderate
Landslide	**High**	Low
Volcanic Event	Low	Moderate
Wildfire	**High**	Moderate
Windstorm	Moderate	Low
Winter Storm	Moderate	Moderate

Source: Clackamas County Hazard Mitigation Advisory Committees 2018.

Community vulnerabilities are an important component of the NHMP risk assessment. Changes to population, economy, built environment, critical facilities, and infrastructure have not significantly influenced vulnerability. New development has complied with the standards of the Oregon Building Code and the county's development code including their floodplain ordinance. For more in-depth information regarding specific community vulnerabilities see Volume III, Appendix C.

Hazard Analysis Matrix and Methodology

For local governments, conducting the hazard analysis is a useful step in planning for hazard mitigation, response and recovery. The method provides the jurisdiction with a sense of hazard priorities but does not predict the occurrence of a hazard.

For the purposes of this NHMP, the County and cities utilized the Oregon Office of Emergency Management (OEM) Hazard Analysis methodology. The hazard analysis methodology in Oregon was first developed by FEMA circa 1983 and gradually refined by OEM over the years.

The methodology produces scores that range from 24 (lowest possible) to 240 (highest possible). Vulnerability and probability are the two key components of the methodology. Vulnerability examines both typical and maximum credible events and probability endeavors to reflect how physical changes in the jurisdiction and scientific research modify the historical record for each hazard. Vulnerability accounts for approximately 60% of the total score and probability approximately 40%. We include the hazard analysis summary here to ensure consistency between the EOP and NHMP.

The Oregon method provides the jurisdiction with a sense of hazard priorities, or relative risk. It doesn't predict the occurrence of a hazard, but it does "quantify" the risk of one hazard compared with another. By doing this analysis, planning can first be focused where the risk is greatest.

In this analysis, severity ratings and weight factors, are applied to the four categories of history, vulnerability, maximum threat (worst-case scenario) and probability.

The hazard analysis matrix involves estimating the damage, injuries and costs likely to be incurred in a geographic area over time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous sections) and (2) the likelihood or probability of the harm occurring.

Table 2-3 presents the updated hazard analysis matrix for Clackamas County. The hazards are listed in rank order from high to low. The table shows that hazard scores are influenced by each of the four categories combined. With considerations for past historical events, the probability or likelihood of a hazard event occurring, the vulnerability to the community and the maximum threat or worst-case scenario, the Cascadia Subduction Zone earthquake, crustal earthquakes, wildfires, and winter storms rank as the top hazard threats to the County (top tier). Droughts, floods, and windstorm events rank in the middle (middle tier). Landslides, volcanic events, and extreme heat events comprise the lowest ranked hazards in the county (bottom tier).

Table 2-3 Hazard Analysis Matrix – Clackamas County

Hazard	History	Vulnerability	Maximum Threat	Probability	Total Threat Score	Hazard Rank	Hazard Tiers
Earthquake - Cascadia	4	45	100	49	198	#1	*Top Tier*
Earthquake - Crustal	6	50	100	21	177	#2	
Wildfire	12	25	70	56	163	#3	
Winter Storm	10	30	70	49	159	#4	
Drought	10	15	50	56	131	#5	*Middle Tier*
Flood	16	20	30	56	122	#6	
Windstorm	14	15	50	42	121	#7	
Landslide	14	15	20	63	112	#8	*Bottom Tier*
Volcanic Event	2	35	50	14	101	#9	
Extreme Heat	2	20	40	14	76	#10	

Source: Clackamas County Hazard Mitigation Advisory Committee (2018)

City Specific Risk Assessment

Each participating jurisdiction (cities and special districts) in Clackamas County completed a jurisdiction specific hazard analysis that assessed each jurisdiction's risks where they vary from the risks facing the entire planning area. The multi-jurisdictional risk assessment information is located within the addenda of Volume II.

Federal Disaster and Emergency Declarations

Reviewing past events can provide a general sense of the hazards that have caused significant damage in the county. 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 2018, FEMA has approved a total of 33 major disaster declarations, 70 fire management assistance declarations and two (2) emergency declarations in Oregon.[1] When governors ask for presidential declarations of major disaster or emergency, they stipulate which counties in their state they want included in the declaration. Table 2-4 summarizes the major disasters declared in Oregon that affected Clackamas County, since 1955. The table shows that there have been nine (9) major disaster declarations for the County (one since 2013). Most of which were related to weather events resulting primarily in flooding, snow and landslide related damage. There has been one disaster declaration for earthquake (1993 Scott Mills).

Table 2-4 FEMA Major Disaster (DR) for Clackamas County

Declaration Number	Declaration Date	Incident Period		Incident	Individual Assistance	Public Assistance Categories
		From	To			
DR-184	12/24/1964	12/24/1964	12/24/1964	Heavy rains and flooding	Yes	A, B, C, D, E, F, G
DR-319	1/21/1972	1/21/1972	1/21/1972	Severe storms, Flooding	Yes	A, B, C, D, E, F, G
DR-413	1/25/1974	1/25/1974	1/25/1974	Severe Storms, Snowmelt, Flooding	Yes	A, B, C, D, E, F, G
DR-985	4/26/1993	3/25/1993	3/25/1993	Earthquake	None	A, B, C, D, E, F, G
DR-1099	1/23/1997	12/25/1996	1/6/1997	Severe Winter Storms/Flooding	Yes	A, B, C, D, E, F, G
DR-1510	2/19/2004	12/26/2003	1/14/2004	Severe winter storms	None	A, B, C, D, E, F, G
DR-1632	2/9/1996	2/4/1996	2/21/1996	Severe storms, Flooding	None	A, B, C, D, E, F, G
DR-1824	3/2/2009	12/13/2008	12/26/2008	Severe Winter Storm, Record and Near Record Snow, Landslides, and Mudslides	None	A, B, C, D, E, F, G
DR-1956	2/17/2011	1/13/2011	1/21/2011	Severe Winter Storm, Flooding, Mudslides, Landslides, And Debris Flows	None	A, B, C, D, E, F, G
DR-4258	2/17/2016	12/6/2015	12/23/2015	Oregon Severe Winter Storms, Straight-line Winds, Flooding, Landslides, and Mudslides	None	A, B, C, D, E, F, G

Source: FEMA, Oregon Disaster History. Major Disaster Declarations.

Table 2-5 summarizes fire management assistance and emergency declarations. Fire Management Assistance may be provided after a State submits a request for assistance to the FEMA Regional Director at the time a "threat of major disaster" for a fire emergency exists. There are two (2) fire management assistance declarations on record for the county.

[1] FEMA, *Declared Disasters by Year or State*, http://www.fema.gov/news/disaster_totals_annual.fema#markS. Accessed July 10, 2018.

An Emergency Declaration is more limited in scope and without the long-term federal recovery programs of a Major Disaster Declaration. Generally, federal assistance and funding are provided to meet a specific emergency need or to help prevent a major disaster from occurring. Clackamas County has two recorded Emergency Declarations related to the 1977 Drought and 2005 Hurricane Katrina evacuation.

Table 2-5 FEMA Fire Management (FM) and Emergency Declarations (EM) for Clackamas County

Declaration Number	Declaration Date	Incident Period		Incident	Individual Assistance	Public Assistance Categories
		From	To			
FM-2043	9/15/81	9/5/81	-	Peavine Peak Fire	None	-
FM-5080	9/16/14	9/15/14	9/26/14	36 Pit Fire	None	-
EM-3039	4/29/77	4/29/77	4/29/77	Drought	None	A, B
EM-3228	9/7/05	8/29/05	10/1/05	Hurricane Katrina Evacuation	None	B

Source: FEMA, Oregon Disaster History. Major Disaster Declarations.

Hazard Profiles

The following subsections briefly describe relevant information for each hazard. For additional background on the hazards, vulnerabilities and general risk assessment information for hazards in Clackamas County, refer to the Risk Assessment for Region 2, Northern Willamette Valley/Portland Metro, of the Oregon NHMP (2015).

In addition, the Oregon Department of Geology and Mineral Industries (DOGAMI) conducted a multi-hazard risk assessment (Risk Report) for portions of unincorporated Clackamas County within the Lower Columbia-Sandy Watershed, including the unincorporated communities of Government Camp and The Villages at Mt. Hood. The study was funded through the FEMA Risk MAP program and was completed in 2018. The Risk Report provides a quantitative risk assessment that informs communities of their risks related to the following natural hazards: channel migration, earthquake, flood, lahar (volcanic event), landslide, and wildfire. The County hereby incorporates the Risk Report) into this NHMP by reference to provide greater detail to hazard sensitivity and exposure (DOGAMI, IMS-59).

Drought

Significant Changes since Previous NHMP:

One (1) significant drought event has occurred since the previous NHMP.

Characteristics

A drought is a period of drier than normal conditions. Drought occurs in virtually every climatic zone, but its characteristics vary significantly from one region to another. Drought is a temporary condition; it differs from aridity, which is restricted to low rainfall regions and is a permanent feature of climate. The extent of drought events depends upon the degree of moisture deficiency and the duration and size of the affected area. Typically, droughts occur as regional events and often affect more than one city and county.

Location and Extent

Droughts occur in every climate zone and can vary from region to region. Drought may occur throughout Clackamas County and may have profound effects on the economy, particularly the agricultural and hydro-power sectors. The extent of drought depends upon the degree of moisture deficiency, and the duration and size of the affected area. Typically, droughts occur as regional events and often affect more than one county. In severe droughts, environmental and economic consequences can be significant. Volume III, Appendix D includes maps detailing average precipitation (Map 2) and river sub-basins (Map 4). The extent of the hazard is shown in Figure 2-3 and Figure 2-4, surface water supply index values below -1.5 indicate low water availability, which could lead to drought.

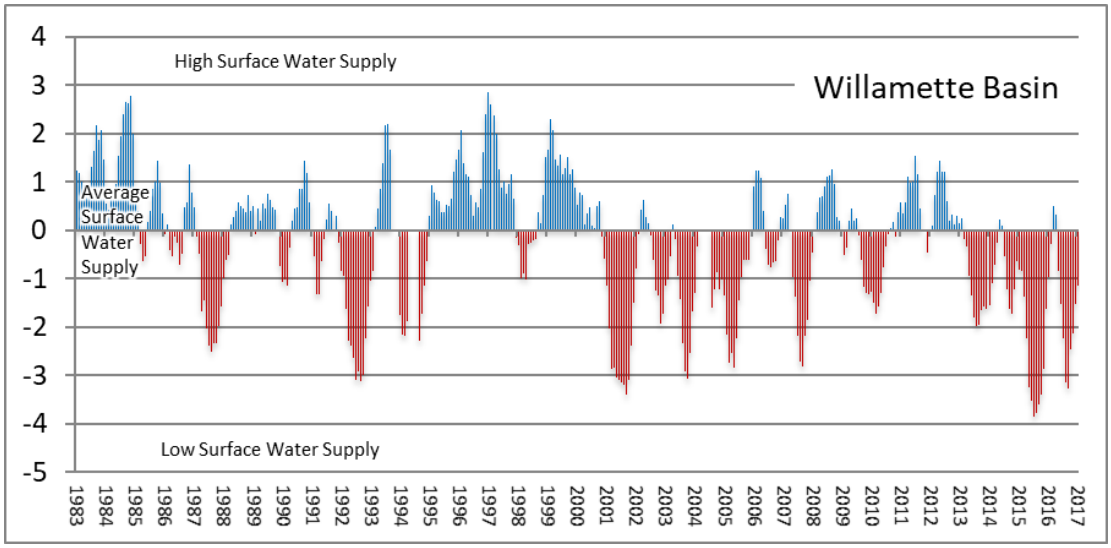
History

Clackamas County experiences annual dry conditions typically during the summer months from July through September. Drought is typically measured in terms of water availability in a defined geographical area. It is common to express drought with a numerical index that ranks severity. Most federal agencies use the Palmer Method which incorporates precipitation, runoff, evaporation and soil moisture. However, the Palmer Method does not incorporate snowpack as a variable. Therefore, it is not believed to provide a very accurate indication of drought conditions in Oregon and the Pacific Northwest.

The Surface Water Supply Index (SWSI) from the Natural Resources Conservation Service is an index of current water conditions throughout the state. The index utilizes parameters derived from snow, precipitation, reservoir and stream flow data. NRCS collects data each month from key stations in each basin. The lowest SWSI value, -4.2, indicates extreme drought conditions (Low Surface Water Supply ranges from -1.6 to -4.2). The highest SWSI value, +4.2, indicates extreme wet conditions (High Surface Water Supply ranges from +1.6 to +4.2). The mid-point is 0.0, which indicates an average water supply (Average Water Supply ranges from +1.5 to -1.5). The figures below show the monthly history of SWSI values from 1983 to 2017 for the Willamette Basin (Figure 2-3, includes all portions of the County that are outside of the Lower Columbia-Sandy Watershed) and Hood, Sandy, and Lower

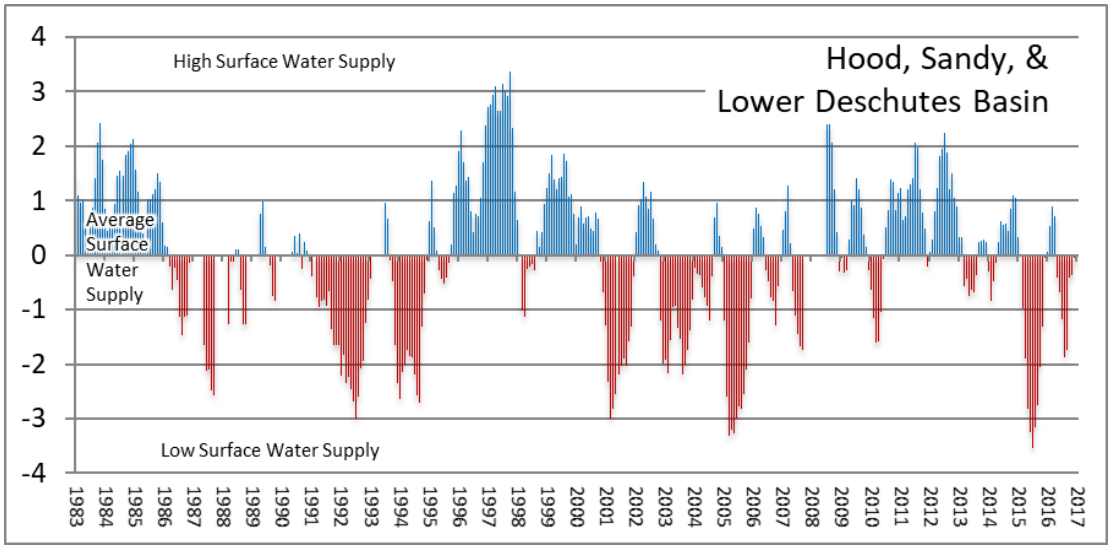
Deschutes Basin (Figure 2-4, includes northeast portion of the County within the Lower Columbia-Sandy Watershed).

Figure 2-3 SWSI Values for the Willamette Basin



Source: Department of Agriculture-Natural Resources Conservation Service, "Surface Water Supply Index, Willamette Basin" www.or.nrcs.usda.gov. Accessed January 2018.

Figure 2-4 SWSI Values for the Hood, Sandy, & Lower Deschutes Basin



Source: Department of Agriculture-Natural Resources Conservation Service, "Surface Water Supply Index, Lower Deschutes Basin". Data also includes the Hood and Sandy basins. www.or.nrcs.usda.gov. Accessed January 2018.

Research shows that the periods of drought have fluctuated; recent drought periods occurred (SWSI < -3.0 for four or more months) in 1991-1992, 2001 and 2015. In addition, two (2) executive orders declaring drought emergencies have occurred in 1991 and 2015; the 2015 drought was also federally declared.[2] Other historically significant regional drought events that affected Clackamas County include 1928 to 1941 and 1976 to 1981.

[2] Oregon Water Resources Department Public Declaration Status Report, http://apps.wrd.state.or.us/apps/wr/wr_drought/declaration_status_report.aspx, accessed January, 2018.

El Niño/La Nina

El Niño Southern Oscillation (ENSO) weather patterns can increase the frequency and severity of drought. During El Niño periods, alterations in atmospheric pressure in equatorial regions yield an increase in the surface temperature off the west coast of North America. This gradual warming sets off a chain reaction affecting major air and water currents throughout the Pacific Ocean; La Niña periods are the reverse with sustained cooling of these same areas. In the North Pacific, the Jet Stream is pushed north, carrying moisture laden air up and away from its normal landfall along the Pacific Northwest coast. In Oregon, this shift results in reduced precipitation and warmer temperatures, normally experienced several months after the initial onset of the El Niño. These periods tend to last nine to twelve months, after which surface temperatures begin to trend back towards the long-term average. El Niño periods tend to develop between March and June, and peak from December to April. ENSO generally follows a two to seven-year cycle, with El Niño or La Niña periods occurring every three to five years. However, the cycle is highly irregular, and no set pattern exists. The last major El Niño was during 1997-1998, and in 2015-2016 Oregon experience a "super" El Niño (the strongest in 15 years, the two previous events occurred in 1982-1983 and 1997-1998) that included record rainfall and snowpack in areas of the state.[3]

Future Climate Variability[4]

Climate models for Oregon suggest, future regional climate changes include increases in temperature around 0.2-1°F per decade in the 21st Century, along with warmer and drier summers, and some evidence that extreme precipitation will increase in the future. Increased droughts may occur in the Willamette Valley under various climate change scenarios because of various factors, including reduced snowpack, rising temperatures, and likely reductions in summer precipitation. Climate models suggest that as the region warms, winter snow precipitation will likely shift to higher elevations and snowpack will be diminished as more precipitation falls as rain altering surface flows.

Probability Assessment

Based on the available data and research the Hazard Mitigation Advisory Committee (HMAC) assessed the **probability of experiencing a locally severe drought as "High,"** meaning one incident is likely within the next 10 to 35 years. *This rating has increased since the previous NHMP.*

Droughts are not uncommon in the State of Oregon, nor are they just an "east of the mountains" phenomenon. They occur in all parts of the state, in both summer and winter. Oregon's drought history reveals many short-term and a few long-term events. The average recurrence interval for severe droughts in Oregon is somewhere between 8 and 12 years. According to SWSI analysis there have been three (3) droughts between 1983 and 2017 (see Figure 2-3 and Figure 2-4).

[3] Cho, Renne. "El Nino and global warming – what's the connection." Phys.org, February 3, 2016. https://phys.org/news/2016-02-el-nino-global-warmingwhat.html

4 Oregon Climate Change Research Institute (OCCRI), 4th Oregon Climate Assessment Report (2019) and Northwest Climate Assessment Report (2013). http://www.occri.net/publications-and-reports/publications/

Vulnerability Assessment

The HMAC rated the County as having **a "low" vulnerability to drought hazards**, meaning it is expected that less than 1% of the unincorporated County's population or assets would be affected by a major drought emergency or disaster. *This rating has not changed since the previous NHMP.*

The environmental and economic consequences can be significant, especially for the agricultural sector. Drought also increases the probability of wildfires – a major natural hazard concern for Clackamas County. Drought can affect all segments of Clackamas County's population, particularly those employed in water-dependent activities (e.g., agriculture, hydroelectric generation, recreation, etc.). Also, domestic water-users may be subject to stringent conservation measures (e.g., rationing) as per the County's water management plan.

All parts of Clackamas County are susceptible to drought; however, the following areas and issues are of concern:

- Drinking water systems
- Power and water enterprises
- Residential and community wells in rural areas
- Fire response capabilities
- Fish and wildlife

Potential impacts to county water supplies and the agriculture industry are the greatest threats. Additionally, long-term drought periods of more than a year can impact forest conditions and set the stage for potentially destructive wildfires.

More information on this hazard can be found in the Risk Assessment for Region 2, Northern Willamette Valley/Portland Metro, of the Oregon NHMP (2015).

Earthquake

Significant Changes since Previous NHMP:

The Oregon Resilience Plan (2013), Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, and the Lower Columbia-Sandy Watershed Multi-Hazard Risk Report have been cited and incorporated where applicable.

Characteristics

The Pacific Northwest in general is susceptible to earthquakes from four sources: 1) the offshore Cascadia Subduction Zone, 2) deep intraplate events within the subducting Juan de Fuca Plate, 3) shallow crustal events within the North American Plate, and 4) earthquakes associated with volcanic activity.

Crustal Fault Earthquakes

Crustal fault earthquakes are the most common earthquakes and occur at relatively shallow depths of 6-12 miles below the surface.[5] While most crustal fault earthquakes are smaller than magnitude 4 and generally create little or no damage, they can produce earthquakes of magnitudes up to 7, which cause extensive damage. Clackamas County has seven documented crustal faults that could cause serious damage to buildings and infrastructure. These include: Portland Hills, Sandy River, Bolton, Mount Angel, Grant Butte, Clackamas Creek, and Mount Hood. These faults could generate earthquakes 6.5 or larger. *Note: The hazards associated with the Portland Hills and Mount Hood faults area discussed in more detail within this profile.*

Deep Intraplate Earthquakes

Occurring at depths from 25 to 40 miles below the earth's surface in the subducting oceanic crust, deep intraplate earthquakes can reach up to magnitude 7.5.[6] 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. A 1965 magnitude 6.5 intraplate earthquake centered south of Seattle-Tacoma International Airport caused seven deaths.[7]

Subduction Zone Earthquakes

The Pacific Northwest is located at a convergent plate boundary, where the Juan de Fuca and North American tectonic plates meet. The two plates are converging at a rate of about 1-2 inches per year. This boundary is called the Cascadia Subduction Zone (CSZ). It extends from British Columbia to northern California. Subduction zone earthquakes are caused by the abrupt release of slowly accumulated stress.[8]

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

[6] Planning for Natural Hazards: The Oregon Technical Resource Guide, Department of Land Conservation and Development (July 2000), Ch. 8, pp. 8.

[7] The Oregonian. "*A region at risk*." March 4, 2001.

[8] Questions and Answers on Earthquakes in Washington and Oregon (February 2001) www.geophys.washington.edu/seis/pnsn/info_general/faq.html.

Subduction zones like the CSZ have produced earthquakes with magnitudes of 8 or larger. Historic subduction zone earthquakes include the 1960 Chile (magnitude 9.5) and 1964 southern Alaska (magnitude 9.2) earthquakes[9] with more recent events being the 2004 Indian Ocean (magnitude 9.1) and 2011 Japan (magnitude 9).

Volcanic Earthquakes

Volcanic earthquakes are usually smaller than magnitude 2.5, roughly the threshold for shaking felt by observers close to the event. Swarms of small earthquakes may persist for weeks to months before eruptions, but little or no earthquake damage would occur to buildings in surrounding communities. Some volcanic related swarms may include earthquakes as large as about magnitude 5.

While all four types of earthquakes have the potential to cause major damage, local crustal faults are expected to be more damaging primarily because of their proximity to densely populated areas.[10]

Location and Extent

The seismic hazard for Clackamas County arises predominantly from major earthquakes on the Cascadia Subduction Zone. Large (M6.8-7.0M), crustal earthquakes in or near Clackamas County could be more damaging than a CSZ earthquake but the likelihood of these events is considerably less. Additional fault zones throughout the county and region may produce localized crustal earthquakes up to 6.0. Table 2-6 presents a list of the different Class A and B fault lines throughout the county. In addition, the Mount Hood Fault (Class C) is located near Mount Hood and runs approximately 55 kilometers north from Clear Lake to the Columbia River.[11] A local earthquake of M 6.0 or a regional M 9.0 earthquake is likely to cause substantial structural damage to bridges, buildings, utilities, and communications systems, as well as the following impacts to infrastructures and the environment:

- Floods and landslides
- Fires, explosions, and hazardous materials incidents
- Disruption of vital services such as water, sewer, power, gas, and transportation routes
- Disruption of emergency response systems and services
- Displaced Households
- Economic losses for buildings
- Economic loss to highways, airports, communications
- Generated debris
- Illness, injury, and death
- Significant damage to critical and essential facilities, including schools, hospitals, fire stations, police departments, city hall

[9] The Oregonian. "*A region at risk*." March 4, 2001.

[10] Bauer, John, William Burns, and Ian Madin. Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon. (2018). DOGAMI

[11] Scott, W.E., and Gardner, C.A., 2017, Field trip guide to Mount Hood, Oregon, highlighting eruptive history and hazards. U.S. Geological Survey Scientific Investigations Report 2017-5022-G.

Table 2-6 Class A and B Faults Located in or near Clackamas County

Name	Class	Fault ID	Primary County, State	Length (km)	Time of Most Recent Deformation	Slip-Rate Category
Canby-Molalla Fault	A	716	Clackamas County	50km	Latest Quaternary (<15ka)	Less than 0.2 mm/yr
Clackamas River Fault Zone	A	864	Marion County	29km	Quaternary (<1.6 Ma)	Less than 0.2 mm/yr
Bull Run Thrust	B	868	Clackamas County	9km	Quaternary (<1.6 Ma)	Less than 0.2 mm/yr
Mount Angel Fault	A	873	Marion County	30km	Latest Quaternary (<15ka)	Less than 0.2 mm/yr
Bolton Fault	B	874	Clackamas County	9km	Quaternary (<1.6 Ma)	Less than 0.2 mm/yr
Oatfield Fault	A	875	Washington County	29km	Quaternary (<1.6 Ma)	Less than 0.2 mm/yr
East Bank Fault	A	876	Multnomah County	29km	Latest Quaternary (<15ka)	Less than 0.2 mm/yr
Portland Hills Fault	A	877	Columbia County	49km	Quaternary (<1.6 Ma)	Less than 0.2 mm/yr
Damascus-Tickle Creek Fault Zone	A	879	Multnomah County	17km	Middle and Late Quaternary (<750ka)	Less than 0.2 mm/yr

Source: Source: US Geological Survey (USGS), Quaternary Fault and Fold Database

For more information on Class A and B faults located in Clackamas County see the US Geological Survey, Quaternary Fault and Fold Database: https://earthquake.usgs.gov/hazards/qfaults/.

The extent of the earthquake hazard is measured in magnitude. Figure 2-5 shows a generalized geologic map of Clackamas County and includes the areas for potential low and moderate liquefaction. The figure also shows that recent earthquakes have registered as Magnitude 5 or less (earthquakes at this magnitude are often felt but cause no damage, or only minor damage). Clackamas County can expect similar earthquake magnitudes to occur in the future. The Cascadia Subduction Zone earthquake has the capacity to cause a magnitude 8.5 or greater earthquake; however, due to the distance from Clackamas County the damage locally is expected to be significant, but less than a local crustal fault. Volume III, Appendix D includes additional maps detailing soil liquefaction (Map 8), soil amplification (Map 9), and relative earthquake hazard (Map 10). Most of the earthquakes shown in the figure below are low-impact events below M 3.0, although several events are shown with M 2 to 5.

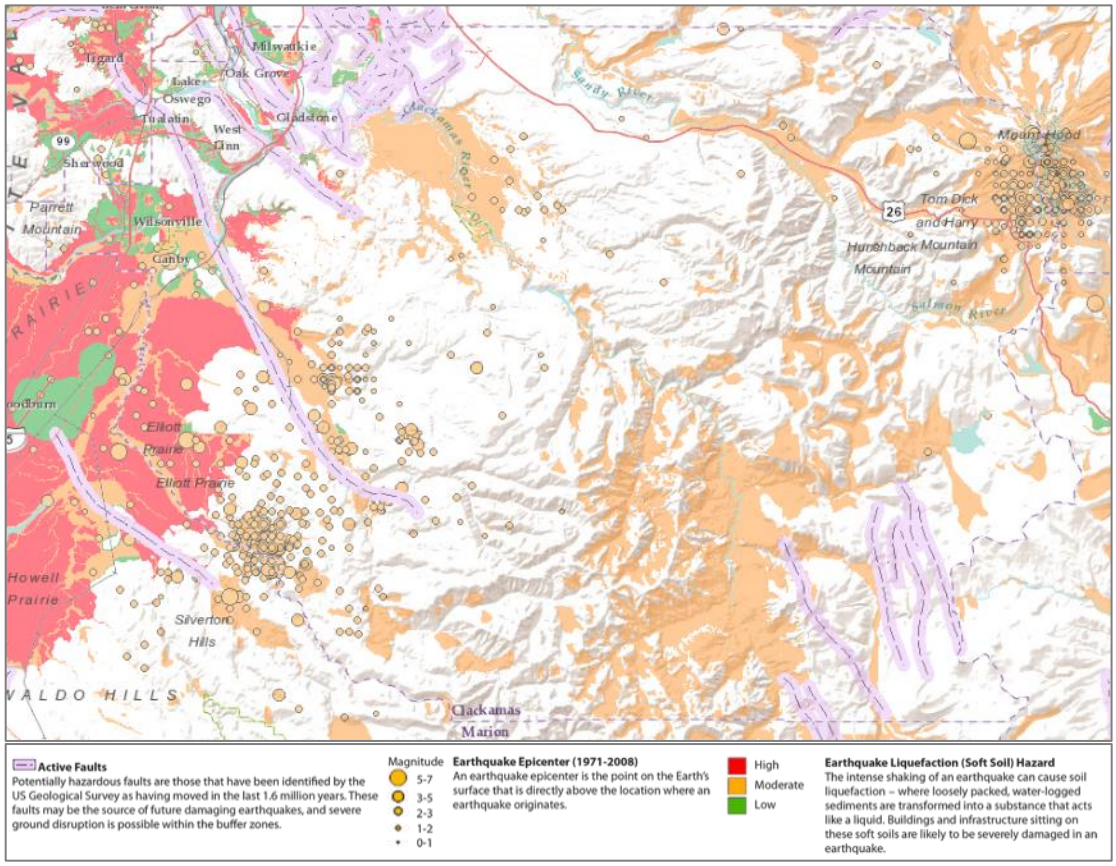
Liquefaction

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

To develop a regional liquefaction hazard map (Volume II, Appendix D, Map 8) for Clackamas County, DOGAMI started by collecting the best available geologic information. Hazard groupings were primarily based on lithologies and checked with individual data points. With

the available information compiled, DOGAMI assigned liquefaction susceptibility classes based on the dominant lithologies for each geologic unit in the study area, checked source data boundaries, and simplified the GIS outputs into four relative hazard classes: None/Very Low, Low, Moderate, and High. Areas with Moderate to High liquefaction susceptibilities are concentrated along the rivers and flood plains in the Willamette Valley, Cascade Range tributaries, and major stream valleys within the Cascade Range. Older river terrace and Missoula Flood deposits in the Willamette Valley were assigned a lower liquefaction hazard yet are still considered susceptible to liquefaction in larger earthquakes. It is important to note that the quality and scale of the available base maps precluded identification of all liquefaction hazard areas, particularly in the eastern portion of the county.

Figure 2-5 Earthquake Active Faults, Epicenters (1971-2008), and Soft Soils



Source: Oregon HazVu: Statewide Geohazards Viewer – *To view map in more detail click hyperlink to left.*

Amplification

Soils and soft sedimentary rocks near the earth's surface can modify ground shaking caused by earthquakes. One of these modifications is amplification. Amplification increases the magnitude of the seismic waves generated by the earthquake. The amount of amplification is influenced by the thickness of geologic materials and their physical properties. The degree of amplification greatly affects the performance of infrastructure in earthquake. Buildings and structures built on soft and unconsolidated soils, for example, face greater risk. Amplification can also occur in areas with deep sediment filled basins and on ridge tops.

DOGAMI developed the ground shaking amplification map (Volume III, Appendix D, Map 9) based generally on the NEHRP 1997 method of categorizing relative hazards and simplified

the GIS outputs into relative hazard classes – Low, Moderate, and High. The resulting map is not intended to be used in place of site-specific studies. The high hazard soils are located along and adjacent to streams and rivers in Clackamas County. The eastern portion of the county is varied, with competent bedrock areas mapped as Low hazard, dense soil areas mapped as Moderate hazard, and younger landslide and alluvial deposit areas mapped as High hazard for ground shaking amplification.[12]

DOGAMI and Clackamas County GIS worked together to combine the ground shaking, amplification, and liquefaction data to develop a composite Relative Earthquake Hazard Map (Volume III, Appendix D, Map 10). This map represents the overall earthquake hazards in Clackamas County.

Due to the expected pattern of damage resulting from a CSZ event, the Oregon Resilience Plan divides the State into four distinct zones and places Clackamas County predominately within the "Valley Zone" (Valley Zone, from the summit of the Coast Range to the summit of the Cascades).

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. DOGAMI has published a number of seismic hazard maps that are available for communities to use. The maps show liquefaction, ground motion amplification, landslide susceptibility and relative earthquake hazards. OPDR used the DOGAMI Statewide Geohazards Viewer to present a visual map of recent earthquake activity, active faults and liquefaction; ground shaking is generally expected to be higher in the areas marked by soft soils in the map above. 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.

For more information, see the following reports:

- Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed, Oregon: Including the cities of Gresham, Sandy, and Troutdale and Unincorporated Communities of Government Camp and The Villages at Mt Hood (2018, IMS-59).
- Earthquake regional impact analysis for Clackamas, Multnomah, and Washington Counties, Oregon (2018, O-18-02).
- Statewide Cascadia earthquake hazard data (2013, O-13-06)
- Cascadia Subduction Zone earthquakes: A magnitude 9.0 earthquake scenario, (2012, O-12-22)
- Multi-Hazard and Risk Study for the Mount Hood Region (2011, O-11-16). *Portions of the earthquake section superseded by the Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed*.
- Statewide seismic needs assessment: Implementation of Oregon 2005 Senate Bill 2 relating to public safety, earthquakes, and seismic rehabilitation of public buildings, (2007, O-07-02).

[12] Hofmeister, Hasenberg, Madin, Wang, 2003. "Earthquake and Landslide Hazard Maps and Future Earthquake Damage Estimates for Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-03-10."

- Map of selected earthquakes for Oregon: 1841-2002 (2003, O-03-02).
- Interpretive Map Series: IMS-9 - Relative earthquake hazard maps for selected urban areas in western Oregon (2000, IMS-9).

Additional reports are available via DOGAMI's Publications Search website: http://www.oregongeology.org/pubs/search.php

Other agency/ consultant reports:

Oregon Resilience Plan (2013)

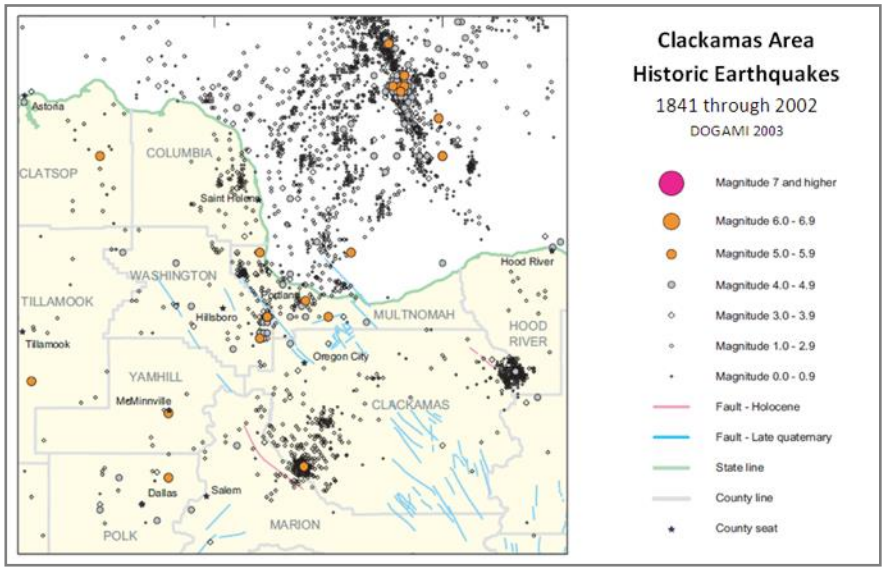
The Mount Hood Fault Zone – Late Quaternary and Holocene fault features newly mapped with high-resolution lidar Imagery (p. 100-109).

History

Dating back to 1841, there have been more than 6,000-recorded earthquakes in Oregon, most with a magnitude below three (Figure 2-5 and Figure 2-6). Portland and its surrounding region is potentially the most seismically active area within Oregon. The Portland metropolitan region has encountered seventeen earthquakes of an estimated magnitude of four and greater, with major earthquakes in. 1877 (magnitude 5.3), 1962 (magnitude 5.2), and 1993 (magnitude 5.6). Although seismograph stations were established as early as 1906 in Seattle and 1944 in Corvallis, improved seismograph coverage of the Portland region did not begin until 1980, when the University of Washington expanded its regional network into northwestern Oregon.

Geologic evidence shows that the Cascadia Subduction Zone has generated great earthquakes, most recently about 300 years ago. It is generally accepted to have been magnitude 9 or greater. The average recurrence interval of these great Cascadia earthquakes is approximately 500 years, with gaps between events as small as 200 years and as large as 1,000 years.

Figure 2-6 Regional Earthquake History (1841-2001)



Source: DOGAMI, Map of Selected Earthquakes for Oregon,1841 through 2002 (O-03-02)

Probability Assessment

Based on the available data and research the HMAC determined the **probability of experiencing a Cascadia Subduction Zone (CSZ) is "moderate",** meaning one incident may occur within the next 35 to 75 years. The HMAC determined the **probability of experiencing a crustal earthquake is "low",** meaning one incident may occur within the next 75 to 100 years. *The previous NHMP rated the CSZ earthquake probability as "moderate" and the crustal earthquake probability also as moderate.*

Clackamas County is susceptible to deep intraplate events within the Cascadia Subduction Zone (CSZ), where the Juan de Fuca Plate is diving beneath the North American Plate and shallow crustal events within the North American Plate.

According to the Oregon NHMP, the return period for the largest of the CSZ earthquakes (Magnitude 9.0+) is 530 years with the last CSZ event occurring 314 years ago in January of 1700. The probability of a 9.0+ CSZ event occurring in the next 50 years ranges from 7 - 12%. Notably, 10 - 20 "smaller" Magnitude 8.3 - 8.5 earthquakes occurred over the past 10,000 years that primarily affected the southern half of Oregon and northern California. The average return period for these events is roughly 240 years. The combined probability of any CSZ earthquake occurring in the next 50 years is 37 - 43%.[13]

Establishing a probability for crustal earthquakes is difficult given the small number of historic events in the region. However, both of the faults used to inform this report (Portland Hills and Mount Hood) have a low probability of rupture. Earthquakes generated by volcanic activity in Oregon's Cascade Range are possible, but likewise unpredictable. For more information, see the DOGAMI reports cited previously.

Vulnerability Assessment

The HMAC rated the County as having a **"high" vulnerability to the Cascadia Subduction Zone (CSZ) earthquake hazard** meaning that more than 10% of the unincorporated County's population or assets would be affected by a major CSZ event. The HMAC rated the County as having a **"high" vulnerability to a crustal earthquake hazard**, meaning that more than 10% of the unincorporated County's population or assets would be affected by a major crustal earthquake event. *These ratings have not changed since the previous NHMP.*

The local crustal faults, the county's proximity to the Cascadia Subduction Zone, potential slope instability and the prevalence of certain soils subject to liquefaction and amplification combine to give the county a high-risk profile.

Factors included in an assessment of earthquake risk include population and property distribution in the hazard area, the frequency of earthquake events, landslide susceptibility, buildings, infrastructure and disaster preparedness of the region. This type of analysis can generate estimates of the damages to the county due to an earthquake event in a specific location.

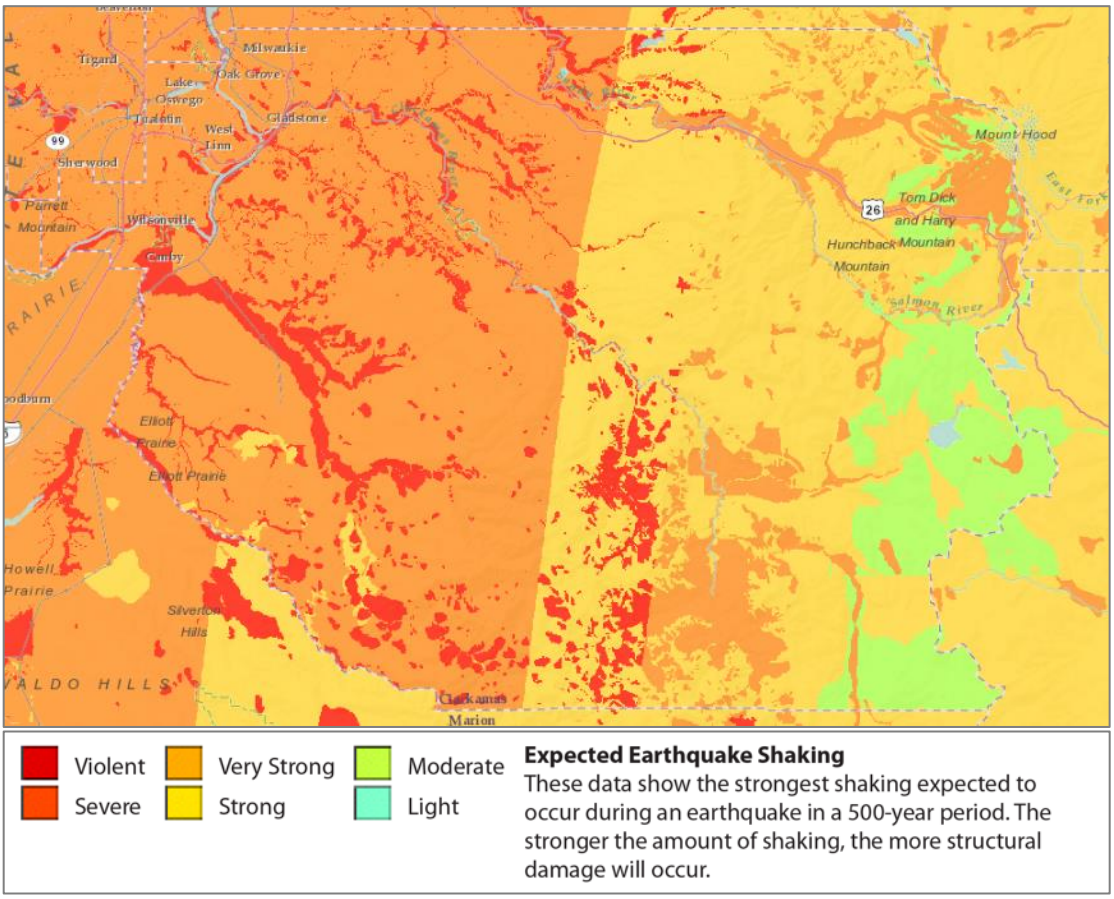
Seismic activity can cause great loss to businesses, either a large-scale corporation or a small retail shop. Losses not only result in rebuilding cost, but fragile inventory and equipment can be destroyed. When a company is forced to stop production for just a day, business loss can

[13] DLCD, Oregon Natural Hazards Mitigation Plan (2015).

be tremendous. Residents, businesses and industry all suffer temporary loss of income when their source of finances is damaged or disrupted.

Figure 2-7 shows the expected shaking/damage potential for Clackamas County as a result of a Cascadia Subduction Zone (CSZ) earthquake event. The figure shows that the county will experience "moderate" to "severe" shaking that will last two to four minutes. The strong shaking will be extremely damaging to lifeline transportation routes including I-5. For more information on expected losses due to a CSZ event see the Oregon Resilience Plan and the Risk Report information provided below. Analysis of the Relative Earthquake Hazard Map (Volume III, Appendix D, Map 10) shows that about 45% of the total county land area is in moderate to high hazard zones. In addition, 19% of total tax parcels are within the high relative earthquake hazard area (Table 2-7).

Figure 2-7 Cascadia Subduction Zone Expected Shaking



Source: Oregon HazVu: Statewide Geohazards Viewer – *To view map in more detail click hyperlink to left.*

Clackamas County considers two main earthquake related vulnerability categories: Life and Property and Critical Facilities and Infrastructure. Both categories are discussed in further detail below.

The amount of property in the relative earthquake high hazard area, as well as the type and value of structures on those properties, is calculated to provide a working estimate for potential losses. Table 2-7 shows potentially impacted parcels, critical and critical facilities, vulnerable populations, and infrastructure within Clackamas County.

Table 2-7 Relative Earthquake Hazard Vulnerability Assessment

	Potentially Impacted Parcels		Potentially Impacted Locations			Infrastructure				
Hazard	Number of Parcels	Percent of Total Parcels	Critical Facilities	Essential Facilities	Vulnerable Populations	Miles of Road	Miles of Sewer Lines	Bridges	Cell Towers	Dams
County Total	158,226	Not Applicable	235	55	576	4911	340	597	17	69
Relative Earthquake Hazard										
High	30,098	19%	26	7	58	636	56	153	3	22

Source: Clackamas County Geographic Information Systems (2018)
Note: Percentage of property in High Relative Earthquake Hazard area may include property in tax lots that intersect the area, including property that does not physically reside in the area itself.

Earthquake Regional Impact Analysis

In 2018 DOGAMI completed a regional impact analysis for earthquakes originating from the Cascadia Subduction Zone and Portland Hills faults (O-18-02). Their study focused on damage to buildings, and the people that occupy them, and to two key infrastructure sectors: electric power transmission and emergency transportation routes. Each earthquake was studied with wet and dry soil conditions and for events that occur during the daytime (2 PM) and night time (2 AM). Impacts to buildings and people were tabulated at the county, jurisdictional, and neighborhood unit level. Estimated damaged varied widely across the study area depending on local geology, soil moisture conditions, type of building, and distance from the studied faults. In general, damage from the Cascadia Subduction Zone scenario was greater in the western portion of the study area, however, damage could still be significant in some areas east of the Willamette River. The report found that damage to high-value commercial and industrial buildings was high since many of these facilities are in areas of high to very high liquefaction hazard (Figure 2-5). Casualties were higher during the daytime scenario (generally double) since more people would be at work and occupying non-wood structures that fare worse in an earthquake. The Portland Hills fault scenario created greater damages than the Cascade Subduction Zone scenario due primarily to its placement relative to population centers and regional assets; however, at distances 15 or more miles from the Portland Hills fault the damages from the Cascadia Subduction Zone scenario generally were higher. In both the Cascadia Subduction Zone and Portland Hills Fault scenarios it is forecasted that emergency transportation routes will be fragmented, affecting the distribution of goods and services, conditions are worse under the Portland Hills Fault scenario. Portions of the electric distribution system are also expected to be impacted under both scenarios, however, the impact is considerably less than it is to the transportation routes. Additional, capacity or redundancy within the electric distribution network may be beneficial in select areas that are likely to have greater impacts.

Table 2-8 shows the buildings that are in regions that are susceptible to liquefaction and landslides, it does not predict that damage will occur in specific areas due to either liquefaction or landslide. The table shows that a small percentage of buildings are located within the area susceptible to liquefaction (4% high and very high) or landslides (2% high to very high).

Table 2-8 Building statistics by Hazus-based liquefaction susceptibility rating and earthquake-induced landslide susceptibility rating

	Number of Buildings	Building Percent	Building Value ($ Million)	Building Value Percent
Liquefaction Susceptibility				
None to low	113,010	63%	36,392	58%
Moderate	58,905	33%	23,738	38%
High	746	0%	276	0%
Very High	6,503	4%	1,984	3%
Landslide Susceptibility				
Low	161,505	90%	56,485	91%
Moderate	14,582	8%	4,890	8%
High to Very High	3,077	2%	1,015	2%
Total	179,164	100%	62,390	100%

Source: DOGAMI, Earthquake regional impact analysis for Clackamas, Multnomah, and Washington Counties, Oregon (2018, O-18-02), Tables 10-5 and 10-6.

Table 2-9 shows building damage expected under the Cascadia Subduction Zone scenario, about 13% of all buildings are expected to be damaged in the "dry" scenario and 15% in the "wet" scenario. Of those, it is expected that 158 buildings will collapse in the "dry" scenario, while 313 are expected to collapse in the "wet" scenario.[14] The unincorporated portions of Clackamas County are expected to have a 5% building loss ratio with a repair cost of $1.5 billion under the CSZ "dry" scenario, and a 7% building loss ratio with a repair cost of $2.18 billion under the CSZ "wet" scenario.[15]

Table 2-9 Number of buildings per damage state for CSZ earthquake and soil moisture scenario

Building Damage State	"Dry" Soil	Building Percent	"Wet" Saturated Soil	Building Percent
None	121,428	68%	119,150	67%
Slight	34,145	19%	33,133	18%
Moderate	15,936	9%	15,386	9%
Extensive	5,390	3%	5,228	3%
Complete	2,265	1%	6,267	3%
Total	179,164	100%	179,164	100%

Source: DOGAMI, Earthquake regional impact analysis for Clackamas, Multnomah, and Washington Counties, Oregon (2018, O-18-02), Table 12-1

Table 2-10 shows building damage expected under the Portland Hills Fault scenario, about 46% of all buildings are expected to be damaged in the "dry" scenario and 49% in the "wet" scenario. Of those, it is expected that 666 buildings will collapse in the "dry" scenario, while 1,066 are expected to collapse in the "wet" scenario.[16] The unincorporated portions of Clackamas County are expected to have a 20% building loss ratio with a repair cost of $5.9

[14] DOGAMI, Earthquake regional impact analysis for Clackamas, Multnomah, and Washington Counties, Oregon (2018, O-18-02), Table 12-3.

[15] Ibid, Tables 12-8 and 12-9.

[16] Ibid, Tables 12-8 and 12-9.

billion under the CSZ "dry" scenario, and a 26% building loss ratio with a repair cost of $7.6 billion under the CSZ "wet" scenario.[17]

Table 2-10 Number of buildings per damage state for Portland Hills Fault earthquake and soil moisture scenario

Building Damage State	"Dry" Soil	Building Percent	"Wet" Saturated Soil	Building Percent
None	50,466	28%	47,990	27%
Slight	46,152	26%	42,988	24%
Moderate	47,122	26%	43,417	24%
Extensive	22,526	13%	20,761	12%
Complete	12,898	7%	24,008	13%
Total	179,164	100%	179,164	100%

Source: DOGAMI, Earthquake regional impact analysis for Clackamas, Multnomah, and Washington Counties, Oregon (2018, O-18-02), Table 12-1

Table 2-11 shows the permanent resident population that lives within buildings that are exposed to different expected levels of building damage. More population is exposed to higher degrees of expected damage under the Portland Hills Fault "wet" scenario than in any other scenario. The unincorporated portions of Clackamas County are expected to have around 778 daytime or 216 nighttime casualties during the CSZ "dry" scenario and 1,058 daytime or 508 nighttime casualties during the CSZ "wet" scenario. In addition, it is expected that there will be a long-term displaced population of around 1,006 for the CSZ "dry" scenario and 4,652 for the CSZ "wet" scenario.[18]

The long-term displaced population and casualties are greatly increased for all the Portland Hills Fault scenarios. The unincorporated portions of Clackamas County are expected to have around 3,582 daytime or 1,500 nighttime casualties during the Portland Hills Fault "dry" scenario and 4,555 daytime or 2,462 nighttime casualties during the Portland Hills Fault "wet" scenario. In addition, it is expected that there will be a long-term displaced population of around 12,036 for the Portland Hills Fault "dry" scenario and 24,307 for the Portland Hills Fault "wet" scenario.[19]

Table 2-11 Permanent residents displaced by building damage state and by earthquake and soil moisture conditions scenario.

Building Damage State	Cascadia Subduction Zone (M9.0)		Portland Hills Fault (M6.8)	
	"Dry" Soil	"Wet" Saturated Soil	"Dry" Soil	"Wet" Saturated Soil
Slight	75,828	73,670	101,881	94,448
Moderate	31,559	30,471	105,523	96,722
Extensive	6,644	6,580	47,996	44,065
Complete	1,931	10,093	25,152	50,802

Source: DOGAMI, Earthquake regional impact analysis for Clackamas, Multnomah, and Washington Counties, Oregon (2018, O-18-02), Table 12-3.
Note: Numbers for permanent residents occupying buildings in the "None" damage state are not included.

[17] Ibid, Tables 12-10 and 12-11

[18] Ibid, Tables 12-8 and 12-9.

[19] Ibid, Tables 12-10 and 12-11.

Recommendations from the report included topics within Planning, Recovery, Resiliency: Buildings, Resiliency: Infrastructure Improvements, Resiliency: Essential and Critical Facilities, Enhanced Emergency Management Tools, Database Improvements, Public Awareness, and Future Reports. The recommendations of this study are largely incorporated within this NHMPs mitigation strategies (Volume I, Section 3). For more detailed information on the report, the damage estimates, and the recommendations see: *Earthquake regional impact analysis for Clackamas, Multnomah, and Washington Counties, Oregon* (2018, O-18-02).

Natural Hazard Risk Report for Lower Columbia-Sandy Watershed

The **Risk Report** (DOGAMI, IMS-59) provides hazard analysis summary tables that identify populations and property within the Lower Columbia-Sandy River Watershed Study Area that are vulnerable to the Cascadia subduction zone earthquake and a local crustal earthquake event associated with the Mount Hood fault. The Risk Report provides distinct profiles for (1) unincorporated Clackamas County within the study area, (2) the unincorporated community of Government Camp, and (3) the unincorporated community of The Villages at Mount. Hood (including Brightwood, Rhododendron, Welches, Wimme, and Zig Zag).

According to the Risk Report the following populations and property within the study area may be impacted by the profiled events:

Unincorporated Clackamas County within the Study Area[20]

Cascadia Subduction Zone event (M9.0 Deterministic): 143 buildings are expected to be damaged (0 critical facilities) for a total potential loss of $37,084,000 (a loss ratio of 4%). In addition, 119 residents may be displaced (about 3% of the population).

Crustal event (Mt Hood M6.9 Probabilistic): 81 buildings are expected to be damaged (0 critical facilities) for a total potential loss of $22,080,000 (a loss ratio of 3%). In addition, 70 residents may be displaced (about 2% of the population).

Government Camp[21]

Cascadia Subduction Zone event (M9.0 Deterministic): 14 buildings are expected to be damaged (0 critical facilities) for a total potential loss of $3,533,000 (a loss ratio of 2%). In addition, 6 residents may be displaced (about 1% of the population).

Crustal event (Mt Hood M6.9 Probabilistic): 348 buildings are expected to be damaged (1 critical facility; Hoodland RFPD #74) for a total potential loss of $67,142,000 (a loss ratio of 46%). In addition, 100 residents may be displaced (about 30% of the population).

The Villages at Mt. Hood[22]

Cascadia Subduction Zone event (M9.0 Deterministic): 304 buildings are expected to be damaged (1 critical facility) for a total potential loss of $56,005,000 (a loss ratio of 7%). In addition, 408 residents may be displaced (about 6% of the population).

[20] DOGAMI, *Lower Columbia-Sandy Watershed Natural Hazard Risk Report* (March 2018 Draft), Table 9-1.

[21] Ibid., Table 9-5.

[22] Ibid., Table 9-7.

Crustal event (Mt Hood M6.9 Probabilistic): 923 buildings are expected to be damaged (2 critical facilities) for a total potential loss of $177,327,000 (a loss ratio of 22%). In addition, 993 residents may be displaced (about 16% of the population).

2007 Rapid Visual Survey

As noted in the community profile approximately 76% of residential buildings were built prior to 1990 (74% are either pre-code or low code according to DOGAMI[23]), which increases the county's vulnerability to the earthquake hazard.

In 2007, DOGAMI completed a rapid visual screening (RVS) of educational and emergency facilities in communities across Oregon, as directed by the Oregon Legislature in Senate Bill 2 (2005). RVS is a technique used by FEMA (FEMA P-154) to identify, inventory and rank buildings that are potentially vulnerable to seismic events. DOGAMI ranked each building surveyed with a 'low,' 'moderate,' 'high,' or 'very high' potential for collapse in the event of an earthquake. It is important to note that these rankings represent a probability of collapse based on limited observed and analytical data and are therefore approximate rankings. To fully assess a buildings potential for collapse, a more detailed engineering study completed by a qualified professional is required, but the RVS study can help to prioritize which buildings to survey.

DOGAMI's Rapid Visual Screening for Clackamas County listed 179 facilities in the unincorporated County and incorporated cities. Information on specific public buildings' (schools and public safety) estimated seismic resistance is available on DOGAMI's website: http://www.oregongeology.org/rvs/default.htm

Mitigation Successes

Seismic retrofit grant awards per the Seismic Rehabilitation Grant Program[24] have been funded to retrofit Clackamas Fire District Fire Station #12 (Logan), (2013-2014 grant award, $94,552); Clackamas Fire District Fire Station #13 (Clarkes), (2013-2014 grant award, $71,582); Molalla Fire District Station 82, (Phase Two of 2015-2017 grant award, $1,189,967); Sunnyside Elementary (Community of Clackamas), North Clackamas School District, (Phase Two of 2015-2017 grant award, $1,500,000); and Whitcomb Elementary, North Clackamas School District (Phase Two of 2015-2017 grant award, $1,500,000).

See city addenda for mitigation successes within each city.

For more information, see: Open-File-Report: O-2007-02 - Statewide seismic needs assessment: Implementation of Oregon 2005 Senate Bill 2 relating to public safety, earthquakes and seismic rehabilitation of public buildings, 2007

More information on this hazard can be found in the Risk Assessment for Region 2, Northern Willamette Valley/Portland Metro, of the Oregon NHMP (2015).

[23] DOGAMI, Earthquake regional impact analysis for Clackamas, Multnomah, and Washington Counties, Oregon (2018, O-18-02), Tables 10-2 and 10-3.

[24] The Seismic Rehabilitation Grant Program (SRGP) 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.

Flood

Significant Changes since Previous NHMP:

This section has updated data from the Lower Columbia-Sandy Watershed Multi-Hazard Risk Report, and the National Flood Insurance Program. Additional information is provided from reports detailing channel migration issues along the Sandy River.

Characteristics

Flooding results when rain and snowmelt create water flow that exceeds 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 destructive natural disasters have been floods.[25]

The flood events in Clackamas County usually occur when storms move in from the Pacific, dropping heavy precipitation into the Willamette valley; flooding is most significant during rain-on-snow events. Flooding in the valley becomes a problem when human activities infringe on the natural floodplain.

Two types of flooding primarily affect Clackamas County: riverine flooding and urban flooding. Channel migration and bank erosion also occurs along the Sandy River. In addition, any low-lying area has the potential to flood. The flooding of developed areas may occur when the amount of water generated from rainfall and runoff exceeds a storm water system's (ditch or sewer) capability to remove it.

Riverine Flooding

Riverine flooding is the overbank flooding of rivers and streams. The natural processes of riverine flooding add sediment and nutrients to fertile floodplain areas. Flooding in large river systems typically results from large-scale weather systems that generate prolonged rainfall over a wide geographic area, causing flooding in hundreds of smaller streams, which then drain into the major rivers. Figure 2-8 shows the various river basins in Clackamas County.

Shallow area flooding is a special type of riverine flooding. FEMA defines shallow flood hazards as areas that are inundated by the 100-year flood with flood depths of only one to three feet. These areas are generally flooded by low velocity sheet flows of water.

Urban flooding

As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Urbanization of a watershed changes the hydrologic systems of the basin. Heavy rainfall collects and flows faster on impervious concrete and asphalt surfaces. The water moves from the clouds, to the ground, and into streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in floodwaters that rise very rapidly and peak with violent force.

[25] Taylor, George H. and Chris Hannan. *The Oregon Weather Book*. Grants Pass, OR: Oregon State University Press. 1999

Almost one-eighth of the area in Clackamas County is incorporated and has a high concentration of impermeable surfaces that either collect water or concentrate the flow of water in unnatural channels. During periods of urban flooding, streets can become swift moving rivers and basements can fill with water. Storm drains often back up with vegetative debris causing additional, localized flooding.

Channel migration and bank erosion

Following the 2011 flood on the Sandy River, County staff began to emphasize the different nature of the flood hazard in the upper reaches of the river, as that of bank erosion due to channel migration. The upper Sandy may not have to reach flood stage to achieve a level of flow capable of mobilizing sediments and impounding gravel and woody debris in the channel. These impoundments can redirect the main channel into the bank and cause failures that exacerbate further erosion downstream. DOGAMI has extensively mapped the channel migration zone (see reports cited at the end of this section for more information).

Sandy River Channel Migration Damage
January 16, 2011
Source: Oregonian

Location and Extent

Because Clackamas County spans a wide range of climatic and geologic regions, there is considerable variation in precipitation, with elevation being the largest factor in precipitation totals. Moving east from Oregon City at 55 feet above sea level to Mt Hood at 11,235 feet above sea level, annual precipitation averages range from 47 inches to over 125 inches, respectively. This change in elevation causes a significant increase in precipitation, in the form of both rain and snow. Although the majority of the county enjoys a fairly mild winter, with less than 5-10 inches of snow per year, the higher elevations surrounding Mt. Hood are covered with snow for the majority of the winter months. This is of primary concern when dealing with potential flood events. Mt. Hood's snowmelt provides a continuous water source throughout the year and can be a major contributor to high waters.

Flooding is most common from October through April, when storms from the Pacific Ocean, 60 miles away, bring intense rainfall to the area.[26] During the rainy season, monthly rainfall totals average far higher than other months of the year. This results in high water, particularly in December and January. The larger floods are the result of heavy rains of two-day to five-day durations augmented by snowmelt at a time when the soil is near saturation from previous rains. Frozen topsoil also contributes to the frequency of floods.[27]

A large portion of Clackamas County's area lies in the lower Willamette River basin. The broad floodplain of the valley can be easily inundated by floodwaters. The surface material

[26] Interagency Hazard Mitigation Team, *State Hazard Mitigation Plan* (2000) Oregon Office of Emergency Management.

[27] Taylor, George H., Hannan, Chris, The Climate of Oregon (1999). Oregon State University Press. Corvallis, Oregon.

includes poorly drained, unconsolidated, fine-grained deposits of Willamette silt, sand, and gravel. Torrential flood events can introduce large deposits of sand and gravel that assist in the drainage of the otherwise poorly drained soils.[28]

After the January 2009 flood event on South Creek Road along Abernethy Creek, Clackamas County sponsored an inquiry to FEMA into mapping errors for transitioning the 1978 FIRM into DFIRM and argued that the original FIRM Approximate A Zone polygon was incorrectly registered that at least two properties in the Approximate A Zone were now outside of the flood zone, even Abernethy Creek itself. Following the 2009 flood event, the County petitioned FEMA for reconsideration and eventually submitted an inquiry through Senator Wyden's office to the Mitigation Directorate at FEMA Headquarters, but the request was denied. Table 2-12 lists the locations of known chronic flooding problems in Clackamas County.

Sandy River Flooding – January 16, 2011
Source: Clackamas County Disaster Management

Table 2-12 Locations of Identified Chronic Flooding Problems

Location	River	Description
Tranquility Lane	Clackamas River	Road
Paradise Park	Clackamas River	Open Space
Welches	Salmon River	Unincorporated community
Lolo Pass	Sandy River	Road
Timberline Rim	Sandy River	Housing development
Dickie Prairie Road	Molalla River	Road
Feyrer Park/Shady Dell	Molalla River	Open space and housing development
Alder Creek Area	Alder Creek	Open space
Canby	Pudding River	City
Dogwood Drive/Rivergrove	Tualatin River	City
Oregon City	Confluence of Willamette River and Clackamas River	City
Johnson Creek Basin	Johnson Creek	Basin
Abernethy Creek Basin	Abernethy Creek	Basin

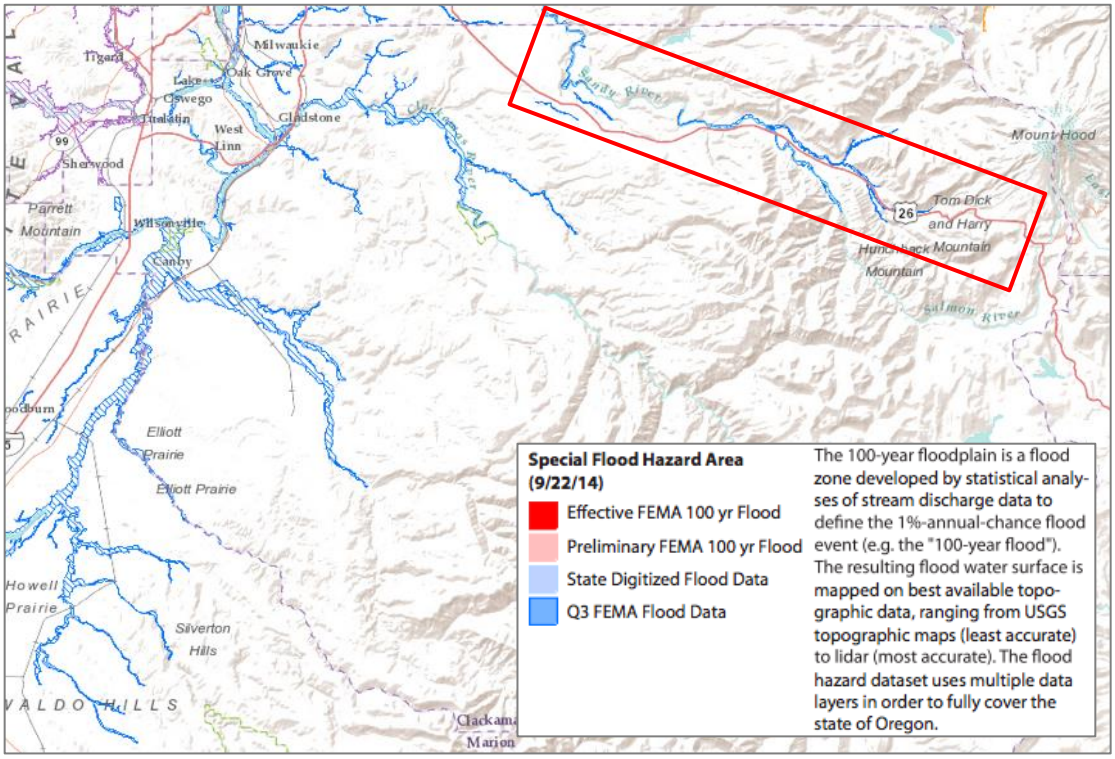
Source: Clackamas County Disaster Management

Floods are described in terms of their extent (including the horizontal area affected and the vertical depth of floodwaters) and the related probability of occurrence. Flood studies often use historical records, such as streamflow gages, to determine the probability of occurrence for floods of different magnitudes. The probability of occurrence is expressed in percentages as the chance of a flood of a specific extent occurring in any given year.

[28] Geologic Hazards of the Bull Run Watershed Multnomah and Clackamas Counties, Oregon. DOGAMI. Bulletin 82. 1974

The magnitude of flood used as the standard for floodplain management in the United States is a flood having a one percent probability of occurrence in any given year. This flood is also known as the 100-year flood or base flood. The most readily available source of information regarding the 100-year flood is the system of Flood Insurance Rate Maps (FIRMs) prepared by FEMA. These maps are used to support the National Flood Insurance Program (NFIP). The FIRMs show 100-year floodplain boundaries for identified flood hazards. These areas are also referred to as Special Flood Hazard Areas (SFHAs) and are the basis for flood insurance and floodplain management requirements. In 2008 FEMA undertook an update of all FIRMs in Clackamas County as part of a recalibration of the datum for measuring elevation into the Digital FIRM (DFIRM) format. Figure 2-8 provides an overview of the flood zones and extent in Clackamas County and Volume III, Appendix D includes maps showing average precipitation (Map 2), FEMA floodplains (Map 3), and river sub-basins (Map 4).

Figure 2-8 Special Flood Hazard Area and preliminary FIRMs study area



Source: Oregon HazVu: Statewide Geohazards Viewer – *To view map in more detail click hyperlink to left.*

For detailed information, refer to the following Flood Insurance Study (FIS) and associated Flood Insurance Rate Maps (FIRMs):

- Clackamas County FIS (2008) - Volume 1 of 3
- Clackamas County FIS (2008) - Volume 2 of 3
- Clackamas County FIS (2008) - Volume 3 of 3

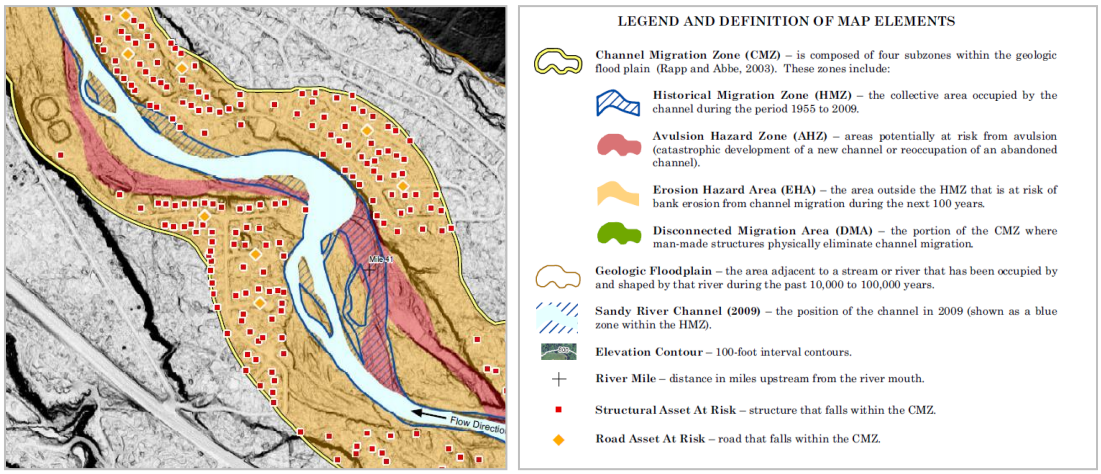
FEMA flood hazard mapping for updating the FIRMs is underway for the Sandy River (area shown in Figure 2-8 red bordered box), preliminary maps were released in March 28, 2016 (effective maps are expected by January 18, 2019). Preliminary FIRMs and revised flood

profiles and floodway data can be downloaded and viewed via FEMA's Flood Map Service Center: https://msc.fema.gov/portal/advanceSearch.

Conventional FIRMs (flood hazard maps) show existing floodplain information. However, in some areas bank erosion causes river channels to migrate, sometimes even in the absence of a flood event.

To address this concern DOGAMI has contributed a Channel Migration Zone mapping study for the Sandy River and generated LiDAR-based maps for the Sandy Basin and other flood-prone areas of the County. Figure 2-9 provides an example map and legend from the report. More information on the report is found below in the vulnerability section. The resulting channel migration zone and subzones represents the likely hazard area over the next 100 years. According to DOGAMI, "[t]he channel migration hazard map should be used as a guide for local governments, land owners, and infrastructure managers to identify assets potentially at risk and to develop effective mitigation measures".[29]

Figure 2-9 Channel Migration Hazard Map for Timberline Rim Area



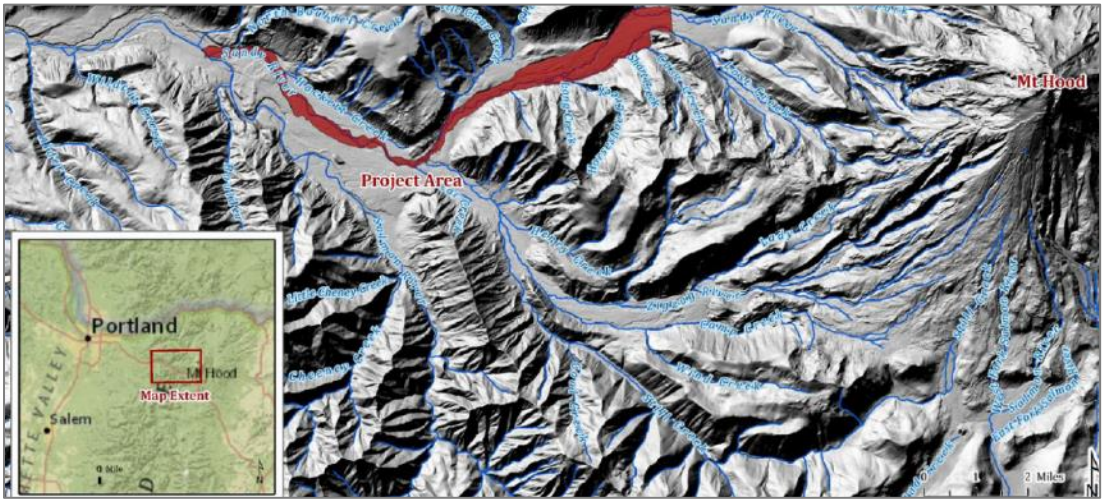
Source: DOGAMI, Open-File Report O-11-13, Plate 10 (superseded by O-13-10).

To refine the data provided by DOGAMI Clackamas County contracted with Natural Systems Design to conduct a Flood Erosion Hazard Mitigation Evaluation for the Upper Sandy River (NSD evaluation). The NSD evaluation was completed in 2015 and was funded through the Hazard Mitigation Grant Program (HMGP) for DR-1956.[30] The NSD evaluation project area (Figure 2-10) is limited to a 10-mile reach of the Sandy River extending from River Mile 37.4 (just above the Salmon River confluence) to River Mile 47.5 (just above the Lost Creek confluence).

[29] DOGAMI, Open-File Report 0-13-10, *Channel migration hazard data and maps for the Sandy River, Multnomah and Clackamas Counties, Oregon*. John T. English, Daniel E. Coe, and Robert D. Chappell.

[30] Natural Systems Design, *Flood Erosion Hazard Mitigation Evaluation: Upper Sandy River*, March 25, 2015.

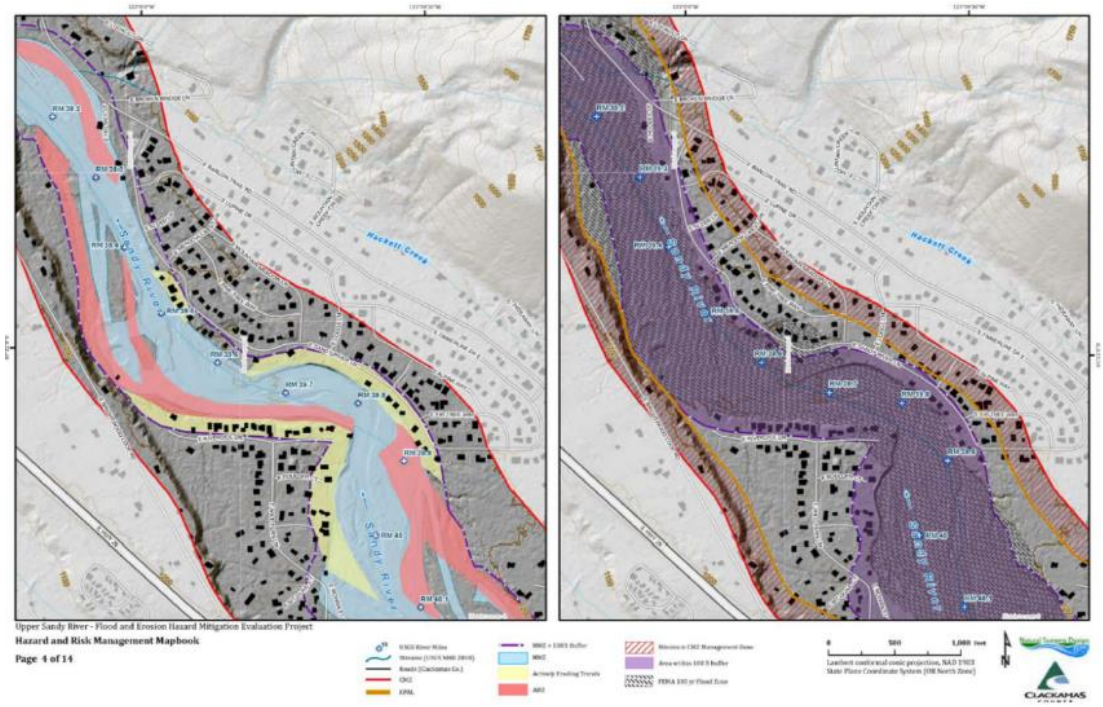
Figure 2-10 Upper Sandy River Project Area (RM 37-47)



Source: Natural Systems Design, Flood Erosion Hazard Mitigation Evaluation: Upper Sandy River, March 25, 2015.

The NSD evaluation's map update recommendations include: (1) expanding the historic migration zone (HMZ) to account for a broader corridor of channel occupancy over the historical record, (2) adding additional avulsion pathways to the avulsion hazard zone (AHZ), (3) increasing the setback from the AHZ to limit future erosion hazards, and (4) removing some areas noted as disconnected migration areas (DMA) which may be at risk to erosion (e.g., areas blocked by roads). The NSD evaluation created an adjusted channel migration zone (CMZ) that averages 2,000 feet wide throughout the project area (Figure 2-11).

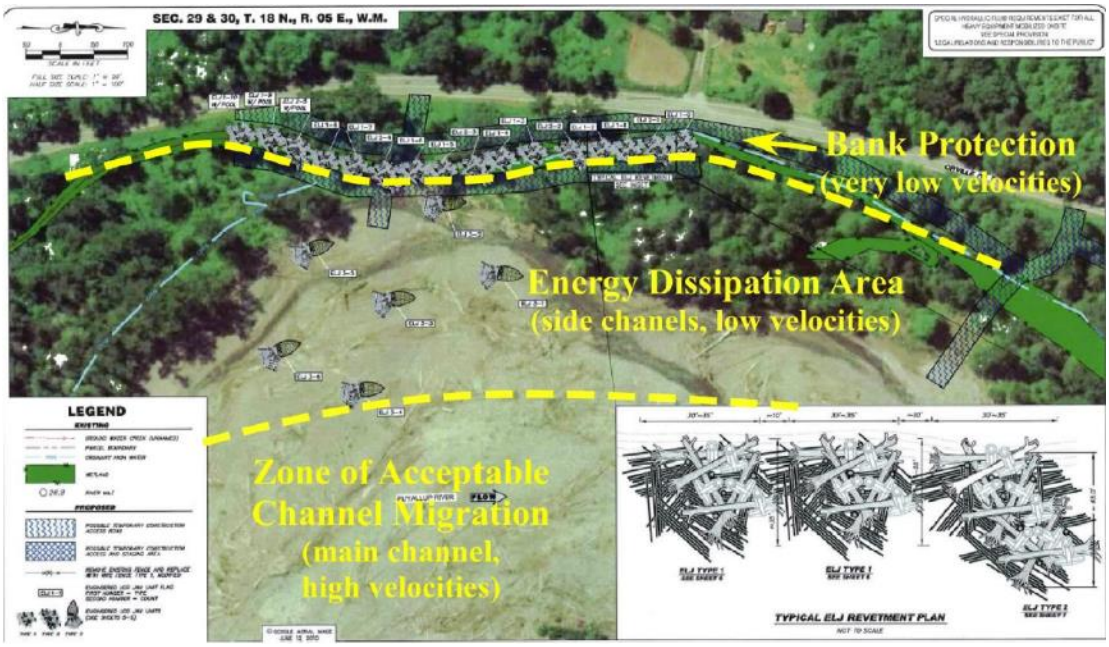
Figure 2-11 NSD Hazard and Risk Maps



Source: Natural Systems Design, Flood Erosion Hazard Mitigation Evaluation: Upper Sandy River, March 25, 2015. Maps show side-by-side hazard (left) and risk (right) maps for the 10-mile reach of the river affected in 2011. These maps characterize the CMZ exposure for the first time and will become the basis for flood mitigation along the Sandy. See Channel Migration Zone Hazard Maps (Risk Hazard Mapbook) for high resolution risk maps.

The NSD evaluation promotes the use of restorative erosion protection measures which take advantage of natural processes to decrease erosive forces while also benefitting fish and wildlife. Restorative measures must: (1) provide the river with sufficient space within an established River Management Corridor (RMC), (2) dissipate the river's energy as it approaches the margins of the RMC by splitting the main channel into smaller side channels, and (3) establish a line of defense at the RMC through the use of restorative bank protection measures (rough and complex) that dissipate energy, protect the bank, and enhance fish habitat.[31] A list of high risk erosion hazard sites is provided in NSD evaluation Table 5 that may be used as a resource when evaluating which sites to prioritize in future mitigation efforts along the Sandy River. An example bank projection strategy is provided in Figure 2-12. For more information review the NSD evaluation: https://dochub.clackamas.us/documents/drupal/e5a6ebef-f7be-4bcd-8f0f-48d33d537afd.

Figure 2-12 Example Bank Protection Strategy



Source: Natural Systems Design, *Flood Erosion Hazard Mitigation Evaluation: Upper Sandy River*, March 25, 2015.

More information on restorative flood protection measures can be found in the FEMA publication: Engineering with Nature: Alternative Techniques to Riprap Bank Stabilization.

Additional reports are available via FEMA's Flood Map Service Center website:

https://msc.fema.gov/portal

Refer to the following DOGAMI reports for additional information:

- Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed, Oregon: Including the cities of Gresham, Sandy, and Troutdale and Unincorporated Communities of Government Camp and The Villages at Mt Hood (2018, IMS-59).
- Statewide subbasin-level channel migration screening (2017, IMS-56).
- Channel migration zone study of Sandy River (2013, O-13-10). *Portions superseded by the Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed*.

[31] Ibid. pp. 62-65.

- Multi-Hazard and Risk Study for the Mount Hood Region (Earthquake, Flood and Channel Migration, Landslide, Volcano) (2011, O-11-16). *Portions of the flood and channel migration section superseded by the Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed*.
- Channel migration hazard maps for the Sandy River, Multnomah and Clackamas counties, Oregon (2011, O-11-12). Superseded by O-13-10.

Additional reports are available via DOGAMI's Publications Search website:

http://www.oregongeology.org/pubs/search.php

Other agency/ consultant reports:

- Natural Systems Design, *Flood Erosion Hazard Mitigation Evaluation: Upper Sandy River*, March 25, 2015.
    - Channel Migration Zone Hazard Maps (Risk Hazard Mapbook)
- Mathie, A.M., and Wood, N., 2013, Residential and service-population exposure to multiple natural hazards in the Mount Hood region of Clackamas County, Oregon: U.S. Geological Survey Open-File Report 2013–1073, available at http://pubs.usgs.gov/of/2013/1073/.

History

Clackamas County has many rivers and small tributaries in both unincorporated and incorporated areas that are susceptible to flooding. Major floods have affected the citizens of the county since as early as 1861, when it was reported that the streets of Oregon City were inundated with about four feet of Willamette overbank flow. Although the 1996 floods were devastating to the entire region, the floods of 1861, 1890, and 1964 were larger. All four floods have been estimated to exceed the 100-year or base flood. Since the previous version of the NHMP there have no presidentially declared flood disaster events in Clackamas County, however, there have been four flood events: 2012, 2014, 2015, and 2016-2017.

Probability Assessment

Based on the available data and research the HMAC determined the **probability of experiencing a flood is "high",** meaning one incident is likely within the next 10 to 35-year period *This rating has not changed since the previous NHMP.*

Flooding can occur every year depending on rainfall, snowmelt or how runoff from development impacts streams and rivers. FEMA has mapped the 100 and 500-year floodplains in portions of Clackamas County (see referenced 2008 FIS for more information; preliminary maps are available for the Sandy River, 2018). This corresponds to a 1% and 0.2% chance of a certain magnitude flood in any given year. The 100-year flood is the benchmark upon which the National Flood Insurance Program (NFIP) is based.

Climate change will likely be an influencing factor for future flood probabilities. Long-term modeling suggests increases in annual average temperatures may translate in the Pacific Northwest to less total accumulated snow pack and faster storm runoff. This could mean flashier flood events for upper watersheds and the need for greater attention to storm water management in floodplains.

Vulnerability Assessment

The HMAC rated the county as having a **"moderate" vulnerability to flood hazards**, meaning that between 1-10% of the unincorporated County's population or assets would be affected by a major flood event. *This rating has not changed since the previous NHMP.*

A floodplain vulnerability assessment combines the floodplain boundary, generated through hazard identification, with an inventory of the property within the floodplain. Understanding the population and property exposed to natural hazards will assist in reducing risk and preventing loss from future events.

The amount of property in the floodplain, as well as the type and value of structures on those properties, is calculated to provide a working estimate for potential flood losses. Table 2-13 shows potentially impacted parcels, critical and critical facilities, vulnerable populations, and infrastructure within Clackamas County's 100-year floodplain.

Table 2-13 Flood Hazard Vulnerability Assessment

	Potentially Impacted Parcels		Potentially Impacted Locations			Infrastructure				
Hazard	Number of Parcels	Percent of Total Parcels	Critical Facilities	Essential Facilities	Vulnerable Populations	Miles of Road	Miles of Sewer Lines	Bridges	Cell Towers	Dams
County Total	158,226	Not Applicable	235	55	576	4911	340	597	17	69
Flooding										
100 year Floodplain	9,921	6%	2	1	4	78	34	140	0	6

Source: Clackamas County Geographic Information Systems (2018)
Note: Percentage of property in the 100-year floodplain may include property in tax lots that intersect the floodplain, including property that does not physically reside in the floodplain itself.

Clackamas County development regulations restrict, but do not prohibit, new development in areas identified as floodplain. This reduces the impact of flooding on future buildings. As new land has been brought into the regional Urban Growth Boundary, the applicable development codes have been applied to prevent the siting of new structures in flood prone areas.

For mitigation planning purposes, it is important to recognize that flood risk for a community is not limited only to areas of mapped floodplains. Other portions of the county outside of the mapped floodplains may also be at relatively high risk from over bank flooding from streams too small to be mapped by FEMA, from channel migration, or from local storm water drainage.

Lower Columbia-Sandy Watershed Natural Hazard Risk Report

The **Risk Report** (DOGAMI, IMS-59) provides hazard analysis summary tables that identify populations and property within the Lower Columbia-Sandy River Watershed Study Area that are vulnerable to the profiled natural hazards. The Risk Report provides distinct profiles for (1) unincorporated Clackamas County within the study area, (2) the unincorporated community of Government Camp, and (3) the unincorporated community of The Villages at Mt. Hood (including Brightwood, Rhododendron, Welches, Wimme, and Zig Zag).

According to the Risk Report the following populations and property are vulnerable:

Unincorporated Clackamas County within the Study Area[32]

[32] DOGAMI, *Lower Columbia-Sandy Watershed Natural Hazard Risk Report* (March 2018 Draft), Table 9-1.

Flood event (100-Year Flood): 74 buildings are expected to be damaged (0 critical facilities) for a total potential loss of $2,989,000 (a loss ratio of < 1%). In addition, 138 residents may be displaced (about 3% of the population).

*Channel migration**: 145 buildings are exposed (0 critical facilities) for a total potential loss of $33,781,000 (an exposure ratio of 4%). In addition, 178 residents may be displaced (about 4% of the population).

Government Camp[33]

Flood event (100-Year Flood): 12 buildings are expected to be damaged (0 critical facilities) for a total potential loss of $182,000 (a loss ratio of < 1%). In addition, 4 residents may be displaced (about 2% of the population).

*Channel migration**: No potential risk to Government Camp.

The Villages at Mt. Hood[34]

Flood event (100-Year Flood): 161 buildings are expected to be damaged (0 critical facilities) for a total potential loss of $2,628,000 (a loss ratio of < 1%). In addition, 285 residents may be displaced (about 1% of the population).

*Channel migration**: 1,307 buildings are exposed (0 critical facilities) for a total potential loss of $233,667,000 (an exposure ratio of 29%). In addition, 1,855 residents may be displaced (about 36% of the population).

*Note: * - The channel migration hazard may be under reported in the DOGAMI Risk Report which does not utilize the Natural Systems Design Flood Erosion Mitigation Evaluation: Upper Sandy River (NSD evaluation) to determine the width of the channel migration zone. Please review the NSD evaluation for more information on the hazard.*

Floodplain Management Plan (Activity 510)

The NHMP functions as, among other things, the County's Floodplain Management Plan so that the County receives credit for, and maintains compliance with, its membership within the National Flood Insurance Program (NFIP) Community Rating System (CRS), which recognizes jurisdictions for participating in floodplain management practices that exceed NFIP minimum requirements. The County was admitted into the CRS program in April 2004 and received a rating of Class 5, becoming the highest rated jurisdiction in Oregon and one of only 23 nationally. Currently, the County's participation in the CRS is rescinded and the County does not receive a discount in flood insurance premiums for residents of unincorporated Clackamas County in a special flood hazard zone.

Below are several CRS related activities that the 2018 NHMP documents for credit under the Activity 510 – Floodplain Management Plan:

[33] Ibid., Table 9-5.

[34] Ibid., Table 9-7.

National Flood Insurance Program (NFIP)

FEMA updated the Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) in 2008 (effective June 17, 2008). Preliminary maps for portions of the County within the Lower Columbia-Sandy River Watershed were released March 28, 2016 (expected to be effective January 18, 2019). Clackamas County has an open Community Assistance Visit (CAV) that was initiated January 11, 2017. The NFIP's Community Rating System (CRS) recognizes jurisdictions for participating in floodplain management practices that exceed NFIP minimum requirements.

Table 2-14 shows that the majority of flood insurance policies are for residential structures, primarily single-family homes. There are 1,311 National Flood Insurance Program (NFIP) policies in force within the unincorporated portion of the County. Of those, 754 are for properties that were developed before development of the initial FIRMs.

Flood insurance covers only the improved land, or the actual building structure. There have been 385 paid claims paid as of July 2018 (294 pre-FIRM and 58 substantial damage) in the unincorporated County totaling just under $10.7 million.

Table 2-14 Flood Insurance Detail

	Clackamas County	Unincorporated Clackamas County
Effective FIRM and FIS	6/17/2008	6/17/2008
InitialFIRM Date	-	3/1/1978
Total Policies	1,957	1,311
Pre-FIRM Policies	1,086	754
Policies by Building Type		
Single Family	1,761	1,231
2 to 4 Family	30	14
Other Residential	58	5
Non-Residential	9	7
Minus Rated A Zone	123	81
Insurance in Force	$541,833,400	$349,852,800
Total Paid Claims	590	385
Pre-FIRM Claims Paid	450	294
Substantial Damage Claims	83	58
Total Paid Amount	$20,830,662	$10,664,411
Repetitive Loss Structures	51	40
Severe Repetitive Loss Properties	4	3
CRS Class Rating	-	10
Last Community Assistance Visit	-	1/11/2017*

Source: Department of Land Conservation and Development, July 2018. The portion of the cities of Portland and Tualatin that are within Clackamas County are not included in this table.
Note: * - The most CAV has been open since 1/11/2017

Risk Analysis - Repetitive Loss Properties:

Clackamas County works to mitigate problems regarding flood issues when they arise. Some areas in the county are more susceptible to flooding issues and have incurred repetitive losses. A repetitive loss property (RL) is defined as a National Flood Insurance Program (NFIP)-insured building that has had at least two paid flood losses of more than $1,000 each

in any 10-year period since 1978. A severe repetitive loss property (SRL) is defined as a building that is covered under an NFIP flood insurance policy and has had at least four paid flood losses of more than $5,000 each or for which at least two separate building claims payments with the cumulative amount exceeding the market value of the building. RL and SRL properties are troublesome because they continue to expose lives and valuable property to the flooding hazard. Local governments as well as federal agencies such as FEMA attempt to address losses through floodplain insurance and attempts to remove the risk from repetitive loss of properties through projects such as acquiring land and improvements, relocating homes or elevating structures. Continued repetitive loss claims from flood events lead to an increased amount of damage caused by floods, higher insurance rates, and contribute to the rising cost of taxpayer funded disaster relief for flood victims.

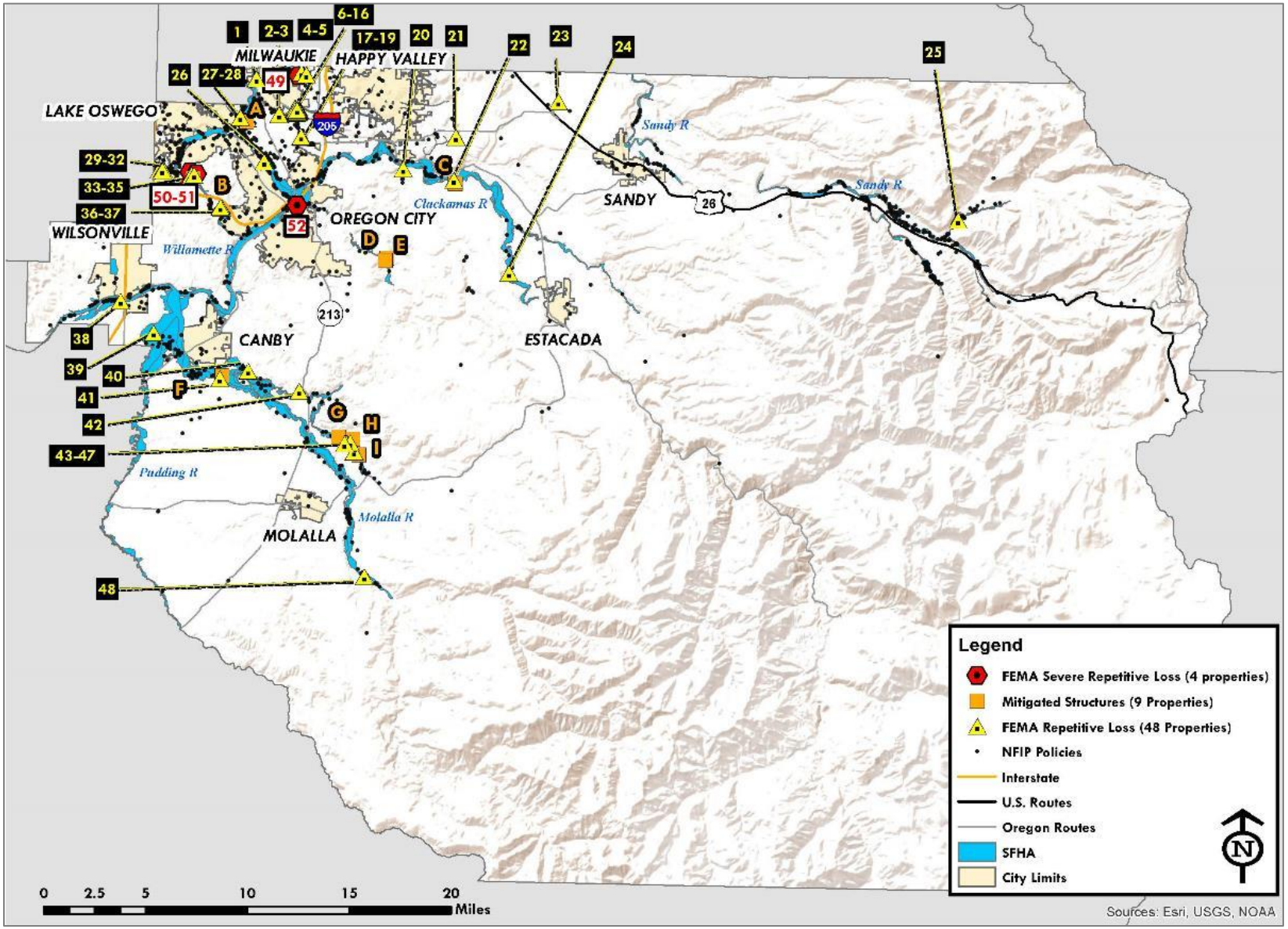
Table 2-15 and Figure 2-13 provide information on the identified RL and SRL properties. The NFIP record identifies 39 RL properties in unincorporated Clackamas County. There have been 112 paid RL claims totaling $3,556,703. Of these properties, three (3) are considered SRL (total paid losses amount to $209,132). Fifteen (15) of the RL/SRL properties are not insured as of July 2018. Most repetitive loss properties are located outside of city limits.

Table 2-15 Repetitive Loss and Severe Repetitive Loss Properties Detail

RL or SRL Property	Location	Currently Insured?	Flood Zone	Occupancy	Historic Building	Total Paid Claims	Total Paid Amount
RL	Property 2	YES	AE	Single Family	No	3	$37,585
RL	Property 4	NO	A	Single Family	No	2	$3,719
RL	Property 6	YES	AE	Single Family	No	2	$141,105
RL	Property 7	YES	AE	Single Family	No	2	$117,381
RL	Property 8	YES	AE	Single Family	No	2	$29,624
RL	Property 9	YES	A02	2-4 Family	No	2	$131,249
RL	Property 10	YES	A02	2-4 Family	No	2	$216,191
RL	Property 11	YES	C	2-4 Family	No	2	$229,582
RL	Property 12	YES	C	2-4 Family	No	2	$224,271
RL	Property 13	YES	C	Other residential	No	2	$262,315
RL	Property 17	NO	X	Single Family	No	2	$15,123
RL	Property 18	YES	A02	Single Family	No	3	$46,901
RL	Property 19	YES	A02	Single Family	No	2	$11,832
RL	Property 20	YES	A07	Single Family	No	2	$14,220
RL	Property 21	NO	X	Single Family	No	2	$30,066
RL	Property 22	YES	A	Single Family	No	2	$11,961
RL	Property 23	NO	X	Single Family	No	2	$17,338
RL	Property 24	YES	X	Single Family	No	3	$63,409
RL	Property 25	YES	A05	Single Family	No	2	$123,375
RL	Property 27	YES	A19	Single Family	No	2	$28,933
RL	Property 28	NO	A19	Single Family	No	2	$125,288
RL	Property 33	YES	C	Single Family	No	2	$84,648
RL	Property 34	YES	A	Single Family	No	2	$42,719
RL	Property 35	YES	A	Single Family	No	2	$74,014
RL	Property 36	YES	B	Single Family	No	2	$80,721
RL	Property 37	NO	X	Single Family	No	2	$18,418
RL	Property 38	YES	C	Single Family	No	2	$84,976
RL	Property 39	NO	AE	Single Family	No	2	$8,949
RL	Property 40	NO	AE	Single Family	No	2	$7,072
RL	Property 41	YES	A05	Single Family	No	3	$77,410
RL	Property 42	YES	A04	Single Family	No	2	$17,494
RL	Property 43	YES	AE	Single Family	No	2	$11,501
RL	Property 44	NO	B	Single Family	No	3	$52,708
RL	Property 45	NO	A	Single Family	No	2	$46,637
RL	Property 46	YES	A04	Single Family	No	2	$8,058
RL	Property 47	YES	B	Single Family	No	2	$39,933
RL	Property 48	NO	C	Single Family	No	2	$16,732
SRL	Property 49	NO	X	Single Family	No	6	$123,952
SRL	Property 50	SDF	A	Single Family	No	2	$41,201
SRL	Property 51	SDF	A	Single Family	No	2	$43,978
Total						89	$2,762,591

Source: Department of Land Conservation and Development, July 2018.
Notes: RL – Repetitive Loss Property, SRL – Severe Repetitive Loss Property
For location details see Figure 2-13

Figure 2-13 NFIP Policies, Repetitive Loss, and Severe Repetitive Loss Properties



Source: Department of Land Conservation and Development, July 2018 (data from July 2017).

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Implementing Flood Hazard Mitigation

Clackamas County works closely with OEM and FEMA to reduce flood losses and seeks to best utilize federal mitigation grant funds to minimze future flood risk. With that said, Clackamas County has demonstrated in the two most recent disaster their investment in flood mitigation actions through priortizing substantially damaged properties and repetitive loss properties when applying for flood acquisition projects. The County considers these buyouts of flood prone properties to be the most cost effective approach to reduce future flood losses for property owners, minimize future disaster-related expenses to the community and provide savings to federal tax payers on a permenant reduction in flood exposed properties.

Table 2-16 and Figure 2-13 provide information on repetitive loss properties that have been mitigated through FEMA HMA grant programs. The record indicates that nine (9) properties in unincorporated Clackamas County have received some form of flood mitigation (buy out, elevation, relocation, etc.). There have been 112 paid repetitive loss claims totaling $3,556,703.

Table 2-16 Mitigated Flood Properties

Location	Currently Insured?	Flood Zone	Occupancy	Historic Building	Total Paid Claims	Total Paid Amount
Property A	YES	X	Single Family	No	2	$90,040
Property B	YES	A	Single Family	No	2	$94,465
Property C	YES	A07	Single Family	No	3	$132,435
Property D	YES	A	Single Family	No	3	$275,678
Property E	NO	C	Single Family	No	3	$60,499
Property F	NO	AE	Single Family	No	3	$36,618
Property G	YES	A	Single Family	No	2	$27,038
Property H	YES	A04	Single Family	No	2	$19,704
Property I	NO	A04	Single Family	No	3	$57,635
Total					23	$794,112

Source: Department of Land Conservation and Development, July 2018.
For location details see Figure 2-13

One of the best investments for implementing hazard mitigation is not only through projects but to affect policy, such as land use planning and even long-term recovery planning. Following the 2011 flood disaster, Clackamas County convened a standing group to address sustainable flood recovery on the upper Sandy River. This group has begun addressing the interdepartmental roles and responsibilities in transitioning from response activities to recovery phase.

Since the previous NHMP was adopted ongoing discussions have occurred on how the expected updated DFIRMS (preliminary in March 28, 2016, expected to be effective January 18, 2019) for the Sandy River will influence the DOGAMI Channel Migration Zone study and possible implications for long-term land use decisions on replacing damaged infrastructure and recovery for private property owners. DOGAMI completed their Channel Migration Study in 2013 (Open-File Report O-13-10). County staff is working with the Sandy River Basin Watershed Council's "restorative flood response" outreach to homeowners and associations on providing education about benefits from combining multiple goals of enriching habitat,

cost-effectiveness, elevated bank protection and equitable performance towards neighboring properties.

The County is also reviewing the level of flood insured properties in the upper Sandy Basin and investing in public outreach to encourage more Preferred Risk policies for residences outside of the Special Flood Hazard Zone and that by having flood insurance, homeowners can also take advantage of the Flood Mitigation Assistance Program for projects like acquisitions that do not require a disaster declaration.

Public outreach was employed several times since the January 2011 flood event to address public concerns, present flood response and recovery operations status, discuss flood threat issues to property owners and promote the purchase of flood insurance.

Urban Area Flood Mitigation

50th Anniversary recognition of the 1964 Christmas flood – Clackamas/Willamette Rivers Confluence

In anticipation of the 2014 holiday season, Clackamas County began collecting images and interviews from residents who directly experienced the 1964 Christmas flood. By focusing on personal photos and accounts, the County used stories rather than agency reports to document how this flood event affected people, neighborhoods and Clackamas history.

Post Flood Actions – December 2015

Clackamas County held a September 2016 community meeting for owners and tenants of flooded homes to review the nature of the flood event, mitigation options with HMGP funds and information resources from federal, state and county agencies and the North Clackamas Urban Watersheds Council.

An NFIP Repetitive Loss residential property along SE Rusk Road that flooded in 1996, 2009, and 2015 is participating in the 2016 Flood Mitigation Assistance (FMA) program. At the time of the NHMP update, the propserty is under consideration for a relocation/elevation on the current parcel but may end up accepting a voluntary flood acquisition if the house's structure can't be raised.

In October 2015 and November 2016, the County organized two "Flood of Information" community education events for urban flood hazards and winter weather safety. Participants included the North Clackamas Urban Watersheds Council, the Greater Oregon City Watershed Council, the Oregon NFIP Coordinator, the US Geological Survey's Portland

Water Resources Office, the Cascades Region of the American Red Cross and staff from multiple County departments.

Surface Water Management – Water Environment Services (WES)

WES administers sanitary sewer, surface water management, and erosion control programs in urban areas of Clackamas County.

Since 2012, WES has completed several in-stream restoration projects, repaired many drainage issues, rehabilitated some stormwater ponds, conducted monitoring, and other storm system-related maintenance. These restoration projects have been done to improve physical habitat and water quality, as well as to correct drainage/flow issues.

- Mt Scott Creek in North Clackamas Park: In-stream restoration and invasive control/native vegetation enhancement, construction of an overlook deck. Completed in partnership w/NCPRD, partial funding from Metro Nature in Neighborhoods Capital Grant program and WES ratepayer fees.
- Happy Valley Park stream stabilization: Replaced a culvert with a bridge, repaired a headcut, improved in-stream habitat in partnership w/City of Happy Valley. Funding by and WES ratepayer fees.
- Cedar Way stream stabilization: Repaired a headcut and stabilized a stream along a walking path in partnership w/City of Happy Valley. Funding from and WES ratepayer fees.
- Rock Creek Confluence project: in-stream restoration, invasive control/native vegetation enhancement, construction of a shelter for use by environmental education program. Partnered with Clackamas River Basin Council, partial funding from Metro Nature in Neighborhoods Capital Grant program, The Nature Conservancy, OWEB, and WES ratepayer fees.
- Carli Creek constructed wetland and stream restoration: currently in construction. In-stream portion completed. Constructed wetland will treat currently untreated stormwater runoff from industrial properties and gradually release treated water back to Carli Creek. Partial funding from PGE's Clackamas Habitat Fund and WES ratepayer fees.

Kellogg Creek Stream Gauge Installation – Water Environment Services (WES)

WES installed satellite communications at its lower Kellogg Creek flow monitoring station near Milwaukie and partnered with NOAA to host the real-time data on its Advanced Hydrologic Prediction Service website. This will not only serve for flood monitoring, but also provide needed stream flow data for watershed planning.
https://water.weather.gov/ahps2/hydrograph.php?wfo=PQR&gage=kcmo3

RiverHealth Stewardship Program – Water Environment Services (WES)

The RiverHealth Stewardship Program grants support a variety of watershed activities with the purpose of enhancing water quality, restoring fish habitat, managing invasive species, organizing volunteer events, and removing trash from waterways.

Since 2013, their RiverHealth Stewardship Program grants have funded over $1 million dollars to support community groups, businesses, and property owners who want to improve the health of watersheds within the surface water areas served by WES. The current 2018-19 funding cycle supports 14 projects with $270,000 in grants.

Benefiting watersheds include Rock Creek, Kellogg Creek, Mt Scott Creek, Phillips Creek, Johnson Creek, and the Clackamas River. The grants will also support the continued stewardship of previously restored project sites, protecting District investments made in recent years.

Rural Area Flood Mitigation

Channel Migration Zone Hazards – Upper Sandy River

In January of 2011, Clackamas County experience a 25-year flood on the upper Sandy River with destruction to three houses, severe damage to roads and bridges, and multiple properties that lost tens of feet of streamside land – all to bank erosion. Since 2011, the County has worked to address an emerging understanding of the basis for the hazard and risk as primarily channel migration on a steep mountain river system and not traditional over-bank flooding. No hydrologic studies had been conducted in the Upper Sandy basin and there was no scientifically based research to use for managing erosion and property losses. Bank armoring using rip rap (rock armoring), permitted and unpermitted, was the normal approach for property by property protection. This historical treatment demonstrated clear evidence of many examples of unintended consequences of erosion along exposed neighboring and downstream properties, often creating escalated armoring and negative impacts to habitat and stream function.

US Army Corps of Engineers (USACE) Public Involvement Pilot Project

In 2013-14 the County was included in a dozen selected communities across the nation as pilot projects for Public Involvement and conflict resolution around flood risk management. The County convened a workgroup of representatives from upper Sandy River communities to consider options for short-term flood recovery and future mitigation.

50th Anniversary recognition of the 1964 Christmas flood – Upper Sandy River Basin

During the 1964 Christmas floods, Clackamas County was the hardest hit area in Oregon and the upper Sandy River communities were the hardest hit on the County, mostly from channel migration damage. 155 homes were destroyed with miles of washed out roads and the loss of numerous bridges. The County used this historic anniversary to emphasize that 50 years later channel migration hazard is still a threat and must be addressed in future policy decisions in planning for flood recovery and community development (Figure 2-11).

Three flood acquisitions due to CMZ damage

Clackamas County acquired three flood erosion-damaged residential properties following the 2011 upper Sandy River disaster declaration using HMGP funds (DR-1956-OR). Channel migration during the high-water event eroded approximately 40 feet of property at each location and undermined the foundations making the residences uninhabitable. All three properties were acquired and transferred to County ownership as open space.

Other flood mitigation assistance

Two repetitive loss properties along South Creek Road have received mitigation assistance against future flood losses. Following the flood of January 2009 along Abernethy Creek, one used HMGP funds to elevate at least eight feet above grade and three feet above the flood of record. The second property was an HMGP flood acquisition along Abernethy Creek that is returning the property to permanent open space in the floodplain. Clackamas County

completed an additional two flood elevations: one along the upper Sandy River in February 2008 using a Flood Mitigation Assistance Grant, and the other along Abernethy Creek in March 2010 using the Hazard Mitigation Grant Program (HMGP).

As of September 2018, the County is using 2016 FMA funds to mitigate a RL residential dwelling along SE Rusk Rd.

Mitigation Success - Abernethy Creek elevation completed in March 2010 and successfully tested on January 19, 2012.
Source: Clackamas County

HMGP 5% Flood Warning System installation, but continuing technical problems.

Following the 2011 flood event, the County sought a means to monitor the stream flows of the three rivers in the upper Sandy Basin to better help provide status and warnings for communities at risk. Improving on the existing three NWS staff gauges, we used HMGP 5% funds to install five new sonar-based, solar powered sensors with radio communication on County-owned bridges (2 on the Sandy, 2 on the Salmon, and 1 on the Zig Zag Rivers). Unfortunately, due to mountainous terrain, extensive tree cover, and harsh winter weather conditions, these five stations have never performed to their expected design capabilities. We are currently exploring additional options for enhancing or replacing them.

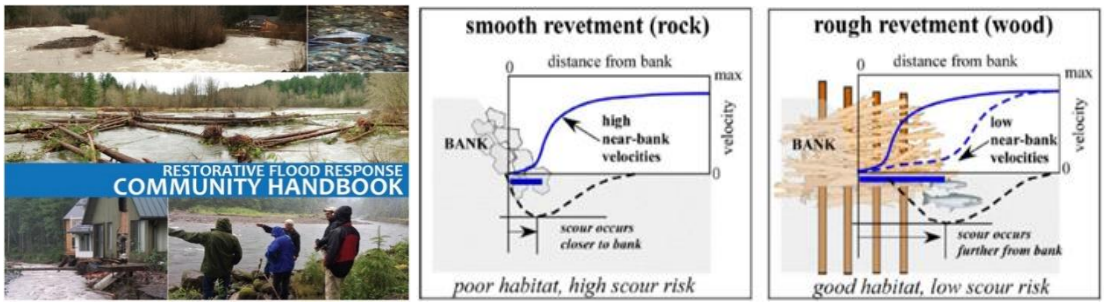
OPDR Channel Migration Zone hazard and risk public opinion survey

During the summer of 2016, the Oregon Partnership for Disaster Resilience (OPDR) used RiskMap outreach funds from the FIRM update of the Sandy River Basin to design and conduct and a public option survey to capture valuable data on community attitudes towards flood risk tolerance and avoidance, preferences on flood mitigation, and the role of government on flood risk management. Out of 3,000 surveys sent, we received

approximately 300 responses, with mixed opinions on flood risk management. Generally, the community has more support for maintaining existing levels of exposure but is willing to have government place more restrictions on future development.

Sandy River Basin Watershed Council (SRBWC) – Restorative Flood Response Community Handbook

The SRBWC has become a vital partner in flood mitigation in the upper Sandy River Basin, due to their work on what they call, "Restorative Flood Response." This approach leverages bank stabilization, with advanced bio engineering practices tailored for the Sandy River, to improve habitat, stream function, and reduces flood risk.



SRBWC Community Handbook – This 2016 handbook is based on the County's 2015 CMZ study and is co-authored by the SRBWC and NSD. The SRBWC is very effective in engaging the public on reach-based stream restoration projects through their non-regulatory role and hands-on volunteer opportunities.

Floodplain Reconnection Project – Columbia Land Trust and SRBWC

Engineered Log Jam (ELJ) – Construction of 3 ELJs, removal of 300 feet of post-1964 flood levees and reconnection of 2,900 feet of side channel to provide refuge for salmonids, absorb flood velocities, and redistribute storm flows across a broader floodplain. Photo: SRBWC.

RiskMap Resilience Meeting for the Upper Sandy River Basin

As a concluding activity for the FIRM update in the Upper Sandy River basin, the County sponsored FEMA's Resilience Meeting in October 2017 to review mitigation opportunities. This meeting was attended by federal, state and local government officials as well as a panel of five community representatives to highlight CMZ issues and express concerns related to homeowners, community planning, or realtors. The County reviewed policy issues that emerged following the 2011 flood and emphasized the strategies of the two following actions underway in 2018:

- **US Army Corps Silver Jackets Project – Upper Sandy River Flood Risk Management Plan**
  The County worked with the Corps' Silver Jackets group to receive a two-year (FFY 2018-19) project for flood risk management planning and community engagement. His effort building on the 2013-14 Public Involvement Pilot and the recommendations from the 2015 Natural Systems Design erosion study.
- **Oregon Solutions assistance with State policy for CMZ regulation**
  The County has been working with Oregon Solutions since 2015 on a project assessment around CMZ polices and is currently supporting Oregon Solutions and the Governor's Resilience Policy Advisor on a statewide examination of the need for CMZ polices and regulations for both property and habitat.

Clackamas County CRS Program Review

In 2009-10 the County requested the University of Oregon's Partnership for Disaster Resilience to lead a project to assess the feasibility and benefits of a more efficient, streamlined and integrated approach to flood mitigation and flood plain management in the county. A 2011 report found that programmatic improvements are expected to reduce the risk of damage to property and life resulting from flood; establish better coordination of mitigation actions and activities across public, private and not-for-profit entities; enhance and restore natural and constructed flood control functionality; and maximize the use of limited resources.[35]

More information on this hazard can be found in the Risk Assessment for Region 2, Northern Willamette Valley/Portland Metro, of the Oregon NHMP (2015).

[35] OPDR, 2011, *Clackamas County Community Rating System Program Review*.

Landslide

Significant Changes since Previous NHMP:

New landslide susceptibility information based on updated Lidar data provided by DOGAMI (O-16-02) has also been included. Analysis from the Lower Columbia-Sandy Watershed Natural Hazard Risk Report is also included.

Characteristics

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.

Clackamas County is subject to landslides or debris flows (mudslides), especially in the Cascade Range in the eastern portion of the county, which may affect buildings, roads and utilities.

Additionally, landslides often occur together with other natural hazards, thereby exacerbating conditions, as described below:

- Shaking due to earthquakes can trigger events ranging from rockfalls and topples to massive slides.
- Intense or prolonged precipitation that causes flooding can also saturate slopes and cause failures leading to landslides.
- Landslides into a reservoir can indirectly compromise dam safety and a landslide can even affect the dam itself.
- Wildfires can remove vegetation from hillsides, significantly increasing runoff and landslide potential.

Location and Extent

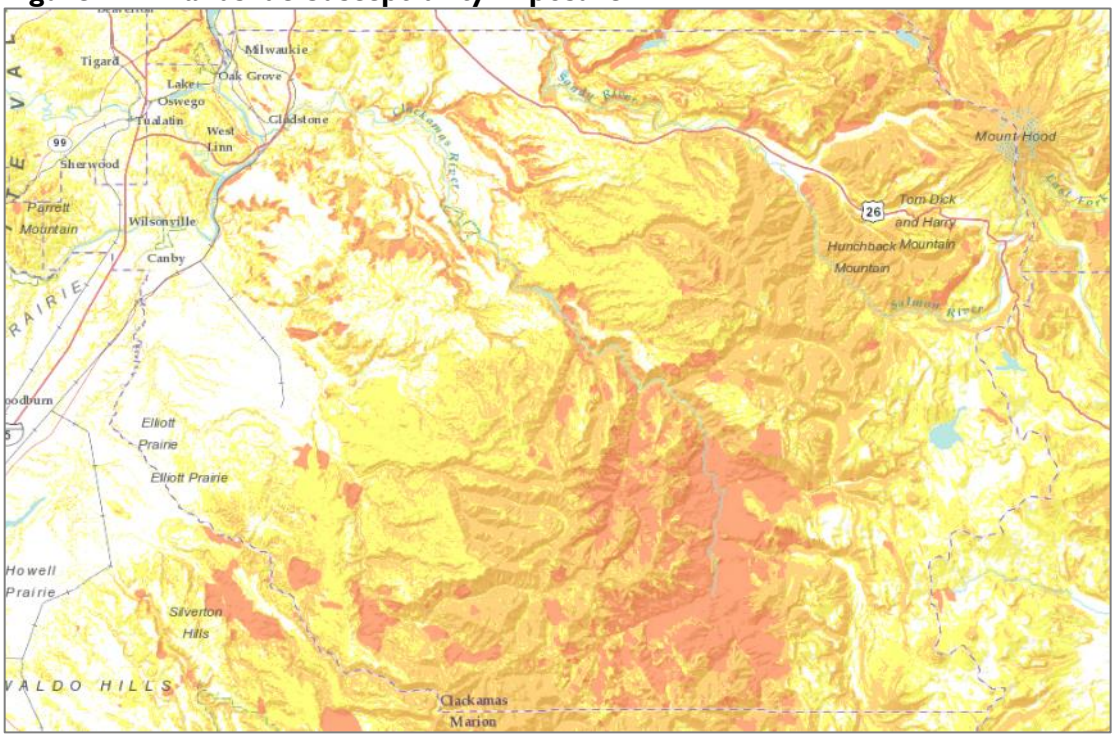
In many parts of Clackamas County, weathering and the decomposition of geologic materials produces conditions conducive to landslides. Human activity has further exacerbated the landslide problem in many parts of the county. A study conducted by Dr. Scott Burns at Portland State University found that changes to the slope through cutting or filling increased the risk of landslides in 76% of the 701 inventoried landslides in the Metro region. The study documented 48 landslides that occurred in Oregon City in February 1996 and found that only about half the slides were considered natural.[36]

For Clackamas County, many high landslide potential areas are in hilly-forested areas (Figure 2-14). Landslides in these areas may damage or destroy some timber and impact logging roads. Many of the major highways in Clackamas County are at risk for landslides at one or

[36] Burns, Burns, James, and Hinchke. Landslides in Portland, Oregon Metropolitan Area (resulting from Storm of 1996: Inventory, Map Data, and Evaluation.)

more locations with a high potential for road closures and damage to utility lines. Especially in the central-eastern portions of the County, with a limited redundancy of road network, such road closures may isolate communities. Additional maps can be found in Volume III, Appendix D: slop stability (Map 5), historic landslides (Map 6), and debris flows (Map 7).

Figure 2-14 Landslide Susceptibility Exposure



Low	**Landsliding unlikely.** Areas classified as Landslide Density = Low (less than 7%) and areas classified as Slopes Prone to Landsliding = Low.
Moderate	**Landsliding possible.** Areas classified as Landslide Density = Low to Moderate (less than 17%) and areas classified as Slopes Prone to Landsliding = Moderate OR areas classified as Landslide Density = Moderate (7%-17%) and areas classified as Slopes Prone to Landsliding = Low.
High	**Landsliding likely.** Areas classified as Landslide Density = High (greater than 17%) and areas classified as Slopes Prone to Landsliding = Low and Moderate OR areas classified as Landslide Density = Low and Moderate (less than 17%) and areas classified as Slopes Prone to Landsliding = High.
Very High	**Existing landslides** Landslide Density and Slopes Prone to Landsliding data were not considered in this category. Note: the quality of landslide inventory (existing landslides) mapping varies across the state.

Source: Oregon HazVu: Statewide Geohazards Viewer – *To view map in more detail click hyperlink to left.*

More detailed landslide hazard assessment at specific locations requires a site-specific analysis of the slope, soil/rock and groundwater characteristics at a specific site. Such assessments are often conducted prior to major development projects in areas with moderate to high landslide potential, to evaluate the specific hazard at the development site.

Table 2-17 shows landslide susceptibility exposure for Clackamas County and the incorporated cities. Approximately 45% of the county has high or very high landslide susceptibility exposure. These are concentrated in areas of high slopes, and close to river valleys (Figure 2-14). In general cities within the County have a lower landslide susceptibility

exposure than does the unincorporated area of the County (see Volume II for more information on each city's exposure). Note that even if a County or city has a high percentage of area in a high or very high landslide exposure susceptibility zone, this does not mean there is a high risk, because risk is the intersection of hazard and assets.

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.

Table 2-17 Landslide Susceptibility Exposure

Jurisdiction	Area, ft^2	Low	Moderate	High	Very High
Clackamas County	52,482,820,515	23.5%	31.1%	34.5%	10.9%
Canby	121,922,939	89.2%	9.0%	1.8%	0.0%
Estacada	62,896,341	59.8%	14.6%	22.9%	2.6%
Gladstone	69,974,152	70.8%	22.2%	4.6%	2.4%
Happy Valley	255,471,143	36.0%	48.6%	15.3%	0.2%
Johnson City	1,896,509	73.9%	23.2%	2.9%	0.0%
Lake Oswego	317,377,635	42.0%	43.6%	12.9%	1.5%
Milwaukie	137,561,959	64.5%	31.2%	4.3%	0.0%
Molalla	65,771,550	95.7%	4.2%	0.1%	0.0%
Oregon City	278,148,504	1.9%	16.1%	8.2%	3.7%
Sandy	93,736,907	52.2%	29.5%	15.0%	3.2%
West Linn	223,398,149	35.3%	44.0%	15.7%	5.0%
Wilsonville	207,231,898	74.0%	20.5%	5.5%	0.1%

Source: DOGAMI Open-File Report, O-16-02, Landslide Susceptibility Overview Map of Oregon (2016)

For more information, refer to the following report and maps provided by DOGAMI:

- Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed, Oregon: Including the cities of Gresham, Sandy, and Troutdale and Unincorporated Communities of Government Camp and The Villages at Mt Hood (2018, IMS-59).
- Statewide Landslide Susceptibility (2016, O-16-02).
- Landslide inventory and susceptibility for northwest Clackamas County (2013, O-13-08).
- Surficial geology for greater Portland area (2012, O-12-02).
- Multi-Hazard and Risk Study for the Mount Hood Region (2011, O-11-16). *Portions of the landslide section superseded by the Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed*.
- Landslide Inventory Maps for the Canby (2009, IMS-32), Damascus (2012, IMS-49), Estacada (2012, IMS-52), Gladstone (2012, IMS-48), Lake Oswego (2010, IMS-32), Oregon City (2010, IMS-30), Redland (2012, IMS-51), Sandy (2012, IMS-38), Sherwood (2012, IMS-50) quadrangles.
- Slope failures in Oregon: GIS inventory for three 1996/97 storm events (2000, Special Paper 34).

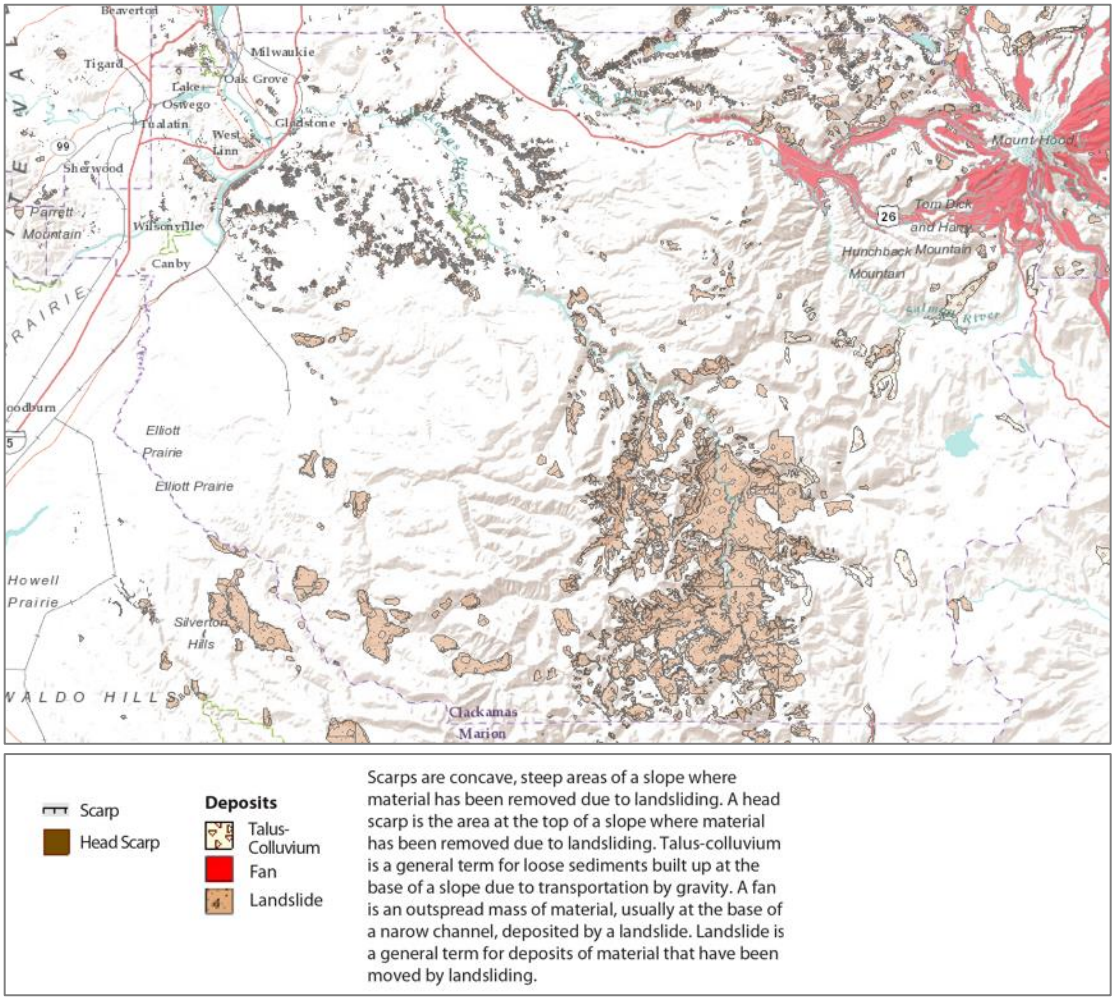
Additional reports are available via DOGAMI's Publications Search website: http://www.oregongeology.org/pubs/search.php

History

Landslides may happen at any time of the year. In addition to landslides triggered by a combination of slope stability and water content, earthquakes may also trigger landslides. Areas prone to seismically triggered landslides are generally the same as those prone to ordinary (i.e., non-seismic) landslides. As with ordinary landslides, seismically triggered landslides are more likely for earthquakes that occur when soils are saturated with water.

Debris flows and landslides are a very common occurrence in hilly areas of Oregon, including portions of Clackamas County. Many landslides occur in undeveloped areas and thus may go unnoticed or unreported. For example, DOGAMI conducted a statewide survey of landslides from four winter storms in 1996 and 1997 and found 9,582 documented landslides, with the actual number of landslides estimated to be many times the documented number. For the most part, landslides become a problem only when they impact developed areas and have the potential to damage buildings, roads or utilities. Figure 2-15 shows the landslide inventory for Clackamas County, for additional information see the historic landslides map in Volume III, Appendix D (Map 6)and the Statewide Landslide Information Database for Oregon.

Figure 2-15 Landslide Inventory



Source: Oregon HazVu: Statewide Geohazards Viewer – *To view map in more detail click hyperlink to left.*

Landslides in Clackamas County are not a localized problem. For example, sediment generated by the slides can affect regional water quality. During the winter of 1972, a relatively small landslide on the north fork of the Bull Run River in the western Cascades introduced a large volume of silt and clay into Portland's main water supply reservoir. Consequently, the city's water supply was discolored for several weeks.[37]

Many landslides are difficult to mitigate, particularly in areas of large historic movement with weak underlying geologic materials. As communities continue to modify the terrain and influence natural processes, it is important to be aware of the physical properties of the underlying bedrock as it, along with climate, dictates hazardous terrain. Without proper planning, landslides will continue to threaten the safety of people, property, and infrastructure.

Development coupled with natural processes such as heavy rainfall or rapid snowmelt can cause landslides or re-activate historical landslide sites. The County has received three Presidential Disaster Declarations since 2002, three of which included major landslide damage to county roads and infrastructure. Although not included within the disaster declaration the County also experienced landslides associated with storm events in 2012, 2014, 2015, and 2016-2017.

Probability Assessment

Based on the available data and research the HMAC determined the **probability of experiencing a landslide or debris flow is "high",** meaning at least one incident is likely within the next 10 to 35-year period. *This rating has not changed since the previous NHMP*.

Landslides are a common hazard in and around Oregon. In fact, a prominent theme of the 1996 flood disaster was that a significant amount of building damage affected structures outside of identified flood hazard areas. Many of the 5,000 Clackamas County applicants eligible for FEMA housing assistance grants were not floodplain cases but were landslide and erosion losses.[38]

The probability of rapidly moving landslide occurring depends on a number of factors, including steepness of slope, slope materials, local geology, vegetative cover, human activity and water. There is a strong correlation between intensive winter rainstorms and the occurrence of rapidly moving landslides (debris flows). Consequently, the National Weather Service tracks storms during the rainy season, monitors rain gauges and snow melt and issues warnings as conditions warrant. Given the correlation between precipitation, snowmelt and rapidly moving landslides, it would be feasible to construct a probability curve. The installation of slope indicators or the use of more advanced measuring techniques could provide information on slower moving slides.

Geo-engineers with DOGAMI estimate widespread landslides about every 20 years; landslides at a local level can be expected every two or three years.[39]

[37] Schlicker, Ht., and Finlayson Ct. (1979) Geologic and Geohazards of NW Clackamas County. Bulletin 99. DOGAMI, OR.)

[38] Interagency Hazard Mitigation Team, State Hazard Mitigation Plan (2000) Oregon Office of Emergency Management.

[39] Mills, K. 2002. Oregon's Debris Flow Warning System. Cordilleran Section–98th Annual Meeting. Corvallis.

Vulnerability Assessment

The HMAC rated the County as having a **"low" vulnerability to landslide hazards**, meaning that less than 1% of the unincorporated County's population or assets would be affected by a major disaster. *This rating has not changed since the previous NHMP.*

To a large degree, landslides are very difficult to predict. Vulnerability assessments assist in predicting how different types of property and population groups will be affected by a hazard.[40] The optimum method for doing this analysis at the city or county level is to use parcel-specific assessment data on land use and structures.[41] Data that includes specific landslide-prone and debris flow locations in the county can be used to assess the population and total value of property at risk from future landslide occurrences.

Landslides can impact major transportation arteries, blocking residents from essential services and businesses. Many aspects of the county are vulnerable to landslides. This includes land use and development patterns, the economy, population segments, ecosystem services and cultural assets.

A quantitative landslide hazard assessment requires overlay of landslide hazards (frequency and severity of landslides) with the inventory exposed to the hazard (value and vulnerability) by considering:

- Extent of landslide susceptible areas;
- Inventory of buildings and infrastructure in landslide susceptible areas;
- Severity of earthquakes or winter storm event (inches of rainfall in 24 hours);
- Percentage of landslide susceptible areas that will move and the range of movements (displacements) likely; and
- Vulnerability (amount of damage for various ranges of movement).

The amount of property in the high landslide area, as well as the type and value of structures on those properties, is calculated to provide a working estimate for potential landslide losses. Table 2-18 shows potentially impacted parcels, critical and critical facilities, vulnerable populations, and infrastructure within Clackamas County's high landslide susceptibility areas.

Table 2-18 Landslide Hazard Vulnerability Assessment

	Potentially Impacted Parcels		Potentially Impacted Locations			Infrastructure				
Hazard	Number of Parcels	Percent of Total Parcels	Critical Facilities	Essential Facilities	Vulnerable Populations	Miles of Road	Miles of Sewer Lines	Bridges	Cell Towers	Dams
County Total	158,226	Not Applicable	235	55	576	4911	340	597	17	69
Landslide Hazard										
High	13,603	9%	7	0	6	532	27	54	0	7

Source: Clackamas County Geographic Information Systems (2018)
Note: Percentage of property in the high landslide susceptibility area may include property in tax lots that intersect the area, including property that does not physically reside in the area itself.

[40] Burby, R., ed. 1998. Cooperating with Nature. Washington D.C.: Joseph Henry Press.

[41] Burby, R., ed. 1998. Cooperating with Nature. Washington D.C.: Joseph Henry Press.

Roads and Bridges

Large losses incurred from landslide hazards in Clackamas County have been associated with roads. The Clackamas County Roads Division is responsible for responding to slides that inhibit the flow of traffic or are damaging a road or a bridge. The roads department does its best to communicate with residents impacted by landslides, but can usually only repair the road itself, as well as the areas adjacent to the slide where the county has the right of way.

It is not cost effective to mitigate all slides because of limited funds and the fact that some historical slides are likely to become active again even with mitigation measures. The County Roads Division alleviates problem areas by grading slides, and by installing new drainage systems on the slopes to divert water from the landslides. This type of response activity is often the most cost-effective in the short-term but is only temporary. Unfortunately, many property owners are unaware of slides and the dangers associated with them.

Lower Columbia-Sandy Watershed Natural Hazard Risk Report

The **Risk Report** (DOGAMI, IMS-59) provides hazard analysis summary tables that identify populations and property within the Lower Columbia-Sandy River Watershed Study Area that are vulnerable to the profiled natural hazards. The Risk Report provides distinct profiles for (1) unincorporated Clackamas County within the study area, (2) the unincorporated community of Government Camp, and (3) the unincorporated community of The Villages at Mt. Hood (including Brightwood, Rhododendron, Welches, Wimme, and Zig Zag).

According to the Risk Report the following populations and property are vulnerable:

Unincorporated Clackamas County within the Study Area[42]

Landslide event (High and Very High Susceptibility): 311 buildings are exposed (0 critical facilities) for a total potential loss of $91,139,000 (an exposure ratio of 10%). In addition, 380 residents may be displaced (about 8% of the population).

Government Camp[43]

Landslide event (High and Very High Susceptibility): 27 buildings are exposed (0 critical facilities) for a total potential loss of $2,295,000 (an exposure ratio of 16%). In addition, 8 residents may be displaced (about 3% of the population).

The Villages at Mt. Hood[44]

Landslide event (High and Very High Susceptibility): 420 buildings are exposed (0 critical facilities) for a total potential loss of $88,719,000 (an exposure ratio of 11%). In addition, 524 residents may be displaced (about 10% of the population).

More information on this hazard can be found in the Risk Assessment for Region 2, Northern Willamette Valley/Portland Metro, of the Oregon NHMP (2015).

[42] DOGAMI, *Lower Columbia-Sandy Watershed Natural Hazard Risk Report* (March 2018 Draft), Table 9-1.

[43] Ibid., Table 9-5.

[44] Ibid., Table 9-7.

Severe Weather

Clackamas County experiences a range of weather-related hazards on an annual basis, such as severe heat, winter storms and wind storms. This section combines the above hazard sections from the previous NHMP into a single Severe Weather section.

Severe weather events may occur throughout Oregon during all seasons. Often originating in the Pacific Ocean, westerly winds pummel the coast, slowing as they cross the Coastal mountain range and head into the inland valleys.[45] Similarly, severe winter storms consisting of rain, freezing rain, ice, snow, cold temperatures, and wind originate from troughs of low pressure offshore in the Gulf of Alaska or in the central Pacific Ocean that ride along the jet stream during fall, winter, and early spring months. [46] In summer, the most common wind directions are from the west or northwest; in winter, they are from the south and east. Local topography, however, plays a major role in affecting wind direction. For example, the north-south orientation of the Willamette Valley channels the wind most of the time, causing predominately north and south winds.

Climate Change Factors

Oregon and the Pacific Northwest experience a variety of extreme weather incidents ranging from severe winter storms and floods to drought and dust storms, often resulting in morbidity and mortality among people living in the impacted regions. According to the Oregon Climate Change Research Institute, climate change is expected to increase the frequency and intensity of some weather incidents.[47]

Climate change poses risks for increased injuries, illnesses and deaths from both direct and indirect effects. Incidents of extreme weather (such as floods, droughts, severe storms, heat waves and fires) can directly affect human health as well as cause serious environmental and economic impacts. Indirect impacts can occur when climate change alters or disrupts natural systems.

Future Climate Variability[48]

Climate models for Oregon suggest, future regional climate changes include increases in temperature around 0.2-1°F per decade in the 21st Century, along with warmer and drier summers, and some evidence that extreme precipitation will increase in the future. Increased droughts may occur in the Willamette Valley under various climate change scenarios because of various factors, including reduced snowpack, rising temperatures, and likely reductions in summer precipitation. Climate models suggest that as the region warms, winter snow precipitation will likely shift to higher elevations and snowpack will be diminished as more precipitation falls as rain altering surface flows.

[45] US Department of Agriculture. http://www.fsa.usda.gov/or/Notice/Flp104.pdf

[46] Interagency Hazard Mitigation Team. 2000. State Hazard Mitigation Plan. Salem, OR: Oregon Office of Emergency Management

[47] Oregon Climate Change Research Institute http://occri.net/wp-content/uploads/2011/04/chapter9ocar.pdf Page 412

[48] Oregon Climate Change Research Institute (OCCRI), 4th Oregon Climate Assessment Report (2019) and Northwest Climate Assessment Report (2013). http://www.occri.net/publications-and-reports/publications/

Extreme Heat

Significant Changes since Previous NHMP:

There have been no significant changes to this section since the previous NHMP.

Characteristics

Between 1979 and 2003, heat waves killed at least 8,015 Americans, according to the Centers for Disease Control and Prevention. That's more than hurricanes, lightning, tornadoes, floods and earthquakes combined. And it's largely an urban problem—the bulk of those deaths occur in cities.[49]

Location and Extent

Cities are more vulnerable to heat waves because that's where more people are concentrated but also because there is less vegetation to permit evaporation, cars and factories give off heat, and the proximity of asphalt roads and buildings store and radiate heat. On a hot summer day, urban areas can be 5°F to 18°F hotter than surrounding rural areas which is enough to turn a heat wave into a serious health crisis.[50]

Mitigation Actions to reduce the urban heat island effect include:

1. Planting appropriate trees to provide shade and passive cooling of buildings and to provide local cooling though evaporation.
2. Improving the reflective surfaces of urban roof tops to bounce light (heat) rather than absorbing it. Ideally, solar panel arrays could absorb sunlight and shade the roof tops from storing heat, while also providing a source of energy for the internal powering of fans, or air conditioning and diminish the draw on local and regional power demands at peak use periods.

History

A severe heat episode or "heat wave" occurs about every two to three years and typically lasting two to three days but can last as many as five days. A severe heat episode can be defined as consecutive days of upper 90s to around 100. Severe heat hazard in the Portland metro region can be described as the average number of days we have temperatures greater than or equal to 90F and 100F. On average the region experiences 13.6 days with temperatures above 90-degrees Fahrenheit and 1.4 days above 100-degrees Fahrenheit, based on new 30-year climate averages (1981-2010) from the National Weather Service – Portland Weather Forecast Office.

The region's last severe heat episode was an event in 2016 when cooling centers were opened in the County. Before that a five-day event in July 2009 delivered three consecutive days in excess of 100F and two days over 90F; high temperatures on July 28-29 of 2009 were recorded at 106F each day. Another event occurred in July 2006.

[49] U.S. Centers for Disease Control and Prevention
http://www.bt.cdc.gov/disasters/extremeheat/heat_guide.asp

[50] Study: Many U.S. Cities Unprepared for Future Heat Waves (*Washington Post: Ezra Klein's Wonk Blog*)

Probability Assessment

Based on the available data and research the HMAC determined the **probability of experiencing a long lasting extreme heat event is "low",** meaning one incident is likely within the next 75 to 100-year period. *This rating has not changed since the previous NHMP*.

Extreme heat events occur every few years within the region, however, they are generally not long lasting. Climate models for Oregon suggest, future regional climate changes include increases in temperature around 0.2-1°F per decade in the 21st Century, along with warmer and drier summers.

Vulnerability Assessment

The HMAC rated the county as having a **"high" vulnerability to extreme heat**, meaning that more than 10% of the unincorporated County's population or assets would be affected by an extreme heat event. *This rating has increased since the previous NHMP*.

Very high temperatures can create serious health problems. Pets are also affected by the higher temperatures. "Prevention is the best defense," said Mel Kohn, M.D., M.P.H., director of Oregon Public Health. "Drinking plenty of water, staying out of the sun during the hottest part of the day, knowing the warning signs of heat-related illness and taking precautions when swimming are a few important steps people can take." Kohn added: "We have had hot weather in the past, but with the climate change we are likely to have more high temperature days in Oregon."[51]

A significant percentage of the population does not have air conditioning, so once temperatures get into the 90s, it is quite uncomfortable. If a hot weather pattern persists for a few days, the situation gets worse because of the number of days in sequence. Reports show that heat-health related problems really increase once you get multiple days in a row of very hot weather. Oregon Public Health officials remind people to take precautions to avoid getting sick from extreme heat and be careful when swimming in Oregon's lakes, streams and the ocean.

The first symptoms of health problems from the heat can include headache, dizziness and weakness. In extreme cases heat-related illness can cause convulsions and sudden loss of consciousness and can be fatal. Those at greatest risk for heat-related illness include infants and children up to 4 years of age, people 65 and older, people who are overweight, and people who are ill or on certain medications, as well as those who work outdoors.

Climate Change Factor

Predicted average increases in summer temperatures will make heat waves a greater likelihood. Without mitigation, increased numbers of extreme heat events will likely result in additional heat-related morbidity and mortality, especially among vulnerable populations, such as the elderly, low income populations, pregnant women and those who work in outdoor occupations.[52]

[51] Oregon Health Authority http://cms.oregon.gov/DHS/news/2010news/2010-0813.pdf

[52] Oregon Climate Change Research Institute http://occri.net/wp-content/uploads/2011/04/chapter9ocar.pdf Page 408.

Windstorm

Significant Changes since Previous NHMP:

The windstorm hazard section has been edited to reference new history since the previous NHMP.

Characteristics

A windstorm is generally a short duration event involving straight-line winds and/or gusts in excess of 50 mph. Although windstorms can affect the entirety of Clackamas County, they are especially dangerous near developed areas with large trees or tree stands. The extent of any particular windstorm is determined by its track, intensity and local terrain.[53] In the southwest Oregon, wind speed is typically 60 mph for 25-year storm events, 70 mph for 50-year storm events and 80 mph for 100-year storm events. Clackamas County has experienced multiple 25-, 50- and 100-year windstorm events over the past century with impacts often occurring countywide. A windstorm will frequently knock down trees and power lines, damage homes, businesses, public facilities and create tons of storm related debris. Windstorms are a common, chronic hazard in Clackamas County.

Location and Extent

The most common type of wind pattern affecting Clackamas County is straight-line winds, which originate as a downdraft of rain-cooled air and reach the ground and spread out rapidly. Straight- line winds can produce gusts of 100 mph or greater. Records of major Pacific windstorms are documented by state agencies and weather stations throughout Oregon, including several official weather stations in Clackamas County's lower valleys. Table 2-19 shows the expected wind speeds from windstorm events in Clackamas County.

Typically, mountainous terrain slows down wind movement, which is why Oregon's sheltered valley areas have the slowest wind speed in the state. However, in the foothills, the wind speeds may increase due to down-sloping winds from the mountains. Although windstorms can affect the entirety of the county, they are especially dangerous in developed areas with significant tree stands and major infrastructure, especially above ground utility lines. A windstorm will frequently knock down trees and power lines, damage homes, businesses, public facilities and create tons of storm related debris.

History

The most destructive windstorm ever recorded in Oregon, in terms of loss of life and property damage, was the Columbus Day storm of 1962. Damage was most severe in the Willamette Valley. The storm killed thirty-eight people and did upwards of $200 million in damage (over $1.7 billion in today's dollars). Hundreds of thousands of homes were without power for short periods of time, while others were without power for two to three weeks. More than 50,000 homes were seriously damaged, and nearly 100 were completely destroyed. The storm destroyed fruit and nut orchards and killed scores of livestock. Intense

[53] State of Oregon Natural Hazard Mitigation Plan (2015)

wind speeds were recorded in the metropolitan areas with gusts of 116 mph on Portland's Morrison Bridge.

Clackamas County has experienced several high wind events. A regional storm in early December 2007 that required a federal disaster declaration along the Oregon Coast brought high winds and heavy rain to the County.

On March 13, 2011, 50 mph winds with 70 mph gusts brought trees down in numerous areas of the County and left power out for tens of thousands of residents. Damages were concentrated in the eastern half of the County along in communities like Molalla and Estacada in the Cascade foothills.

Windstorm damage – March 13, 2011

Source: Clackamas County Disaster Management

Since 2007 the National Weather Service reports three tornadoes that have touched down in or near Clackamas County: On January 10, 2008 an EF1 tornado touched down in Vancouver, Washington causing considerable damage; October 26, 2009 an EF0 tornado touched down near Oregon City causing damage to many houses; and on December 14, 2010 a damaging EF2 tornado struck in the City of Aumsville in Marion County not far from the southern border of Clackamas County. On October 12, 2017 another EF0 tornado touched down near Canby at the Aurora State Airport impacting airplanes and buildings.

Windstorms were also part of winter storms that occurred each year between 2014 and 2017.

Several additional, small windstorm events have occurred since the previous NHMP, see the Storm Events Database provided by the National Oceanic and Atmospheric Administration for more information. According to historical records, there have been an estimated six major windstorm events in the past 100 years, which is about one every 16-17 years.

Probability Assessment

Based on the available data and research the HMAC determined the **probability of experiencing a windstorm is "moderate",** meaning one severe incident is likely within the next 35 to 75-year period. *This rating has not changed since the previous NHMP.*

Windstorms in the county usually occur in the winter from October to March and their extent is determined by their track, intensity (the air pressure gradient they generate) and local terrain. Summer thunderstorms may also bring high winds along with heavy rain and/ or hail. The National Weather Service uses weather forecast models to predict oncoming

windstorms, while monitoring storms with weather stations in protected valley locations throughout Oregon.

Table 2-19 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 period. The table shows that structures in Region 2, which includes Clackamas County, can expect to be exposed to 65 mph winds in a 25-year recurrence interval (4% annual probability).

Table 2-19 Probability of Severe Wind Events (Region 2)

	25-Year Event (4% annual probability)	50-Year Event (2% annual probability)	100-Year Event (1% annual probability)
Region 2: North Willamette Valley	65 mph	72 mph	80 mph

Source: Oregon State Natural Hazard Mitigation Plan, 2012

Vulnerability Assessment

The HMAC rated the county as having a **"low" vulnerability to windstorm hazards**, meaning that less than 1% of the unincorporated County's population or assets would be affected by a major disaster. *This rating has not changed since the previous NHMP*.

Many buildings, utilities and transportation systems within Clackamas County are vulnerable to wind damage. This is especially true in open areas, such as natural grasslands or farmlands. It is also true in forested areas, along tree-lined roads and electrical transmission lines and on residential parcels where trees have been planted or left for aesthetic purposes. Structures most vulnerable to high winds include insufficiently anchored manufactured homes and older buildings in need of roof repair.

Fallen trees are especially troublesome. They can block roads and rails for long periods of time, impacting emergency operations. In addition, up-rooted or shattered trees can down power and/or utility lines and effectively bring local economic activity and other critical facilities to a standstill. Much of the problem may be attributed to a shallow or weakened root system in saturated ground. In Clackamas County, trees are more likely to blow over during the winter (wet season).

More information on this hazard can be found in the Risk Assessment for Region 2, Northern Willamette Valley/Portland Metro, of the Oregon NHMP (2015).

Winter Storm

Significant Changes since Previous NHMP:

The winter storm hazard section has been edited to reference new history since the previous NHMP.

Characteristics

Winter storms affecting Clackamas County are generally characterized by a combination of heavy rains and high winds throughout the county, sometimes with snowfall, especially at higher elevations in the eastern portion of the County. Heavy rains can result in localized or widespread flooding, as well as debris slides and landslides. High winds commonly result in tree falls which primarily affect the electric power system, but which may also affect roads, buildings and vehicles. This chapter deals primarily with the snow and ice effects of winter storms.

The winter storms that affect Clackamas County typically are not local events affecting only small geographic areas. Rather, winter storms are usually large cyclonic low-pressure systems that move in from the Pacific Ocean and affect large areas of Oregon and/or the whole Pacific Northwest. These storms are most common from October through March.

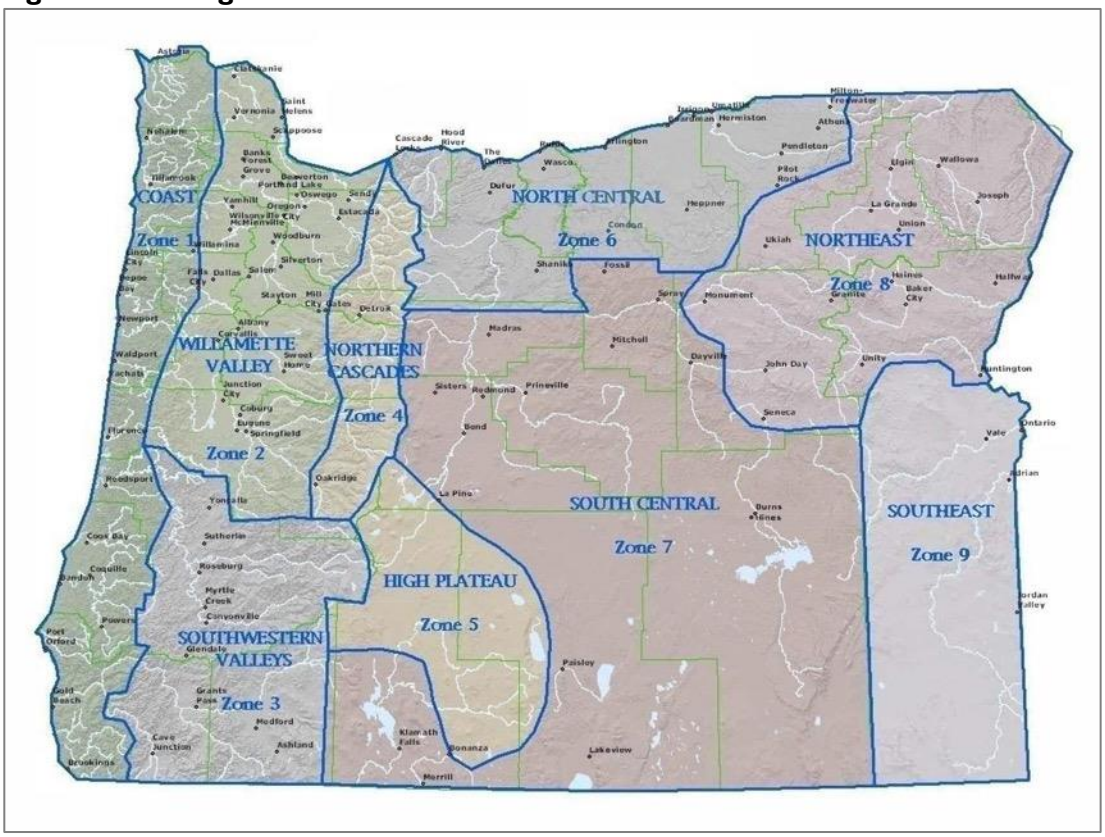
Ice storms are comprised of cold temperatures and moisture, but subtle changes can result in varying types of ice formation which may include freezing rain, sleet and hail. Of these, freezing rain can be the most damaging of ice formations.

Outside of mountainous areas, significant snow accumulations are much less likely in western Oregon than on the east side of the Cascades. However, if a cold air mass moves northwest through the Columbia Gorge and collides with a wet Pacific storm, then a larger than average snow fall may result.

Location and Extent

The National Climatic Data Center has established climate zones in the United States for areas that have similar temperature and precipitation characteristics. Oregon's latitude, topography and proximity to the Pacific Ocean give the state diversified climates. Figure 2-16 shows that Clackamas County is located within Zone 2: Willamette Valley and Zone 4: Northern Cascades. Winter storm events have relatively predictable and longer speeds of onset and the effects of winter storms are often long lasting. The area of Clackamas County within Zone 4 generally has longer lasting winter storms that include colder temperatures and greater snow depth.

Figure 2-16 Oregon Climate Divisions



Source: Oregon Climate Service

The principal types of winter storms that occur include:

- **Snowstorms:** require three ingredients: cold air, moisture and air disturbance. The result is snow, small ice particles that fall from the sky. In Oregon, the further inland and north one moves, the more snowfall can be expected. Blizzards are included in this category.
- **Ice storms:** are a type of winter storm that forms when a layer of warm air is sandwiched by two layers of cold air. Frozen precipitation melts when it hits the warm layer and refreezes when hitting the cold layer below the inversion. Ice storms can include sleet (when the rain refreezes before hitting the ground) or freezing rain (when the rain freezes once hitting the ground).
- **Extreme Cold:** Dangerously low temperatures accompany many winter storms. This is particularly dangerous because snow and ice storms can cause power outages, leaving many people without adequate heating.

Unlike most other hazards, it is not simple to systematically map winter storm hazard zones. The entire County is susceptible to damaging severe weather. Winter storms that bring snow and ice can impact infrastructure, business and individuals. Those resources that exist at higher elevations will experience more risk of snow and ice, but the entire County can face damage from winter storms and, for example, the hail or life threateningly cold temperatures that winter storms bring.

History

Winter storms occur yearly; more destructive storms occur once or twice per decade, most recently in 2011.[54] More recent winter storm events occurred in 2012, 2014, 2015, 2016, and 2017, however, these winter storm events did not lead to a disaster declaration within the County.

The County received a FEMA Disaster Declaration for an extended severe winter weather event from December 22 through December 28, 2008, when Clackamas County (and Oregon in general) experienced heavy snow accumulations, ice, and sustained freezing temperatures that caused extensive property damage. Transportation networks were significantly affected, as major freeways railways, and the Portland International Airport were periodically closed.

Downed trees disrupted power to several portions of the county, leaving many residents without heat or water for several days. Residential care facilities, home-bound ill personnel requiring daily treatment, hospital patients, and anyone requiring emergency assistance was affected by this winter storm because obstructed roadways prevented emergency vehicle movement. The damage to fire stations, equipment, roads, and other infrastructure affected the ability to effectively respond, as well as reducing the operating budgets of these facilities.

Car covered in ice, 2004

Source: Clackamas County Disaster Management

Probability Assessment

Based on the available data and research the HMAC determined the **probability of experiencing a winter storm is "moderate",** meaning one incident is likely within the next 35 to 75-year period. *This rating has decreased since the previous NHMP*.

The recurrence interval for a moderate to severe winter storm is about once every year; however, there can be many localized storms between these periods. Severe winter storms occur in western Oregon regularly from November through February. Clackamas County experiences moderate winter storms every year to every other year, more damaging winter storms happen less often. According to historical records, there have been an estimated 16 severe winter storm events in the past 100 years, which is about one every six years.

Vulnerability Assessment

The HMAC rated the County as having a **"moderate" vulnerability to winter storm hazards**, meaning that between 1 and 10% of the unincorporated County's population or assets would be affected by a major disaster. *This rating has not changed since the previous NHMP.*

[54] https://www.ncdc.noaa.gov/stormevents/listevents

Given current available data, no quantitative assessment of the risk of winter storm was possible at the time of this NHMP update. However, assessing the risk to the County from winter storms should remain an ongoing process determined by community characteristics and physical vulnerabilities. Weather forecasting can give County resources (emergency vehicles, warming shelters) time to prepare for an impending storm, but the changing character of the County population and resources will determine the impact of winter storms on life and property in Clackamas County.

The most likely impact of snow and ice events on Clackamas County are road closures limiting access/egress to/from some areas, especially roads to higher elevations. Winter storms with heavy wet snow or high winds and ice storms may also result in power outages from downed transmission lines and/or poles.

Winter storms which bring snow, ice and high winds can cause significant impacts on life and property. Many severe winter storm deaths occur as a result of traffic accidents on icy roads, heart attacks may occur from exertion 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.

Property is at risk due to flooding and landslides that may result if there is a heavy snowmelt. Additionally, ice, wind and snow can affect the stability of trees, power and telephone lines and TV and radio antennas. Downed 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.

Severe winter weather also can cause the temporary closure of key roads and highways, air and train operations, businesses, schools, government offices and other important community services. Below freezing temperatures can also lead to breaks in un-insulated water lines serving schools, businesses, industries and individual homes. All of these effects, if lasting more than several days, can create significant economic impacts for the affected communities and the surrounding region. In the rural areas of the county severe winter storms can isolate small communities, farms, and ranches.

At the time of this update, sufficient data was not available to determine winter storm vulnerability in terms of explicit types and numbers of existing and future buildings, infrastructure or critical infrastructure.

More information on this hazard can be found in the Risk Assessment for Region 2, Northern Willamette Valley/Portland Metro, of the Oregon NHMP (2015).

Volcanic Event

Significant Changes since Previous NHMP:

Updated vulnerability information from Clackamas County GIS and analysis from the Lower Columbia-Sandy Watershed Natural Hazard Risk Report is included.

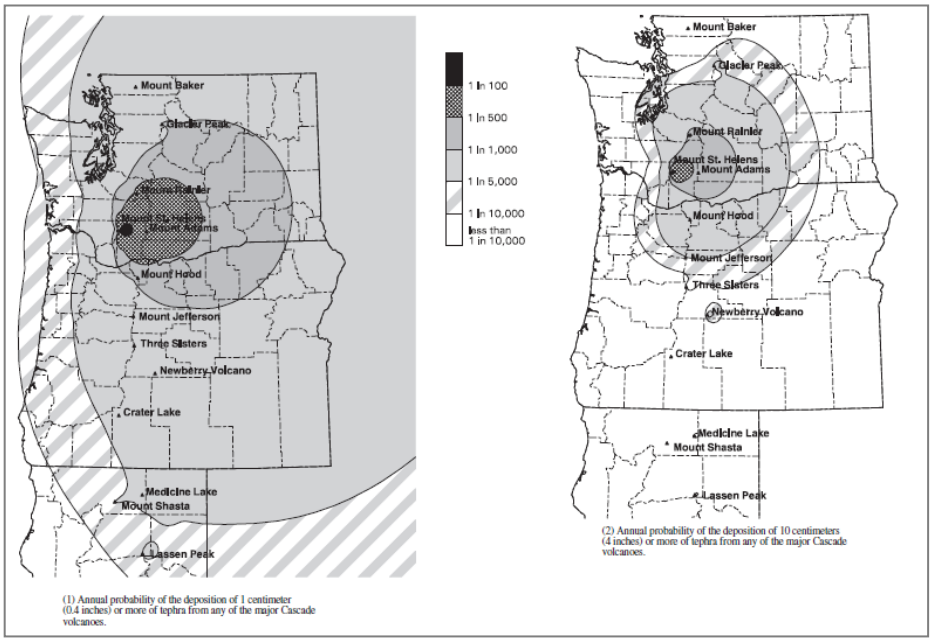
Characteristics

The Pacific Northwest, lies 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 molten material, or magma, rises to the surface.

Location and Extent

Scientists 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. Regional tephra fall shows the annual probability of ten centimeters or more of ash accumulation from Pacific Northwest volcanoes. Figure 2-17 depicts the potential and geographical extent of volcanic ash fall in excess of ten centimeters from a large eruption of Mt. St. Helens.

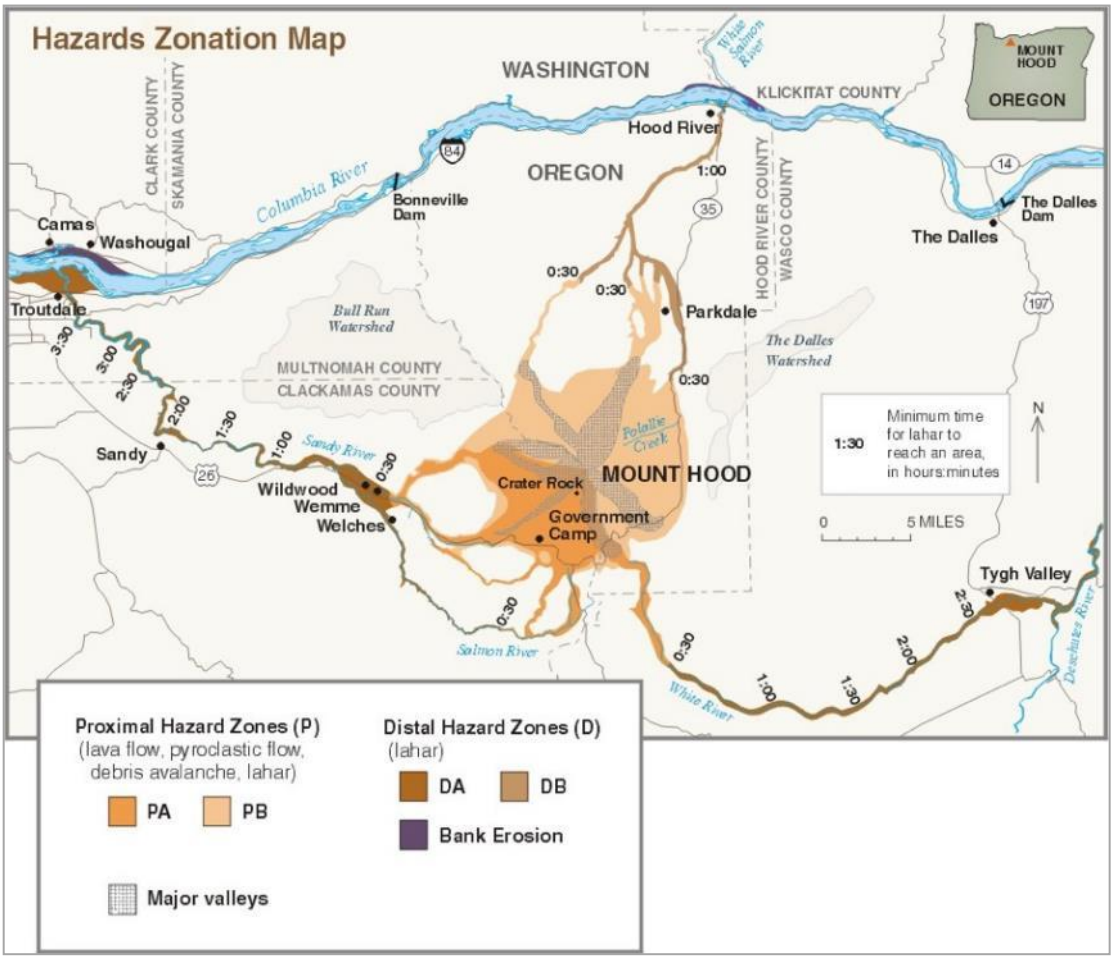
Figure 2-17 Regional Tephra-fall Maps



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

The USGS/Cascades Volcano Observatory (CVO) produced a volcanic hazard zonation report for Mount Hood in 1997 and 2000. The report includes a description of potential hazards that may occur to immediate communities. The hazard zones illustrated on Map (USGS 060-00) were determined based on the distance from the volcano, vent location, and type of hazardous events. The two proximal zones show two potential eruptive scenarios. The zone shown in peach indicates failure of the vents on the north, east, or western flanks. The proximal hazard zone shown in orange is the more likely scenario, which is a failure of the lava dome, Crater Rock, and primarily would affect the drainages in the Sandy River basin in Clackamas County.

Figure 2-18 Hazards Zonation Map



Source: USGS, Cascades Volcano Observatory, Volcano Hazards Program

Geologic hazard maps have been created for most of the volcanoes in the Cascade Range (including Mt. St Helens, Mt. Adams, Mt. Hood, and Mt. Jefferson) 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. Volcanic activity from more distant volcanoes will have less impact upon the County.

Refer to the following DOGAMI reports for additional information:

- Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed, Oregon: Including the cities of Gresham, Sandy, and Troutdale and Unincorporated Communities of Government Camp and The Villages at Mt Hood (2018, IMS-59).
- Multi-Hazard and Risk Study for the Mount Hood Region (2011, O-11-16). *Portions of the volcano section superseded by the Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed*. See also, Mount Hood Hazards and Assets Viewer.

Additional reports are available via DOGAMI's Publications Search website:

http://www.oregongeology.org/pubs/search.php

Other agency/ consultant reports:

- Mathie, A.M., and Wood, N., 2013, Residential and service-population exposure to multiple natural hazards in the Mount Hood region of Clackamas County, Oregon: U.S. Geological Survey Open-File Report 2013–1073, available at http://pubs.usgs.gov/of/2013/1073/.
- Ewert, J.W., Diefenbach, A.K., and Ramsey, D.W., 2018, 2018 update to the U.S. Geological Survey national volcanic threat assessment: U.S. Geological Survey Scientific Investigations Report 2018–5140, 40 p., https://doi.org/10.3133/sir20185140.

History

Mount Hood and Mount St. Helens are two active volcanoes near Clackamas County. Mount Hood is several hundred miles north of the county and is more than 500,000 years old. It has had two significant eruptive periods, one about 1,500 years ago and another about 200 years ago. Mount St. Helens is in southern Washington State and has been active throughout its 50,000-year lifetime. In the past 200 years, seven of the Cascade volcanoes have erupted, including (from north to south): Mt. Baker, Glacier Peak, Mt. Rainier, Mount St. Helens (Washington), Mt. Hood (Oregon), Mt. Shasta and Mt. Lassen (California).

There has been no recent volcanic activity near the county associated with Mount Hood. The 1980 explosion of Mount St. Helens in southern Washington State is the latest on record; both Mount St. Helens and Mount Hood remain listed as active volcanoes.

Probability Assessment

Based on the available data and research the HMAC determined the **probability of experiencing volcanic activity is "low",** meaning one incident is likely within the next 75 to 100-year period. *This rating has not changed since the previous NHMP*.

The Sandy River drainage is within proximal hazard Zone PA and has a return period of 5000 to 1,000 years (0.1% to 0.2% annual chance of occurrence).[55]

The United States Geological Survey-Cascades Volcano Observatory (CVO) produced volcanic hazard zonation reports for Mount St. Helens and Mount Hood in 1995 and 1997. The reports include a description of potential hazards that may occur to immediate communities. The CVO created an updated annual probability of tephra (ash) fall map for

[55] DOGAMI, 2011. *Multi-Hazard and Risk Study for the Mount Hood Region, Multnomah, Clackamas, and Hood River Counties, Oregon*, Open File Report O-11-13.

the Cascade region in 2001, which could be a rough guide for Clackamas County in forecasting potential tephra hazard problems (Figure 2-17). The map identifies the location and extent of the hazard.

The CVO Volcanic tephra fall map is based on the combined likelihood of tephra-producing eruptions occurring at Cascade volcanoes. Probability zones extend farther east of the range because winds blow from westerly directions most of the time. The map shows annual probabilities for a fall of one centimeter (about 0.4 inch). The patterns on the map show the dominating influence of Mount St. Helens as a tephra producer. Because small eruptions are more numerous than large eruptions, the probability of a thick tephra fall at a given locality is lower than that of a thin tephra fall. The annual probability of a fall of one centimeter or more of tephra is about 1 in 10,000 for Clackamas County. This is small when compared to other risks faced by the County.

Vulnerability Assessment

The HMAC rated the county as having a **"moderate" vulnerability to volcanic activity**, meaning that between 1-10% of the unincorporated County's population or assets would be affected by a major disaster (volcanic ash/lahar). *This rating has not changed since the previous NHMP*.

The U.S. Geological Survey (USGS) lists the threat potential of volcanoes. According to the USGS there are nine volcanoes with Very High or High threat potentials in Oregon and Washington (listed here in order of threat potential): Mount St. Helens, Mount Rainier, Mount Hood, Three Sisters, Newberry, Mount Baker, Glacier Peak, Crater Lake, and Mount Adams (High).[56]

The primary threat to lives and property from active volcanoes is from violent eruptions that unleash tremendous blast forces, generate mud and debris flows (lahars), or produce flying debris and ash clouds. Volcano hazards are divided into proximal (near the volcano) and distal (far from the volcano). Mount Hood poses the greatest threat to the population of Clackamas County. Proximal hazard zones for Mount Hood are about 15 miles from the summit and are subject to several hazards including rapidly moving landslides, pyroclastic surges, and debris avalanches. The Sandy Watershed is located within proximal hazard Zone PA (Figure 2-19).

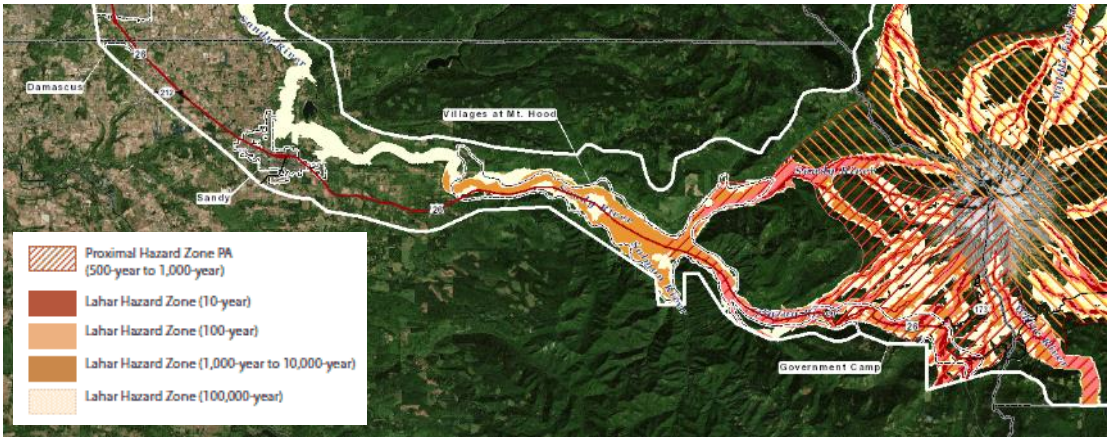
The most severed, widespread, and hazardous consequence of a Mount Hood eruption would include lahars sweeping down the length of the Sandy River valley impacting Government Camp, The Villages at Mount Hood, and the City of Sandy. A Mount Hood eruption could impact up to 68 percent of homes, 60 percent of residents, 73 percent of businesses and 87 percent of employees in the Hoodland Area (including parts of Clackamas and Hood River counties). A mega-eruption scenario would increase population exposure, but the increase is not substantial—typically 10 percent or less of an increase in population exposed.

Population exposure to volcano hazards is largest in the proximal hazard zone, including 65 percent of the local workforce, 80 percent of educational facilities, 82 to 100 percent of

[56] Ewert, J.W., Diefenbach, A.K., and Ramsey, D.W., 2018, 2018 update to the U.S. Geological Survey national volcanic threat assessment: U.S. Geological Survey Scientific Investigations Report 2018–5140, 40 p., https://doi.org/10.3133/sir20185140.

daytime visitors to recreation sites (summer and winter month averages, respectively), and approximately two thirds of overnight visitors.

Figure 2-19 Proximal and Distal Volcano Hazard Zones



Source: DOGAMI, Mount Hood Hazards and Assets Viewer

According to County GIS about 8% of total county acres are exposed to volcano hazards. These areas are centralized around potential failure areas in the proximal zone, as well as the Sandy River valley in the distal zones. Only 5% of total county parcels are exposed, as the volcanic landscape generally does not lend itself well to development (Table 2-20).

Volcanic activity from ash clouds that drift downwind to the county from near or distant eruptions is possible from Mount Saint Helens, Three Sisters, Mount Bachelor and the Newberry Crater areas. Because the distance to these potentially active volcanic areas is so great, the only adverse effect that would impact areas of Clackamas County is ash fallout, with perhaps some impact on water supplies. The area affected by ash fallout depends upon the height attained by the eruption column and the atmospheric conditions at the time of the eruption. Volcanic ash can contaminate water supplies, cause electrical storms, create health problems and collapse roofs.

The amount of property exposed to the volcanic eruption hazard area, as well as the type and value of structures on those properties, is calculated to provide a working estimate for potential volcanic eruption losses. Table 2-20 shows potentially impacted parcels, critical and critical facilities, vulnerable populations, and infrastructure within Clackamas County's volcanic eruption area.

Table 2-20 Volcanic Eruption Hazard Vulnerability Assessment

	Potentially Impacted Parcels		Potentially Impacted Locations			Infrastructure				
Hazard	Number of Parcels	Percent of Total Parcels	Critical Facilities	Essential Facilities	Vulnerable Populations	Miles of Road	Miles of Sewer Lines	Bridges	Cell Towers	Dams
County Total	158,226	Not Applicable	235	55	576	4911	340	597	17	69
Volcano										
Exposed	7,778	5%	7	1	2	271	21	59	1	1

Source: Clackamas County Geographic Information Systems (2018)
Note: Percentage of property exposed to the volcanic eruption area may include property in tax lots that intersect the area, including property that does not physically reside in the area itself.

Risk to Life & Property: High

Proximal Hazard Zones 1 and 2 are areas subject to rapidly moving debris avalanches, pyroclastic flows, and lahars that can reach the hazard boundary in less than 30 minutes, as well as slow-moving lava flows. Areas within proximal hazard zones should be evacuated before an eruption begins because there is little time to get people out of harm's way once an eruption starts. Most pyroclastic flows, lava flows, and debris avalanches will stop within the proximal hazard zone, but lahars can travel much farther. Evacuation may prove problematic, as volcanoes are difficult to predict, and there is only one primary route (Hwy 26) off the mountain. In addition, Mount Hood is a prime destination for visitors during all seasons. For these reasons, the threat to life is quite high.

Risk to Critical Facilities and Infrastructure: High

Distal Hazard Zone 3 includes areas adjacent to rivers that are pathways for lahars. Estimated travel time for lahars to reach these zones is more than 30 minutes, which may allow individuals time to move to higher ground and greater safety if given notice. Lahars could affect transportation corridors by damaging or destroying roads and can damage Bull Run pipelines that cross the Sandy River. Although only one critical facility is exposed to the volcano hazard, the effect of lahars and pyroclastic flows and ashfall on equipment and infrastructure will be devastating.

Lower Columbia-Sandy Watershed Natural Hazard Risk Report

The **Risk Report** (DOGAMI, IMS-59) provides hazard analysis summary tables that identify populations and property within the Lower Columbia-Sandy River Watershed Study Area that are vulnerable to the profiled natural hazards. The Risk Report provides distinct profiles for (1) unincorporated Clackamas County within the study area, (2) the unincorporated community of Government Camp, and (3) the unincorporated community of The Villages at Mt. Hood (including Brightwood, Rhododendron, Welches, Wimme, and Zig Zag).

According to the Risk Report the following populations and property are vulnerable:

Unincorporated Clackamas County within the Study Area[57]

Volcanic event (lahar, medium – 1% annual chance): Risk was not calculated for other unincorporated regions of the County.

Government Camp[58]

Volcanic event (lahar, medium – 1% annual chance): 611 buildings are exposed (1 critical facility; Hoodland RFPD #74) for a total potential loss of $92,477,000 (an exposure ratio of 63%). In addition, 163 residents may be displaced (about 64% of the population).

The Villages at Mt. Hood[59]

Volcanic event (lahar, medium – 1% annual chance): 342 buildings are exposed (0 critical facilities) for a total potential loss of $51,338,000 (an exposure ratio of 9%). In addition, 218 residents may be displaced (about 4% of the population).

More information on this hazard can be found in the Risk Assessment for Region 2, Northern Willamette Valley/Portland Metro, of the Oregon NHMP (2015).

[57] DOGAMI, *Lower Columbia-Sandy Watershed Natural Hazard Risk Report* (March 2018 Draft), Table 9-1.

[58] Ibid., Table 9-5.

[59] Ibid., Table 9-7.

Wildfire

Significant Changes since Previous NHMP:

The wildfire hazard has been edited to reference the recently updated Clackamas County Community Wildfire Protection Plan and analysis from the Lower Columbia-Sandy Watershed Natural Hazard Risk Report.

Recent fires in Oregon and across the western United States have increased public awareness of the potential losses to life, property, and natural and cultural resources. In June of 2004, the Board of Clackamas County Commissioners (BCC) directed the County Departments to work with state and federal agencies, fire protection districts, and community organizations throughout the County to develop an integrated wildfire plan. The BCC initiated this effort to reduce wildfire risk to citizens, the environment, and quality of life within Clackamas County.

The 2017 Clackamas County Community Wildfire Protection Plan (CWPP) was completed in May 2018. The CWPP is hereby incorporated into this NHMP by reference and it will serve as the wildfire chapter. The following presents a brief summary of key information; refer to the full CWPP for a complete description and evaluation of the wildfire hazard.

Characteristics

Wildfires occur in areas with large amounts of flammable vegetation that require a suppression response due to uncontrolled burning. Fire is an essential part of Oregon's ecosystem, but can also pose a serious threat to life and property particularly in the state's growing rural communities. Wildfire can be divided into three categories: interface, wildland and firestorms. 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 built-up urban areas, they have also left behind readily available fire services providing structural protection. Recent fires in Oregon and across the western United States have increased public awareness over the potential losses to life, property and natural and cultural resources that fire can pose.

The following three factors contribute significantly to wildfire behavior and can be used to identify wildfire hazard areas.

Topography: As slope increases, the rate of wildfire spread increases. South-facing slopes are also subject to more solar radiation, making them drier and thereby intensifying wildfire behavior. However, ridgetops may mark the end of wildfire spread, since fire spreads more slowly or may even be unable to spread downhill.

Fuel: The type and condition of vegetation plays a significant role in the occurrence and spread of wildfires. Certain types of plants are more susceptible to burning or will burn with greater intensity. Dense or overgrown vegetation increases the amount of combustible material available to fuel the fire (referred to as the "fuel load"). The ratio of living to dead plant matter is also important. The risk of fire is increased significantly during periods of prolonged drought as the moisture content of both living and dead plant matter decreases. The fuel's continuity, both horizontally and vertically, is also an important factor.

Weather: The most variable factor affecting wildfire behavior is weather. Temperature, humidity, wind and lightning can affect chances for ignition and spread of fire. Extreme weather, such as high temperatures and low humidity, can lead to extreme wildfire activity. By contrast, cooling and higher humidity often signals reduced Wildfire occurrence and easier containment.

The frequency and severity of wildfires is also dependent upon other hazards, such as lightning, drought, equipment use, railroads, recreation use, arson and infestations. If not promptly controlled, wildfires may grow into an emergency or disaster. Even small fires can threaten lives and resources and destroy improved properties. In addition to affecting people, wildfires may severely affect livestock and pets. Such events may require emergency watering/feeding, evacuation and shelter.

The indirect effects of wildfires can be catastrophic. In addition to stripping the land of vegetation and destroying forest resources, large, intense fires can harm the soil, waterways and the land itself. Soil exposed to intense heat may lose its capability to absorb moisture and support life. Exposed soils erode quickly and enhance siltation of rivers and streams, thereby enhancing flood potential, harming aquatic life and degrading water quality. Lands stripped of vegetation are also subject to increased debris flow hazards, as described above.

Location and Extent

Wildfire hazard areas are commonly identified in regions as the Wildland Urban Interface (WUI). The interface is the urban-rural fringe where homes and other structures are built into a densely forested or natural landscape. If left unchecked, it is likely that fires in these areas will threaten lives and property. One challenge Clackamas County faces is from the increasing number of houses being built in the urban/rural fringe. The “interface” between urban or suburban areas and the resource lands has significantly increased the threat to life and property from fires. Responding to fires in the expanding Wildland Urban Interface area may tax existing fire protection systems beyond original design or current capability.

The ease of fire ignition further determines ranges of the wildfire hazard due to natural or human conditions and the difficulty of fire suppression. The wildfire hazard is also magnified by several factors related to fire suppression/control, such as the surrounding fuel load, weather, topography and property characteristics.

Fire susceptibility throughout the county dramatically increases in late summer and early autumn as summer thunderstorms with lightning strikes increases and vegetation dries out, decreasing plant moisture content and increasing the ratio of dead fuel to living fuel. However, various other factors, including humidity, wind speed and direction, fuel load and fuel type and topography can contribute to the intensity and spread of wildland. In addition, common causes of wildfires include arson and negligence from industrial and recreational activities.

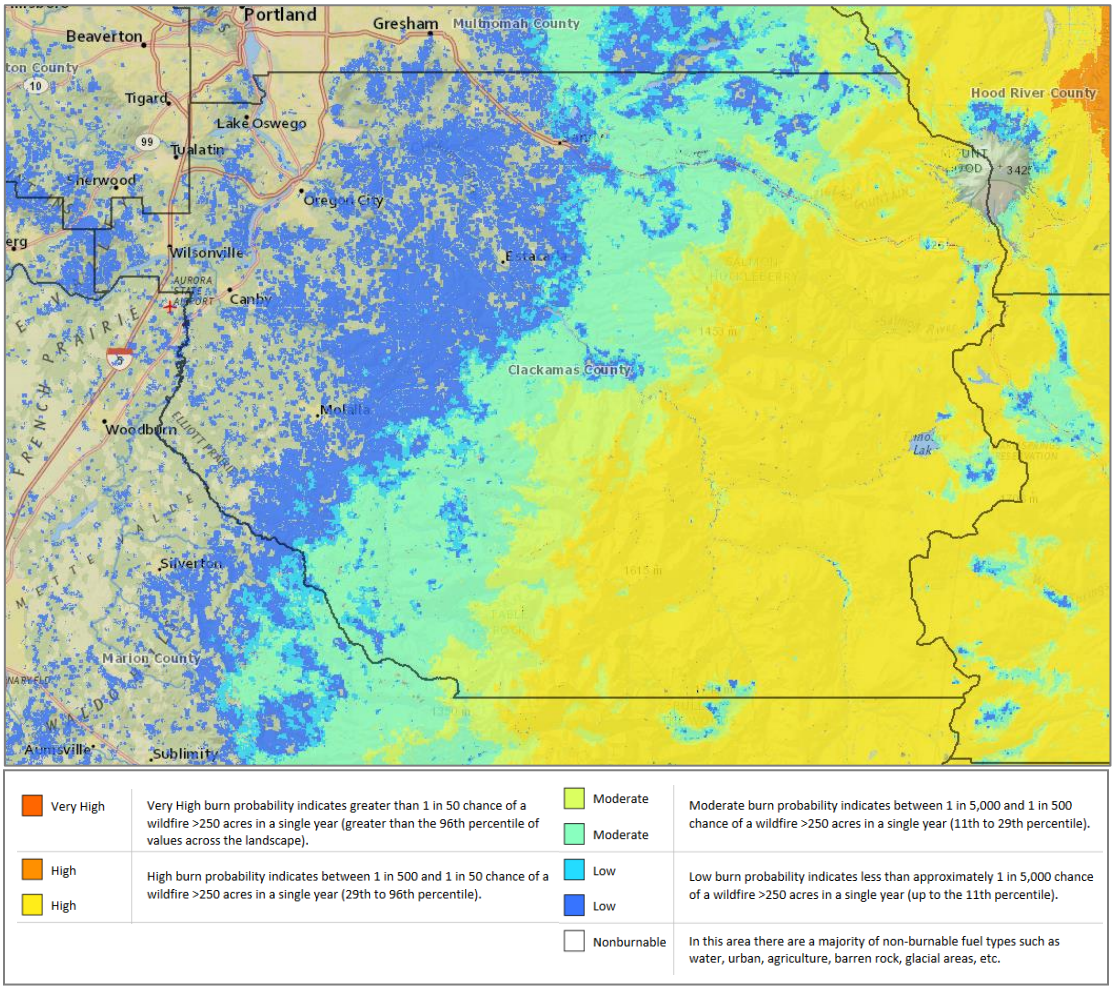
The CWPP addresses wildfires countywide and defined each local fire district or department as individual Community at Risk. Communities that are particularly vulnerable to wildfires are shown in Map #2 and Table 4-1 of the CWPP.[60]

The extent of the hazard is greatest along the counties mountainous eastern and southern boundaries (see Figure 2-20). In these areas, there is high burn probability with expected

[60] Clackamas County Community Wildfire Protection Plan (2018)

flame lengths greater than 8-feet under normal weather conditions. Most of the developed portion of the county (about 55%) has less severe (low to moderate) wildfire burn probability that include expected flame lengths less than 8-feet under normal weather conditions. However, conditions vary widely and with local topography, fuels, and local weather (including wind) conditions. Under warm, dry, windy, and drought conditions expect higher likelihood of fire starts, higher intensity, more ember activity, and a more difficult to control wildfire that will include more fire effects and impacts.

Figure 2-20 Extent of Wildfire Hazard (Burn Probability)



Source: Oregon Wildfire Risk Explorer

The 2018 CWPP continues to take a more localized approach to wildfire planning by creating individual CWPP's for each fire agency. Chapter 10: Clackamas County Fire Agencies has been expanded to include a brief description of wildfire hazards, emergency operations, structural ignitability, community outreach and education and fuels reduction priorities for each local fire agency. Local Communities at Risk were also identified. Each Fire Agency CWPP is complete with action plans to address wildfire issues specific to the local area.

Other agency/ consultant reports:

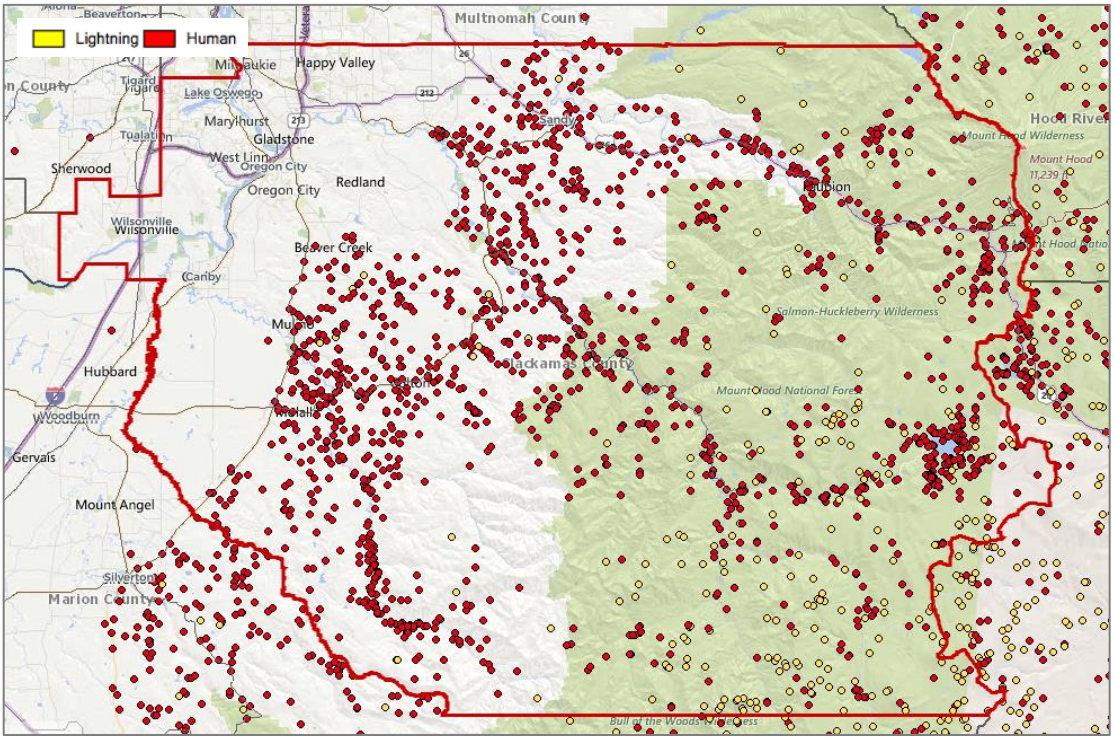
- Mathie, A.M., and Wood, N., 2013, Residential and service-population exposure to multiple natural hazards in the Mount Hood region of Clackamas County, Oregon:

U.S. Geological Survey Open-File Report 2013–1073, available at http://pubs.usgs.gov/of/2013/1073/.

History

In the last 10 years there have been 723 fires that have burned 6,752 acres.[61] Figure 2-21 shows fire starts from 1992-2017, fires ignited by humans are shown in red, lightning caused fires are shown in yellow. In the past 10 years 16% of all fires were caused by lightning and 84% of fires were caused by human activity (ranging from arson and debris burning to equipment use and fires caused along powerlines). In general, the human caused wildfires are in populated areas and within river and stream corridors near transportation routes, while lightning caused wildfires are often in more remote locations.

Figure 2-21 Local Fire Starts (1992-2017)

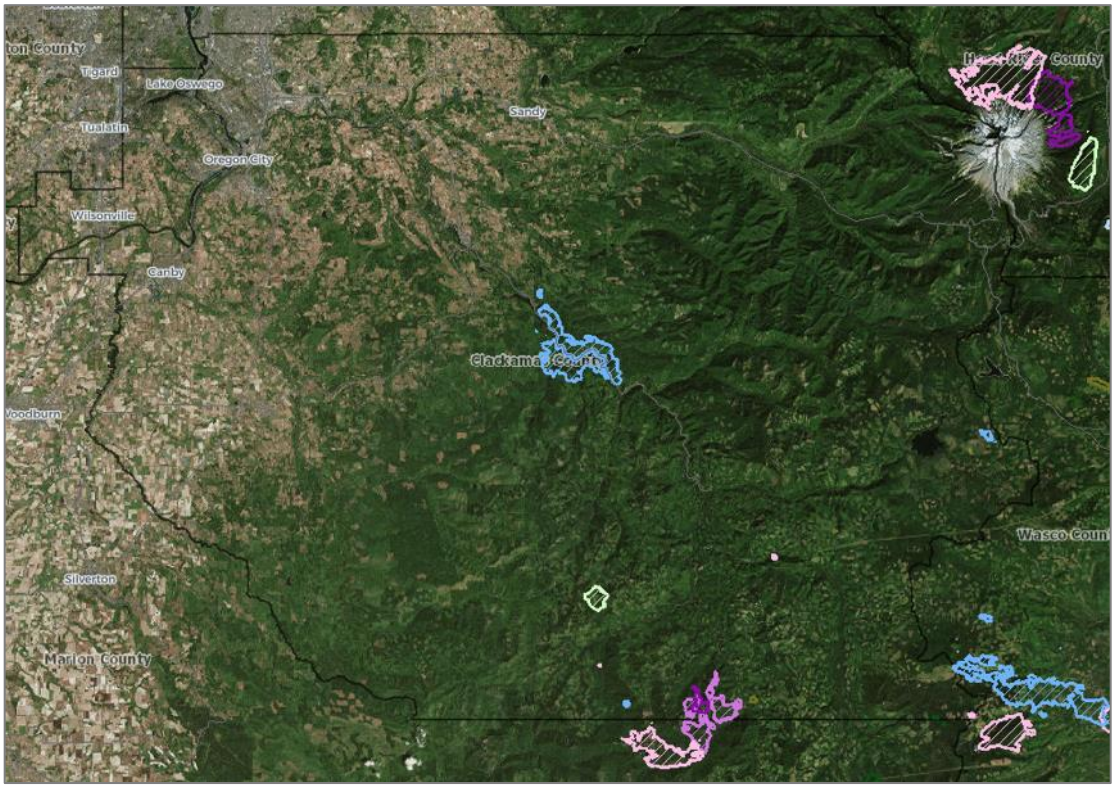


Source: Oregon Wildfire Risk Explorer

[61] Oregon Wildfire Risk Explorer, Area of Interest Report, Clackamas County, accessed July 9, 2018. http://oe.oregonexplorer.info/ExternalContent/wildfire_reports/WildfireRisk_AreaofInterestReport_clackamas_county.pdf

While the majority of fire ignitions occurred along travel corridors and the edges of major urban areas, the fires that escape initial suppression efforts tend to be in more remote areas and are more likely to occur in some portions of the landscape than others (see Figure 2-22). The figure includes the 36 Pit Fire (2014) in the center Blister Fire (2006) just to the south. On the southern edge of the county are the View Lake Fire Complex (2010) and the Bull of the Woods Fire (2010). Several other wildfire have threatened the county as shown just outside the southeast boundary of the county: Logging Unit Complex (2014) and High Cascades Complex (2011) and around Mt. Hood in the northeast: Dollar Lake Fire (2011), Gnarl Ridge Fire (2008), and Mt. Hood Complex (2006). The Eagle Creek Fire (2017), just outside the figure to the north, threatened the Bull Run Watershed that provides water to 950,000 customers in the Portland metropolitan region.

Figure 2-22 Large Fire Perimeters



Source: Oregon Wildfire Risk Explorer

Probability Assessment

Based on the available data and research the HMAC determined the **probability of experiencing a Wildfire is "high",** meaning one incident is likely within the next 10 to 35-year period. *This rating has increased since the previous NHMP.*

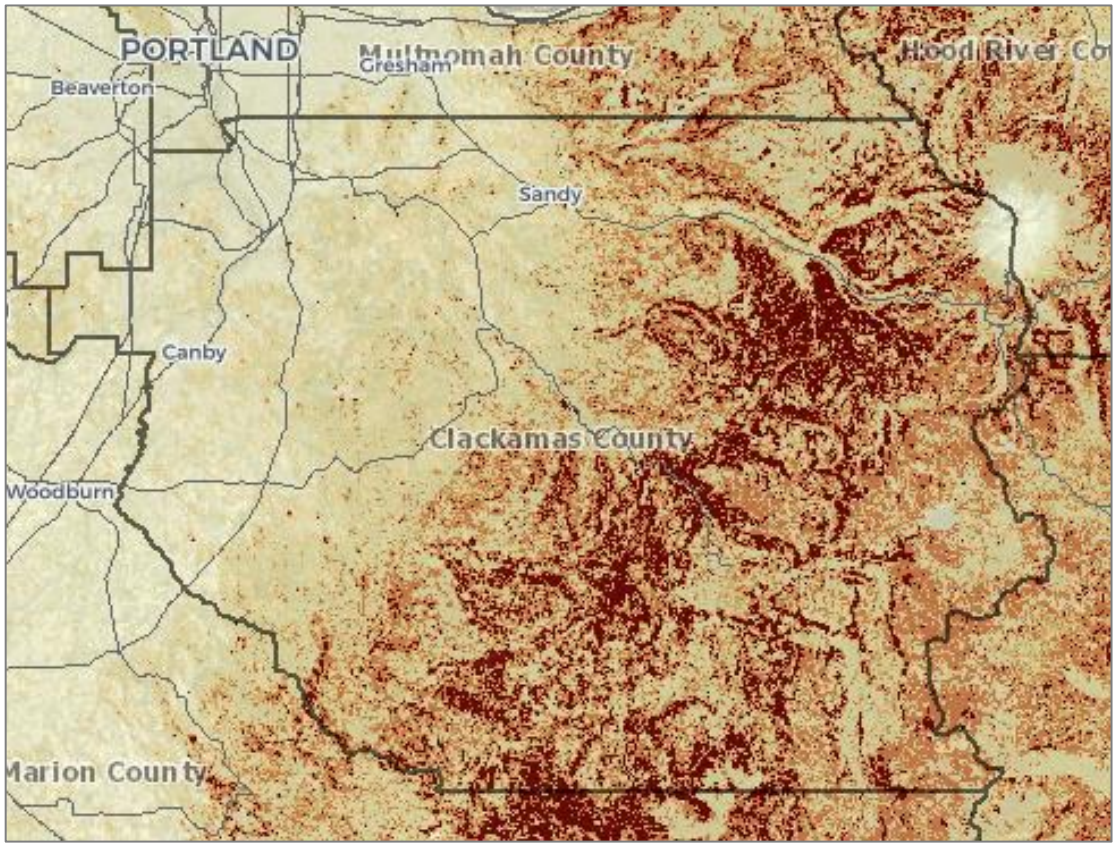
Certain conditions must be present for significant interface fires to occur. The most common are hot, dry and windy weather; the inability of fire protection forces to contain or suppress the fire; the occurrence of multiple fires that overwhelm committed resources; and a large fuel load (dense vegetation). Once a fire has started, several conditions influence its behavior, including fuel, topography, weather, drought and development. Many of these conditions are demonstrated across large areas within Clackamas County, creating a significant collective risk.

Vulnerability Assessment

The HMAC rated the county as having a **"moderate" vulnerability to wildfire hazards**, meaning that between 1-10% of the County's population or assets would be affected by a major disaster. *This rating has not changed since the previous NHMP*.

Potential impact to structure from wildfire is shown in Figure 2-23, darker areas have higher risk to structures if fire ignites nearby. The areas of greater risk are generally located in more rural parts of the county, that are hillier, and more heavily vegetated and forested.

Figure 2-23 Oregon Wildfire Risk Explorer – Potential Impact to Structure



Source: Oregon Wildfire Risk Explorer

Additional wildfire hazard information for Clackamas County and cities is available via Oregon Explorer's Wildfire Risk Explorer: http://oregonexplorer.info/topics/wildfire-risk?ptopic=62

The amount of property exposed to the wildfire risk hazard area, as well as the type and value of structures on those properties, is calculated to provide a working estimate for potential wildfire losses. Table 2-21 shows potentially impacted parcels, critical and critical facilities, vulnerable populations, and infrastructure within Clackamas County's wildfire risk hazard area.

Table 2-21 Wildfire Hazard Vulnerability Assessment

	Potentially Impacted Parcels		Potentially Impacted Locations			Infrastructure				
Hazard	Number of Parcels	Percent of Total Parcels	Critical Facilities	Essential Facilities	Vulnerable Populations	Miles of Road	Miles of Sewer Lines	Bridges	Cell Towers	Dams
County Total	158,226	Not Applicable	235	55	576	4911	340	597	17	69
Overall Wildfire Risk										
High	1,650	1%	0	0	2	349	4	21	7	5

Source: Clackamas County Geographic Information Systems (2018)
Note: Percentage of property exposed to wildfire risk may include property in tax lots that intersect the area, including property that does not physically reside in the area itself.

Lower Columbia-Sandy Watershed Natural Hazard Risk Report

The **Risk Report** (DOGAMI, IMS-59) provides hazard analysis summary tables that identify populations and property within the Lower Columbia-Sandy River Watershed Study Area that are vulnerable to the profiled natural hazards. The Risk Report provides distinct profiles for (1) unincorporated Clackamas County within the study area, (2) the unincorporated community of Government Camp, and (3) the unincorporated community of The Villages at Mt. Hood (including Brightwood, Rhododendron, Welches, Wimme, and Zig Zag).

According to the Risk Report the following populations and property are vulnerable:

Unincorporated Clackamas County within the Study Area[62]

Wildfire event (High Risk): 31 buildings are exposed (0 critical facilities) for a total potential loss of $9,036,000 (an exposure ratio of 1%). In addition, 44 residents may be displaced (< 1% of the population).

Government Camp[63]

Wildfire event (High Risk): 2 buildings are exposed (0 critical facilities) for a total potential loss of $534,000 (an exposure ratio of < 1%). In addition, 1 resident may be displaced (< 1% of the population).

The Villages at Mt. Hood[64]

Wildfire event (High Risk): 47 buildings are exposed (0 critical facilities) for a total potential loss of $9,855,000 (an exposure ratio of 12%). In addition, 53 residents may be displaced (about 1% of the population).

Refer to the following DOGAMI reports for additional information:

- Multi-Hazard Risk Report for the Lower Columbia-Sandy Watershed, Oregon: Including the cities of Gresham, Sandy, and Troutdale and Unincorporated Communities of Government Camp and The Villages at Mt Hood (2018, IMS-59).

More information on this hazard can be found in the Clackamas County Community Wildfire Protection Plan (2018) and the Risk Assessment for Region 2, Northern Willamette Valley/Portland Metro, of the Oregon NHMP (2015).

[62] DOGAMI, *Lower Columbia-Sandy Watershed Natural Hazard Risk Report* (March 2018 Draft), Table 9-1.

[63] Ibid., Table 9-5.

[64] Ibid., Table 9-7.

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SECTION 3: MITIGATION STRATEGY

This section outlines Clackamas County's strategy to reduce or avoid long-term vulnerabilities to the identified hazards. Specifically, this section presents a mission and specific goals and actions thereby addressing the mitigation strategy requirements contained in 44 CFR 201.6(c). The NHMP Hazard Mitigation Advisory Committee (HMAC) viewed and updated the mission, goals, and action items documented in this NHMP. Additional planning process documentation is in Volume III, Appendix B.

Mitigation Plan Mission

The NHMP mission states the purpose and defines the primary functions of Clackamas County's NHMP. It is intended to be adaptable to any future changes made to the NHMP and need not change unless the community's environment or priorities change.

The mission of the Clackamas County NHMP is to:

> ***Promote sound public policy designed to protect citizens, critical facilities, infrastructure, private property, and the environment from natural hazards.***

This can be achieved by increasing public awareness, documenting the resources for risk reduction and loss-prevention, and identifying activities to guide the county towards building a safer, more sustainable community.

Note: The 2018 NHMP HMAC reviewed the previous NHMP's mission statement and agreed to retain it without modifications.

Mitigation Plan Goals

Mitigation plan goals are more specific statements of direction that Clackamas County citizens and public and private partners can take while working to reduce the County's risk from natural hazards. These statements of direction form a bridge between the broad mission statement and action items. The goals listed here serve as checkpoints as agencies and organizations begin implementing mitigation action items.

Meetings with the HMAC, previous hazard event reports, and the previous county NHMPs served as methods to obtain input and identify priorities in developing goals for reducing risk and preventing loss from natural hazards in Clackamas County.

The 2018 Clackamas County NHMP HMAC reviewed the previous NHMP goals in comparison to the State NHMP (2015) goals and determined that they would retain their original goals without modifications.

All the NHMP goals are important and are listed below in no order of priority. Establishing community priorities within action items neither negates nor eliminates any goals, but it establishes which action items to consider implementing first, should funding become available.

GOAL 1: PROTECT LIFE AND PROPERTY

- Implement activities that assist in protecting lives by making homes, businesses, infrastructure, critical facilities, and other property more resistant to natural hazards.
- Reduce losses and repetitive damages for chronic hazard events while promoting insurance coverage for catastrophic hazards.
- Improve hazard assessment information to make recommendations for discouraging new development and encouraging preventative measures for existing development in areas vulnerable to natural hazards.

GOAL 2: ENHANCE NATURAL SYSTEMS

- Balance watershed planning, natural resource management, and land use planning with natural hazards mitigation to protect life, property, and the environment.
- Preserve, rehabilitate, and enhance natural systems to serve natural hazard mitigation functions.

GOAL 3: AUGMENT EMERGENCY SERVICES

- Establish policy to ensure mitigation projects for critical facilities, services, and infrastructure.
- Strengthen emergency operations by increasing collaboration and coordination among public agencies, non-profit organizations, and business, and industry.
- Coordinate and integrate natural hazards mitigation activities, where appropriate, with emergency operations plans and procedures.

GOAL 4: ENCOURAGE PARTNERSHIPS FOR IMPLEMENTATION

- Strengthen communication and coordinate participation among and within public agencies, citizens, non-profit organizations, business, and industry to gain a vested interest in implementation.
- Encourage leadership within public and private sector organizations to prioritize and implement local, county, and regional hazard mitigation activities.

GOAL 5: PROMOTE PUBLIC AWARENESS

- Develop and implement education and outreach programs to increase public awareness of the risks associated with natural hazards.
- Provide information on tools, partnership opportunities, and funding resources to assist in implementing mitigation activities.

Action Item Development Process

Action items identified through the planning process are an important part of the mitigation plan. Action items are detailed recommendations for activities that local departments, citizens, and others could engage in to reduce risk. Development of action items was a multi-step, iterative process that involved brainstorming, discussion, review and revisions. Action items can be developed through many sources. Figure 3-1 illustrates some of these sources.

Figure 3-1 Development of Action Items

Most of the action items were first created during the previous NHMP planning processes. During these processes, the HMAC developed maps of local vulnerable populations, facilities and infrastructure in respect to each identified hazard. Review of these maps generated discussion around potential actions to mitigate impacts to the vulnerable areas. The Oregon Partnership for Disaster Resilience (OPDR) provided guidance in the development of action items by presenting and discussing actions that were used in other communities. OPDR also took note of ideas that came up in HMAC meetings and drafted specific actions that met the intent of the HMAC. All actions were then reviewed by the HMAC, discussed at length and revised as necessary before becoming a part of this document.

Action Item Matrix

The action item matrix (Table 3-1) portrays the overall action plan framework and identifies linkages between the NHMP goals, partnerships (coordination and partner organizations), and actions. The matrix documents a brief description of the action, coordinating and partner (internal) organizations, timeline (ongoing, short term, long term), priority (low, medium, high), and NHMP goals addressed. Refer to Volume III, Appendix A for detailed information for each action.

Action Item Categories

The HMAC categorized action items within the following categories:

EDUCATION AND OUTREACH

Enhancing individual jurisdictional responsibility and accountability is a low-cost, high-benefit way to increase resilience throughout the county. Education and outreach programs already exist. The actions in this category are intended in some cases for the general public,

but are predominantly aimed at better educating and informing local officials about actions they can take to make their communities more disaster resilient.

GIS/MAPPING

The actions in this category address mapping needs that are essential to the NHMPs risk assessment of each hazard. The ability to utilize data gathered by the county's GIS department and other local and state organizations allows the risk assessment to continually be updated and reviewed.

MAINTENANCE/PLANNING

Actions in this category stress the importance of maintaining elements of this Clackamas County NHMP, the date that supports the Clackamas County NHMP, and promote the development of plans and reports that support the goals of the Clackamas County NHMP.

CRITICAL INFRASTRUCTURE/ESSENTIAL FACILITIES

The actions within this category address critical infrastructure and public facilities that are essential to the basic functioning of society, and fundamentally necessary for effective emergency response, as well as recovery and redevelopment efforts following a disaster event.

LAND USE/DEVELOPMENT

Actions within this category seek to utilize laws, regulations, and other tools regarding the use and development of land as methods of protecting lives and property.

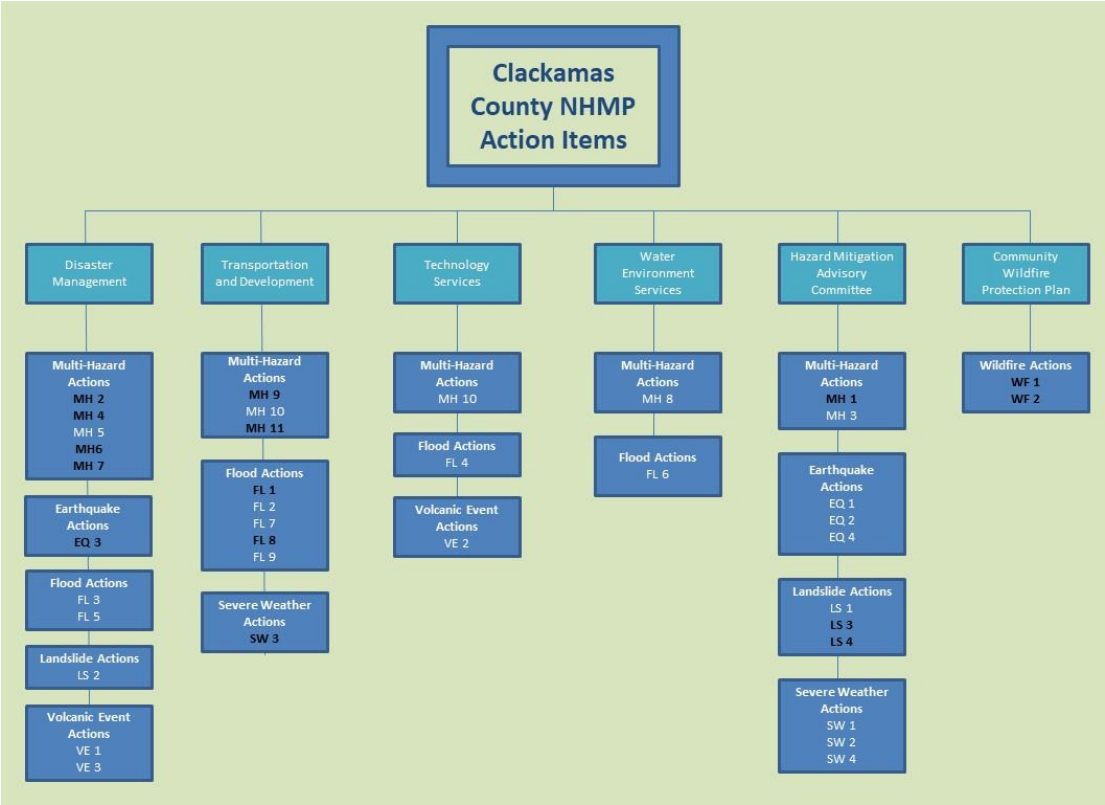
Action Item Framework

Many of the Clackamas County NHMP's recommendations are consistent with the goals and objectives of the County's existing plans and policies. Where possible, Clackamas County will implement the NHMP's recommended actions through existing plans and policies. Plans and policies already in existence have support from residents, businesses, and policy makers. Many land-use, comprehensive, and strategic plans get updated regularly, and can adapt easily to changing conditions and needs. Implementing the NHMP's action items through such plans and policies increases their likelihood of being supported and implemented.

Figure 3-2 outlines which county department or committee is the lead responsible for implementing and documenting progress on each action item.

See Volume II for the Priority Actions for each participating city.

Figure 3-2 Action Item Framework



Source: Clackamas County Hazard Mitigation Advisory Committee
Note: High Priority Actions are noted in **bold black text**.

Action Item Prioritization

The HMAC decided to modify the prioritization of action items in this update to reflect current conditions and needs. Because all action items are important to the NHMP, the group prioritized the action items with tiered priorities (low, medium, high). Each functional category contains a set of specific action items. High priority actions are shown in **bold** text with grey highlight within Table 3-1 (see page 3-2 for full text of the referenced plan goals).

During the February 28, 2018 meeting the HMAC agreed to maintain the existing categorization of the action items, to revise some existing actions to make them more specific, to remove one action that no longer applies, and to add three actions (see Volume III, Appendix A for an updated list of action items and Appendix B for information on changes).

The HMAC will prioritize the following actions to focus their attention, and resource availability, upon an achievable set of high leverage activities over the next five-years.

In addition to the actions listed below **Wildfire #1** (see Appendix A) is considered high priority. See the Clackamas Community Wildfire Protection Plan for detailed information.

EDUCATION AND OUTREACH

- **Multi-Hazard (MH) #4:** Identify, improve, and sustain collaborative programs focusing on the real estate and insurance industries, public and private sector organizations, and individuals to avoid activity that increases risk to natural hazards.
- **Multi-Hazard (MH) #7:** Strengthen emergency services preparedness and response by linking emergency services with natural hazard mitigation programs and enhancing and implementing public education programs on a regional scale.
- **Flood (FL) #1:** Identify opportunities to educate people within Clackamas County's public and private flood prone properties and identify feasible mitigation options.
- **Flood (FL) #8**: Encourage purchase of flood insurance.
- **Landslide (LS) #3:** Continue to limit activities in identified potential and historical landslide areas through regulation and public outreach.
- **Wildfire (WF) #2:** Encourage private landowners to create and maintain defensible space around homes and other buildings.

GIS/MAPPING

- No action within this category was identified as a priority.

MAINTENANCE/PLANNING

- **Multi-Hazard (MH) #1:** Integrate the goals and action items from the Clackamas County Natural Hazard Mitigation Plan into existing regulatory documents and programs, where appropriate.
- **Multi-Hazard (MH) #2:** Identify and pursue funding opportunities to develop and implement local and county mitigation activities.
- **Severe Weather (SW) #3:** Monitor and implement programs to keep trees from threatening lives, property, and public infrastructure during windstorm events.

CRITICAL INFRASTRUCTURE/ESSENTIAL FACILITIES

- **Multi-Hazard (MH) #6:** Update and Maintain inventories of at-risk buildings and infrastructure and prioritize mitigation projects.
- **Multi-Hazard (MH) #11:** Perform pre-disaster assessments on County owned and/or operated buildings and facilities, potential shelter sites, and essential facilities.
- **Earthquake (EQ) #3:** Encourage seismic strength evaluations for existing critical facilities in the County to identify vulnerabilities for mitigation of schools and universities, public infrastructure, and critical facilities to meet current seismic standards.

LAND USE/DEVELOPMENT

- **Multi-Hazard (MH) #9:** Enhance strategies for debris management.
- **Landslide (LS) #4:** Recommend construction and subdivision design that can be applied to steep slopes to reduce the potential adverse impacts from development.

Although this methodology provides a guide for the HMAC in terms of implementation, the HMAC has the option to implement any of the action items at any time. This option to consider all action items for implementation allows the committee to consider mitigation strategies as new opportunities arise, such as capitalizing on funding sources that could pertain to an action item that is not the highest priority.

Table 3-1 Clackamas County Action Items

Natural Hazard Action ID	Action Item	Coordinating Organization (Lead)	Internal Partners	Priority	Timing	Plan Goals Addressed				
						Goal 1	Goal 2	Goal 3	Goal 4	Goal 5
Education and Outreach										
Multi-Hazard #4	**Identify, improve, and sustain collaborative programs focusing on the real estate and insurance industries, public and private sector organizations, and individuals to avoid activity that increases risk to natural hazards**	**Disaster Management**	**PGA BCS**	**High**	**Ongoing**	✓		✓	✓	
Multi-Hazard #7	**Strengthen emergency services preparedness and response by linking emergency services with natural hazard mitigation programs and enhancing and implementing public education programs on a regional scale.**	**Disaster Management**	**DTD PGA TS H3S**	**High**	**Ongoing**	✓	✓		✓	
Flood #1	**Identify opportunities to educate people within Clackamas County's public and private flood prone properties and identify feasible mitigation options**	**Transportation and Development**	**DM HMAC**	**High**	**Ongoing**	✓		✓		
Flood #3	Develop better flood warning systems	Disaster Management	TS DTD	Medium	Ongoing	✓	✓			
Flood #8	**Encourage purchase of flood insurance**	**Transportation and Development**	**HMAC DM**	**High**	**Ongoing**	✓			✓	
Landslide #1	Continue to improve knowledge of landslide hazard areas and understanding of vulnerability and risk to life and property in hazard-prone areas	Hazard Mitigation Advisory Committee	DTD TS	Medium	Short Term	✓			✓	
Landslide #3	**Continue to limit activities in identified potential and historical landslide areas through regulation and public outreach**	**Hazard Mitigation Advisory Committee**	**TS DTD**	**High**	**Ongoing**	✓			✓	✓
Severe Weather #2	Continue to educate the public on severe weather mitigation activities.	Hazard Mitigation Advisory Committee	PGA	Medium	Ongoing	✓			✓	

Natural Hazard Action ID	Action Item	Coordinating Organization (Lead)	Internal Partners	Priority	Timing	Plan Goals Addressed				
						Goal 1	Goal 2	Goal 3	Goal 4	Goal 5
Earthquake #2	Encourage purchase of earthquake hazard insurance	Hazard Mitigation Advisory Committee	DM	Low	Ongoing	✓			✓	
Earthquake #4	Encourage reduction of nonstructural and structural earthquake hazards in homes, schools, businesses, and government offices through public education	Hazard Mitigation Advisory Committee	DM	Medium	Ongoing	✓	✓		✓	
Volcanic Event #3	Strengthen response and recovery programs, and work with the USGS-CVO to enhance public education programs for volcanic eruption hazards.	Disaster Management	-	Low	Long Term	✓	✓		✓	
Wildfire #2	**Encourage private landowners to create and maintain defensible space around homes and other buildings.**	**Disaster Management**	**DTD**	**High**	**Ongoing**	✓			✓	✓
GIS/Mapping										
Multi-Hazard #10	*This is a repeated action. See description under "Maintenance/Planning"*	*Technology Services*	*DTD DM*	*Medium*	*Long Term*	✓		✓		
Flood #4	Maintain data and mapping for floodplain information within the county and identify and map flood-prone areas outside of designated floodplains	Technology Services	DTD DM	Medium	Ongoing	✓				
Volcanic Event #2	Utilize existing risk assessments and collaborate with USGS-CVO and related agencies to develop ash fall models that are specific to Clackamas County	Technology Services	DM	Low	Long Term	✓		✓	✓	
Maintenance/Planning										
Multi-Hazard #1	**Integrate the goals and action items from the Clackamas County Natural Hazard Mitigation Plan into existing regulatory documents and programs, where appropriate.**	**Hazard Mitigation Advisory Committee**	**DM Finance DTD**	**High**	**Ongoing**			✓		

Natural Hazard Action ID	Action Item	Coordinating Organization (Lead)	Internal Partners	Priority	Timing	Plan Goals Addressed				
						Goal 1	Goal 2	Goal 3	Goal 4	Goal 5
Multi-Hazard #2	**Identify and pursue funding opportunities to develop and implement local and county mitigation activities.**	**Disaster Management**	**DTD**	**High**	**Ongoing**			✓		
Multi-Hazard #3	Establish a formal role for the Clackamas County Natural Hazards Mitigation Committee to develop a sustainable process for implementing, monitoring, and evaluating countywide mitigation activities	Hazard Mitigation Advisory Committee	DM, DTD, TS, CA	Medium	Ongoing			✓		
Multi-Hazard #5	Develop public and private partnerships to foster natural hazard mitigation program coordination and collaboration in Clackamas County	Disaster Management	DTD, PGA, BCS	Medium	Ongoing			✓		
Multi-Hazard #10	Update County Comprehensive Plan to integrate most current natural hazard mapping data for Clackamas County and make available to county GIS to improve technical analysis of earthquake hazards.	Transportation and Development	TS DM	Medium	Long Term	✓		✓		
Flood #7	Establish a framework to compile and coordinate surface water management plans and data throughout the county.	WES	DTD, TS	Medium	Short Term	✓		✓		
Flood #9	Develop a floodplain management plan as a standalone for the CRS program	Transportation and Development	DM WES CA	Medium	Short Term			✓		
Landslide #2	Identify public education tools and opportunities in high-risk debris flow and landslide areas.	Disaster Management	DTD	Medium	Short Term	✓	✓			
Severe Weather #1	Develop and implement programs to coordinate maintenance and mitigation activities to reduce risk to public infrastructure from severe weather	Hazard Mitigation Advisory Committee	DTD	Medium	Ongoing		✓	✓		

Natural Hazard Action ID	Action Item	Coordinating Organization (Lead)	Internal Partners	Priority	Timing	Plan Goals Addressed				
						Goal 1	Goal 2	Goal 3	Goal 4	Goal 5
Severe Weather #3	**Monitor and implement programs to keep trees from threatening lives, property, and public infrastructure during windstorm events**	**Transportation and Development**	**BCS**	**High**	**Ongoing**		✓	✓		
Volcanic Event #1	Work with the state and other impacted jurisdictions to update and exercise the Mount Hood Inter-Agency Volcano Coordination Plan	Disaster Management	DTD TCA	Medium	Long Term		✓	✓	✓	
Critical Infrastructure/Essential Facilities										
Multi-Hazard #6	**Update and Maintain inventories of at-risk buildings and infrastructure and prioritize mitigation projects**	**Disaster Management**	**DTD Finance TS**	**High**	**Ongoing**	✓		✓		
Multi-Hazard #11	**Perform pre-disaster assessments on County owned and/or operated buildings and facilities, potential shelter sites, and essential facilities.**	**Transportation and Development**	**DM Finance**	**High**	**Short Term**	✓		✓		
Flood #6	Identify and address surface water drainage problematic sites for all parts of unincorporated Clackamas County	Water Environment Services	DTD TS	Medium	Ongoing	✓				
Earthquake #1	Pursue funding opportunities for structural and nonstructural retrofitting of homes, schools, businesses, and government offices that are identified as seismically vulnerable	Hazard Mitigation Advisory Committee	DM CA	Medium	Ongoing			✓	✓	
Earthquake #3	**Encourage seismic strength evaluations for existing critical facilities in the County to identify vulnerabilities for mitigation of schools and universities, public infrastructure, and critical facilities to meet current seismic standards**	**Disaster Management**	**DTD HMAC**	**High**	**Ongoing**	✓	✓			

Natural Hazard Action ID	Action Item	Coordinating Organization (Lead)	Internal Partners	Priority	Timing	Plan Goals Addressed				
						Goal 1	Goal 2	Goal 3	Goal 4	Goal 5
Land Use/Development										
Multi-Hazard #8	Use technical knowledge of natural ecosystems and events to link natural resources management and land use organizations to mitigation activities and technical assistance.	Water Environment Services	DTD	Medium	Ongoing					✓
Multi-Hazard #9	**Enhance strategies for debris management**	**Transportation and Development**	**DM**	**High**	**Short Term/ Ongoing**		✓	✓		✓
Flood #2	Recommend revisions to requirements for development within the floodplain, where appropriate	Transportation and Development	DM, TS WES	Low	Long Term	✓				
Flood #5	Encourage development of acquisition and management strategies to preserve open space for flood mitigation, fish habitat, and water quality in the floodplain and reduce risk to flood prone properties as well as preserve space for open space property.	Disaster Management	WES DTD	Medium	Ongoing	✓				✓
Landslide #4	**Recommend construction and subdivision design that can be applied to steep slopes to reduce the potential adverse impacts from development.**	**Hazard Mitigation Advisory Committee**	**DTD**	**High**	**Short Term**	✓			✓	✓
Severe Weather #4	Support/encourage electrical utilities to use underground construction methods where possible to reduce power outages from windstorms.	Transportation and Development	DM	Medium	Ongoing			✓		✓

Source Clackamas County NHMP Hazard Mitigation Advisory Committee, updated 2018
Note: Full text of the plan goals referenced in this table is located on page 3-2.

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SECTION 4:
PLAN IMPLEMENTATION AND MAINTENANCE

This section details the formal process that will ensure that the NHMP remains an active and relevant document. The NHMP implementation and maintenance process includes a schedule for monitoring and evaluating the NHMP semi-annually, as well as producing an updated NHMP every five years. Finally, this section describes how the County will integrate public participation throughout the NHMP maintenance and implementation process.

Implementing the NHMP

The success of the Clackamas County NHMP depends on how well the outlined action items are implemented. In an effort to ensure that the activities identified are implemented, the following steps will be taken: 1) the NHMP will be formally adopted, 2) a Hazard Mitigation Advisory Committee (HMAC) will be assigned, 3) a convener shall be designated, 4) semi-annual meetings will be held (flood group meets semi-monthly), 5) the identified activities will be prioritized and evaluated, and 6) the NHMP will be implemented through existing plans, programs and policies.

NHMP Adoption

The Clackamas County NHMP was developed and will be implemented through a collaborative process. After the NHMP is locally reviewed and deemed complete, the Clackamas County Resilience Coordinator, or their designee, shall submit it to the State Hazard Mitigation Officer (SHMO) at the Oregon Office of Emergency Management (OEM). OEM submits the NHMP to FEMA-Region X for review. This review addresses the federal criteria outlined in the FEMA Interim Final Rule 44 CFR Part 201. Upon acceptance by FEMA, the County will adopt the NHMP via resolution. At that point, the County will gain eligibility for the Pre-Disaster Mitigation (PDM) Grant Program, the Hazard Mitigation Grant Program (HMGP) and Flood Mitigation Assistance (FMA) grant program funds. Following adoption by the County, the participating jurisdictions should convene local decision makers and adopt the Clackamas County Multijurisdictional NHMP.

Convener

The Board of County Commissioners (BCC) will adopt the Clackamas County NHMP, and the HMAC will take responsibility for plan implementation. The County Administrator or designee (Clackamas County Resilience Coordinator) will serve as the NHMP convener to facilitate the HMAC meetings and will assign tasks such as updating and presenting the NHMP to the members of the committee.

- Coordinate HMAC meeting dates, times, locations, agendas and member notification;
- Document the discussions and outcomes of committee meetings;
- Serve as a communication conduit between the HMAC and the public/stakeholders;
- Identify emergency management-related funding sources for natural hazard mitigation projects; and
- Utilize the Risk Assessment as a tool for prioritizing proposed natural hazard risk reduction projects.

NHMP implementation and evaluation will be a shared responsibility among all HMAC members.

Hazard Mitigation Advisory Committee

The HMAC serves as the coordinating body for the NHMP and is responsible for coordinating implementation of NHMP action items and undertaking the formal review process. The BCC will assign representatives from county agencies, including, but not limited to, the current HMAC members.

Roles and responsibilities of the HMAC include:

- Attending future meetings;
- Prioritizing projects and recommending funding for natural hazard risk reduction projects;
- Participation in the NHMP update process;
- Documenting successes and lessons learned;
- Evaluating and updating the NHMP following a disaster;
- Evaluating and updating the NHMP in accordance with the prescribed maintenance schedule; and
- Development and coordination of ad hoc and/or standing subcommittees as needed.

HMAC Members

The following jurisdictions, agencies and/or organizations were represented and served on the HMAC during the development of the Clackamas County NHMP and may be represented during implementation and maintenance phase (for a list of individuals see *Acknowledgements*):

County Departments	Participating Cities	Other
Application Services	City of Canby	Clackamas Soil and Water Conservation District
Disaster Management	City of Estacada	Clackamas River Water Providers
Public Health	City of Gladstone	Clackamas Co. Fire District #1
Public Works	City of Happy Valley	Oregon Department of Geology and Mineral Industries
Transportation and Development	City of Johnson City	Oregon Department of Land Conservation and Development
Water Environment Services	City of Milwaukie	Oregon Office of Emergency Management
	City of Molalla	United States Army Corps of Engineers
	City of Lake Oswego	
	City of Oregon City	
	City of Sandy	
	City of West Linn	
	City of Wilsonville	

To make the coordination and review of the Clackamas County NHMP as broad and useful as possible, the HMAC will engage additional stakeholders and other relevant hazard mitigation organizations and agencies to implement the identified action items. Specific organizations have been identified as partners in the action item matrices.

Implementation through existing programs

The NHMP includes a range of action items that, when implemented, will reduce loss from hazard events in the county. Within the NHMP, FEMA requires the identification of existing programs that might be used to implement these action items. Clackamas County and the participating cities currently address statewide planning goals and legislative requirements through their comprehensive land use plans, capital improvement plans, mandated standards and building codes. To the extent possible, Clackamas County and participating cities will work to incorporate the recommended mitigation action items into existing programs and procedures.

Many of the recommendations contained in the NHMP are consistent with the goals and objectives of the participating City and County's existing plans and policies. Where possible, Clackamas County and participating cities should implement the recommended actions contained in the NHMP through existing plans and policies. Plans and policies already in existence often have support from residents, businesses and policy makers. Many land-use, comprehensive and strategic plans get updated regularly and can adapt easily to changing conditions and needs. Implementing the action items contained in the NHMP through such plans and policies increases their likelihood of being supported and implemented.

Examples of plans, programs or agencies that may be used to implement mitigation activities include:

- City and County Budgets
- Community Wildfire Protection Plans
- Comprehensive Land Use Plans
- Economic Development Action Plans
- Zoning Ordinances and Building Codes

For additional examples of plans, programs or agencies that may be used to implement mitigation activities refer to list of plans in Volume I, Section 2.

NHMP Maintenance

NHMP maintenance is a critical component of the NHMP. Proper maintenance of the NHMP ensures that it will maximize the County and participating Cities' efforts to reduce the risks posed by natural hazards. This section was developed by OPDR and includes a process to ensure that a regular review and update of the NHMP occurs. The HMAC and local staff are responsible for implementing this process, in addition to maintaining and updating the NHMP through a series of meetings outlined in the maintenance schedule below.

Meetings

The HMAC will meet on a **semi-annual basis** to complete the following tasks (the County flood group meets semi-monthly). During the first meeting the HMAC will:

- Review existing action items to determine appropriateness for funding;
- Educate and train new members on the NHMP and mitigation in general;
- Identify issues that may not have been identified when the NHMP was developed; and
- Prioritize potential mitigation projects using the methodology described below.

During the second meeting, the HMAC will:

- Review existing and new risk assessment data;
- Discuss methods for continued public involvement; and
- Document successes and lessons learned during the year.

The county's Resilience Coordinator will host a meeting once a year with the city leads for participating jurisdictions. This meeting is an opportunity for the cities to report back to the county on progress that has been made towards their NHMP Addenda. This meeting will also serve as a means for the Resilience Coordinator to provide information regarding potential funding sources for mitigation projects, as well as provide additional support for the cities steering committees.

The convener will be responsible for documenting the outcome of the semi-annual meetings in Volume III, Appendix B. The process the coordinating body will use to prioritize mitigation projects is detailed in the section below. The NHMP's format allows the county and participating jurisdictions to review and update sections when new data becomes available. New data can be easily incorporated, resulting in a NHMP that remains current and relevant to the participating jurisdictions.

Project Prioritization Process

Chapter 3 describes the process the HMAC used to establish the current prioritization of action items. Understanding that priorities may change over time depending on new events or resource availability, the Disaster Mitigation Act of 2000 requires that jurisdictions identify a process for future action item prioritization. Potential mitigation activities often come from a variety of sources; therefore, the project prioritization process needs to be flexible. Committee members, local government staff, other planning documents or the risk assessment may be the source to identify projects. Figure 4-1 illustrates the project development and prioritization process that the HMAC can use in the future.

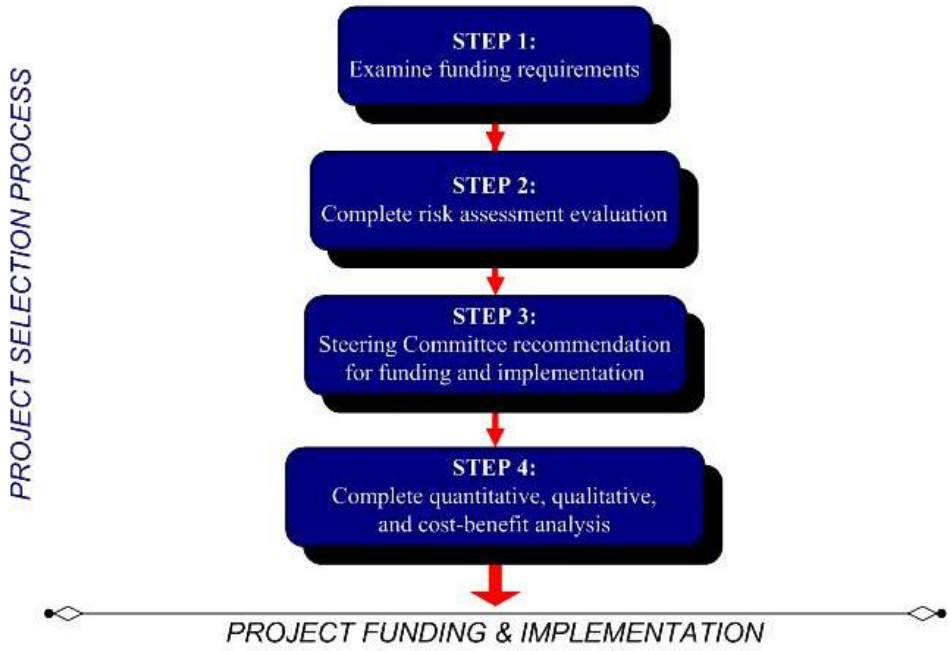
Step 1: Examine funding requirements

The first step in prioritizing the NHMP's action items is to determine which funding sources are open for application. Several funding sources may be appropriate for the County's proposed mitigation projects. Examples of mitigation funding sources include but are not limited to: FEMA's Pre-Disaster Mitigation (PDM) competitive grant program, Hazard Mitigation Grant Program (HMGP), Flood Mitigation Assistance (FMA) grant program, National Fire Plan (NFP), Community Development Block Grants (CDBG), local general funds and private foundations, among others. Please see Volume II, Appendix F for a more comprehensive list of potential grant programs.

Because grant programs open and close on differing schedules, the HMAC will examine upcoming funding streams' requirements to determine which mitigation activities would be eligible. The HMAC may consult with the funding entity, OEM, or other appropriate state or

regional organizations about project eligibility requirements. This examination of funding sources and requirements will happen during the HMAC's semi-annual NHMP maintenance meetings.

Figure 4-1 Action Item and Project Review Process



Source: Oregon Partnership for Disaster Resilience, 2008.

Step 2: Complete risk assessment evaluation

The second step in prioritizing the NHMP's action items is to examine which hazards the selected actions are associated with and where these hazards rank in terms of community risk. The HMAC will determine whether the NHMP's risk assessment supports the implementation of eligible mitigation activities. This determination will be based on the location of the potential activities, their proximity to known hazard areas and whether community assets are at risk. The HMAC will additionally consider whether the selected actions mitigate hazards that are likely to occur in the future or are likely to result in severe/catastrophic damages.

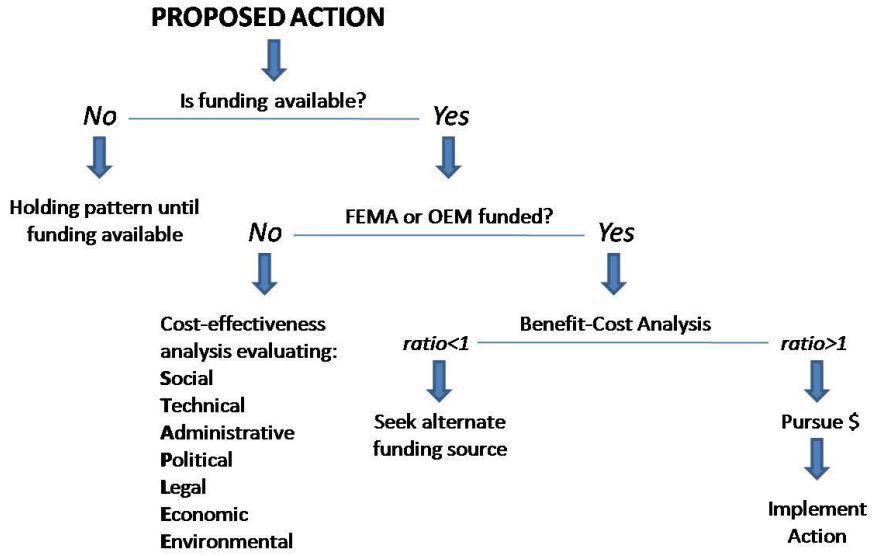
Step 3: Hazard Mitigation Advisory Committee Recommendation

Based on the steps above, the HMAC will recommend which mitigation activities should be moved forward. If the HMAC decides to move forward with an action, the coordinating organization designated in the matrix will be responsible for taking further action and, if applicable, documenting success upon project completion. The HMAC will convene a meeting to review the issues surrounding grant applications and to share knowledge and/or resources. This process will afford greater coordination and less competition for limited funds.

Step 4: Complete quantitative and qualitative assessment and economic analysis

The fourth step is to identify the costs and benefits associated with the selected natural hazard mitigation strategies, measures or projects. Two categories of analysis that are used in this step are: (1) cost-benefit analysis and (2) cost-effectiveness analysis. Conducting cost-benefit analysis for a mitigation activity assists in determining whether a project is worth undertaking now, in order to avoid disaster-related damages later. Cost-effectiveness analysis evaluates how best to spend a given amount of money to achieve a specific goal. Determining the economic feasibility of mitigating natural hazards provides decision makers with an understanding of the potential benefits and costs of an activity, as well as a basis upon which to compare alternative projects. Figure 4-2 shows decision criteria for selecting the appropriate method of analysis.

Figure 4-2 Benefit Cost Decision Criteria



Source: Oregon Partnership for Disaster Resilience, 2010.

If the activity requires federal funding for a structural project, the HMAC will use a FEMA-approved cost-benefit analysis tool to evaluate the appropriateness of the activity. A project must have a cost-benefit ratio of greater than one in order to be eligible for FEMA grant funding.

For non-federally funded or nonstructural projects, a qualitative assessment will be completed to determine the project's cost effectiveness. The HMAC will use a multivariable assessment technique called STAPLE/E to prioritize these actions. STAPLE/E stands for Social, Technical, Administrative, Political, Legal, Economic and Environmental. Assessing projects based upon these seven variables can help define a project's qualitative cost effectiveness. OPDR at the University of Oregon's Community Service Center has tailored the STAPLE/E technique for use in natural hazard action item prioritization.

Continued Public Involvement and Participation

The participating jurisdictions are dedicated to involving the public directly in the continual reshaping and updating of the Clackamas County NHMP. Although members of the HMAC represent the public to some extent, the public will also have the opportunity to continue to provide feedback about the NHMP.

To ensure that these opportunities will continue, the County and participating jurisdictions will:

- Post copies of their NHMP on corresponding websites;
- Place articles in the local newspaper directing the public where to view and provide feedback; and
- Use existing newsletters such as schools and utility bills to inform the public where to view and provide feedback.
- Continue to host a booth at the Clackamas County Fair and other countywide events on an annual basis and present information about hazard mitigation.
- Clackamas County Disaster Management will continue to utilize their social media platforms to involve the public.

In addition to the involvement activities listed above, Clackamas County will ensure continued public involvement by posting the Clackamas County NHMP on the county's website (https://www.clackamas.us/dm). The NHMP will also be archived and posted on the University of Oregon Libraries' Scholar's Bank Digital Archive (https://scholarsbank.uoregon.edu).

Five-Year Review of NHMP

This NHMP will be updated every five years in accordance with the update schedule outlined in the Disaster Mitigation Act of 2000. **The Clackamas County NHMP is due to be updated before April 12, 2024.** The Convener will be responsible for organizing the HMAC to address NHMP update needs. The HMAC will be responsible for updating any deficiencies found in the NHMP and for ultimately meeting the Disaster Mitigation Act of 2000's NHMP update requirements.

The following 'toolkit' can assist the Convener in determining which NHMP update activities can be discussed during regularly-scheduled NHMP maintenance meetings and which activities require additional meeting time and/or the formation of sub-committees.

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Table 4-1 Natural Hazard Mitigation Plan Update Toolkit

Question	Yes	No	Plan Update Action
Is the planning process description still relevant?			Modify this section to include a description of the plan update process. Document how the planning team reviewed and analyzed each section of the plan, and whether each section was revised as part of the update process. (This toolkit will help you do that).
Do you have a public involvement strategy for the plan update process?			Decide how the public will be involved in the plan update process. Allow the public an opportunity to comment on the plan process and prior to plan approval.
Have public involvement activities taken place since the plan was adopted?			Document activities in the "planning process" section of the plan update
Are there new hazards that should be addressed?			Add new hazards to the risk assessment section
Have there been hazard events in the community since the plan was adopted?			Document hazard history in the risk assessment section
Have new studies or previous events identified changes in any hazard's location or extent?			Document changes in location and extent in the risk assessment section
Has vulnerability to any hazard changed?			Document changes in vulnerability in the risk assessment section
Have development patterns changed? Is there more development in hazard prone areas?			Document changes in vulnerability in the risk assessment section
Do future annexations include hazard prone areas?			Document changes in vulnerability in the risk assessment section
Are there new high risk populations?			Document changes in vulnerability in the risk assessment section
Are there completed mitigation actions that have decreased overall vulnerability?			Document changes in vulnerability in the risk assessment section
Did the plan document and/or address National Flood Insurance Program repetitive flood loss properties?			Document any changes to flood loss property status

Source: Oregon Partnership for Disaster Resilience, 2010.

Table 4-1 Natural Hazard Mitigation Plan Update Toolkit (continued)

Question	Yes	No	Plan Update Action
Did the plan identify the number and type of existing and future buildings, infrastructure, and critical facilities in hazards areas?			1) Update existing data in risk assessment section, or 2) determine whether adequate data exists. If so, add information to plan. If not, describe why this could not be done at the time of the plan update
Did the plan identify data limitations?			If yes, the plan update must address them: either state how deficiencies were overcome or why they couldn't be addressed
Did the plan identify potential dollar losses for vulnerable structures?			1) Update existing data in risk assessment section, or 2) determine whether adequate data exists. If so, add information to plan. If not, describe why this could not be done at the time of the plan update
Are the plan goals still relevant?			Document any updates in the plan goal section
What is the status of each mitigation action?			Document whether each action is completed or pending. For those that remain pending explain why. For completed actions, provide a 'success' story.
Are there new actions that should be added?			Add new actions to the plan. Make sure that the mitigation plan includes actions that reduce the effects of hazards on both new and existing buildings.
Is there an action dealing with continued compliance with the National Flood Insurance Program?			If not, add this action to meet minimum NFIP planning requirements
Are changes to the action item prioritization, implementation, and/or administration processes needed?			Document these changes in the plan implementation and maintenance section
Do you need to make any changes to the plan maintenance schedule?			Document these changes in the plan implementation and maintenance section
Is mitigation being implemented through existing planning mechanisms (such as comprehensive plans, or capital improvement plans)?			If the community has not made progress on process of implementing mitigation into existing mechanisms, further refine the process and document in the plan.

Source: Oregon Partnership for Disaster Resilience, 2010.