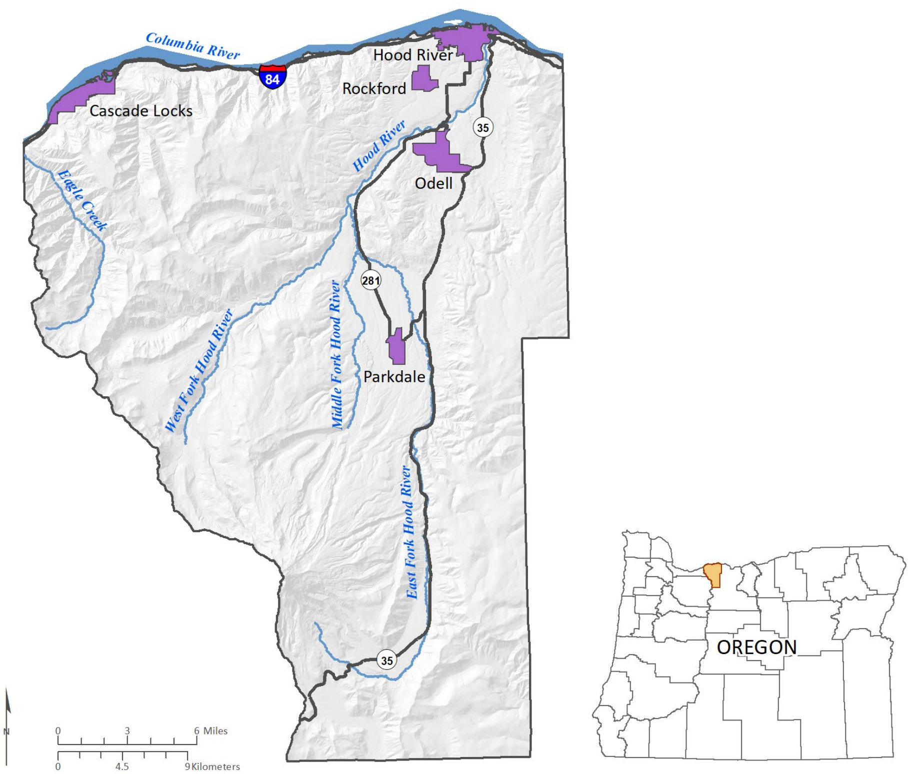
State of Oregon
Oregon Department of Geology and Mineral Industries
Brad Avy, State Geologist

OPEN-FILE REPORT O-21-05

NATURAL HAZARD RISK REPORT FOR HOOD RIVER COUNTY, OREGON

INCLUDING THE CITIES OF CASCADE LOCKS AND HOOD RIVER AND UNINCORPORATED COMMUNITIES OF ODELL, PARKDALE, AND ROCKFORD



by Matt C. Williams[1] and Ian P. Madin[1]

2021

[1]Oregon Department of Geology and Mineral Industries, 800 NE Oregon Street, Suite 965, Portland, OR 97232

DISCLAIMER

This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication.

Cover image: Study area of the Hood River County Risk Report. Map depicts Hood River County, Oregon and communities included in this report.

WHAT'S IN THIS REPORT?

This report describes the methods and results of natural hazard risk assessments for Hood River County communities. The risk assessments can help communities better plan for disaster.

Expires: 06/30/2022

Oregon Department of Geology and Mineral Industries Open-File Report O-21-05
Published in conformance with ORS 516.030

For additional information:
Administrative Offices
800 NE Oregon Street, Suite 965
Portland, OR 97232
Telephone (971) 673-1555
http://www.oregongeology.org
http://oregon.gov/DOGAMI/

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAP PLATES

Appendix E

GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

See the digital publication folder for files.
Geodatabase is Esri® version 10.2 format. Metadata are embedded in the geodatabase and are also provided as separate .xml format files.

Hood River_County_Risk_Report_Data.gdb

Feature dataset: Asset_Data

feature classes:

- Building_footprints (polygons)
- Communities (polygons)
- UDF_points (points)

Metadata in .xml file format:

Each dataset listed above has an associated, standalone .xml file containing metadata in the Federal Geographic Data Committee Content Standard for Digital Geospatial Metadata format

EXECUTIVE SUMMARY

This report was prepared for the communities of Hood River County, Oregon, with funding provided by the Federal Emergency Management Agency (FEMA). It describes the methods and results of natural hazard risk assessments performed in 2018 and 2021 by the Oregon Department of Geology and Mineral Industries (DOGAMI) within the study area. The purpose of this project is to provide communities within the study area a detailed risk assessment of the natural hazards that affect them to enable them to compare hazards and act to reduce their risk. The risk assessment contained in this project quantifies the impacts of natural hazards to these communities and enhances the decision-making process in planning for disaster.

We arrived at our findings and conclusions by completing three main tasks for each community: compiling an asset database, identifying and using best available hazard data, and performing natural hazard risk assessments.

In the first task, we created a comprehensive asset database for the entire study area by synthesizing assessor data, U.S. Census information, FEMA Hazus®-MH general building stock information, and building footprint data. This work resulted in a single dataset of building points and their associated building characteristics. With these data we were able to represent accurate spatial location and vulnerability on a building-by-building basis.

The second task was to identify and use the most current and appropriate hazard datasets for the study area. Most of the hazard datasets used in this report were created by DOGAMI; some were produced using high-resolution lidar topographic data. While not all the data sources used in the report are countywide, each hazard dataset was the best available at the time of writing.

In the third task, we performed risk assessments using Esri® ArcGIS Desktop® software. We took two risk assessment approaches: (1) estimated loss (in dollars) to buildings from flood (recurrence intervals) and earthquake scenarios using Hazus-MH methodology, and (2) calculated number of buildings, their value, and associated populations exposed to earthquake, and flood scenarios, or susceptible to varying levels of hazard from landslides, wildfire, channel migration, and lahar.

The findings and conclusions of this report show the potential impacts of hazards in communities within Hood River County. An earthquake can cause extensive damage and losses throughout the county. Hazus-MH earthquake simulations illustrate the potential reduction in earthquake damage through seismic retrofits. Some communities in the study area have moderate risk from flooding, and we quantify the number of elevated structures that are less vulnerable to flood hazard. Our analysis shows that new landslide mapping based on improved methods and lidar information will increase the accuracy of mapping in the City of Cascade Locks. During the time of writing, the best available data show that wildfire risk is high for parts of the unincorporated county, Odell, and Hood River. Exposure to channel migration hazard is limited to portions of unincorporated county outside of Odell and Parkdale. Volcanic lahar hazard is a potential risk for the community of Parkdale. Our findings indicate that most of the critical facilities in the study area are at high risk from an earthquake and wildfire. We also note that the two biggest causes of population displacement are earthquake and wildfire hazard. Lastly, we demonstrate that this risk assessment can be a valuable tool to local decisionmakers.

Results were broken out for the following geographic areas:

- Unincorporated Hood River County (rural)
- Community of Parkdale
- City of Cascade Locks
- Community of Odell
- Community of Rockford

City of Hood River

Selected Countywide Results Total buildings: 14,394 Total estimated building value: $3.9 billion	
2500-year Probabilistic Magnitude 7.0 Earthquake Red-tagged buildings[a]: 628 Yellow-tagged buildings[b]: 1,929 Loss estimate: $1.3 billion	**100-year Flood Scenario** Number of buildings damaged: 68 Loss estimate: $1.5 million
Landslide (High and Very High-Susceptibility) Number of buildings exposed: 1,286 Exposed building value: $287 million	**Channel Migration Zone (High Risk):** Number of buildings exposed: 47 Exposed building value: $10 million
Wildfire Results (High Risk): Number of buildings exposed: 2,537 Exposed building value: $700 million	**Lahar (100-year Scenario):** Number of buildings exposed: 141 Exposed building value: $42 million
[a]Red-tagged buildings are considered uninhabitable due to complete damage [b]Yellow-tagged buildings are considered limited habitability due to extensive damage	

1.0 INTRODUCTION

> ***Key Terms:***
> - *Vulnerability:* Characteristics that make people or assets more susceptible to a natural hazard.
> - *Risk:* Probability multiplied by consequence; the degree of probability that a loss or injury may occur as a result of a natural hazard.

A natural hazard is a naturally occurring phenomenon that can negatively impact humans, which is typically characterized as risk. A natural hazard risk assessment analyzes how a hazard could affect the built environment, population, the cost of recovery, and identifies potential risk. In natural hazard mitigation planning, risk assessments are the basis for developing mitigation strategies and actions. A risk assessment enhances the decision- making process, so that steps can be taken to prepare for a potential hazard event.

This is the first natural hazard risk assessment analyzing individual buildings and resident population in Hood River County. It is therefore the most detailed and comprehensive analysis to date of natural hazard risk and provides a comparative perspective never before available. In this report, we describe our assessment results, which quantify the various levels of risk that each hazard presents to Hood River County communities.

Hood River County is situated along the Columbia Gorge on the eastern edge of the Cascade Range and is subject to natural hazards including earthquakes, riverine flooding, landslides, wildfires, channel migration, and volcanic lahars. This region of the state is sparsely developed in the rural areas, with some moderate development in the City of Hood River. Where natural hazards have the potential to damage assets or harm people, the result is natural hazard risk. The primary goal of the risk assessment is to inform communities of the risk posed by various natural hazards and to be a resource for risk reduction actions.

1.1 Purpose

The purpose of this project is to help communities in the study area better understand their risk and increase resilience to natural hazards that are present in their communities. This is accomplished by providing accurate, detailed, and best available information about these hazards and by measuring the number of people and buildings at risk.
The main objectives of this study are to:

- compile and/or create a database of critical facilities, tax assessor data, buildings, and population distribution data,
- incorporate and use existing data from previous geologic, hydrologic, and wildfire hazard studies,
- perform exposure and Hazus–based risk analysis, and
- share this report widely so that all interested parties have access to its information and data.

The body of this report describes the methods and results for these objectives. Two primary methods (Hazus-MH or exposure), depending on the type of hazard, were used to assess risk. Results for each hazard type are reported on a countywide basis within each hazard section, and community based results are reported in detail in **Appendix A: Community Risk Profiles**. **Appendix B** contains detailed risk assessment tables. **Appendix C** is a more detailed explanation of the Hazus-MH methodology. **Appendix D** lists acronyms and definitions of terms used in this report. **Appendix E** contains tabloid-size maps showing county-wide hazard maps.

1.2 Study Area

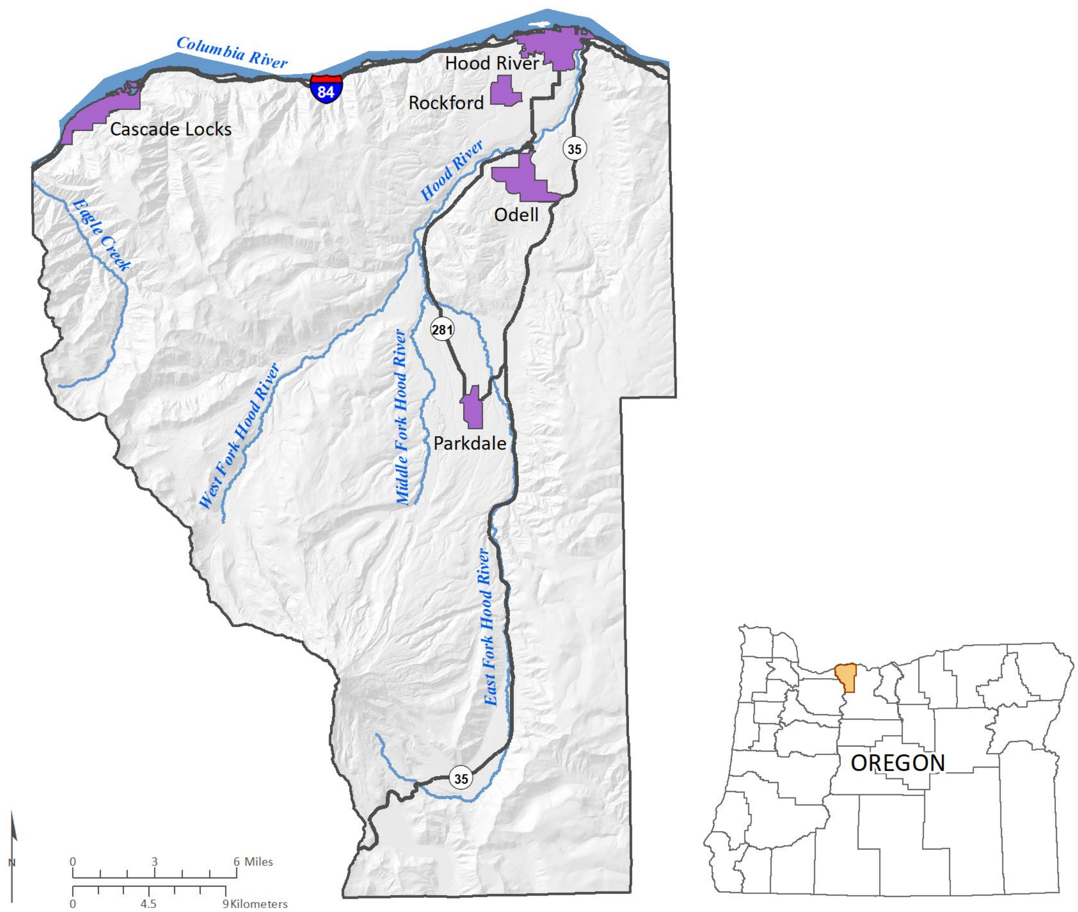
The study area for this project is the entirety of Hood River County, Oregon. Hood River County is located in the northcentral portion of the state and is bordered by Multnomah and Clackamas Counties on the west, Wasco County on the south and east, and by the Columbia River on the north. The total area of Hood River County is 523 square miles (1,355 square kilometers). A significant portion of the county (approximately 65%) is within the Mount Hood National Forest.

The geography consists of the Cascade Range and the Columbia River Gorge and Hood River valleys. Mount Hood, the highest point in Oregon at 11,250 feet (3,429 meters), is located along the southwestern limit of the study area. From Mount Hood, the terrain descends from the heavily timbered slopes of the mountain transitioning into the farmlands of the valley.

The population of Hood River County is 22,346 according to the 2010 U.S. Census Bureau (2010a). The county seat and county's largest community is the City of Hood River. Most of the residents in the county reside in the gentler terrain found in the lowlands of the Hood River Valley. The incorporated communities of the study area are Cascade Locks and Hood River (**Figure 1-1**). The unincorporated communities in the study area are Parkdale, Odell, and Rockford.

We selected these unincorporated communities based on population size and density, which makes them distinct from the overall unincorporated county jurisdiction. We based the boundary of the unincorporated communities generally on the 2010 census block areas.

Figure 1-1. Study area: Hood River County with communities in this study identified in purple.



1.3 Project Scope

For this risk assessment, we applied a quantitative approach to buildings and population. We limited the project scope to buildings and population because of data availability, the strengths and limitations of the risk assessment methodology, and funding availability. We did not analyze impacts to the local economy, land values, or the environment. Depending on the natural hazard, we used one of two methodologies: loss estimation or exposure. Loss estimation was modeled using methodology from Hazus®-MH (FEMA, 2012a, 2012b, 2012c), a tool developed by FEMA for calculating damage to buildings from flood and earthquake. Exposure is a simpler methodology, where buildings are categorized based on their location relative to various hazard zones. To account for impacts on population (permanent residents only), 2010 U.S. Census data (U.S. Census Bureau, 2010a) were associated with residential buildings.

A critical component of this risk assessment is a countywide building inventory developed from building footprint data and the Hood River County tax assessor database. The other key component is a suite of datasets that represent the currently best available science for a variety of natural hazards. The geologic hazard scenarios were selected by DOGAMI staff based on their expert knowledge of the datasets; most datasets are DOGAMI publications. In addition to geologic hazards, we included wildfire hazard in this risk assessment. The following is a list of the natural hazards and the risk assessment methodologies that were applied. See **Table 1-1** for data sources.

Earthquake Risk Assessment

- Hazus-MH loss estimation from a 2500-year probabilistic magnitude (Mw) 7.0 scenario

Flood Risk Assessment

- Hazus-MH loss estimation to two recurrence intervals (1%, 0.2% annual chance)
- Exposure to 1% annual chance recurrence interval

Landslide Risk Assessment

- Exposure based on Landslide Susceptibility Index (low to very high)

Wildfire Risk Assessment

- Exposure based on Fire Risk Index (low to high)

Channel Migration Risk Assessment

- Exposure based on channel migration zones (exposed, not exposed)

Volcanic Risk Assessment

- Exposure based on lahar hazard zones (low to high)

Table 1-1. Hazard data sources for Hood River County.

Hazard	Scenario or Classes	Scale/Level of Detail	Data Source
Earthquake (includes liquefaction and coseismic landslides)	2,500-year probabilistic Mw 7.0	Statewide	DOGAMI (Madin and others, 2021)
Flood	Depth grids: 1% (100-yr) 0.2% (500-yr)	Countywide	FEMA – draft data generated for 2021 Countywide National Flood Insurance Program mapping.
Landslide*	Susceptibility (Low, Moderate, High, Very High)	Statewide	DOGAMI (Burns and others, 2016)
Channel Migration	Susceptibility (Not Exposed, Exposed)	Portions of Hood River within the study area	DOGAMI (Burns and others, 2011) | Natural Systems Design (Abbe and others, 2015)
Wildfire	Risk (Low, Moderate, High)	Regional (Western United States)	Oregon Department of Forestry (Sanborn Map Company, Inc., 2013)
Lahar	Local source:** S - 10% (10-yr) M - 1% (100-yr) L - 0.2-0.1% (500-1,000-yr) XL - 0.001% (100,000-yr)	Mount Hood	DOGAMI (Burns and others, 2011)

*Landslide data comprise a composite dataset where the level of detail varies greatly from place to place within the state. Refer to Section 3.4.1 or the report by Burns and others (2016) for more information.

**Lahar scenarios: S = Small, M = Medium, L = Large, XL = Extra Large

1.4 Previous Studies

Two previous risk assessments that include Hood River County have been conducted by DOGAMI. Wang and Clark (1999: DOGAMI Special Paper 29) ran two general level Hazus-MH earthquake analyses, a magnitude 8.5 CSZ earthquake and a 500-year probabilistic earthquake scenario, for the entire state of Oregon. In those analyses Hood River County was estimated to experience a minor amount of damage from a magnitude 8.5 CSZ earthquake or the 500-year probabilistic scenario.

Another Hazus-based multi-hazard risk study was conducted for the Mount Hood Region and the Hood River Valley (Burns and others, 2011). In that study, earthquake scenarios were run in Hazus-MH, flood scenarios were run using the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) program, lahar scenarios were run using the GIS-based program LAHARZ (see section 3.7.1 for details) and landslide, wildfire, and channel migration were examined as hazards for the region.

We did not compare the results of this project with the results of the previous studies because of limited time and funding and differences in methodologies.

2.0 METHODS

2.1 Hazus-MH Loss Estimation

According to FEMA (FEMA, 2012a, p. 1-1), "Hazus provides nationally applicable, standardized methodologies for estimating potential wind, flood, and earthquake losses on a regional basis. Hazus can be used to conduct loss estimation for floods and earthquakes [...]. The multi-hazard Hazus is intended for use by local, state, and regional officials and consultants to assist mitigation planning and emergency response and recovery preparedness. For some hazards, Hazus can also be used to prepare real-time estimates of damages during or following a disaster."

Key Terms:

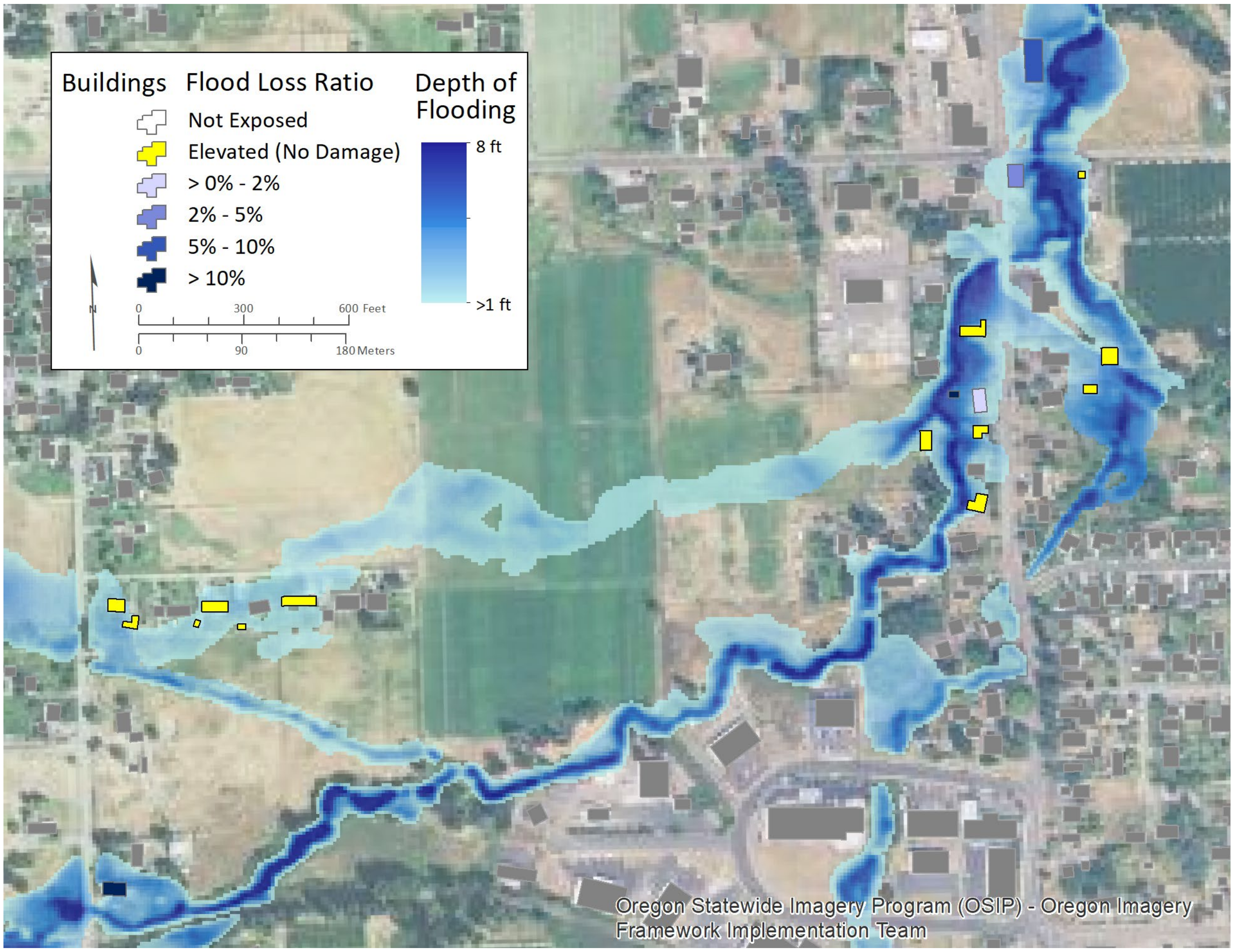
- *Loss estimation:* Damage that occurs to a building in an earthquake or flood scenario, as modeled with Hazus-MH methodology.
- *Loss ratio:* Percentage of estimated loss relative to the total value.

Hazus-MH can be used in different modes depending on the level of detail required. Given the high spatial precision of the building inventory data and quality of the natural hazard data available for this study, we chose the user-defined facility (UDF) mode. This mode makes loss estimations for individual buildings relative to their "cost," which we then aggregate to the community level to report loss ratios. Cost used in this mode are associated with rebuilding using new materials, also known as replacement cost. Replacement cost is based on a method called RSMeans valuation (Charest, 2017) and is calculated by multiplying the building square footage by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus-MH database.

Damage functions are at the core of Hazus-MH. The damage functions stored within the Hazus-MH data model were developed and calibrated from the observed results of past disasters. Estimates of loss are made by intersecting building locations with natural hazard layers and applying damage functions based on the hazard severity and building characteristics. **Figure 2-1** illustrates the range of building loss estimates from Hazus-MH flood analysis.

We used Hazus-MH version 3.0 (FEMA, 2015), which was the latest version available when we began this risk assessment.

Figure 2-1. 100-year flood zone and building loss estimates example in the community of Odell.



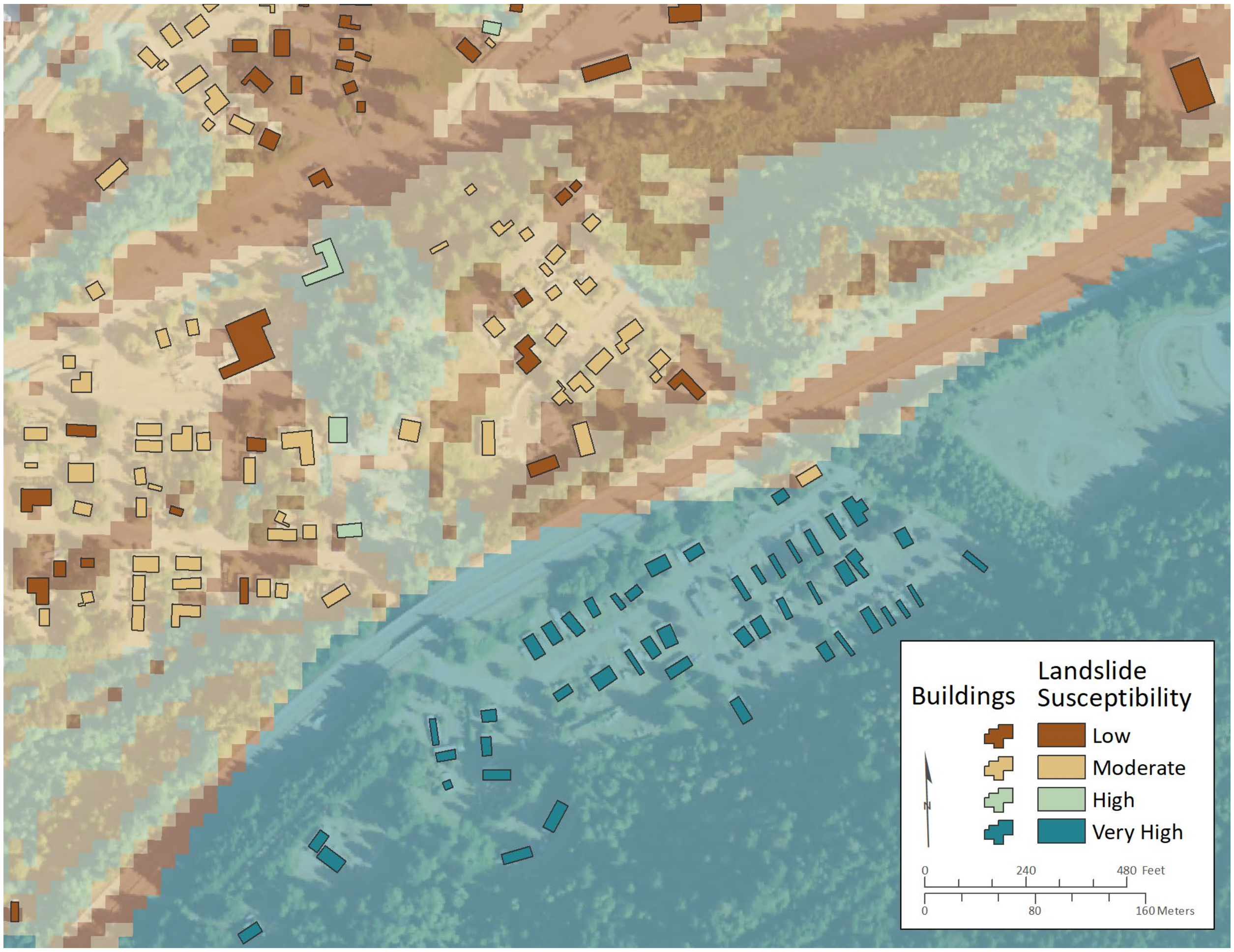
2.2 Exposure

> ***Key Terms:***
> - *Exposure:* Determination of whether a building is within or outside of a hazard zone. No loss estimation is modeled.
> - *Building value:* Total monetary value of a building. This term is used in the context of exposure.

Exposure methodology identifies the buildings and population that are within a particular natural hazard zone. This is an alternative for natural hazards that do not have readily available damage functions to relate damage to the intensity of the hazard. It provides a way to easily quantify what is and what is not threatened. Exposure results are communicated in terms of total building value exposed, rather than a loss estimate because without a damage function a loss ratio cannot be calculated. For example, **Figure 2-2** shows buildings that are exposed to different areas of landslide susceptibility.

Exposure is used for landslide, wildfire, channel migration, and lahar. For comparison with loss estimates, exposure is also used for the 1% annual chance flood.

Figure 2-2. Landslide susceptibility areas and building exposure example in the Hood River County.



2.3 Building Inventory

A key piece of the risk assessment is the countywide building inventory. This inventory consists of all buildings larger than 500 square feet (46 square meters), as determined from existing building footprints. **Figure 2-3** shows an example of building inventory occupancy types used in the Hazus-MH and exposure analyses in Hood River County. See also **Appendix B, Table B-1** and **Appendix E, Plate 1** and **Plate 2.**

To use the building inventory within the Hazus-MH methodology, we converted the building footprints to points and migrated them into a UDF database with standardized field names and attribute domains. The UDF database formatting allows for the correct damage function to be applied to each building. Hazus-MH version 2.1 technical manuals (FEMA, 2012a, 2012b, 2012c) provide references for acceptable field names, field types, and attributes. The fields and attributes used in the UDF database (including building seismic codes) are discussed in more detail in **Appendix C.2.2.**

Figure 2-3. Building occupancy types, City of Hood River, Oregon.

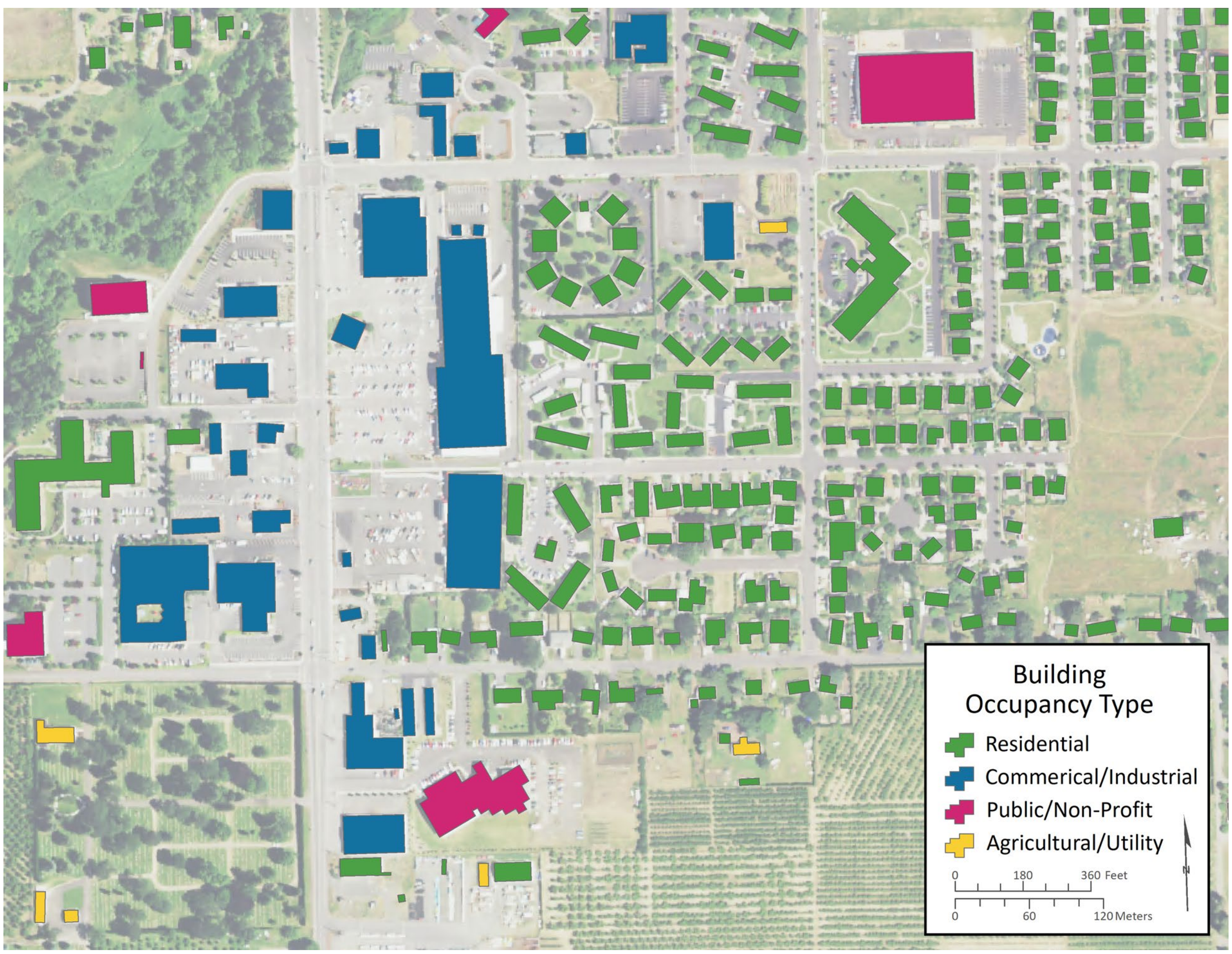


Table 2-1 shows the distribution of building count and value within the UDF database for Hood River County. A table detailing the occupancy class distribution by community is included in **Appendix B: Detailed Risk Assessment Tables**.

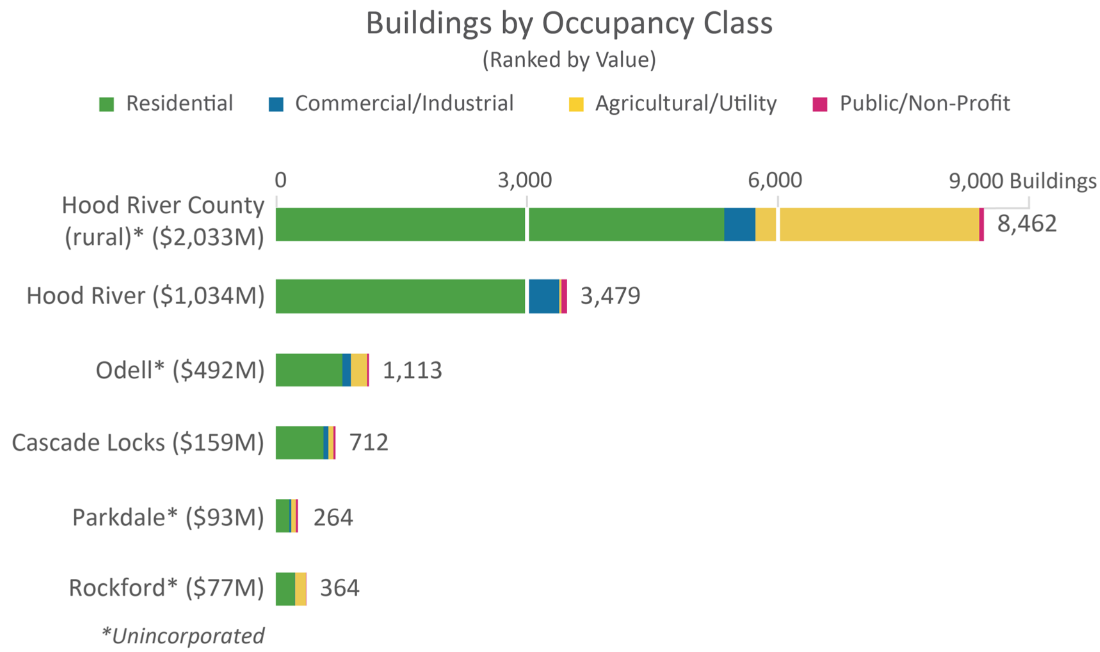
Table 2-1. Hood River County building inventory.

Community	Total Number of Buildings	Percentage of Buildings of Hood River County	Total Estimated Building Value ($)	Percentage of Building Value of Hood River County
Unincorporated County (rural)	8,462	58%	2,033,052,000	52%
Odell	1,113	8%	491,501,000	13%
Parkdale	264	2%	93,342,000	2%
Rockford	364	3%	76,960,000	2%
Total Unincorporated County	10,203	71%	2,694,855,000	69%
Cascade Locks	712	4.9%	158,540,000	4%
Hood River	3,479	24%	1,033,462,000	27%
Total Hood River County	14,394	100%	3,886,857,000	100%

The building inventory was developed from several data sources and was refined for use in loss estimation and exposure analyses. Building footprints in the database were digitized from high-resolution lidar collected in 2009 (Portland Lidar Consortium and Puget Sound Lidar Consortium, Hood to Coast; see http://www.oregongeology.org/lidar/collectinglidar.htm). The building footprints provide a spatial location and 2D representation of a structure. The total number of buildings within the study area was 14,394.

Hood River County supplied assessor data and it was formatted for use in the risk assessment. The assessor data contains an array of information about each improvement (i.e., building). Tax lot data, which contains property boundaries and other information regarding the property, was obtained from the county assessor and was used to link the buildings with assessor data. The linkage between the two datasets resulted in a database of UDF points that contain attributes for each building. These points are used in the risk assessments for both loss estimation and exposure analysis. **Figure 2-4** illustrates the building value and occupancy class across the communities of Hood River County.

Figure 2-4. Community building value in Hood River County by occupancy class.



Note that "Hood River County (rural)" excludes incorporated communities, Odell, Parkdale, and Rockford.

We attributed critical facilities in the UDF database so that they could be highlighted in the results. Critical facilities data came from the DOGAMI Statewide Seismic Needs Assessment (SSNA; Lewis, 2007). We updated the SSNA data by reviewing Google Maps™ data. The critical facilities we attributed include hospitals, schools, fire stations, police stations, emergency operations, and military facilities. In addition to these standard building types, we considered other building types based on local input or special considerations that are specific to the study area that would be essential during a natural hazard event, such as public works and water treatment facilities. Critical facilities are important to note because these facilities play a crucial role in emergency response efforts. Communities that have critical facilities that can function during and immediately after a natural disaster are more resilient than those with critical facilities that are inoperable after a disaster. **Table 2-2** shows the critical facilities on a community basis. Critical facilities are listed for each community in **Appendix A**.

Table 2-2. Hood River County critical facilities inventory.

Community	Hospital & Clinic		School		Police/Fire		Emergency Services		Military		Other*		Total	
	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)
(all dollar amounts in thousands)														
Unincorp. County (rural)	0	0	2	39,900	4	3,054	1	1,248	0	0	4	2,251	11	46,453
Odell	0	0	2	27,340	2	1,702	0	0	0	0	0	0	4	29,042
Parkdale	0	0	1	6,576	1	2,239	0	0	0	0	1	929	3	9,744
Rockford	0	0	0	0	1	1,596	0	0	0	0	0	0	1	1,596
Total Unincorp. County	0	0	5	73,816	8	8,591	1	1,248	0	0	5	3,180	19	86,835
Cascade Locks	0	0	1	6,229	1	1,624	1	1,550	0	0	3	3,159	6	12,562
Hood River	1	19,095	2	18,478	2	3,429	2	3,300	1	2,165	2	8,449	10	54,916
Total Hood River Co.	1	19,095	8	98,523	11	13,644	4	6,098	1	2,165	10	14,788	35	154,313

Note: Facilities with multiple buildings were consolidated into one building.

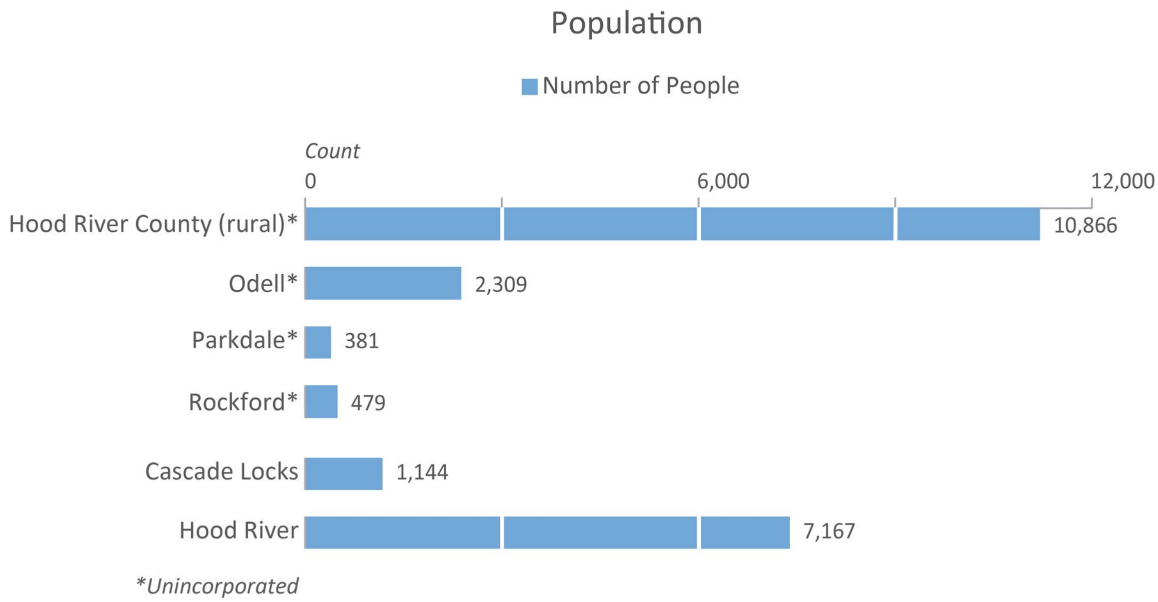
* Category includes buildings that are not traditional (emergency response) critical facilities but considered critical during an emergency based on input from local stakeholders (e.g., water treatment facilities or airports).

2.4 Population

Within the UDF database, the population of permanent residents reported per census block was distributed among residential buildings and pro-rated based on square footage (**Figure 2-5**). We did not examine the impacts of natural hazards on non-permanent populations (e.g., tourists), whose total numbers fluctuate seasonally. Due to lack of information within the assessor and census databases, the distribution includes vacation homes, which in many communities make up some of the total residential building stock. From information reported in the 2010 U.S. Census, American FactFinder regarding vacation rentals within the county, it is estimated that approximately 5% of residential buildings are vacation rentals in Hood River County (U.S. Census Bureau, 2010b).

From the census data, we analyzed the 22,346 residents within the study area that could be affected by a natural hazard scenario. For each natural hazard, with the exception of the earthquake scenario, a simple exposure analysis was used to find the number of potentially displaced residents within a hazard zone. For the earthquake scenario the number of potentially displaced residents was based on residents in buildings estimated to be significantly damaged by the earthquake.

Figure 2-5. Population by Hood River County community.



3.0 ASSESSMENT OVERVIEW AND RESULTS

This risk assessment considers six natural hazards (earthquake, flood, landslide, channel migration, wildfire, and volcanic lahar) that pose a risk to Hood River County. The assessment describes both localized vulnerabilities and the widespread challenges that impact all communities. The loss estimation and exposure results, as well as the rich dataset included with this report, can lead to greater understanding of the potential impact of disasters. Communities can use the results to update plans as part of the work toward becoming more resilient to future disasters.

3.1 Hazards and Countywide Results

In this section, results are presented for the entire study area. The study area includes all unincorporated areas, unincorporated communities, and cities within Hood River County. Individual community results are in **Appendix A: Community Risk Profiles**.

3.2 Earthquake

An earthquake is a sudden movement of rock on each side of a fault in the earth's crust that abruptly releases strain accumulated over a long period of time. The movement along the fault produces waves of strong shaking that spread in all directions. If an earthquake occurs near populated areas, it may cause causalities, economic disruption, and extensive property damage (Madin and Burns, 2013).

Two earthquake-induced hazards are liquefaction and landslides. Liquefaction occurs when saturated soils substantially lose bearing capacity due to ground shaking, causing the soil to behave like a liquid; this action can be a source of tremendous damage. Coseismic landslides are mass movement of rock, debris, or soil induced by ground shaking. All earthquake damages in this report include damages derived from shaking and from liquefaction and landslide factors.

3.2.1 Data sources

Hazus-MH offers two scenario methods for estimating loss from earthquake, probabilistic and deterministic (FEMA, 2012b). A probabilistic scenario uses U.S. Geological Survey (USGS) National Seismic Hazard Maps which are derived from seismic hazard curves calculated on a grid of sites across the United States that describe the annual frequency of exceeding a set of ground motions as a result of all possible earthquake sources (USGS, 2017). A deterministic scenario is based on a specific seismic event, such as a Cascadia Subduction Zone magnitude 9.0 event. We used the probabilistic scenario method for this study along with the UDF database so that loss estimates could be calculated on a building-by-building basis.

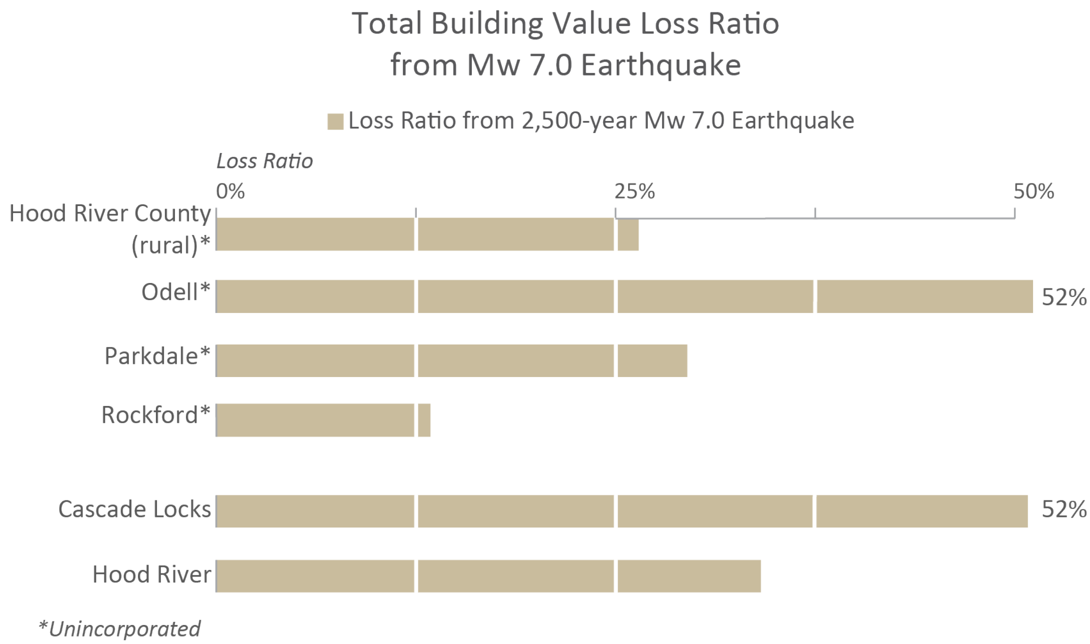
The 2% in 50 years or 2,500-year (actually 2,475-year) probabilistic shaking map by Madin and others (2021) was selected as the most appropriate for communicating earthquake risk for Hood River County. We based this decision on several factors such as previous Hazus-MH earthquake analyses in the region, available seismic data (historical events, fault locations, etc.), existing building code standards, and an analysis that simulates a worst-case scenario. It is important to note that the probabilistic shaking map is based on the highest level of shaking that could reasonably be expected to occur once every 2,475 years. For practical purposes it can be considered a worst-case event, although it does not represent shaking that occurs simultaneously in a single earthquake. The probabilistic earthquake results should be used carefully for risk assessment and emergency response planning purposes.

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): National Earthquake Hazard Reduction Program (NEHRP) soil classification, peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03), and liquefaction susceptibility. We also used landslide susceptibility data derived from the work of Burns and others (2016). The liquefaction and landslide susceptibility layers together with PGA were used by the Hazus-MH tool to calculate the probability and magnitude of permanent ground deformation caused by these factors. Although the probabilistic shaking map encompasses all possible earthquake sources, Hazus uses a characteristic magnitude value to calculate the impacts of liquefaction and landslides. For this study, we followed the example of Madin and others (2021) and used Mw 7 as the characteristic event.

3.2.2 Countywide results

Because an earthquake can affect a wide area, it is unlike other hazards in this report—every building in Hood River County is exposed to significant probabilistic shaking hazard (though not necessarily simultaneously). Hazus-MH loss estimates (see **Appendix B, Table B-2)** for each building are based on a formula where coefficients are multiplied by each of the five damage state percentages (none, low, moderate, extensive, and complete). These damage states are correlated to loss ratios that are then multiplied by the building dollar value to obtain a loss estimate (FEMA, 2012b). **Figure 3-1** shows the loss estimates by community for Hood River County from an earthquake scenario described in this report.

Figure 3-1. Earthquake loss ratio by Hood River County community.



In keeping with earthquake damage reporting conventions, we used the ATC-20 post-earthquake building safety evaluation color-tagging system to represent damage states (Applied Technology Council, 2015). Red-tagged buildings correspond to a Hazus-MH damage state of "complete," which means the building is uninhabitable. Yellow-tagged buildings are in the "extensive" damage state, indicating limited habitability. The number of red or yellow-tagged buildings we report for each community is based on an aggregation of the probabilities for individual buildings (FEMA, 2012b).

Critical facilities were considered non-functioning if the Hazus-MH earthquake analysis showed that a building or complex of buildings had a greater than 50% chance of being at least moderately damaged (FEMA, 2012b). Because building specific information is more readily available for critical facilities and due to their importance after a disaster, we chose to report the results of these buildings individually.

The number of potentially displaced residents from an earthquake scenario described in this report was based on the formula: ([Number of Occupants] * [Probability of Complete Damage]) + (0.9 * [Number of Occupants] * [Probability of Extensive Damage]) (FEMA, 2012b). The probability of damage state was determined in the Hazus-MH earthquake analysis results.

Hood River County 2,500-year probabilistic Mw 7.0 earthquake results:

- Number of red-tagged buildings: 628
- Number of yellow-tagged buildings: 1,929
- Loss estimate: $1,309,753,000
- Loss ratio: 34%
- Non-functioning critical facilities: 31
- Potentially displaced population: 1,100

The results indicate that Hood River County could incur significant losses (34%) due to the earthquakes represented in the probabilistic shaking map. These results are strongly influenced by ground deformation from liquefaction. Moderate to high liquefaction susceptibility exists throughout the county, which increases the risk from earthquake. Developed areas in the communities of Cascade Locks, Odell, and Hood River that are built on highly liquefiable soils have higher estimates of damage from this earthquake scenario than other communities in the study area.

Although damage caused by coseismic landslides was not specifically looked at in this report, it likely contributes a small amount of the estimated damage from the earthquake hazard in Hood River County. Landslide exposure results show that 7% of buildings in Hood River County are within a very high or high susceptibility zone. This indicates that a similar percentage of the loss estimated in this study may be due to coseismic landslide.

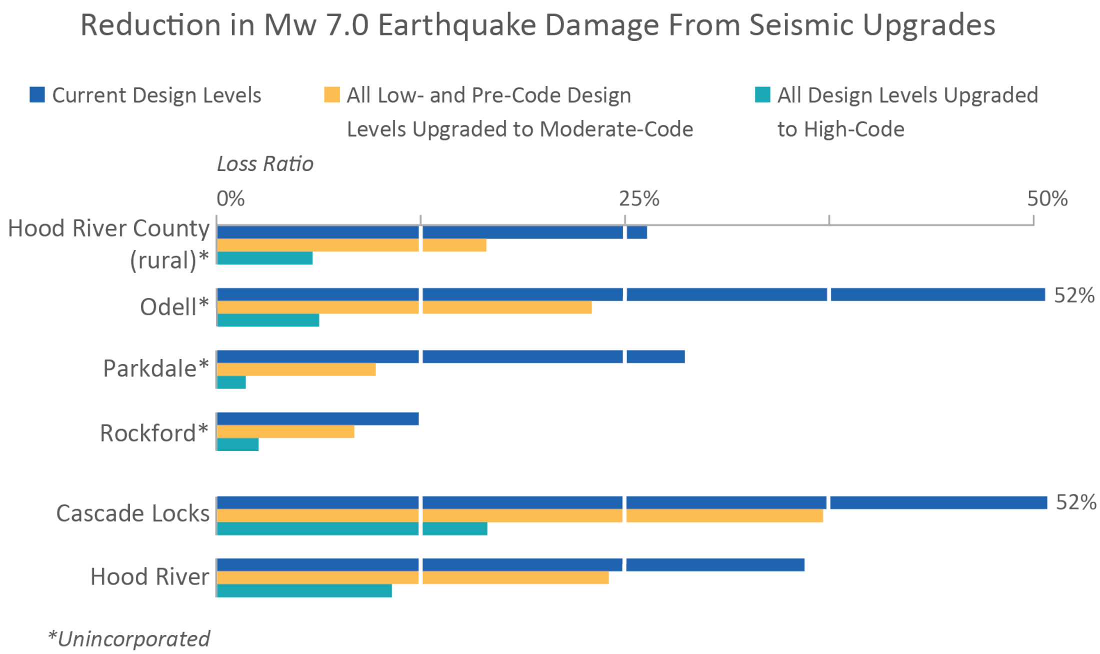
Building vulnerabilities such as the age of the building stock and occupancy type are also contributing factors in damage estimates. The first seismic buildings codes were implemented in Oregon in the 1970's (Judson, 2012) and by the 1990's modern seismic building codes were being enforced. Nearly 70% of Hood River County's buildings were built before this time. In Hazus-MH, manufactured homes are one occupancy type that performs poorly in earthquake damage modeling. Communities that are composed of an older building stock and more vulnerable occupancy types are expected to experience more damage from earthquake than communities with fewer of these vulnerabilities.

If buildings could be seismically retrofitted to moderate or high code standards, earthquake risk would be greatly reduced. In this study, a simulation in Hazus-MH earthquake analysis shows that loss ratios drop from 34% to 20%, when all buildings are upgraded to at least moderate code level. While retrofits can decrease earthquake vulnerability, for areas of high landslide or liquefaction, additional geotechnical mitigation may be necessary to have an effect on losses. **Figure 3-2** illustrates the reduction in loss estimates from the probabilistic Mw 7.0 earthquake through two simulations where all buildings are upgraded to moderate code standards or to high code standards.

Key Terms:

- *Seismic retrofit:* Structural modification to a building that improves its resilience to earthquake.
- *Design level:* Hazus-MH terminology referring to the quality of a building's seismic building code (i. e. pre, low, moderate, and high). Refer to **Appendix C.2.3** for more information.

Figure 3-2. 2,500-year probabilistic Mw 7.0 earthquake loss ratio in Hood River County, with simulated seismic building code upgrades.



3.2.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to earthquake hazard:

- High liquefaction areas in Cascade Locks, Hood River, and the unincorporated community of Odell which increases the likelihood of substantial ground deformation and building damage from an earthquake.
- Based on the assessor's data used in this study, many buildings in the communities of Odell and Parkdale are older and less likely to meet modern building design standards. Older buildings in these communities may be more vulnerable to substantial damage during an earthquake. However, with the year-built information for many buildings in these communities unavailable, we took a conservative approach (worst-case) and assumed pre-code status. This certainly skewed the damage results higher.
- 31 of the 35 critical facilities in the study area are estimated to be non-functioning due to an earthquake similar to the one simulated in this study.

3.3 Flooding

In its most basic form, a flood is an accumulation of water over normally dry areas. Floods become hazardous to people and property when they inundate an area where development has occurred, causing losses. Floods are a commonly occurring natural hazard in Hood River County and have the potential to create public health hazards and public safety concerns, close and damage major highways, destroy railways, damage structures, and cause major economic disruption. Flood issues like flash flooding, ice jams, post-wildfire floods, and dam safety were not examined in this report.

A typical method for determining flood risk is to identify the probability of flooding and the impacts of flooding. The annual probabilities calculated for flood hazard used in this report are 1%, and 0.2%, henceforth referred to as 100-year and 500-year scenarios, respectively. The ability to assess the probability of a flood, and the level of accuracy of that assessment is influenced by modeling methodology advancements, better knowledge, and longer periods of record for the stream or water body in question.

The major streams within the county are the Hood, East Fork Hood, Middle Fork Hood, West Fork Hood, and Columbia rivers and Neal Creek. All the listed rivers are subject to flooding and can cause damage to buildings within the floodplain.

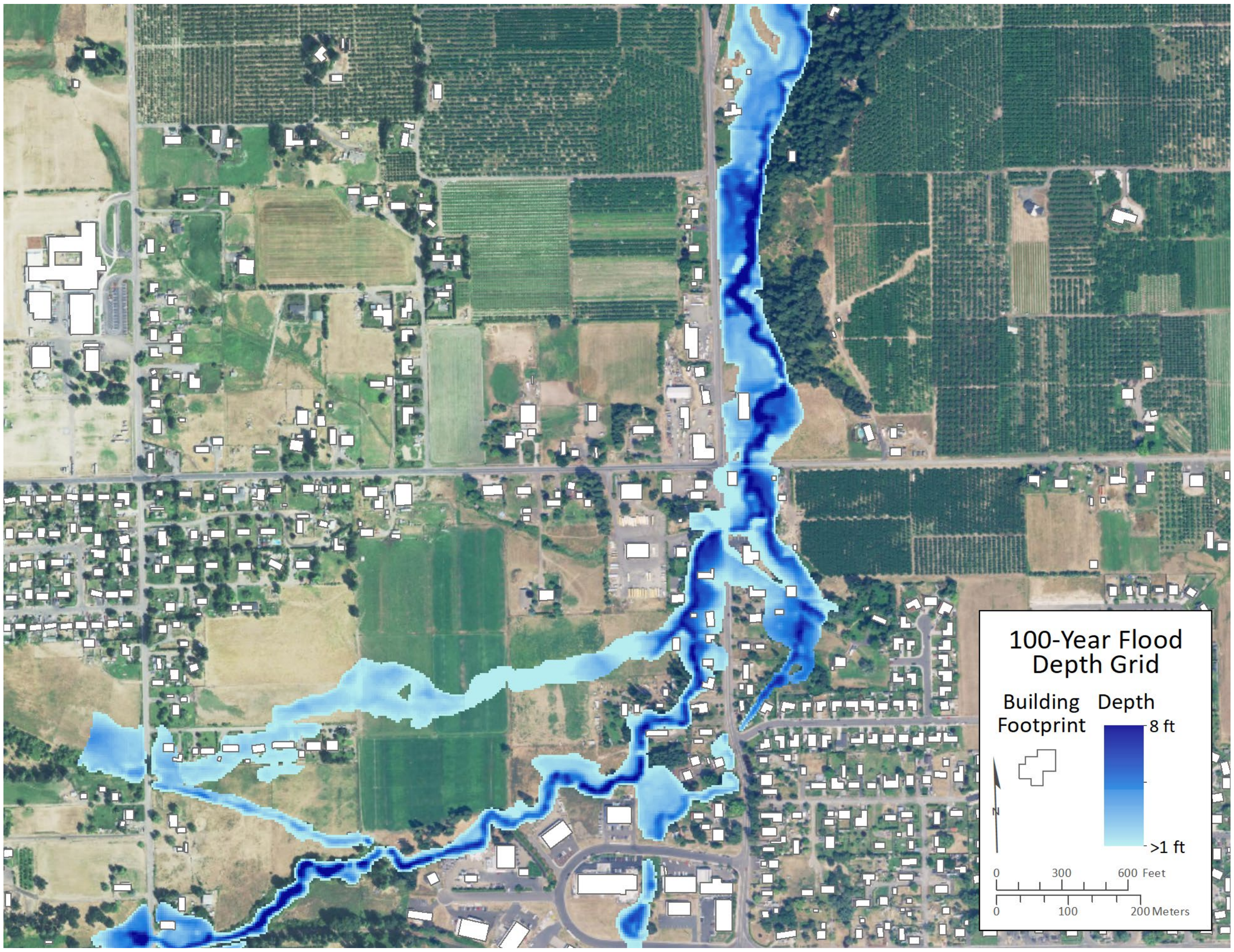
The impacts of flooding are determined by adverse effects to human activities within the natural and built environment. Through strategies such as flood hazard mitigation these adverse impacts can be reduced. Examples of common mitigating activities are elevating structures above the expected level of flooding or removing the structure through FEMA's property acquisition ("buyout") program.

3.3.1 Data sources

The Flood Insurance Study (FIS) and Flood Insurance Rate Maps for Hood River County were in the process of being updated by FEMA as of 2021; this is the primary data source for the flood risk assessment in this report. In doing this update, FEMA provided DOGAMI depth grids for flood risk assessment. These depth grids are considered draft and are subject to possible change. FEMA approved of their usage in this report as they are considered the best available for the study area. Further information regarding the National Flood Insurance Program (NFIP) can be found on the FEMA website: https://www.fema.gov/flood-insurance. These were the only flood data sources that we used in the analysis, but flooding does occur in areas outside of the detailed mapped areas.

The depth grids provided by FEMA were used in this risk assessment to determine the level to which buildings are impacted by flooding. Depth grids are raster GIS datasets in which each digital pixel value represents the depth of flooding at that location within the flood zone **(Figure 3-3)**. Though considered draft at the time of this analysis, the depth grid data are the best available flood hazard data. Depth grids for two flooding scenarios (100- and 500-year) were used for loss estimations and, for comparative purposes, exposure analysis.

Figure 3-3. Flood depth grid example in the community of Odell.



Building loss estimates are determined in Hazus-MH by overlaying building data on a depth grid. Hazus-MH uses individual building information, specifically the first-floor height above ground and the presence of a basement, to calculate the loss ratio from a particular depth of flood.

For Hood River County, occupancy type and basement presence attributes were available from the assessor database for most buildings. Where individual building information was not available from assessor data, we used oblique imagery and street level imagery to estimate these important building attributes. Only buildings in a flood zone or within 500 feet (152 meters) of a flood zone were examined closely to attribute buildings with more accurate information for first-floor height and basement presence. Because our analysis accounted for building first-floor height, buildings that have been elevated above the flood level were not given a loss estimate—but we did count residents in those structures as displaced. We did not look at the duration that residents would be displaced from their homes due to flooding. For information about structures exposed to flooding but not damaged, see the **Exposure analysis** section below.

3.3.2 Countywide results

For this risk assessment, we imported the countywide UDF data and depth grids into Hazus-MH and ran a flood analysis for two flood scenarios (100- and 500-year). We used the 100-year flood scenario as the primary scenario for reporting flood results (also see **Appendix E, Plate 4**). The 100-year flood has traditionally been used as a reference level for flooding and is the standard probability that FEMA uses for regulatory purposes. See **Appendix B, Table B-4** for multi-scenario cumulative results.

Hood River countywide 100-year flood loss:

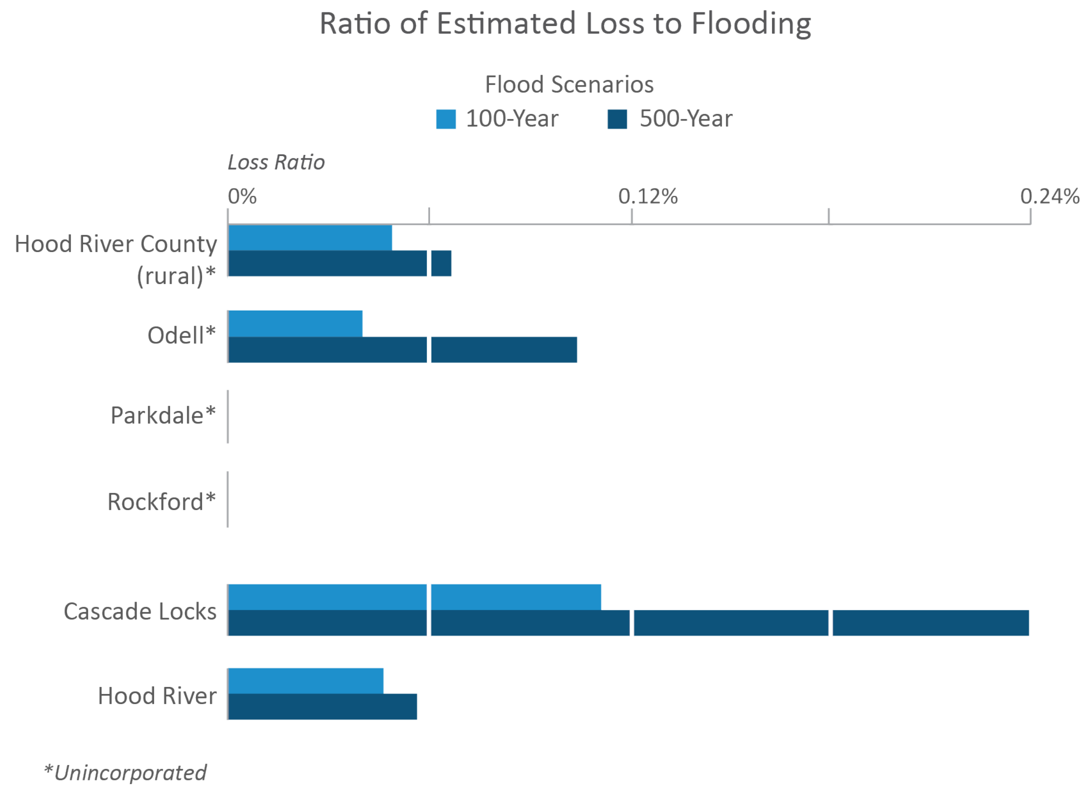
- Number of buildings damaged: 68
- Loss estimate: $1,489,000
- Loss ratio: 0.04%
- Damaged critical facilities: 1
- Potentially displaced population: 166

3.3.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario for the entire county is more than $1.4 million. While the overall loss ratio for flood damage in Hood River County is only 0.04%, 100-year flooding has a moderate impact to Hood River County where development exists near streams that are prone to flooding (**Figure 3-4**). In situations with communities where most residents are not within flood designated zones, the loss ratio may not be as helpful as the actual replacement cost and number of residents displaced to assess the level of risk from flooding. The Hazus-MH analysis also provides useful flood data on individual communities so that planners can identify problems and consider which mitigating activities will provide the greatest resilience to flooding.

The main flooding problems within Hood River County are limited a small residential area in Cascade Locks due to potential flooding from Dry Creek and in the community of Odell from Odell Creek. Other communities, such as Parkdale and Rockford, are estimated to have no damages from flooding (**Figure 3-4**). There are few areas of concentrated flood damage in the study area. The small amount of damage that is estimated is scattered across the county at various places along the mapped streams.

Figure 3-4. Ratio of flood loss estimates by Hood River County community.



3.3.4 Exposure analysis

Separate from the Hazus-MH flood analysis, we did an exposure analysis by overlaying building locations on the 100-year flood extent. We did this to estimate the number of buildings that are elevated above the level of flooding and the number of displaced residents. This was done by comparing the number of non-damaged buildings from Hazus-MH with the number of exposed buildings in the flood zone. Some (1.2%) of Hood River County's buildings were found to be within designated flood zones. Of the 163 buildings that are exposed to flooding, we estimate that 95 are above the height of the 100-year flood. This evaluation also estimates that 166 residents might have mobility or access issues due to surrounding water. See **Appendix B, Table B-5** for community-based results of flood exposure.

3.3.5 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to flood hazard:

- A small area of residential building in Cascade Locks is at risk from flooding from Dry Creek.
- A section of buildings in Odell is at risk from flooding from Odell Creek.

3.4 Landslide Susceptibility

Landslides are mass movements of rock, debris, or soil most commonly downhill. There are many different types of landslides in Oregon. In Hood River County, the most common are debris flows and shallow- and deep-seated landslides. Landslides can occur in many sizes, at different depths, and with varying rates of movement. Generally, they are large, deep, and slow moving or small, shallow, and rapid.

Some factors that influence landslide type are hillside slope, water content, and geology. Many triggers can cause a landslide: intense rainfall, earthquakes, or human-induced factors like excavation along a landslide toe or loading at the top. Landslides can cause severe damage to buildings and infrastructure. Fast-moving landslides may pose life safety risks and can occur throughout Oregon (Burns and others, 2016).

3.4.1 Data sources

The Statewide Landslide Information Layer for Oregon (SLIDO), release 3.2 (Burns and Watzig, 2014) is an inventory of mapped landslides in the state of Oregon. SLIDO is a compilation of past studies; some studies were completed very recently using new technologies, like lidar-derived topography, and some studies were performed more than 50 years ago. Consequently, SLIDO data vary greatly in scale, scope, and focus and thus in accuracy and resolution across the state.

Burns and others (2016) used SLIDO inventory data along with maps of generalized geology and slope to create a landslide susceptibility overview map of Oregon that shows zones of relative susceptibility: Very High, High, Moderate, and Low. SLIDO data directly define the Very High landslide susceptibility zone, while SLIDO data coupled with statistical results from generalized geology and slope maps define the other relative susceptibility zones (Burns and others, 2016). Statewide landslide susceptibility map data have the inherent limitations of SLIDO and of the generalized geology and slope maps used to create the map. Therefore, the statewide landslide susceptibility map varies significantly in quality across the state, depending on the quality of the input datasets. Another limitation is that susceptibility mapping does not include some aspects of landslide hazard, such as runout, where the momentum of the landslide can carry debris beyond the zone deemed to be a high hazard area.

The quality of mapping within the study area varies in accuracy from inventory mapping conducted during the 1980’s and 1990’s to high-quality lidar derived inventory for the slopes of Mount Hood and the Hood River Valley as discussed in Multi-Hazard and Risk Study for the Mount Hood Region, Multnomah, Clackamas, and Hood River Counties, Oregon (Burns and others, 2011). While much of the uninhabited portions of the study area and the City of Cascade Locks were mapped using older techniques and would benefit from newer mapping methods outlined in DOGAMI Special Paper 42 (SP-42: Burns and others, 2009), nearly 94% of the building inventory in the study area has been mapped using the newer technique.

We used the data from the statewide landslide susceptibility map (Burns and others, 2016) in this report to identify the general level of susceptibility of given area to landslide hazards, primarily shallow and deep landslides. We overlaid building and critical facilities data on landslide susceptibility zones to assess the exposure for each community (see **Appendix B, Table B-6**). The total dollar value of exposed buildings was summed for the study area and is reported below. We also estimated the number of people threatened by landslides. Land value losses due to landslides and potentially hazardous unmapped areas that may pose real risk to communities were not examined for this report.

3.4.2 Countywide results

Some of Hood River County’s communities have a moderate amount of exposure to landslide hazard. Communities that developed in terrain with moderate to steep slopes or at the base of steep hillsides may be exposed to landslides. Some developed areas in Cascade Locks and the City of Hood River are highly susceptible to landslide hazard. While these areas are highly prone to landslides, most of the populated areas are outside these zones. The percentage of building value exposed to very high and high landslide susceptibility is approximately 7% for the entire study area.

We combined high and very high susceptibility zones as the primary scenarios to provide a general sense of community risk for planning purposes (see **Appendix E, Plate 5**). It was useful to combine exposure for both susceptibility zones to best communicate the level of landslide risk to communities. These susceptibility zones represent areas most susceptible to landslides with the highest impact to the community.

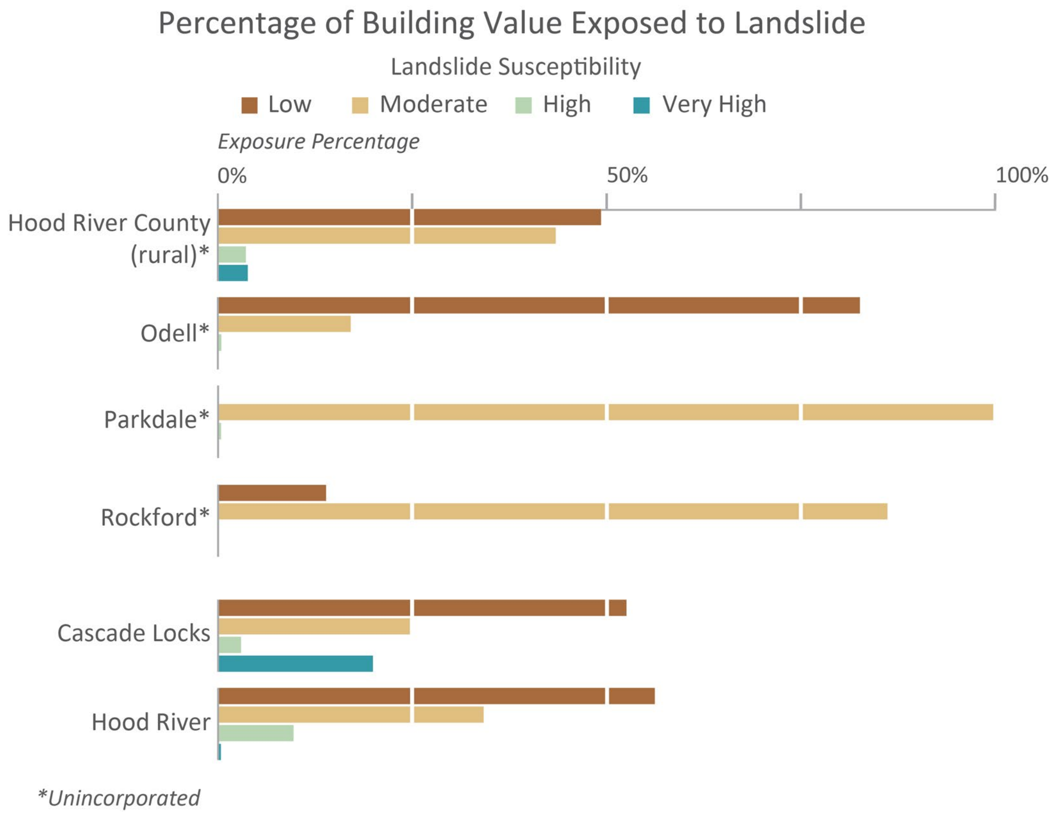
For this risk assessment we compared building locations to geographic extents of the landslide susceptibility zones (**Figure 3-5**). The exposure results shown below are for the high and very high susceptibility zones. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Hood River countywide landslide exposure (High and Very High susceptibility):

- Number of buildings: 1,286
- Value of exposed buildings: $286,860,000
- Percentage of total county value exposed: 7.4%
- Critical facilities exposed: 3
- Potentially displaced population: 1,642

Most of the developed land in Hood River County is located on the gentle terrain found in the river valleys which are typically low susceptibility landslide zones. Despite this development pattern, there are a large number of the study area's buildings that have exposure to high or very high susceptibility to landslides. Landslide hazard is ubiquitous in a large percentage of undeveloped land and may present challenges for planning and mitigation efforts. Awareness of nearby areas of landslide hazard is beneficial to reducing risk for every community and rural area of Hood River County.

Figure 3-5. Landslide susceptibility exposure by Hood River County community.



3.4.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to landslide hazard:

- The landslide hazard for Cascade Locks poses the biggest natural hazard risk to the community. A preexisting landslide zone, which is considered very high susceptibility to landslides, has been designated for a significant portion of Cascade Locks.
- The hilly portions of Hood River's downtown have high susceptibility to landslides.

3.5 Wildfire

Wildfires are a natural part of the ecosystem in Oregon. However, wildfires can present a substantial hazard to life and property because communities often grow into the transition areas between developed areas and undeveloped areas, commonly called the wildland-urban interface (WUI) (Sanborn Map Company, Inc., 2013). The most common wildfire conditions include 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, its behavior is influenced by numerous conditions, including fuel, topography, weather, drought, and development (Sanborn Map Company, Inc., 2013). Post-wildfire geologic hazards can also present risk. These usually include flooding, debris flows, and landslides. Post-wildfire geologic hazards were not evaluated in this project.

There is potential for losses due to WUI fires in Hood River County. According to the Forests cover approximately 70% of Hood River County. Forests play an important role in the local economy but also surround homes and businesses (Mackwell, 2006). To limit exposure to wildfire, the Hood River County Zoning Ordinance requires a 50-foot (15-meter) firebreak and a 100-foot (30-meter) secondary firebreak for dwellings built in forested zones (Hood River County Community Development, 2017). Contact the Hood River County Community Development for specific requirements related to the county's comprehensive plan.

3.5.1 Data sources

The West Wide Wildfire Risk Assessment (WWA; Sanborn Map Company, Inc., 2013) is a comprehensive report that includes a database developed over the course of several years for 17 Western states and some Pacific Islands. The steward of this database in Oregon is the Oregon Department of Forestry (ODF). The database was created to assess the level of risk residents and structures have to wildfire. For this project, the Fire Risk Index (FRI) dataset, a dataset included in the WWA database, was used to measure the level of risk to communities in Hood River County.

Using guidance from ODF, we categorized the FRI into low, moderate, and high hazard zones for the wildfire exposure analysis. The FRI hazard zones are based on a combination of the impacts of wildfire (Fire Effects Index) and the probability of wildfire (Fire Threat Index). Both indices are the result of an integration of several input datasets. Broadly, the Fire Effects Index is based on potentially impacted assets and the difficulty of suppression. The components that make up the Fire Threat Index are fire occurrence, fire behavior, and fire suppression effectiveness (Sanborn Map Company, Inc., 2013).

We overlaid the buildings layer and critical facilities on each of the wildfire hazard zones to determine exposure. In certain areas no wildfire data are present which indicates areas that have minimal risk to wildfire hazard (see **Appendix B, Table B-8**). The total dollar value of exposed buildings in the study area is reported below. We also estimated the number of people threatened by wildfire. Land value losses due to wildfire were not examined for this project.

3.5.2 Countywide results

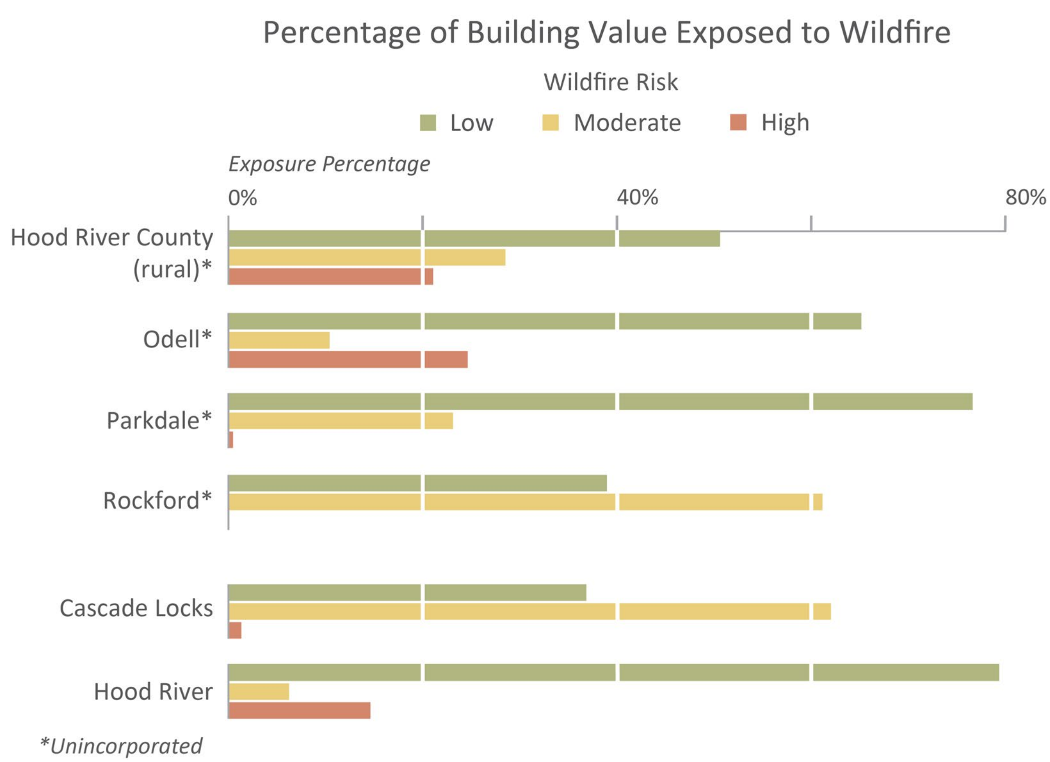
The high hazard category was chosen as the primary scenario for this report because that category represents areas that have the highest potential for losses. However, a large amount of loss would occur if the moderate hazard areas were to burn, as almost every community has at least 20% of exposure to moderate or high wildfire hazard. Still, the focus of this section is on high hazard areas within Hood River County to emphasize the areas where lives and property are most at risk.

Hood River countywide wildfire exposure (High hazard):

- Number of buildings: 2,537
- Value of exposed buildings: $700,357,000
- Percentage of total county value exposed: 18%
- Critical facilities exposed: 5
- Potentially displaced population: 4,142

For this risk assessment, the building locations were compared to the geographic extent of the wildfire risk categories. Some of the communities in Hood River County have high risk exposure to wildfire. The primary areas of exposure to this hazard are in the forested unincorporated areas along and to the east of state Highway 35 (see **Appendix E, Plate 6**). The communities of Hood River and Odell are at a higher risk to wildfire than other communities in the study area. **Figure 3-6** illustrates the level of risk from wildfire for the different communities of Hood River County. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Figure 3-6. Wildfire hazard exposure by Hood River County community.



3.5.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to wildfire hazard:

- Exposure to wildfire risk is high for many homes in the forested areas of the county along and to the east of state Highway 35.
- The City of Hood River is especially threatened by wildfire with 15% of the buildings being exposed to high wildfire risk.
- Exposure to wildfire risk is high for the eastern portions of the community of Odell.

3.6 Channel Migration

Channel migration is a dynamic process by which a stream's course changes over time due to bank erosion and stream deposition. Many factors determine stream channel volatility. The steepness of terrain, sensitivity to erosion, channel shape, water volume, and the size and shape of the floodplain are the primary determining factors for how a channel changes its course. These factors affect how energy is dispersed from high water flows. Straight and confined streams have high erosive power, while wide and flat floodplains slow the flow, deposit sediments, and allow a channel to meander and create secondary channels (Rapp and Abbe, 2003).

The area in which a stream channel moves laterally over a given time is known as a channel migration zone (CMZ). In places where development has occurred within the CMZ, structures are at risk for severe damage to foundations and infrastructure. The CMZ typically extends beyond the limits of the regulatory floodplain, but little consideration is given to this potential hazard. This factor contributes greatly to the level of risk that exists for many developed areas along streams (Rapp and Abbe, 2003).

3.6.1 Data sources

The channel migration zones used for this report were developed for portions of Hood River by English and others (2013). The approach used to define the CMZ is based on methods developed by Rapp and Abbe (2003) and combines several related zones which together encompass the area in which a stream channel is expected to move. CMZ exposure combines areas of know migration, historical channel position, and erosion potential within the floodplain (Rapp and Abbe, 2003). An analysis includes the geology of the region because some rock types, deposits, and soils influence the mutability of the channel.

To assess the exposure for each community, we overlaid buildings and critical facilities on the CMZ. The total dollar value of exposed buildings was summed for the study area and is reported below. We were also able to estimate the number of people potentially displaced from the CMZ. Land value losses due to CMZ were not examined for this report.

3.6.2 Countywide results

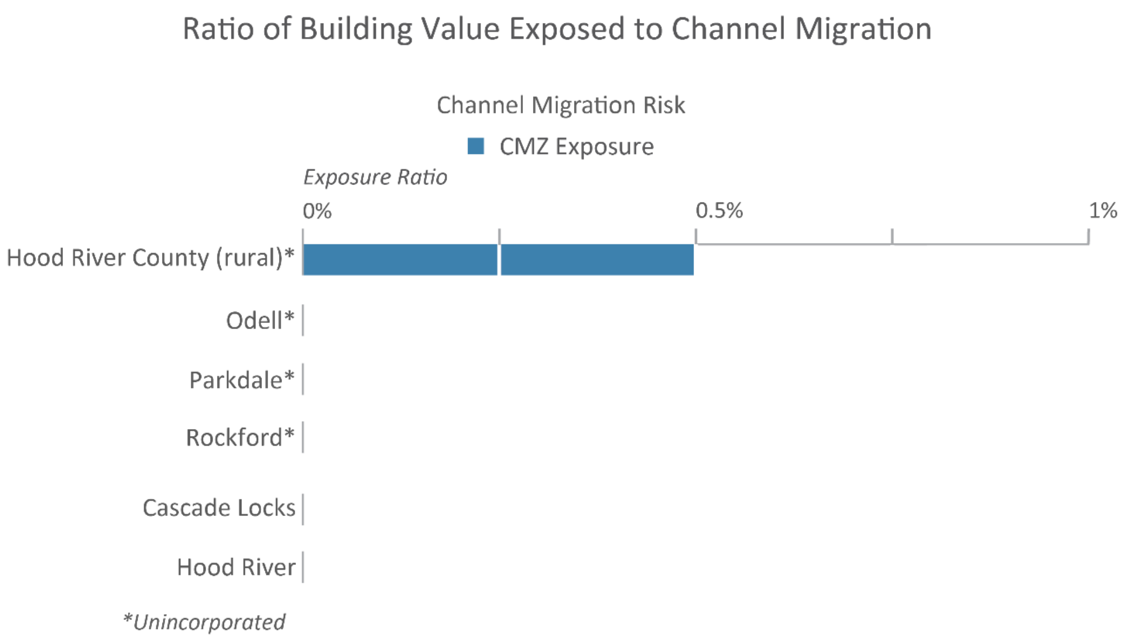
While channel migration areas have been mapped along the Hood River and East Fork Hood River, there is very little exposure to this hazard. To quantify risk, the exposure analysis was conducted by determining which buildings were within or outside of the CMZ (see **Appendix E, Plate 7**). A small number of buildings in the unincorporated county were built within areas where channel migration is likely to occur.

Hood River countywide channel migration exposure:

- Number of buildings: 58
- Value of exposed buildings: $10,117,000
- Percentage of total county value exposed: 0.3%
- Critical facilities exposed: 0
- Potentially displaced population: 60

Most buildings located near the Hood River and East Fork Hood River, where channel migration has been mapped, are outside of the hazardous areas. The areas where exposure to channel migration occurs are along Hood River north of Odell and along East Fork Hood River east of Parkdale. **Figure 3-7** illustrates the distribution of exposed building value due to channel migration with the different communities of Hood River County. See **Appendix B: Detailed Risk Assessment Tables** for complete analysis results.

Figure 3-7. Channel Migration Exposure by Hood River County community.



3.6.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to channel migration hazard:

- Channel migration exposure is a present in areas along Hood River north of Odell and along East Fork Hood River east of Parkdale.

3.7 Volcano Hazard – Lahar

A lahar is a water-saturated mixture of muddy debris and rock fragments that originates from a volcano and flows down channels at a rapid speed. Lahars are typically generated from a volcanic eruption but can be initiated during heavy rains or by a sudden outburst of glacial melt. They are most common when a volcano that is covered with heavy loads of snow and ice erupts. When water mixes with materials from eruptions and lahars, a volcanic debris flow can occur (Driedger and Scott, 2008).

Distal volcanic hazard zones, as opposed to proximal volcanic hazard zones, are hazard types that affect outer areas away from the center of geologic activity. A lahar is considered a distal volcanic hazard, because a lahar is capable of traveling long distances and causing damage (Burns and others, 2011). Because a lahar moves like flowing concrete it has the capacity destroy most things in its path. Lahar deposits tend to exacerbate flooding and channel migration risk in the river valleys that they affect (Driedger and Scott, 2008).

Mount Hood has had several notable eruptions in the past 30,000 years, from which many extensive lahars have been created. The Old Maid eruptive period, which occurred approximately 200 years ago, is the most recent in the region and impacted several streams flowing from Mount Hood (Burns and others, 2011).

3.7.1 Data sources

The lahar zones used in this report were created by Burns and others (2011) using the software application LAHARZ (Iverson and others, 1998). The LAHARZ software is a GIS-based application that calculates the area expected to be within the volcanic debris flow based on certain inputs. The data parameters necessary to run the model are a starting location, a volume of debris material, and a digital elevation model (DEM). The starting locations for modeled runs were placed at points where the total upstream drainage area was greater than 10,700 square feet (994 square meters). This was based on recommendations provided from Griswold and Iverson (2008). Lahar volume amounts used in the model were based on recommendations from Scott and others (1997) and Iverson and others (1998). The different volume amounts used in the final analysis are related to annual probability and recurrence intervals. The recurrence intervals associated with the lahar exposure scenarios are as follows (Burns and others, 2011): XL: 100,000 years; L: 500-1,000 years; M: 100 years; and Sm: 10 years.

For this risk assessment, we compared the location of buildings and critical facilities to the geographic extent of the lahar inundation zones to assess the exposure for each community (see **Appendix E, Plate 7**). The exposure results shown below are for only the medium (M) scenario, but data for other scenarios is provided in **Appendix C**. The total dollar value of exposed buildings was summed for the study area and is reported below. We also estimated the number of people at risk from lahar hazard.

3.7.2 Countywide results

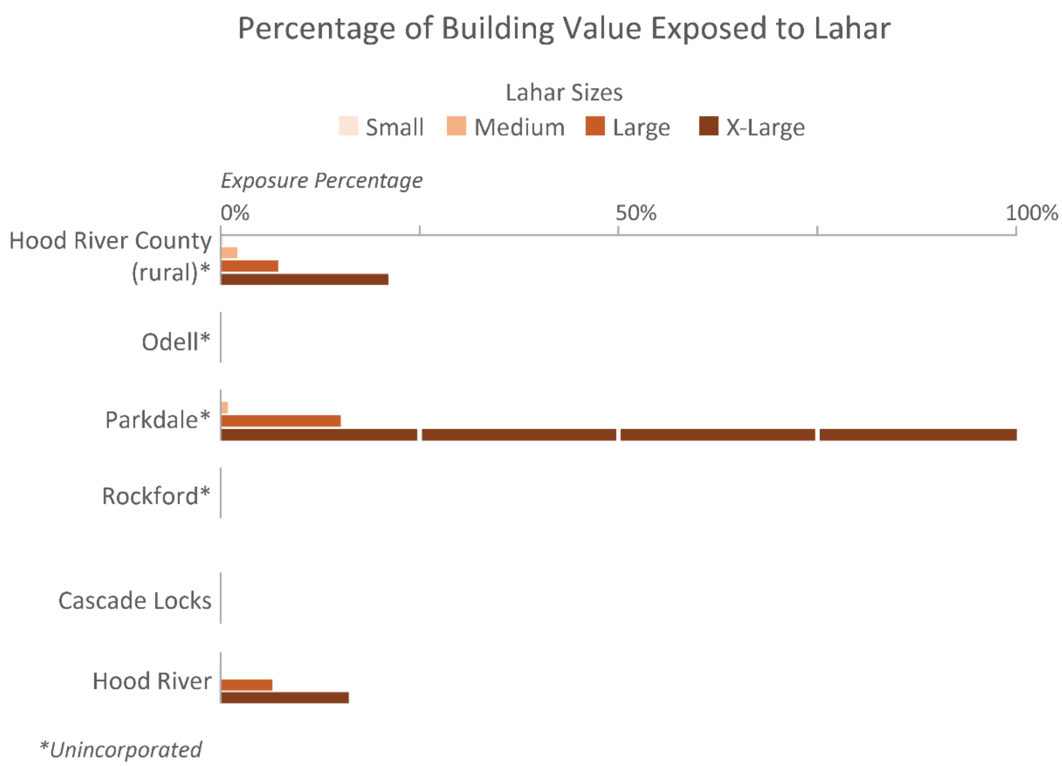
While much of the development in Hood River County is located within the major river valleys originating from Mount Hood, the amount of exposure to lahar hazard is fairly low for the higher frequency intervals. The less probable scenarios, which are much larger events, would have very significant impacts to most of the communities within the Hood River Valley (see **Appendix C**). The community of Parkdale is highly exposed to the large (L) scenario, but a negligible amount in the more likely (M) scenario.

Hood River countywide lahar exposure (Medium):

- Number of buildings: 141
- Value of exposed buildings: $42,019,000
- Percentage of total county value exposed: 1.1%
- Critical facilities exposed: 0
- Potentially displaced population: 226

Most of the buildings located near the Hood River and East Fork Hood River, where lahars are expected to flow from Mount Hood are outside of the hazardous areas. The community of Parkdale is most threatened from a volcanic eruption and lahar event in the study area when the larger, less probable, events are considered. **Figure 3-8** illustrates the distribution of exposed building value due to lahar hazard with the different communities of Hood River County. See **Appendix B: Detailed Risk Assessment Tables** for cumulative multi-scenario analysis results.

Figure 3-8. Lahar exposure by Hood River County community.



3.7.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to lahar hazard:

- The 500-year (M) return scenario is a threat for residents in Parkdale with 15% exposure while the exposure to the 100,000-year (XL) scenario is 100%.

4.0 CONCLUSIONS

The purpose of this study is to provide a better understanding of potential impacts from multiple natural hazards at the community scale. We accomplished this by using the latest natural hazard mapping and loss estimation tools to quantify expected damage to buildings and potential displacement of permanent residents, or determine which buildings and residents are exposed to a hazard. This comprehensive and detailed approach to the analysis provides new context for the county's risk reduction efforts. We note several important findings based on the results of this study:

- **Extensive overall damage and losses can occur from an earthquake—**Based on the results of a 2,500-year probabilistic Mw 7.0 earthquake, every community in Hood River County will experience significant impact and disruption. Results show that an earthquake can cause building losses of 30% to 50% to nearly all communities in the study area. Some communities like Cascade Locks and Odell can expect a high percentage of losses due to ground deformation related to liquefaction. The high vulnerability of the building inventory (building age and occupancy type) and the number of buildings constructed on liquefiable soils contribute to the estimated levels of losses expected in the study area.
- **Retrofitting buildings to modern seismic building codes can reduce damages and losses from earthquake shaking—**Seismic building codes have a major influence on earthquake shaking damage estimated in this study. We examined potential loss reduction from seismic retrofits (modifications that improve building's seismic resilience) in simulations by using Hazus-MH building code "design level" attributes of pre, low, moderate, and high codes (FEMA, 2012b) in earthquake scenarios. The simulations were accomplished by upgrading every pre (non-existent) and low seismic code building to moderate seismic code levels in one scenario, and then by upgrading all buildings to high (current) code in another scenario. We found that retrofitting to at least moderate code was the most cost-effective mitigation strategy because the additional benefit from retrofitting to high code was minimal. In our simulation of upgrading buildings to at least moderate code, the estimated loss for the entire study area was reduced from 34% to 20%. We found further reduction in estimated loss in our simulation to 7.6% by upgrading all buildings to high code. Some communities would see greater loss reduction than the county as a whole due to older building stock constructed at pre or low code seismic building code standards. An example is the community of Odell where a significant loss reduction (from 52% to 24%) could occur by retrofitting all buildings to at least moderate code. This stands in contrast to areas with younger building stock, such as the unincorporated county suburbs around the City of Hood River, which would see small reductions in damage estimates. While seismic retrofits are an effective strategy for reducing earthquake shaking damage, it should be noted that earthquake-induced landslide and liquefaction hazards will also be present in some areas, and these hazards require different geotechnical mitigation strategies. Future research focused on landslide and liquefaction hazard specific risk assessments are areas needing a clear understanding of the hazard to inform local decision-makers.
- **Some communities in the study area are at moderate risk from flooding—**Many buildings within the floodplain are vulnerable to significant damage from flooding. At first glance, Hazus-MH flood loss estimates may give a false impression of lower risk because they show lower damages for a community relative to other hazards we examined. This is due to the difference between loss estimation and exposure results, as well as the limited area impacted by flooding. Another consideration is that flood is one of the most frequently occurring natural hazard. An

average of 5.7% loss was calculated when looking at just the buildings within the 100-year flood zone. The areas that are most vulnerable to flood hazard within the study are some residential buildings in Cascade Locks along Dry Creek and portion of Odell along Odell Creek.

- **Elevating structures in the flood zone reduces vulnerability**—Flood exposure analysis was used in addition to Hazus-MH loss estimation to identify buildings that were not damaged but that were within the area expected to experience a 100-year flood. By using both analyses in this way, the number of elevated structures within the flood zone could be quantified. This showed possible mitigation needs in flood loss prevention and the effectiveness of past activities. For example, in the communities of Odell, Parkdale, Rockford, and the City of Hood River nearly all of the buildings exposed to flooding are elevated above the base flood elevation. Based on the number of buildings exposed to flooding throughout the unincorporated county, many would benefit from elevating above the level of flooding.
- **New landslide mapping would increase the accuracy of estimating landslide risk in the City of Cascade Locks**—The landslide hazard data used in this risk assessment for the City of Cascade Locks was created before the advent of modern mapping technology; future risk assessments using lidar-derived landslide hazard data would provide more accurate results. Exposure analysis was used to assess the threat from landslide hazard. Landslide is present for some communities within the county. The cities of Cascade Locks and Hood River have areas that are exposed to high or very high landslide susceptibility.
- **Wildfire risk is significant for the overall study area**—Exposure analysis shows that buildings along and east of state Highway 35 are more vulnerable to wildfire hazard than the rest of the study area. High wildfire hazard is present throughout the county, with concentrations occurring in the forested portions of the Hood River and Columbia River valleys. The communities of Hood River and Odell, as well as the unincorporated county, have a 15% to 25% exposure to high wildfire hazard.
- **Exposure analysis show that some buildings in the riverine valleys of the study area are at risk to channel migration hazard**—Exposure analysis shows that channel migration hazard is not a threat to communities in the study area from the streams that have been mapped. This hazard can be a consideration for future development along the Hood River and East Fork Hood River.
- **Exposure analysis shows that community of Parkdale at risk to volcanic lahar hazard**—Exposure analysis shows that volcanic lahar hazard is a minor threat to some communities in the study area. The community of Parkdale, while minimally exposed to the 500-year event, is very vulnerable to larger, but less probable events. Parkdale has 100% exposure to the least likely 100,000-year return scenario (XL scenario).
- **Most of the study area's critical facilities are at significant risk to earthquake and wildfire hazards**—Critical facilities were identified and were specifically examined within this report. We have estimated that 89% (31 of 35) of Hood River County's critical facilities will be non-functioning after a 2,500-year probabilistic earthquake. Additionally, 15% (5 of 35) of critical facilities are exposed to high wildfire risk and 9% (3 of 35) to very high or high landslide hazard. We found no exposure of critical facilities to flood, channel migration, or lahar hazards.
- **The biggest causes of displacement to population are earthquake and wildfire hazards**—Potential displacement of permanent residents from natural hazards was estimated within this report. We estimated that 19% of the population in the county to be displaced due an earthquake. Wildfire hazard is a potential threat to 15% of permanent residents and landslide hazard puts 7%

vulnerable to displacement. A small percentage of residents are vulnerable to displacement from flood, channel migration, and lahar hazards.

- **The results allow communities the ability to compare across hazards and prioritize their needs**—Each community within the study area was assessed for natural hazard exposure and loss. This allowed for comparison of risk for a specific hazard between communities. It also allows for a comparison between different hazards, though care must be taken to distinguish loss estimates and exposure results. The loss estimates and exposure analyses can assist in developing plans that address the concerns for those individual communities.

5.0 LIMITATIONS

There are several limitations to keep in mind when interpreting the results of this risk assessment.

- **Spatial and temporal variability of natural hazard occurrence** – Flood, earthquake, landslide, and wildfire are extremely unlikely to occur across the fully mapped extent of the hazard zones. For example, areas mapped in the 1% annual chance flood zone will be prone to flooding on occasion in certain watersheds during specific events, but not all at once throughout the entire county or even the entire community. While we report the overall impacts of a given hazard scenario, the losses from a single hazard event probably will not be as severe and widespread.
- **Loss estimation for individual buildings** – Hazus-MH is a model, not reality, which is an important factor when considering the loss ratio of an individual building. On-the-ground mitigation, such as elevation of buildings to avoid flood loss, has been only minimally captured. Also, due to a lack of building material information, assumptions were made about the distribution of wood, steel, and un-reinforced masonry buildings. Loss estimation is most insightful when individual building results are aggregated to the community level because it reduces the impact of data outliers.
- **Loss estimation versus exposure** – We recommend careful interpretation of exposure results. This is due to the spatial and temporal variability of natural hazards (described above) and the inability to perform loss estimations due to the lack of Hazus-MH damage functions. Exposure is reported in terms of total building value, which could imply a total loss of the buildings in a particular hazard zone, but this is not the case. Exposure is simply a calculation of the number of buildings and their value and does not make estimates about the level to which an individual building could be damaged.
- **Population variability** – Some of the communities in Hood River County have a number of vacation homes and rentals, which are typically occupied during the summer. Our estimates of potentially displaced people rely on permanent populations published in the 2010 U.S. Census (U.S. Census Bureau, 2010b). As a result, we are slightly underestimating the number of people that may be in harm's way on a summer weekend.
- **Data accuracy and completeness** – Some datasets in our risk assessments had incomplete coverage or lacked high-resolution data within the study area. We used lower-resolution data to fill gaps where there was incomplete coverage or where high-resolution data were not available. Assumptions to amend areas of incomplete data coverage were made based on reasonable methods described within this report. However, we are aware that some uncertainty has been introduced from these data amendments at an individual building scale. At community-wide scales the effects of the uncertainties are slight. Data layers in which assumptions were made to

fill gaps are building footprints, population, some building specific attributes, and landslide susceptibility. Many of the datasets included known or suspected artifacts, omissions and errors, identifying or repairing these problems was beyond the scope of the project and are areas needing additional research.

6.0 RECOMMENDATIONS

The following areas of implementation are needed to better understand hazards and reduce risk to natural hazard through mitigation planning. These implementation areas, while not comprehensive, touch on all phases of risk management and focus on awareness and preparation, planning, emergency response, mitigation funding opportunities, and hazard-specific risk reduction activities.

6.1 Awareness and Preparation

Awareness is crucial to lowering risk and lessening the impacts of natural hazards. When community members understand their risk and know the role that they play in preparedness, the community in general is a much safer place to live. Awareness and preparation not only reduce the initial impact from natural hazards, but they also reduce the amount of recovery time for a community to bounce back from a disaster—this ability is commonly referred to as "resilience."

This report is intended to provide local officials a comprehensive and authoritative profile of natural hazard risk to underpin their public outreach efforts.

Messaging can be tailored to stakeholder groups. For example, outreach to homeowners could focus on actions they can take to reduce risk to their property. The DOGAMI Homeowners Guide to Landslides (https://www.oregongeology.org/Landslide/ger_homeowners_guide_landslides.pdf) provides a variety of risk reduction options for homeowners who live in high landslide susceptibility areas. This guide is one of many existing resources. Agencies partnering with local officials in the development of additional effective resources could help reach a broader community and user groups.

6.2 Planning

Information presented here are available for local decision-makers in developing their local plans and help identify geohazards and associated risks to the community. The primary framework for accomplishing this is through the comprehensive planning process. The comprehensive plan sets the long-term trajectory of capital improvements, zoning, and urban growth boundary expansion, all of which are planning tools that can be used to reduce natural hazard risk.

Another framework is the Natural Hazard Mitigation Plan (NHMP) process. NHMP plans focus on characterizing natural hazard risk and identifying actions to reduce risk. Additionally, the information presented here can be a resource when updating the mitigation actions and inform the vulnerability assessment section of the NHMP plan.

While there are many similarities between this report and an NHMP, the hazards or critical facilities in the two reports can vary. Differences between the reports may be due to data availability or limited methodologies for specific hazards. The critical facilities considered in this report may not be identical to those listed in a typical NHMP due to the lack of damage functions in Hazus-MH for non-building structures and to different considerations about emergency response during and after a disaster.

6.3 Emergency Response

Critical facilities will play a major role during and immediately after a natural disaster. This study can help emergency managers identify vulnerable critical facilities and develop contingencies in their response plans. Additionally, detailed mapping of potentially displaced residents can be used to re-evaluate evacuation routes and identify vulnerable populations to target for early warning.

The building database that accompanies this report presents many opportunities for future pre-disaster mitigation, emergency response, and community resilience improvements. Vulnerable areas can be identified and targeted for awareness campaigns. These campaigns can be aimed at pre-disaster mitigation through, for example, improvements of the structural connection of the frame to the foundation. Emergency response entities can benefit from the use of the building dataset through identification of potential hazards and populated buildings before and during a disaster. Both reduction of the magnitude of the disaster and a decrease in the response time contribute to a community's overall resilience.

6.4 Mitigation Funding Opportunities

Several funding options are available to communities that are susceptible to natural hazards and have specific mitigation projects they wish to accomplish. State and federal funds are available for projects that demonstrate cost effective natural hazard risk reduction. The Oregon Office of Emergency Management (OEM) State Hazard Mitigation Officer (SHMO) can provide communities assistance in determining eligibility, finding mitigation grants, and navigating the mitigation grant application process.

At the time of writing this report, FEMA has two programs that assist with mitigation funding for natural hazards: Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation (PDM) Grant Program. FEMA also has a grant program specifically for flooding called Flood Mitigation Assistance (FMA). The SHMO can help with finding further opportunities for earthquake and tsunami assistance and funding.

6.5 Hazard-Specific Risk Reduction Actions

6.5.1 Earthquake

- Evaluate critical facilities for seismic preparedness by identifying structural deficiencies and vulnerabilities to dependent systems (e.g., water, fuel, power).
- Evaluate vulnerabilities of critical facilities. We estimate that 89% of critical facilities (**Appendix A: Community Risk Profiles**) will be damaged by an earthquake scenario described in this report, which will have many direct and indirect negative effects on first-response and recovery efforts.
- Identify communities and buildings that would benefit from seismic upgrades.

6.5.2 Flood

- Map areas of potential flood water storage areas.
- Identify structures that have repeatedly flooded in the past and would be eligible for FEMA's "buyout" program.

6.5.3 Landslide

- Create modern landslide inventory and susceptibility maps.
- Monitor ground movement in high susceptibility areas.
- Consider land value losses due to landslide in future risk assessments.

6.5.4 Wildfire-related geologic hazards

- Evaluate post-wildfire geologic hazards including flood, debris flows, and landslides.

6.5.5 Channel migration

- Create modern channel migration hazard maps.
- Consider land value losses due to channel migration in future risk assessments.

6.5.6 Volcanic hazard – lahar

- Create volcanic lahar hazard maps based on best practices and updated lidar information.

7.0 ACKNOWLEDGMENTS

This natural hazard risk assessment was conducted by DOGAMI in 2018. Revisions to the earthquake and flood analyses were conducted in 2021. It was funded by FEMA Region 10 through its Risk Mapping, Assessment, and Planning (Risk MAP) program (Cooperative Agreement EMW-2014-CA-00288 and EMS-2019-CA-00021). In addition to FEMA, DOGAMI worked closely with the Oregon Department of Land Conservation and Development (DLCD) to complete the risk assessment and produce this report. DLCD is coordinating with communities on the next NHMP update, which will incorporate the findings from this risk assessment.

Many people contributed to this report at different points during the analysis phase and during the writing phase and at various levels. We are grateful to everyone who contributed, especially the following from DOGAMI: John Bauer, Jed Roberts, and Deb Schueller.

Additionally, we would like to thank people from other agencies and entities who also assisted on this project – from FEMA: Rynn Lamb, Cynthia McCoy and David Ratte; from DLCD: Tricia Sears, Christine Shirley, and David Lentzner.

8.0 REFERENCES

Applied Technology Council, 2015, Rapid visual screening of buildings for potential seismic hazards: a handbook (3rd ed.): Redwood City, Calif., FEMA Publication 154. https://www.fema.gov/media-library-data/1426210695633-d9a280e72b32872161efab26a602283b/FEMAP-154_508.pdf

Burns, W. J. and Madin, I. P., 2009, Protocol for Inventory Mapping of Landslide Deposits from Light Detection and Ranging (Lidar) Imagery: Oregon Department of Geology and Mineral Industries Special Paper 42, 30 p. https://www.oregongeology.org/pubs/sp/p-SP-42.htm

Burns, W. J., Hughes, K. L. B., Olson, K. V., McClaughry, J. D., Mickelson, K. A., Coe, D. E., English, J. T., Roberts, J. T., Lyles-Smith, R. R., and Madin, I. P., 2011, Multi-Hazard and Risk Study for the Mount Hood Region, Multnomah, Clackamas, and Hood River Counties, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-11-16, 186 p. http://www.oregongeology.org/pubs/ofr/p-O-11-16.htm

Burns, W. J., and Watzig, R. J., 2014, Statewide landslide information layer for Oregon, release 3 [SLIDO-3.0]: Oregon Department of Geology and Mineral Industries, 35 p., 1 pl., 1:750,000, geodatabase.

Burns, W. J., Mickelson, K. A., and Madin, I. P., 2016, Landslide susceptibility overview map of Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-16-02, 48 p. https://www.oregongeology.org/pubs/ofr/p-O-16-02.htm

Business Oregon, 2015, Oregon benefit-cost analysis tool for evaluation of seismic rehabilitation grant program applications: user's guide: Salem, Oreg., Infrastructure Finance Authority Division, 34 p. http://www.orinfrastructure.org/assets/apps/IFA/2015Oregon-SRGP/BCAusersGuideAppend.pdf

Charest, A. C. (ed.), 2017, Square foot costs with RSMeans® data (38th annual edition): Rockland, Md., Gordian Group, Inc., 563 p. https://www.rsmeans.com/products/books/2017-cost-databooks/2017-square-foot-costs-book.aspx

Driedger, Carolyn L., and Scott, William E., 2008, Mount Rainier; living safely with a volcano in your backyard: U.S. Geological Survey Fact Sheet 2008-3062 http://pubs.usgs.gov/fs/2008/3062/

Federal Emergency Management Agency, 2012a, Hazus®-MH 2.1 User manual, Flood model: Washington, D.C., 382 p. https://www.fema.gov/media-library-data/20130726-1820-25045-8814/hzmh2_1_fl_um.pdf

Federal Emergency Management Agency, 2012b, Hazus®-MH 2.1 Technical manual, Earthquake model: Washington, D.C., 718 p. https://www.fema.gov/media-library-data/20130726-1820-25045-6286/hzmh2_1_eq_tm.pdf

Federal Emergency Management Agency, 2012c, Hazus®-MH 2.1, Technical manual, Flood model: Washington, D.C., 569 p. https://www.fema.gov/media-library-data/20130726-1820-25045-8292/hzmh2_1_fl_tm.pdf

Federal Emergency Management Agency, 2015, Hazus-MH software: FEMA's tool for estimating potential losses from natural disasters, version 3.0. https://www.fema.gov/media-library-data/1450218789512-a8b8b9976c9b2da6beb200555336004a/Hazus_3.0_USER_Release_Notes_v0.5.pdf

English, J. T., Coe, D. E., and Chappell, R. D., 2013, Channel migration hazard data and maps for the Hood River, Hood River County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-13-11, 12 PDF map plates. https://www.oregongeology.org/pubs/ofr/p-O-13-11.htm

Griswold, J. P., and Iverson, R. M., 2008, Mobility statistics and automated hazard mapping for debris flows and rock avalanches: U.S. Geological Survey Scientific Investigations Report 2007-5276, 59 p. http://pubs.usgs.gov/sir/2007/5276

Hood River County Community Development, 2017, Hood River County Zoning Ordinance: Zoning regulations Hood River County, Oregon: Hood River County Community Development, 790 p. http://hrccd.co.hood-river.or.us/images/uploads/documents/%2B%2BZONING_ARTICLES_-_JANUARY_2017.pdf

Iverson, R. M., Schilling, S. P., and Vallance, J.W., 1998, Objective delineation of lahar-inundation hazard zones: Geological Society of America Bulletin, v. 110, no. 8, p. 972-984.

Judson, S., 2012, Earthquake design history: a summary of requirements in the State of Oregon: State of Oregon, Building Codes Division, Feb. 7, 2012, 7 p. http://www.oregon.gov/bcd/codes-stand/Documents/inform-2012-oregon-sesmic-codes-history.pdf

Lewis, D., 2007, Statewide seismic needs assessment: Implementation of Oregon 2005 Senate Bill 2 relating to public safety, earthquakes, and seismic rehabilitation of public buildings: Oregon Department of Geology and Mineral Industries Open-File Report O-07-02, 140 p. https://www.oregongeology.org/pubs/ofr/p-O-07-02.htm

Mackwell, P., 2006, Hood River County 2006 Community Wildfire Protection Plan: Hood River County Board of Commissioners, 123 p. https://www.oregon.gov/ODF/Documents/Fire/CWPP/HoodRiverCounty.pdf

Madin, I. P., and Burns, W. J., 2013, Ground motion, ground deformation, tsunami inundation, coseismic subsidence, and damage potential maps for the 2012 Oregon Resilience Plan for Cascadia subduction zone earthquakes: Oregon Department of Geology and Mineral Industries Open-File Report O-13-06, 36 p. 38 pl., GIS data. https://www.oregongeology.org/pubs/ofr/p-O-13-06.htm

Madin, I. P., Franczyk, J. J., Bauer, J. M., and Azzopardi, C. J. M., 2021, Oregon Seismic Hazard Database, release 1.0: Oregon Department of Geology and Mineral Industries Digital Data Series OSHD-1. https://www.oregongeology.org/pubs/dds/p-OSHD-1.htm

Oregon Building Codes Division, 2002, Oregon manufactured dwelling and park specialty code, 2002 ed.: Oregon Manufactured Housing Association and Oregon Building Codes Division, Department of Consumer and Business Services, 176 p. http://www.oregon.gov/bcd/codes-stand/Documents/md-2002-mdparks-code.pdf

Oregon Building Codes Division, 2010, 2010 Oregon manufactured dwelling installation specialty code: Department of Consumer and Business Services, Building Codes Division, 67 p. http://www.oregon.gov/bcd/codes-stand/Documents/md-2010omdisc-codebook.pdf

Rapp, C. F., and Abbe, T. B., 2003, A framework for delineating channel migration zones: Olympia, Wash., Washington State Department of Ecology Publication 03-06-027, 65 p.

Sanborn Map Company, Inc., 2013, The West Wide Wildfire Risk Assessment, final report: report to Oregon Department of Forestry and others, March 31, 2013, 105 p. https://www.thewflc.org/sites/default/files/WWA_FinalReport_3-6-2016-1.pdf

Scott, W.E., Pierson, T.C., Schilling, S.P., Costa, J.E., Gardner, C.A., Vallance, J.W., and Major, J.J., 1997, Volcano hazards in the Mount Hood region, Oregon: U.S. Geological Survey Open-File Report 97–89, 14 p., 1 map. https://pubs.usgs.gov/of/1997/0089/

U.S. Census Bureau, 2010a, Master Address File/Topologically Integrated Geographic Encoding and Referencing system or database: Oregon census block. ftp://ftp2.census.gov/geo/tiger/TIGER2010BLKPOPHU/tabblock2010_41_pophu.zip

U.S. Census Bureau, 2010b, American FactFinder: Profile of General Population and Housing Characteristics: U.S. Census Bureau, accessed March 14, 2018. https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml

U.S. Geological Survey, 2017, Earthquake hazards 101 — the basics, web page. Retrieved from https://earthquake.usgs.gov/hazards/learn/basics.php

Wang, Y., and Clark, J. L., 1999, Earthquake damage in Oregon: Preliminary estimates of future earthquake losses: Oregon Department of Geology and Mineral Industries Special Paper 29, 59 p. https://www.oregongeology.org/pubs/sp/SP-29.pdf

9.0 APPENDICES

APPENDIX A. COMMUNITY RISK PROFILES

A risk analysis summary for each community is provided in this section to encourage ideas for natural hazard risk reduction. Increasing disaster preparedness, public hazards communication, and education, ensuring functionality of emergency services, and ensuring access to evacuation routes are actions that every community can take to reduce their risk. This appendix contains community specific data to provide an overview of the community and the level of risk from each natural hazard analyzed. In addition, for each community a list of critical facilities and assumed impact from individual hazards is provided.

A.1 Unincorporated Hood River County (rural)

Table A-1. Unincorporated Hood River County hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Unincorporated Hood River County	10,866	8,462	11	2,033,052,000

Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	66	0.6%	38	1	802,000	0.04%
Earthquake	2500-year Probabilistic	267	2.5%	1,164	7	550,666,000	27%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	895	8.2%	762	2	148,646,000	7.3%
Wildfire	High Risk	2,269	21%	1,686	3	426,973,000	21%
Channel Migration	High Hazard	58	0.5%	47	0	10,117,000	0.5%
Lahar	Medium (1% Annual Chance)	0	0%	0	0	0	0%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with "First floor height" above the level of flooding (base flood elevation).

Table A-2. Unincorporated Hood River County critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High Risk**	**Channel Migration**	**Lahar**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Backup EOC - Columbia River Inter-tribal Fisheries Enforcement				X		
Communications				X		
Dee RFPD		X				
Hood River Electric Co-op		X				
Hood River High School		X				
Mt Hood Town Hall		X	X			
Parkdale RFPD - Mt Hood Station			X			
Pine Grove VFD						
Powerplant	X	X		x		
Westside Elementary		X				
Westside RFPD		X				

A.2 Unincorporated community of Odell

Table A-3. Unincorporated community of Odell hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Odell		2,309	1,113		4		491,501,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	34	1.5%	8	0	220,000	0.04%
Earthquake	2500-year Probabilistic	174	7.5%	315	4	256,384,000	52%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	19	0.8%	10	0	1,887,000	0.4%
Wildfire	High Risk	517	22%	209	0	120,739,000	25%
Channel Migration	High Hazard	0	0%	0	0	0	0%
Lahar	Medium (1% Annual Chance)	0	0%	0	0	0	0%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with “First floor height” above the level of flooding (base flood elevation).

Table A-4. Unincorporated community of Odell critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High Risk**	**Channel Migration**	**Lahar**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Mid-Valley Elementary		X				
Odell RFPD						
Odell RFPD - WyEast Fire District		X				
Wy'east Middle School		X				

A.3 Unincorporated community of Parkdale

Table A-5. Unincorporated community of Parkdale hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Parkdale		381	264		3	93,342,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake	2500-year Probabilistic	0	0.0%	14	3	27,486,000	29%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	0	0%	1	0	224,000	0.2%
Wildfire	High Risk	0	0%	1	0	361,000	0.4%
Channel Migration	High Hazard	0	0%	0	0	0	0%
Lahar	Medium (1% Annual Chance)	5	1.3%	4	0	755	0.8%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with “First floor height” above the level of flooding (base flood elevation).

Table A-6. Unincorporated community of Parkdale critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High Risk**	**Channel Migration**	**Lahar**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Hood River County Road Dept		X				
Parkdale Elementary School		X				
Parkdale RFPD		X				

A.4 Unincorporated community of Rockford

Table A-7. Unincorporated community of Rockford hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Rockford	479	364	1	76,960,000	

Hazus-MH Analysis Summary

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake	2500-year Probabilistic	3	0.6%	20	0	9,945,000	13%

Exposure Analysis Summary

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	0	0%	0	0	0	0%
Wildfire	High Risk	0	0%	0	0	0	0%
Channel Migration	High Hazard	0	0%	0	0	0	0%
Lahar	Medium (1% Annual Chance)	0	0%	0	0	0	0%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with "First floor height" above the level of flooding (base flood elevation).

Table A-8. Unincorporated community of Rockford critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High Risk**	**Channel Migration**	**Lahar**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
West Side RFPD Station 1						

A.5 City of Cascade Locks

Table A-9. City of Cascade Locks hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Cascade Locks		1,144	712		6		158,540,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	50	4.4%	16	0	218,000	0.1%
Earthquake	2500-year Probabilistic	179	16%	301	5	82,930,000	52%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	279	24%	178	0	36,161,000	23%
Wildfire	High Risk	0	0%	11	1	1,990,000	1.3%
Channel Migration	High Hazard	0	0%	0	0	0	0%
Lahar	Medium (1% Annual Chance)	0	0%	0	0	0	0%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with "First floor height" above the level of flooding (base flood elevation).

Table A-10. City of Cascade Locks critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Risk	Channel Migration	Lahar
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Cascade Locks City Hall		X				
Cascade Locks Fire Dept.						
Cascade Locks Public Works		X				
Cascade Locks School		X				
Highway Department		X				
Port of Cascade Locks		X		X		

A.6 City of Hood River

Table A-11. City of Hood River hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Hood River		7,167	3,479		10		1,033,462,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	17	0.2%	6	0	250,000	0.0%
Earthquake	2500-year Probabilistic	477	6.7%	743	12	382,342,000	37%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	450	6.3%	335	1	99,941,000	9.7%
Wildfire	High Risk	1,356	19%	630	3	150,294,000	15%
Channel Migration	High Hazard	0	0%	0	0	0	0%
Lahar	Medium (1% Annual Chance)	0	0%	0	0	0	0%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with "First floor height" above the level of flooding (base flood elevation).

Table A-12. City of Hood River critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Risk	Channel Migration	Lahar
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
EOC - County Offices		X				
Hood River City Hall and Police Dept		X				
Hood River County Public Works		X		X		
Hood River County Sheriffs Office		X				
Hood River Fire Dept				X		
Hood River Hospital		X	X			
Hood River Middle School		X		X		
May Street Elementary		X				
National Guard		X				
Port of Hood River		X				

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

Table B-1. Hood River County building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Nonprofit			All Buildings			
Community	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Number of Buildings per County Total	Building Value ($)	Building Value per County Total
Unincorporated County (rural)	5,360	1,152,381	57%	374	345,296	17%	2,675	461,544	23%	53	73,830	3.6%	8,462	59%	2,033,052	52%
Odell	796	134,473	27%	102	285,954	58%	193	34,319	7.0%	22	36,755	7.5%	1,113	7.7%	491,501	13%
Parkdale	162	26,988	29%	22	42,835	46%	56	8,137	8.7%	24	15,382	16%	264	1.8%	93,342	2.4%
Rockford	226	51,076	66%	4	1,519	2.0%	132	21,878	28%	2	2,488	3.2%	364	2.5%	76,960	2.0%
Total Unincorporated County	6,544	1,364,918	51%	502	675,604	25%	3,056	525,878	20%	101	128,455	4.8%	10,203	71%	2,694,855	69%
Cascade Locks	570	101,954	62%	58	32,784	21%	60	7,903	4.8%	24	15,899	10%	712	4.9%	158,540	4.1%
Hood River	2,990	600,790	58%	398	345,479	33%	26	3,365	0.3%	65	83,828	8.1%	3,479	24%	1,033,462	27%
Total Hood River County	10,104	2,067,662	53%	958	1,053,867	27%	3,142	537,146	14%	190	228,182	5.9%	14,394	100%	3,886,857	100%

Table B-2. Earthquake loss estimates.

(all dollar amounts in thousands)

Community	Total Number of Buildings	Total Estimated Building Value ($)	Buildings Damaged				All Buildings Changed to At Least Moderate Code			
			Yellow-Tagged Buildings	Red-Tagged Buildings	Sum of Economic Loss	Loss Ratio	Yellow-Tagged Buildings	Red-Tagged Buildings	Sum of Economic Loss	Loss Ratio
Unincorporated County (rural)	8,462	2,033,052	921	244	550,666	27%	593	125	344,654	17%
Odell	1,113	491,501	231	84	256,384	52%	126	17	115,962	24%
Parkdale	264	93,342	13	1	27,486	29%	2	0	9,323	10%
Rockford	364	76,960	18	3	9,945	13%	10	2	6,638	9%
Total Unincorporated County	10,203	2,694,855	1,183	332	844,481	31%	731	144	476,577	18%
Cascade Locks	712	158,540	169	131	82,930	52%	186	53	60,536	38%
Hood River	3,479	1,033,462	577	166	382,342	37%	479	117	254,978	25%
Total Hood River County	14,394	3,886,857	1,929	629	1,309,753	34%	1,396	314	792,091	20%

Table B-3. Flood loss estimates.

Community	Total Number of Buildings	Total Estimated Building Value ($)	1% (100-yr) Number of Buildings	1% (100-yr) Loss Estimate	1% (100-yr) Loss Ratio	0.2% (500-yr) Number of Buildings	0.2% (500-yr) Loss Estimate	0.2% (500-yr) Loss Ratio
			(all dollar amounts in thousands)					
Unincorporated County (rural)	8,462	2,033,052	38	802	0.0%	51	1,125	0.1%
Odell	1,113	491,501	8	220	0.0%	25	588	0.1%
Parkdale	264	93,342	0	0	0.0%	0	0	0.0%
Rockford	364	76,960	0	0	0.0%	0	0	0.0%
Total Unincorporated County	10,203	2,694,855	46	1,022	0.0%	76	1,713	0.1%
Cascade Locks	712	158,540	16	218	0.1%	23	386	0.2%
Hood River	3,479	1,033,462	6	250	0.0%	6	286	0.0%
Total Hood River County	14,394	3,886,857	68	1,490	0.04%	105	2,385	0.1%

Table B-4. Flood exposure.

Community	Total Number of Buildings	Total Population	1% (100-yr) Potentially Displaced Residents from Flood Exposure	1% (100-yr) % Potentially Displaced Residents from Flood Exposure	1% (100-yr) Number of Flood Exposed Buildings	1% (100-yr) % of Flood Exposed Buildings	1% (100-yr) Number of Flood Exposed Buildings Without Damage
Unincorporated County (rural)	8,462	10,865	66	0.6%	96	1.1%	58
Odell	1,113	2,309	34	1.5%	24	2.2%	16
Parkdale	264	381	0	0.0%	3	1.1%	3
Rockford	364	479	0	0.0%	1	0.3%	1
Total Unincorporated County	10,203	14,034	100	0.7%	124	1.2%	78
Cascade Locks	712	1,144	50	4.4%	24	3.4%	8
Hood River	3,479	7,167	17	0.2%	15	0.4%	9
Total Hood River County	14,394	22,345	167	0.7%	163	1.1%	95

Table B-5. Landslide exposure.

			(all dollar amounts in thousands)								
			Very High Susceptibility			**High Susceptibility**			**Moderate Susceptibility**		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**
Unincorporated County (rural)	8,462	2,033,052	384	76,857	3.8%	378	71,790	3.5%	4,275	882,937	43%
Odell	1,113	491,501	0	0	0%	10	1,887	0.4%	255	83,719	17%
Parkdale	264	93,342	0	0	0%	1	224	0.2%	263	93,118	99%
Rockford	364	76,960	0	0	0%	0	0	0%	309	66,292	86%
Total Unincorporated County	10,203	2,694,855	384	76,857	2.9%	389	73,901	2.7%	5,102	1,126,066	42%
Cascade Locks	712	158,540	152	31,544	20%	26	4,617	2.8%	204	39,078	24%
Hood River	3,479	1,033,462	1	53	0%	334	99,888	9.7%	1,398	352,950	34%
Total Hood River County	14,394	3,886,857	537	108,454	2.8%	749	178,406	4.6%	6,704	1,518,094	39%

Table B-6. Wildfire exposure.

			(all dollar amounts in thousands)					
			High Hazard			**Moderate Hazard**		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**
Unincorporated County (rural)	8,462	2,033,052	1,686	426,973	21%	2,826	578,254	28%
Odell	1,113	491,501	209	120,739	25%	245	50,800	10%
Parkdale	264	93,342	1	361	0.4%	121	21,512	23%
Rockford	364	76,960	0	0	0%	217	47,019	61%
Total Unincorporated County	10,203	2,694,855	1,896	548,073	20%	3,409	697,585	26%
Cascade Locks	712	158,540	11	1,990	1.2%	496	98,243	59%
Hood River	3,479	1,033,462	630	150,294	15%	284	63,795	6.2%
Total Hood River County	14,394	3,886,857	2,537	700,357	18%	4,189	859,623	22%

Table B-7. Channel Migration exposure.

(all dollar amounts in thousands)

Community	Total Number of Buildings	Total Population	Total Estimated Building Value ($)	Channel Migration Hazard: Potentially Displaced Residents from channel migration Exposure	% Potentially Displaced Residents from channel migration Exposure	Number of Buildings Exposed	Building Value ($)	Ratio of Exposure Value
Unincorporated County (rural)	8,462	10,866	2,033,052	58	0.5%	47	10,117	0.5%
Odell	1,113	2,309	491,501	0	0%	0	0	0%
Parkdale	264	381	93,342	0	0%	0	0	0%
Rockford	364	479	76,960	0	0%	0	0	0%
Total Unincorporated County	10,203	14,035	2,694,855	58	0.4%	47	10,117	0.4%
Cascade Locks	712	1,144	158,540	0	0%	0	0	0%
Hood River	3,479	71,67	1,033,462	0	0%	0	0	0%
Total Hood River County	14,394	22,346	3,886,857	58	0.3%	47	10,117	0.3%

Table B-8. Volcanic Lahar exposure.

(all dollar amounts in thousands)

			Small: 10% (10-yr)			Medium: 1% (100-yr)			Large: 0.2-0.1% (500 to 1000-yr)			Extra Large: 0.001% (100,000-yr)		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**
Unincorporated County (rural)	8,462	2,033,052	4	3,997	0.2%	137	41,244	2.0%	651	144,155	7.1%	2,221	436,718	21%
Odell	1,113	491,501	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Parkdale	264	93,342	0	0	0%	4	775	0.8%	64	14,068	15%	264	93,342	100%
Rockford	364	76,960	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Unincorporated County	10,203	2,694,855	4	3,997	0.1%	141	42,019	1.4%	715	158,223	5.9%	2,485	530,060	20%
Cascade Locks	712	158,540	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Hood River	3,479	1,033,462	0	0	0%	0	0	0%	86	66,361	6.4%	310	161,384	16%
Total Hood River County	14,394	3,886,857	4	3,997	0.1%	141	42,019	1.1%	801	224,584	5.8%	2,795	691,444	18%

APPENDIX C. HAZUS-MH METHODOLOGY

C.1 Software

We performed all loss estimations using Hazus®-MH 3.0 and ArcGIS® Desktop® 10.2.2.

C.2 User-Defined Facilities (UDF) Database

A UDF database was compiled for all buildings in Hood River County for use in both the flood and earthquake modules of Hazus-MH. The Hood River County assessor database (acquired in 2018) was used to determine which tax lots had improvements (i.e., buildings) and how many building points should be included in the UDF database.

C.2.1 Locating buildings points

The Oregon DOGAMI used its existing dataset of building footprints (unpublished) to help precisely locate the centroid of each building. Where the building footprint dataset lacked coverage in the eastern portion of the county the centroid of the tax lot was taken, and for tax lots larger than 10 acres the building centroid was moved and approximated using orthoimagery. Extra effort was spent to locate building points along the 1% and 0.2% annual chance inundation fringe. When buildings were partially within the inundation zone, the building point was moved to the centroid of the portion of the building within the inundation zone. An iterative approach was used to further refine locations of building points for the flood module by generating results, reviewing the highest value buildings, and moving the building point over a representative elevation on the lidar DEM to ensure an accurate first floor height.

C.2.2 Attributing building points

Populating the required attributes for Hazus-MH was achieved through a variety of approaches. The Hood River County assessor database was used whenever possible, but in many cases that database did not provide the necessary information. The following is list of attributes and their sources:

- **Longitude** and **Latitude** – Location information that provides Hazus-MH the x and y-position of the UDF point. This allows for an overlay to occur between the UDF point and the flood or earthquake input data layers. The hazard model uses this spatial overlay to determine the correct hazard risk level that will be applied to the UDF point. The format of the attribute must be in decimal degrees. A simple geometric calculation using GIS software is done on the point to derive this value.
- **Occupancy class** – An alphanumeric attribute that indicates the use of the UDF (e.g. ‘RES1’ is a single family dwelling). The alphanumeric code is composed of seven broad occupancy types (RES = residential, COM = commercial, IND = industrial, AGR = agricultural, GOV = public, REL = non-profit/religious, EDU = education) and various suffixes that indicate more specific types. This code determines the damage function to be used for flood analysis. It is also used to attribute the Building Type field, discussed below, for the earthquake analysis. The code was interpreted from “Stat Class” or “Description” data found in the Hood River County assessor database. When data was not available, the default value of RES1 was applied throughout.
- **Cost** – The replacement cost of an individual UDF. Loss ratio is derived from this value. Replacement cost is based on a method called RSMeans valuation (Charest, 2017) and is

calculated by multiplying the building square footage by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus database.

- **Year built** – The year of construction that is used to attribute the Building Design Level field for the earthquake analysis (see "Building Design" below). The year a UDF was built is obtained from Hood River County assessor database. When not available, the year of "1900" was applied.
- **Square feet** – The size of the UDF is used to pro-rate the total improvement value for tax lots with multiple UDFs. The value distribution method will ensure that UDFs with the highest square footage will be the most expensive on a given tax lot. This value is also used to pro-rate the **Number of People** field for Residential UDFs within a census block. The value was obtained from DOGAMI's building footprints; where (RES) footprints were not available, we used the Hood River County assessor database.
- **Number of stories** – The number of stories for an individual UDF, along with Occupancy Class, determines the applied damage function for flood analysis. The value was obtained from the Hood River County assessor database when available. For UDFs without assessor information for number of stories that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used for attribution.
- **Foundation type** – The UDF foundation type correlates with First Floor Height values in feet (see Table 3.11 in the Hazus-MH Technical Manual for the Flood Model [FEMA Hazus-MH, 2012a]). It also functions within the flood model by indicating if a basement exists or not. UDFs with a basement have a different damage function from UDFs that do not have one. The value was obtained from the Hood River County assessor database when available. For UDFs without assessor information for basements that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used to ascertain if one exists or not.
- **First floor height** – The height in feet above grade for the lowest habitable floor. The height is factored during the depth of flooding analysis. The value is used directly by Hazus-MH, where Hazus-MH overlays a UDF location on a depth grid and using the **first floor height** determines the level of flooding occurring to a building. It is derived from the Foundation Type attribute or observation via oblique imagery or Google Street View™ mapping service.
- **Building type** – This attribute determines the construction material and structural integrity of an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information was unavailable from the Hood River County assessor data, so instead it was derived from a statistical distribution based on **Occupancy class**.
- **Building design level** – This attribute determines the seismic building code for an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information is derived from the **Year Built** attribute (Hood River Assessor) and state/regional seismic building code benchmark years.
- **Number of people** – The estimated number of permanent residents living within an individual residential structure. It is used in the post-analysis phase to determine the amount of people affected by a given hazard. This attribute is derived from default Hazus database (U.S. Census Bureau, 2010a) of population per census block and distributed across residential UDFs.
- **Community** – The community that a UDF is within. These areas are used in the post-analysis for reporting results. The communities were based on incorporated area boundaries; unincorporated community areas were based on building density.

C.2.3 Seismic building codes

Oregon initially adopted seismic building codes in the mid-1970s (Judson, 2012). The established benchmark years of code enforcement are used in determining a "design level" for individual buildings. The design level attributes (pre code, low code, moderate code, and high code) are used in the Hazus-MH earthquake model to determine what damage functions are applied to a given building (FEMA, 2012b). The year built or the year of the most recent seismic retrofit are the main considerations for an individual design level attribute. Seismic retrofitting information for structures would be ideal for this analysis but was not available for Hood River County. **Table C-1** outlines the benchmark years that apply to buildings within Hood River County.

Table C-1. Hood River County seismic design level benchmark years.

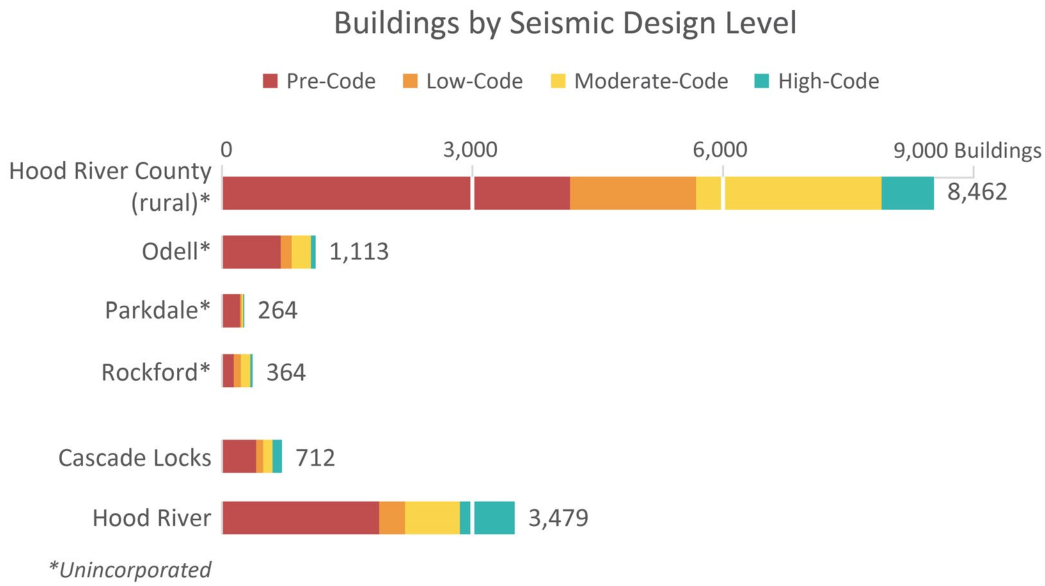
Building Type	Year Built	Design Level	Basis
Single-Family Dwelling (includes Duplexes)	prior to 1976	Pre Code	Interpretation of Judson (Judson, 2012)
	1976–1991	Low Code	
	1992–2003	Moderate Code	
	2004–2016	High Code	
Manufactured Housing	prior to 2003	Pre Code	Interpretation of OR BCD 2002 Manufactured Dwelling Special Codes (Oregon Building Codes Division, 2002)
	2003–2010	Low Code	
	2011–2016	Moderate Code	Interpretation of OR BCD 2010 Manufactured Dwelling Special Codes Update (Oregon Building Codes Division, 2010)
All other buildings	prior to 1976	Pre Code	Business Oregon 2014-0311 Oregon Benefit-Cost Analysis Tool, p. 24 (Business Oregon, 2015)
	1976–1990	Low Code	
	1991–2016	Moderate Code	

Table C-2 and corresponding **Figure C-1** illustrate the current state of seismic building codes for the county.

Table C-2. Seismic design level in Hood River County.

		Pre Code		Low Code		Moderate Code		High Code	
Community	Total Number of Buildings	Number of Buildings	Percentage of Buildings	Number of Buildings	Percentage of Buildings	Number of Buildings	Percentage of Buildings	Number of Buildings	Percentage of Buildings
Unincorporated County (rural)	8,462	4138	49%	1497	18%	2204	26%	623	7%
Odell	1,113	698	63%	129	12%	230	21%	56	5%
Parkdale	264	215	81%	17	6%	21	8%	11	4%
Rockford	364	141	39%	83	23%	113	31%	27	7%
Total Unincorporated County	10,203	5192	51%	1726	17%	2568	25%	717	7%
Cascade Locks	712	406	57%	84	12%	111	16%	111	16%
Hood River	3,479	1868	54%	309	9%	651	19%	651	19%
Total Hood River County	14,394	7466	52%	2119	15%	3330	23%	1479	10%

Figure C-1. Seismic design level by Hood River County community.



C.3 Flood Hazard Data

FEMA developed flood hazard data in 2020 for a revision of the Hood River County FEMA FIS. The hazard data were based on new flood studies and new riverine hydrologic and hydraulic analyses. For riverine areas, the flood elevations for the 100- and 500-year events for each stream cross-section were used to develop depth of flooding raster datasets or "depth grids."

A countywide, 2-meter (~6.5 foot), lidar-based depth grid was developed for each of the 100- and 500-year annual chance flood events. The depth grids were imported into Hazus-MH for determining the depth of flooding for areas within the FEMA flood zones.

Once the UDF database was developed into a Hazus-compliant format, the Hazus-MH methodology was applied using a Python (programming language) script developed by DOGAMI. The analysis was then run for a given flood event, and the script cross-referenced a UDF location with the depth grid to find the depth of flooding. The script then applied a specific damage function, based on a UDF's Occupancy Class [OccCls], which was used to determine the loss ratio for a given amount of flood depth, relative to the UDF's first-floor height.

C.4 Earthquake Hazard Data

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): National Earthquake Hazard Reduction Program (NEHRP) soil classification, peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03), and liquefaction susceptibility. We also used landslide susceptibility data derived from the work of Burns and others (2016). The liquefaction and landslide susceptibility layers together with PGA were used by the Hazus-MH tool to calculate permanent ground deformation and associated probability.

During the Hazus-MH earthquake analysis, each UDF was analyzed given its site-specific parameters (ground motion and ground deformation) and evaluated for loss, expressed as a probability of a damage state. Specific damage functions based on Building type and Building design level were used to calculate the damage states given the site-specific parameters for each UDF. The output provided probabilities of the five damage states (None, Slight, Moderate, Extensive, Complete) from which losses in dollar amounts were derived.

C.5 Post-Analysis Quality Control

Ensuring the quality of the results from Hazus-MH flood and earthquake modules is an essential part of the process. A primary characteristic of the process is that it is iterative. A UDF database without errors is highly unlikely, so this part of the process is intended to limit and reduce the influence these errors have on the final outcome. Before applying the Hazus-MH methodology, closely examining the top 10 largest area UDFs and the top 10 most expensive UDFs is advisable. Special consideration can also be given to critical facilities due to their importance to communities.

Identifying, verifying, and correcting (if needed) the outliers in the results is the most efficient way to improve the UDF database. This can be done by sorting the results based on the loss estimates and closely scrutinizing the top 10 to 15 records. If corrections are made, then subsequent iterations are necessary. We continued checking the “loss leaders” until no more corrections were needed.

Finding anomalies and investigating possible sources of error are crucial in making corrections to the data. A wide range of corrections might be required to produce a better outcome. For example, floating homes may need to have a first-floor height adjustment or a UDF point position might need to be moved due to issues with the depth grid. Incorrect basement or occupancy type attribution could be the cause of a problem. Commonly, inconsistencies between assessor data and taxlot geometry can be the source of an error. These are just a few of the many types of problems addressed in the quality control process.

APPENDIX D. ACRONYMS AND DEFINITIONS

D.1 Acronyms

CRS	Community Rating System
CSZ	Cascadia subduction zone
DLCD	Oregon Department of Land Conservation and Development
DOGAMI	Department of Geology and Mineral Industries (State of Oregon)
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FRI	Fire Risk Index
GIS	Geographic Information System
NFIP	National Flood Insurance Program
NHMP	Natural hazard mitigation plan
NOAA	National Oceanic and Atmospheric Administration
ODF	Oregon Department of Forestry
OEM	Oregon Emergency Management
OFR	Open-File Report
OPDR	Oregon Partnership for Disaster Resilience
PGA	Peak ground acceleration
PGD	Permanent ground deformation
PGV	Peak ground velocity
Risk MAP	Risk Mapping, Assessment, and Planning
SHMO	State Hazard Mitigation Officer
SLIDO	State Landslide Information Layer for Oregon
UDF	User-defined facilities
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WUI	Wildland-urban interface
WWA	West Wide Wildfire Risk Assessment

D.2 Definitions

1% annual chance flood – The flood elevation that has a 1-percent chance of being equaled or exceeded each year. Sometimes referred to as the 100-year flood.

0.2% annual chance flood – The flood elevation that has a 0.2-percent chance of being equaled or exceeded each year. Sometimes referred to as the 500-year flood.

Base flood elevation (BFE) – Elevation of the 1-percent-annual-chance flood. This elevation is the basis of the insurance and floodplain management requirements of the NFIP.

Critical facilities – Facilities that, if damaged, would present an immediate threat to life, public health, and safety. As categorized in HAZUS-MH, critical facilities include hospitals, emergency operations centers, police stations, fire stations and schools.

Exposure – Determination of whether a building is within or outside of a hazard zone. No loss estimation is modeled.

Flood Insurance Rate Map (FIRM) – An official map of a community, on which FEMA has delineated both the Special Flood Hazard Areas and the risk premium zones applicable to the community.

Flood Insurance Study (FIS) – Contains an examination, evaluation, and determination of the flood hazards of a community and, if appropriate, the corresponding water-surface elevations.

Hazus-MH – A GIS-based risk assessment methodology and software application created by FEMA and the National Institute of Building Sciences for analyzing potential losses from floods, hurricane winds, and earthquakes.

Lidar – A remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. Lidar is popularly used as a technology to make high-resolution maps.

Liquefaction – Describes a phenomenon whereby a saturated soil substantially loses strength and stiffness in response to an applied stress, usually an earthquake, causing it to behave like liquid.

Loss Ratio – The expression of loss as a fraction of the value of the local inventory (total value/loss).

Magnitude – A scale used by seismologists to measure the size of earthquakes in terms of energy released.

Risk – Probability multiplied by consequence; the degree of probability that a loss or injury may occur as a result of a natural hazard. Sometimes referred to as vulnerability.

Risk MAP – The vision of this FEMA strategy is to work collaboratively with state, local, and tribal entities to deliver quality flood data that increases public awareness and leads to action that reduces risk to life and property.

Riverine – Of or produced by a river. Riverine floodplains have readily identifiable channels.

Susceptibility – Degree of proneness to natural hazards that is determined based on physical characteristics that are present.

Vulnerability – Characteristics that make people or assets more susceptible to a natural hazard.

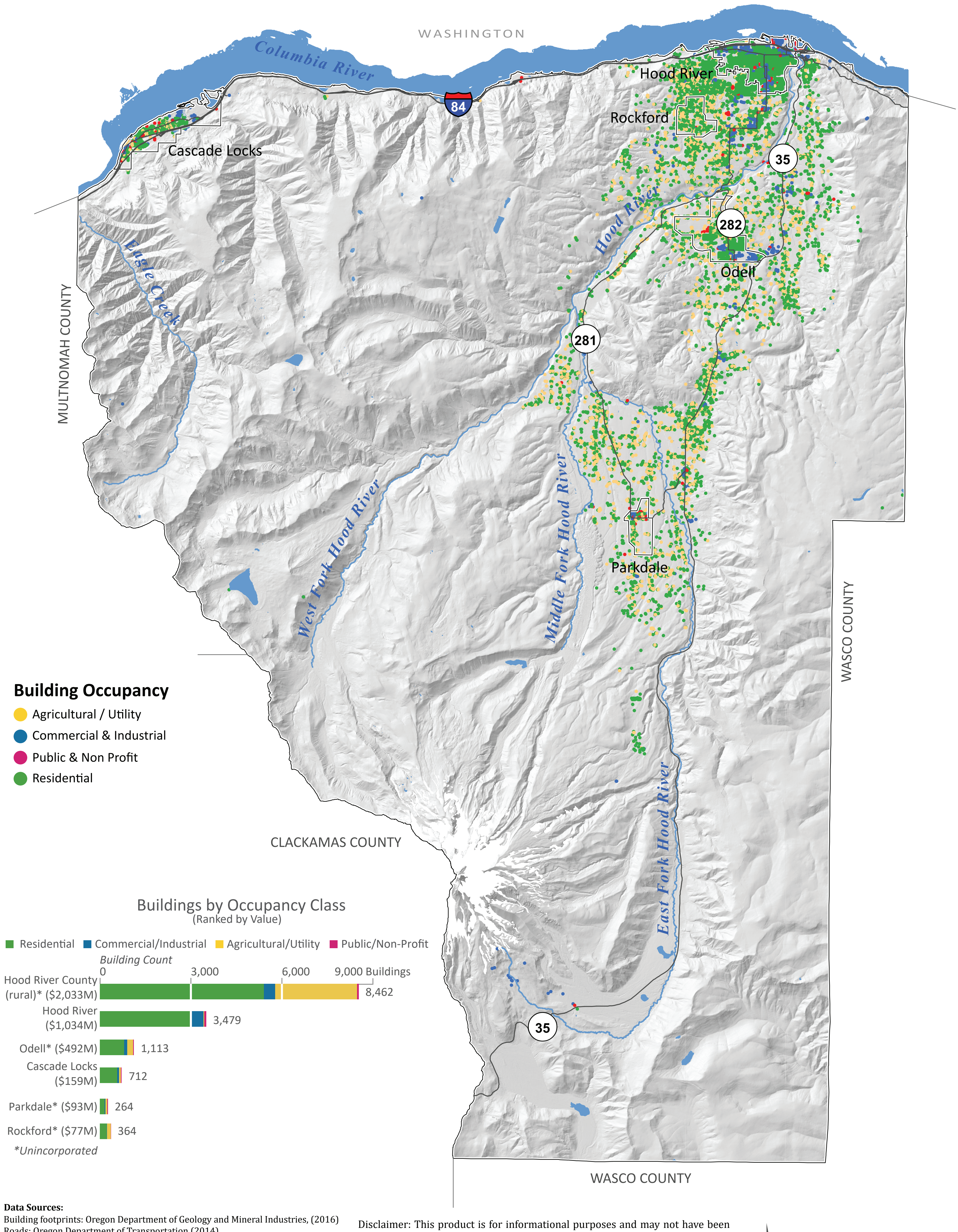
APPENDIX E. MAP PLATES

See appendix folder for individual map PDFs.

PLATE 1

Building Distribution Map of Hood River County, Oregon

Study Location Map



Data Sources:
Building footprints: Oregon Department of Geology and Mineral Industries, (2016)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6
Cartography by: Lowell Anthony, 2018

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

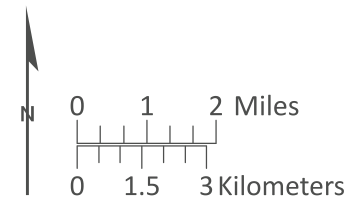
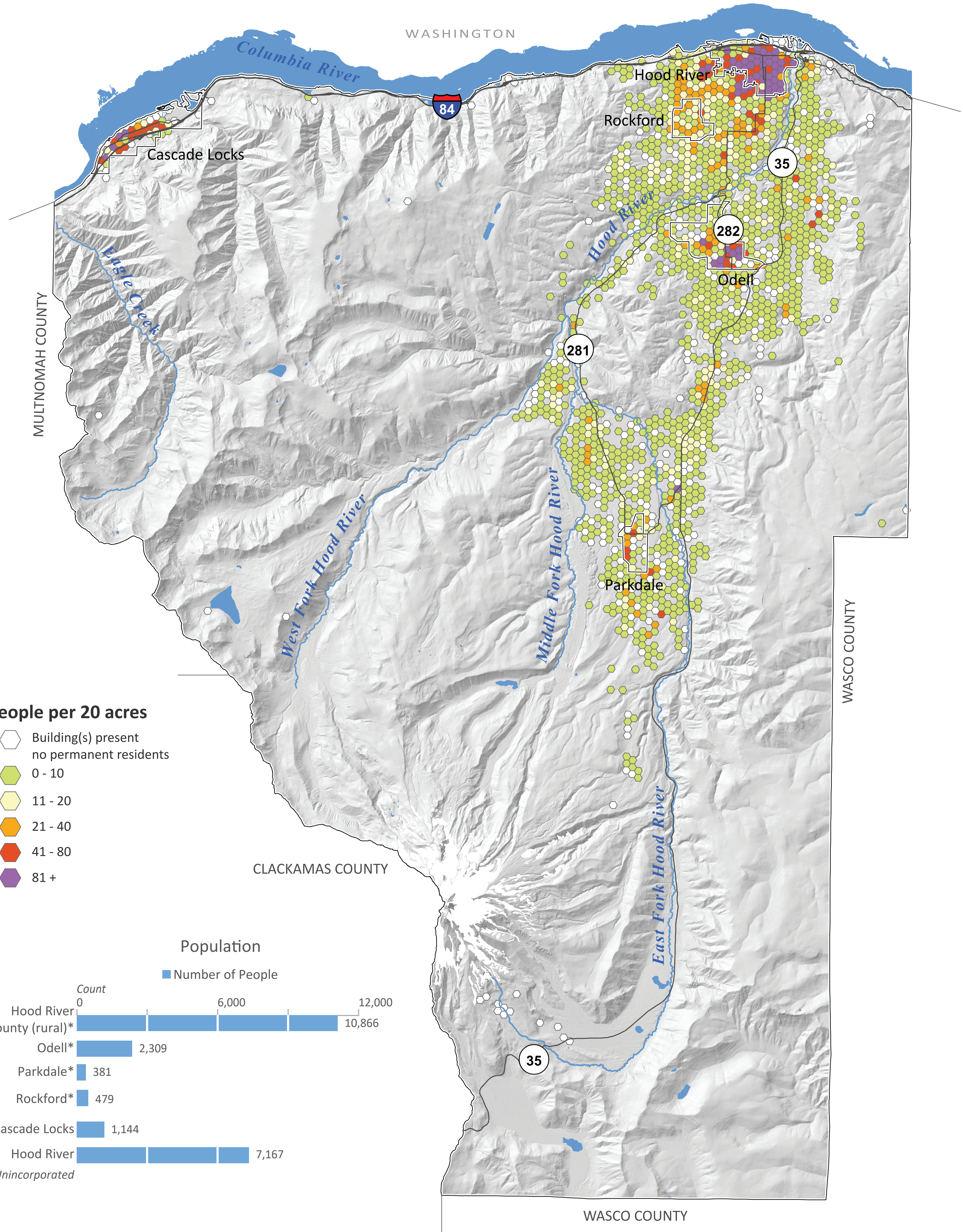


PLATE 2

Population Density Map of Hood River County, Oregon



Data Sources:
Population data: U.S. Census (2010)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

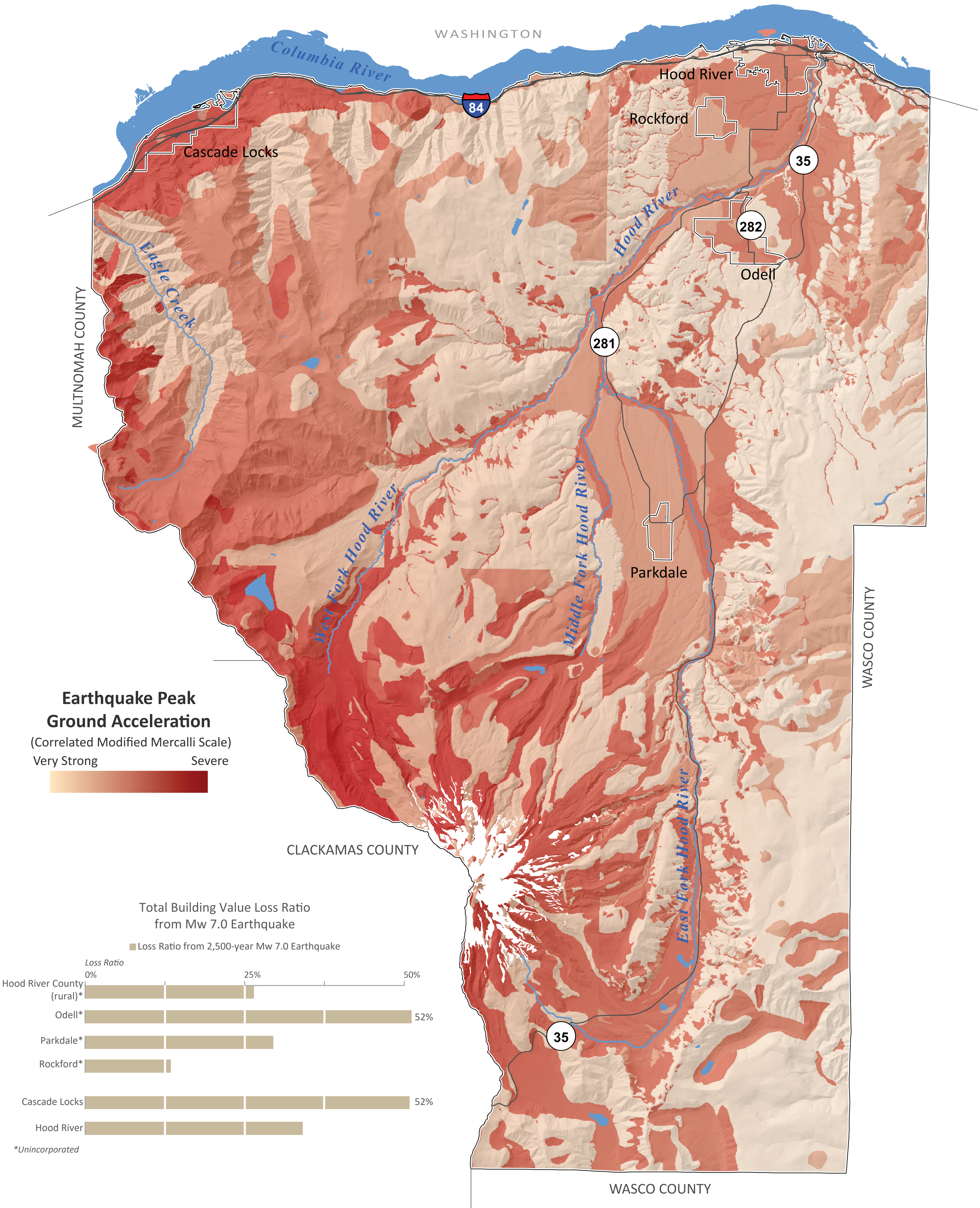
N
0 1 2 Miles
0 1.5 3 Kilometers

PLATE 3

2,500-year Probabilistic Earthquake Shaking Map of Hood River County, Oregon

Study Location Map

Peak Ground Acceleration (PGA) is the maximum acceleration in a given location or rather how hard the ground is shaking during an earthquake. It is one measurement of ground motion, which is closely associated with the level of damage that occurs from an earthquake.



Data Sources:
2,475-year probabilistic PGA: Oregon Seismic Hazard Database, Madin and others (2021)
Roads: Oregon Department of Transportation Signed Routes (2014)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

N

0 1 2 Miles

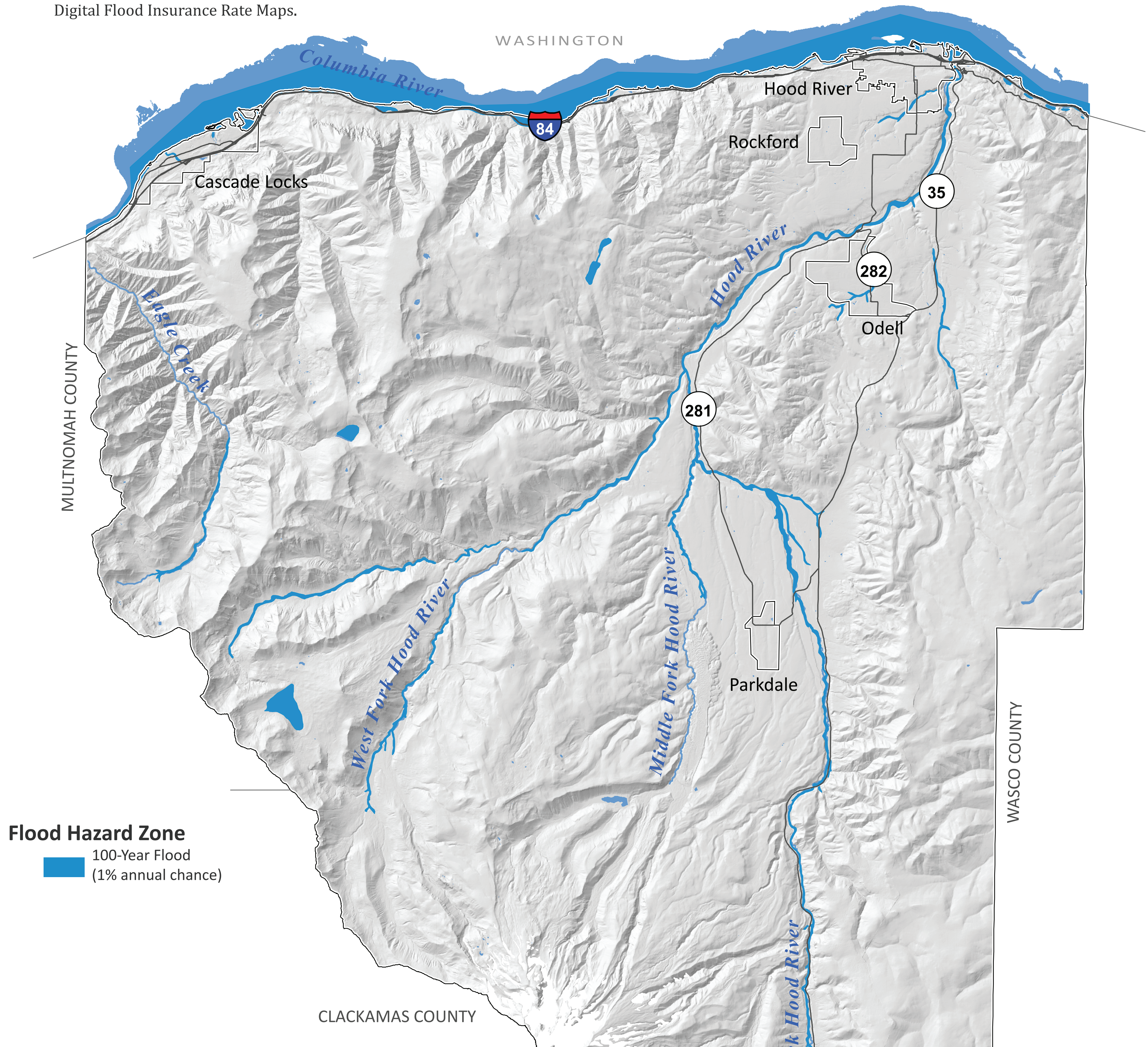
0 1.5 3 Kilometers

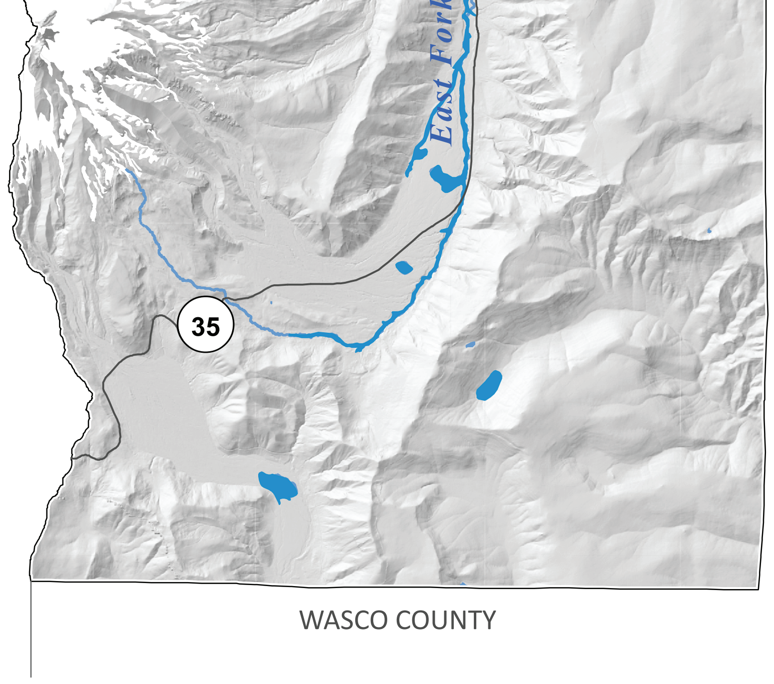
PLATE 4

Flood Hazard Map of Hood River County, Oregon

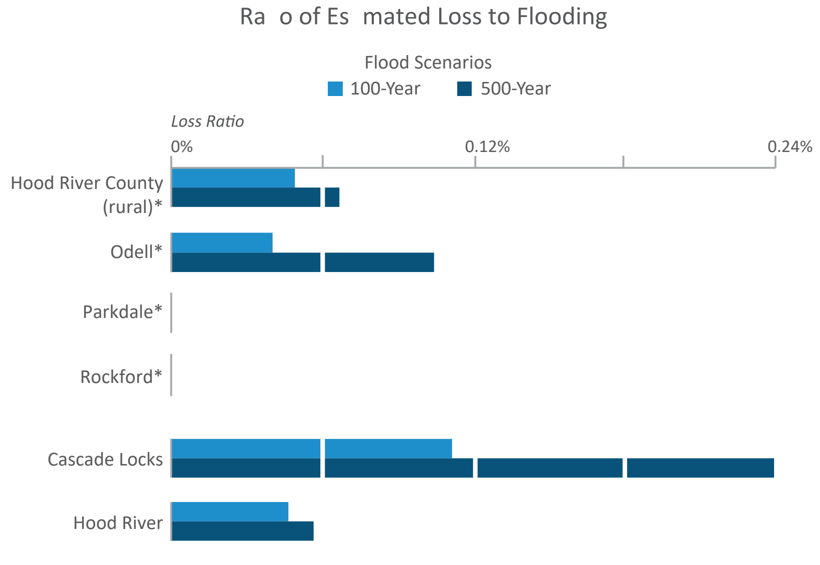
Study Loca on Map

The lood hazard data show areas expected to be inundated during a 100-year lood event. Flooding sources include riverine. Areas are consistent with the regulatory lood zones depicted in Hood River County's Digital Flood Insurance Rate Maps.





Ra o of Es mated Loss to Flooding



Data Sources:
Flood hazard zone (100-year): FEMA (1984)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri ArcMap 10, Adobe Illustrator CS6
Cartography by: Lowell Anthony, 2018

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-speci ic investigations by quali ied practitioners. Site-speci ic data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

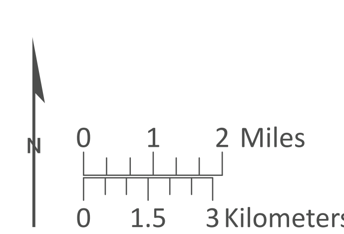
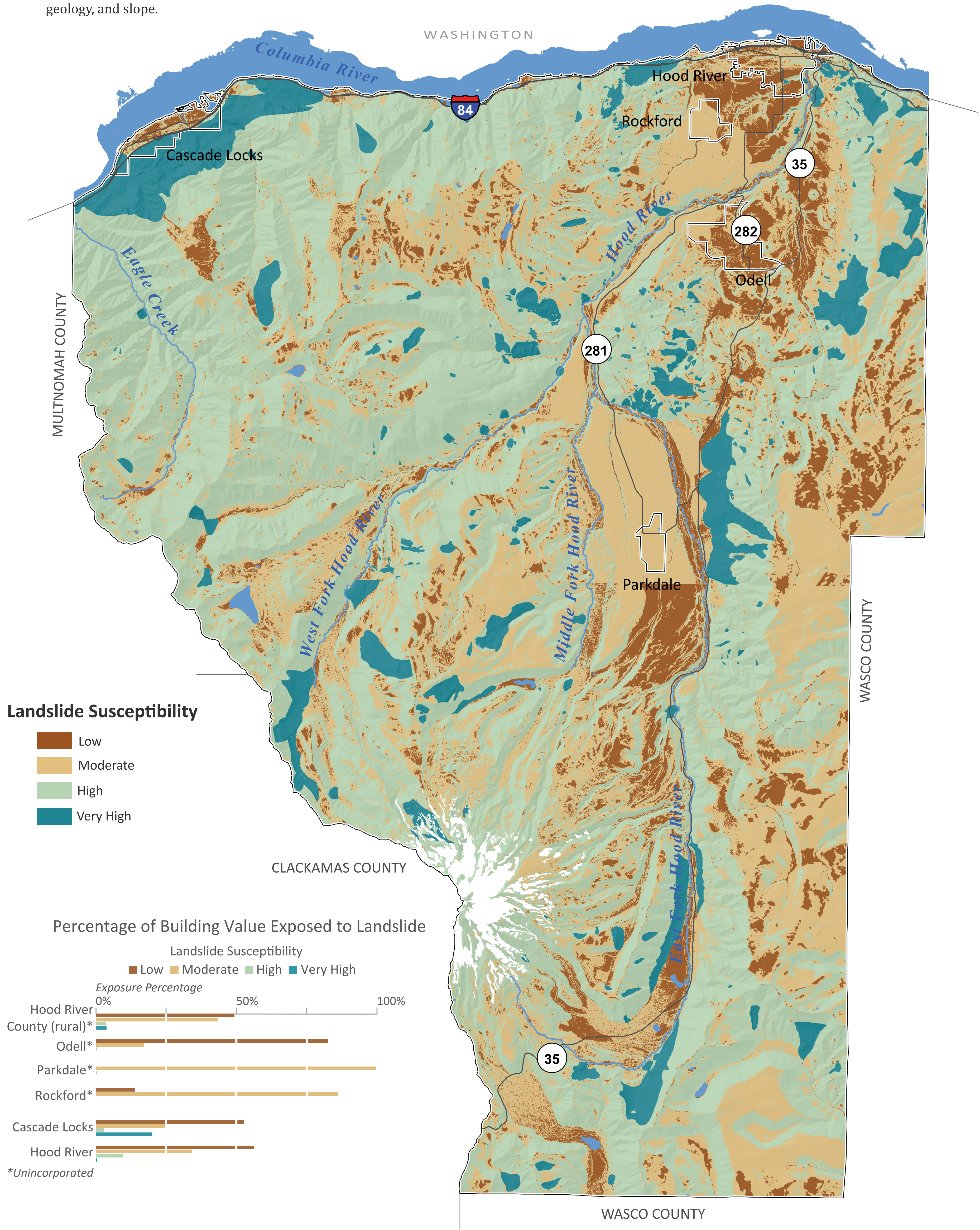


PLATE 5

Landslide Susceptibility Map of Hood River County, Oregon

Landslide susceptibility is categorized as Low, Moderate, High, and Very High which describes the general level of susceptibility to landslide hazard. The dataset is an aggregation of three primary sources: landslide inventory (SLIDO), generalized geology, and slope.



Data Sources:
Landslide susceptibility: Burns and others (2016)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

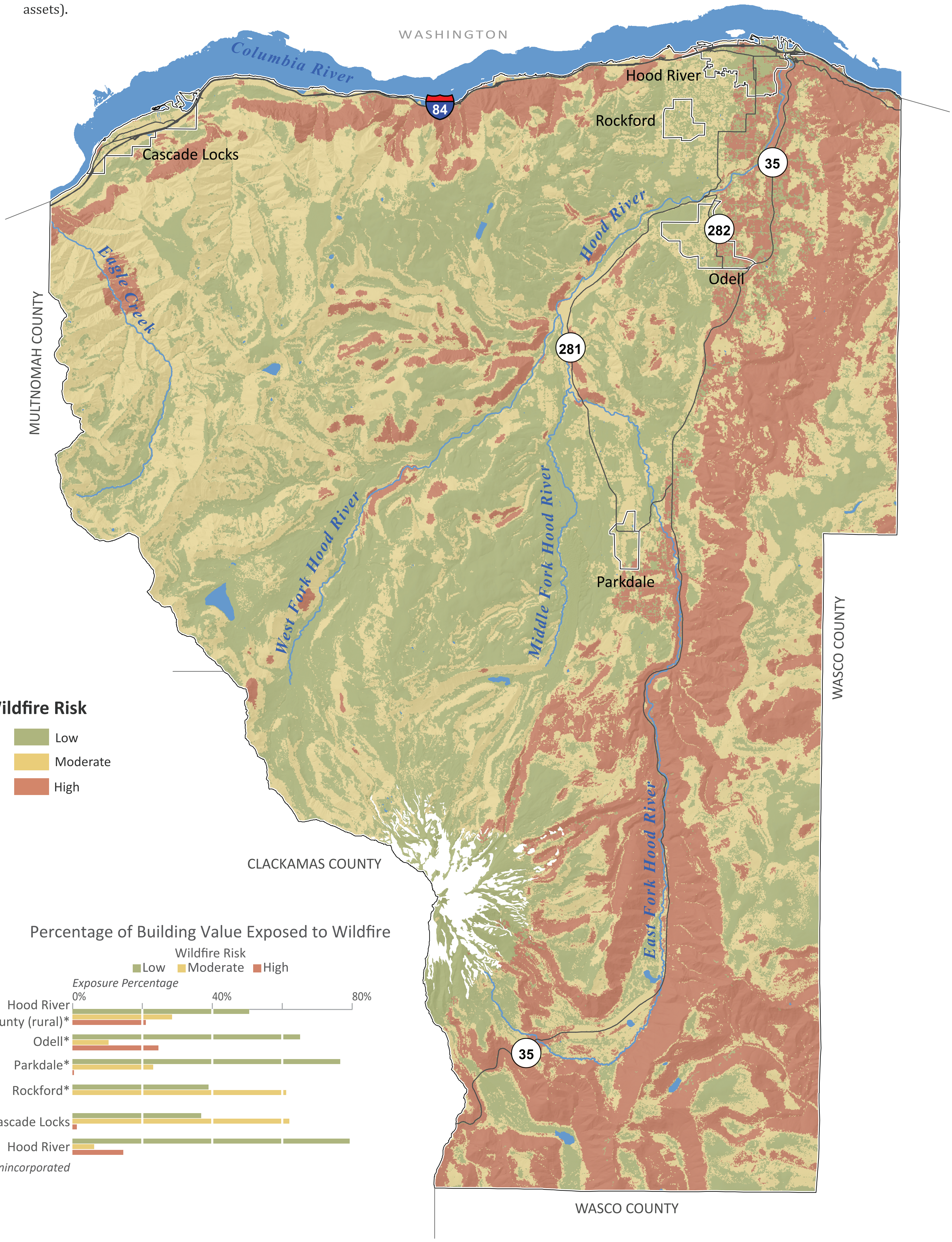
Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

PLATE 6

Wildfire Risk Map of Hood River County, Oregon

Study Location Map

Wildfire Risk is categorized as Low, Moderate, and High and indicates the level of risk a location has to wildfire hazard. The Wildfire Risk data layer (Fire Risk Index) is derived from a combination of the Fire Threat Index (fire history and behavior) and the Fire Effects Index (infrastructure and assets).



Wildfire Risk

- Low
- Moderate
- High

Percentage of Building Value Exposed to Wildfire
Wildfire Risk
Low Moderate High
Exposure Percentage
0%
40%
80%
Hood River County (rural)*
Odell*
Parkdale*
Rockford*
Cascade Locks
Hood River
*Unincorporated

Data Sources:
Wildfire risk data: Oregon Department of Forestry (2013)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

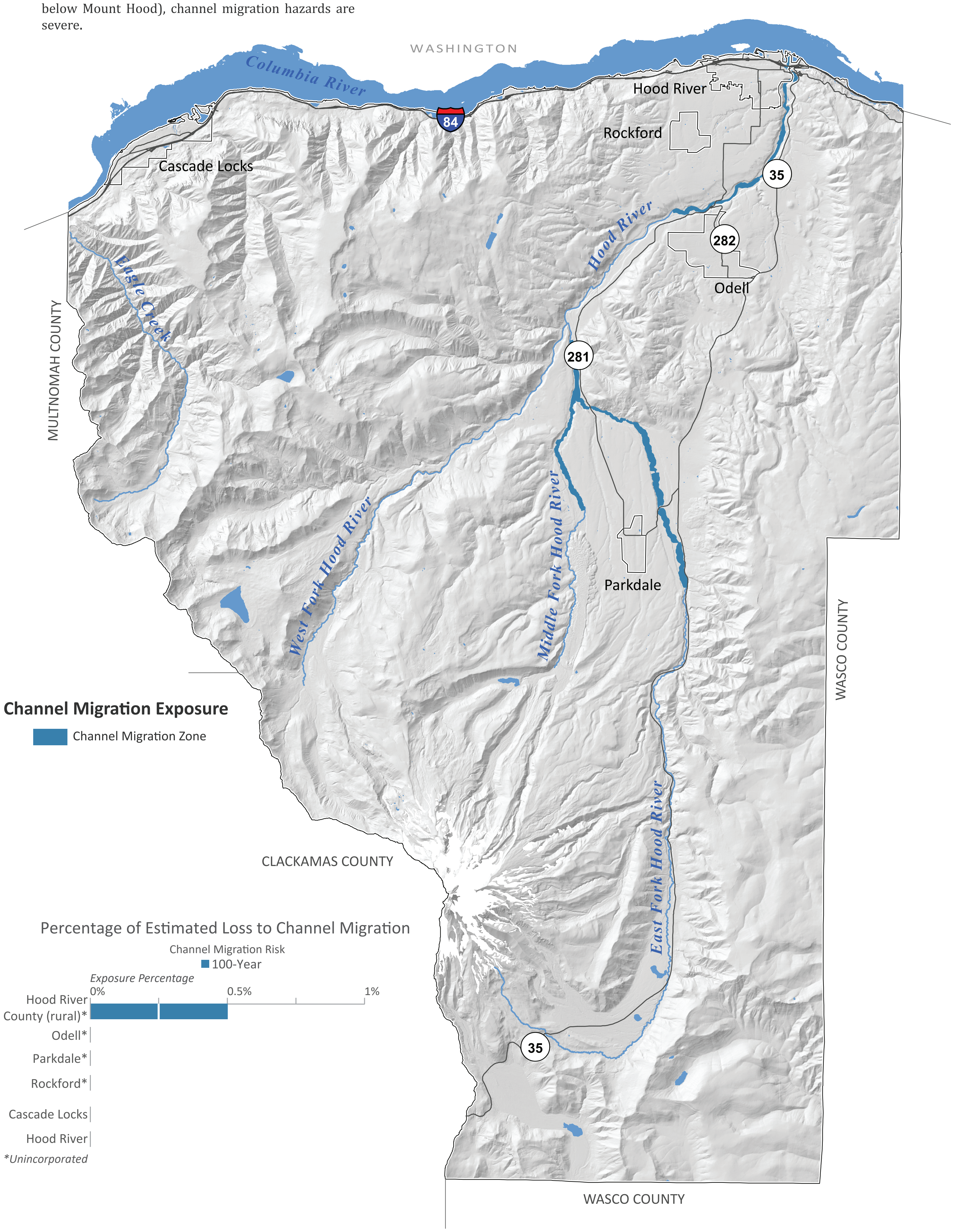
N
0 1 2 Miles
0 1.5 3 Kilometers

PLATE 7

Channel Migration Hazard Map of Hood River County, Oregon

Study Location Map

The channel migration hazard data show areas expected to be exposed in a 100-year period. In the upper portions of drainages in the study area (just below Mount Hood), channel migration hazards are severe.



Data Sources:
Channel Migration hazard zone (100-year): Burns and others (2011)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

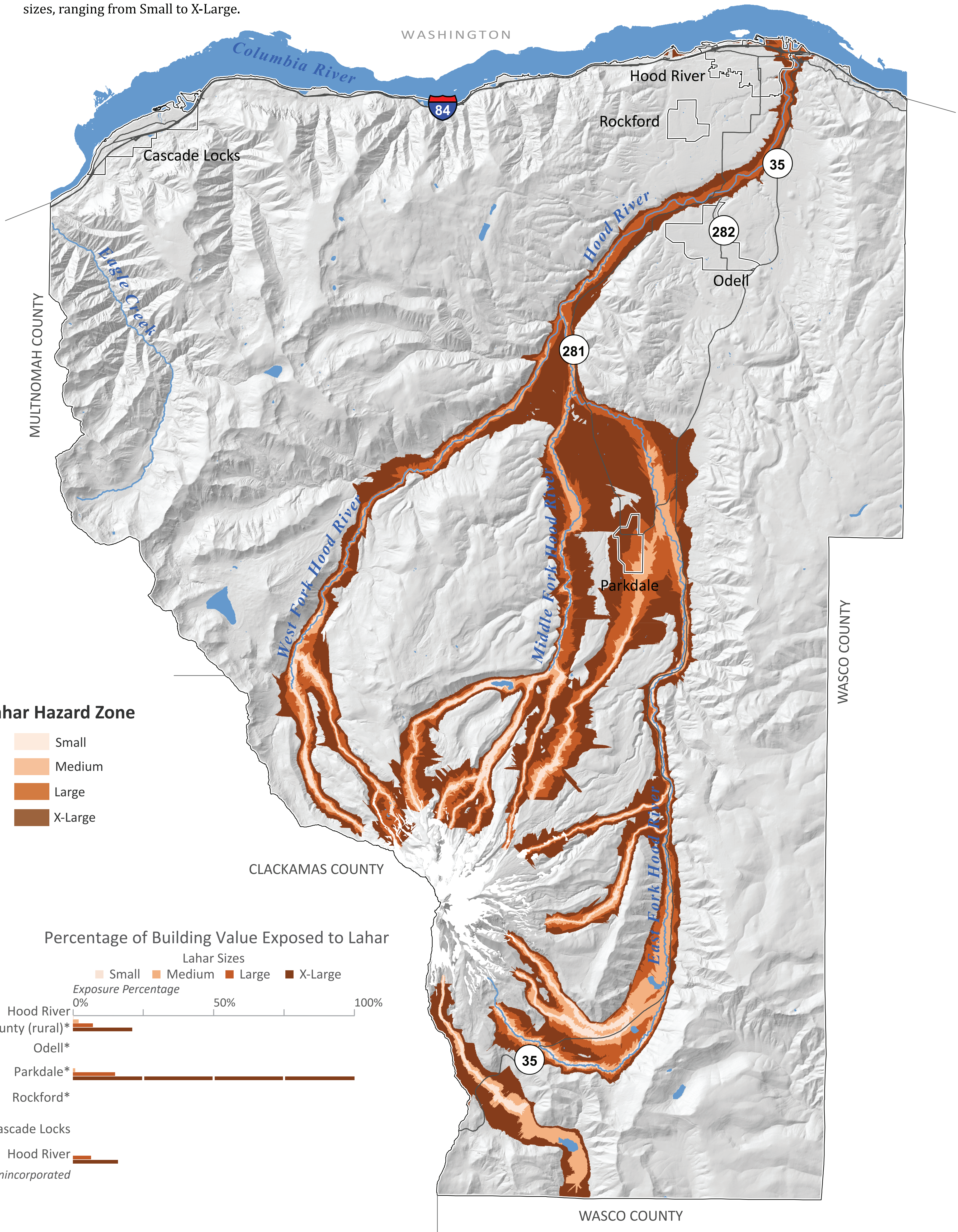
Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

N
0 1 2 Miles
0 1.5 3 Kilometers

PLATE 8

Lahar Exposure Map of Hood River County, Oregon

The lahar hazard data show areas of expected exposure from several local lahar scenarios produced from a volcanic event on Mt Hood. The scenarios were categorized based on "t-shirt" sizes, ranging from Small to X-Large.



Data Sources:
Lahar Hazard Zones: Burns and others (2011)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

N
0 1 2 Miles
0 1.5 3 Kilometers