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

OPEN-FILE REPORT O-21-07

NATURAL HAZARD RISK REPORT FOR WASCO COUNTY, OREGON

INCLUDING THE CITIES OF ANTELOPE, DUFUR, MAUPIN, MOSIER, SHANIKO, THE DALLES AND UNINCORPORATED COMMUNITIES OF CHENOWETH, TYGH VALLEY, PINE HOLLOW AND THE WARM SPRINGS RESERVATION

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2021

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DISCLAIMER

Cover photo: Wheatfield burns from a fast-moving wildfire southest of The Dalles, Oregon, July 18, 2018. Credit: Mark Graves, The Oregonian via AP. https://www.columbian.com/news/2018/jul/19/tractor-operator-dies-trying-to-suppress-oregon-wildfire/

WHAT'S IN THIS REPORT?

This report describes the methods and results of a natural hazard risk assessment for Wasco County communities. The risk assessment can help communities better plan for disaster.

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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.

Wasco_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 Wasco County, Oregon, with funding provided by the Federal Emergency Management Agency (FEMA). It describes the methods and results of the natural hazard risk assessment performed in 2018 by the Oregon Department of Geology and Mineral Industries (DOGAMI) within the study area. In 2021, we also performed an update to the earthquake and flood analysis. 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 locations 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.

To complete the third task, we performed the risk assessment 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 the number of buildings, their value, and associated populations exposed to earthquake and flood scenarios, or susceptible to varying levels of hazard from landslides and wildfires.

The findings and conclusions of this report show the potential impacts of hazards in communities within Wasco County. An earthquake can cause moderate 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 future risk assessments. During the time of writing, the best available data show that wildfire risk is very high for the overall study area. Our findings also indicate that most of the critical facilities in the study area are at high risk from earthquake and wildfire hazards. We found that the biggest causes of population displacement are wildfire and landslide hazards. 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 Wasco County (rural)
- Community of Pine Hollow
- Warm Springs Reservation
- City of Dufur
- City of Mosier
- City of The Dalles
- Community of Chenoweth
- Community of Tygh Valley
- City of Antelope
- City of Maupin
- City of Shaniko

Selected countywide results
Total buildings: 18,481
Total estimated building value: $3.9 billion

2,500-year Probabilistic Magnitude 7.0 Earthquake
Red-tagged buildings[a]: 1,104
Yellow-tagged buildings[b]: 2,118
Loss estimate: $870 million

100-year Flood Scenario
Number of buildings damaged: 560
Loss estimate: $20 million

Landslide (High and Very High-Susceptibility)
Number of buildings exposed: 3,013
Exposed building value: $499 million

Wildfire Results (High Risk):
Number of buildings exposed: 4,057
Exposed building value: $694 million

[a]Red-tagged buildings are considered to be uninhabitable due to complete damage.
[b]Yellow-tagged buildings are considered to be of 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 Wasco 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 Wasco County communities.

The Cascade Range and the Columbia and Deschutes Valleys are subject to several significant natural hazards, including earthquakes, riverine flooding, landslides, and wildfires. This region of the state is sparsely populated with most of the development in the City of The Dalles and surrounding unincorporated communities. 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. We describe the methods for creating the building and population information used in this project. 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 countywide hazard maps.

1.2 Study Area

The study area for this project is the entirety of Wasco County, Oregon. Wasco County is located in the northcentral portion of the state and is bordered by Hood River and Clackamas Counties on the west, Jefferson County on the south, Sherman and Wheeler Counties on the east, and by the Columbia River on the north. The total area of Wasco County is 2,395 square miles (6,203 square kilometers). Large areas of the county are within the Mount Hood National Forest or are administered by the Bureau of Land Management. The Warm Springs Reservation comprises a large portion of the southern part of the county.

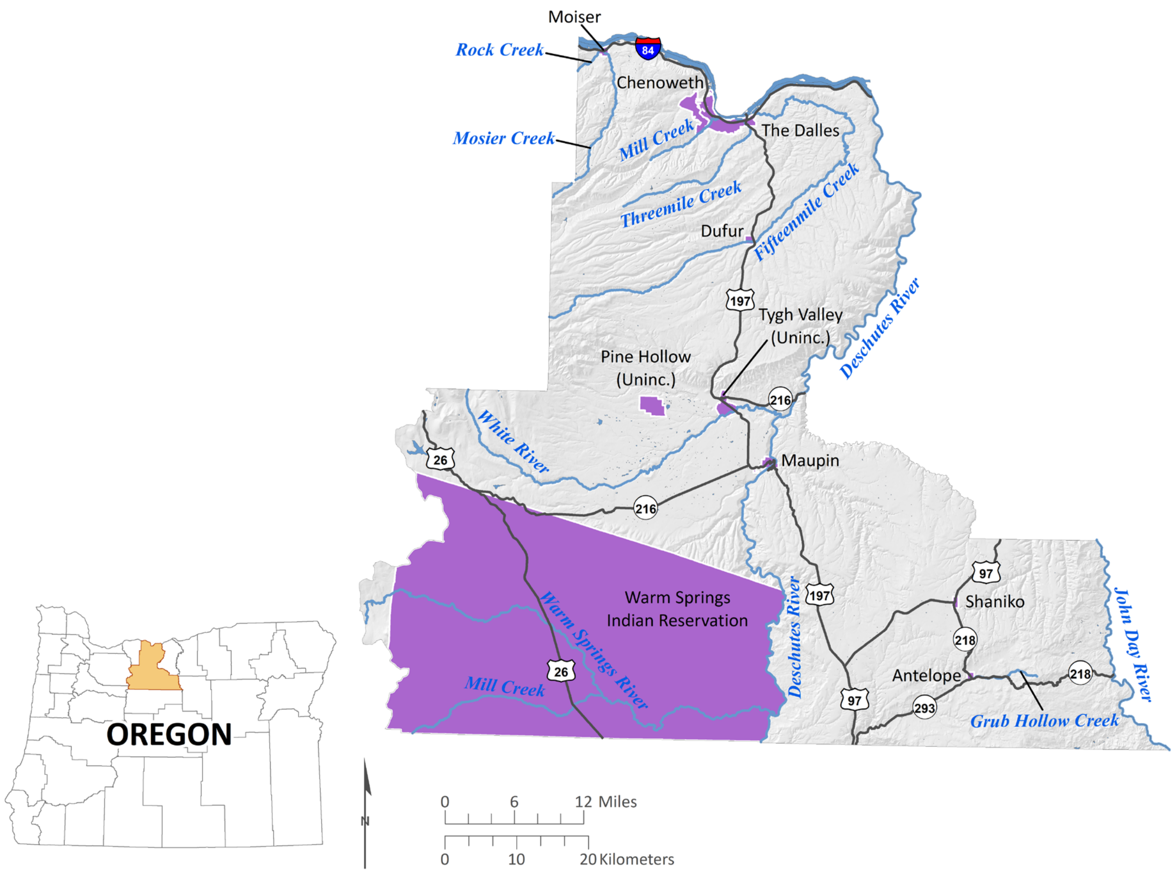
The geography of the region consists of the east slope of the Cascade Range which transitions into the gently rolling Columbia Plateau, cut by the canyons of the White, Warm Springs, John Day and Deschutes rivers and smaller streams that drain into the Columbia River. The Cascade slopes are forested, and the plateau and canyons are more arid and support grasslands or sagebrush steppe.

The population of Wasco County is 25,213 according to the 2010 U.S. Census Bureau (2010a). The county seat and county's largest community is the City of The Dalles. Most of the residents in the county reside within a few miles from the Columbia River. The incorporated communities are Antelope, Dufur, Maupin, Mosier, Shaniko and The Dalles (**Figure 1-1**). The unincorporated communities in the study area are Chenoweth, Tygh Valley, and Pine Hollow.

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

The Warm Springs Reservation is the federally recognized tribal lands of the Confederated Tribes of the Warm Springs Reservation of Oregon and is a community that is also identified in this report. The northern portion of the Warm Springs Reservation is located within the boundary of Wasco County. All results included in this report for the Warm Springs Reservation are only for the portion within the Wasco County boundary.

Figure 1-1. Study area: Wasco 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. The decision to limit the project scope to buildings and population was driven by data availability, 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 Wasco 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 2,500-year probabilistic magnitude 7.0 scenario

Flood Risk Assessment

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

Landslide Risk Assessment

- Exposure based on landslide susceptibility (low to very high)

Wildfire Risk Assessment

- Exposure based on wildfire risk index (low to high)

Table 1-1. Hazard data sources for Wasco 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: 0.1% (100-yr) 0.02% (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)
Wildfire	Risk (Low, Moderate, High)	Regional (Western United States)	Oregon Department of Forestry (Sanborn Map Company, Inc., 2013)

*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.

1.4 Previous Studies

One previous earthquake risk assessment including Wasco County has been conducted by DOGAMI. Wang and Clark (1999: DOGAMI Special Paper 29) ran two general level Hazus-MH earthquake analyses, a magnitude 8.5 Cascadia Subduction Zone (CSZ) earthquake and a 500-year probabilistic earthquake scenario, for the entire state of Oregon. In those analyses Wasco County was ranked in the lower range for loss ratio relative to most counties in the state.

We did not compare the results of this project with the results of the previous study 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:

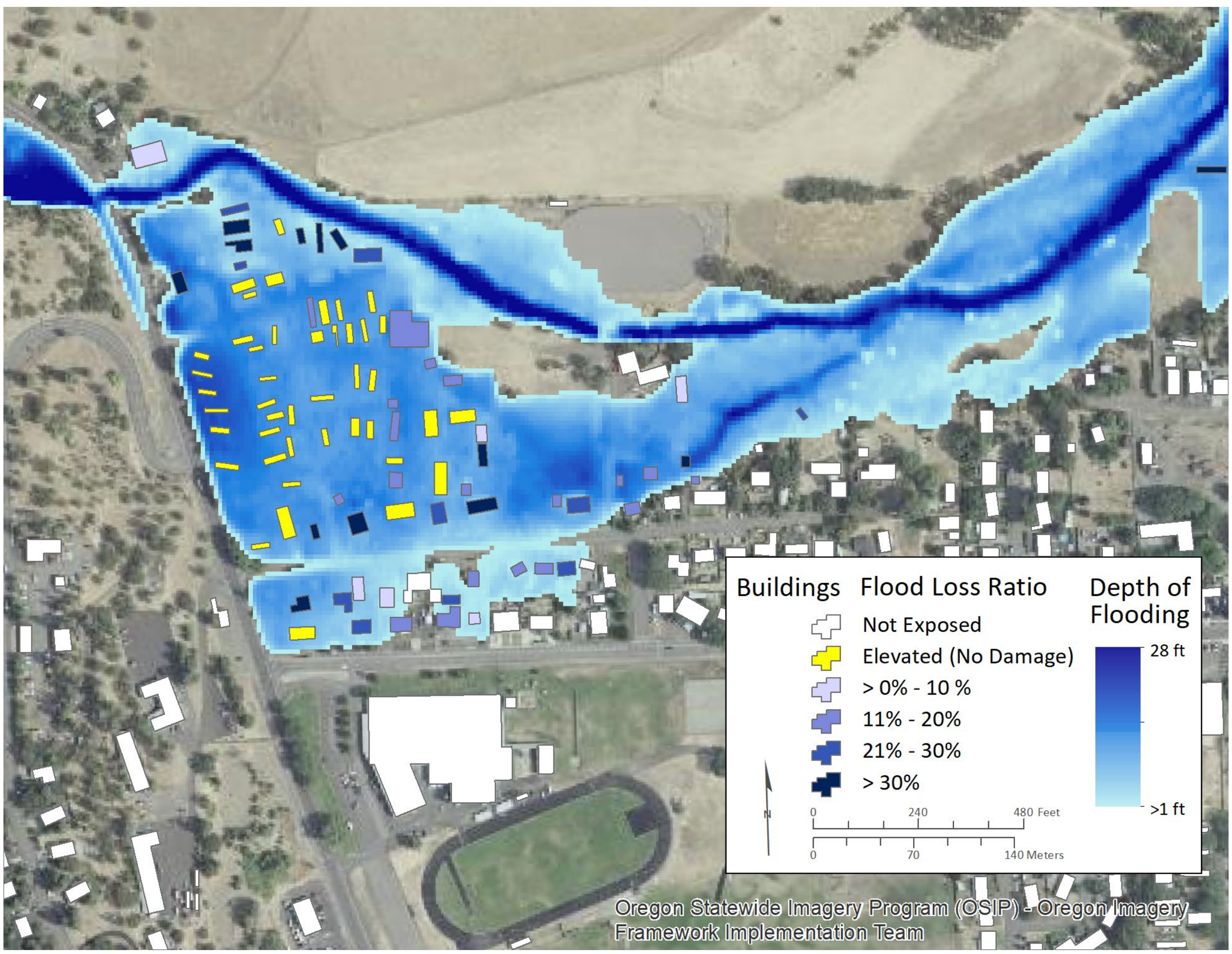
- *Loss estimation:* Damage that occurs to a building in an earthquake or flood scenario, as modeled with Hazus-MH methodology.
- *Loss ratio:* Percentage of estimated loss relative to the total value.

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 City of The Dalles.



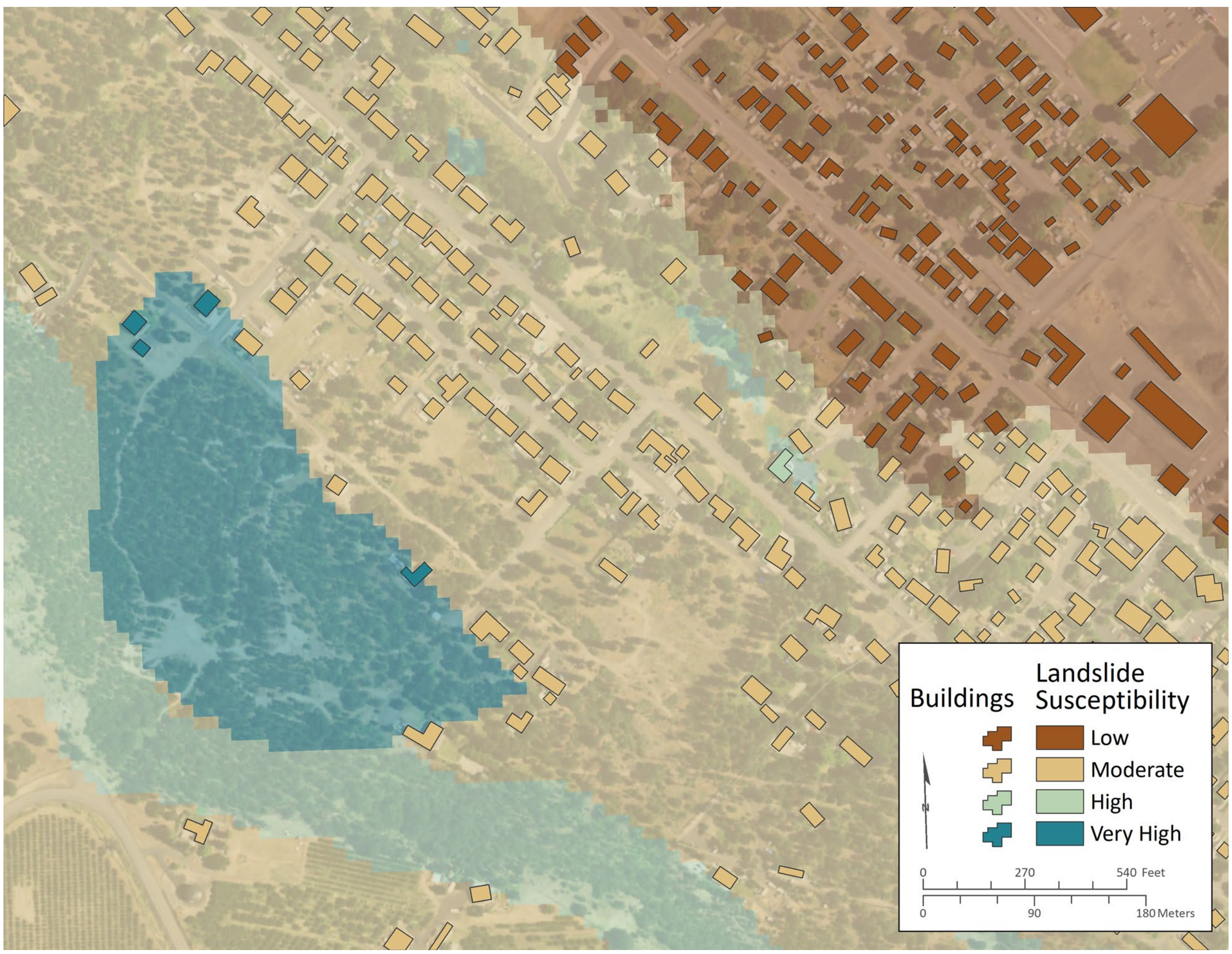
2.2 Exposure

> **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 and wildfire to quantify buildings and residents at risk. For comparison with loss estimates, exposure is also used for the 1% annual chance flood.

Figure 2-2. Landslide susceptibility and building exposure example in Wasco 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 or tax assessor data. **Figure 2-3** shows an example of building inventory occupancy types used in the Hazus-MH and exposure analyses in Wasco County. See also **Appendix B, Detailed Risk Assessment Tables** 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, portion of the City of The Dalles.

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

Table 2-1. Wasco County building inventory.

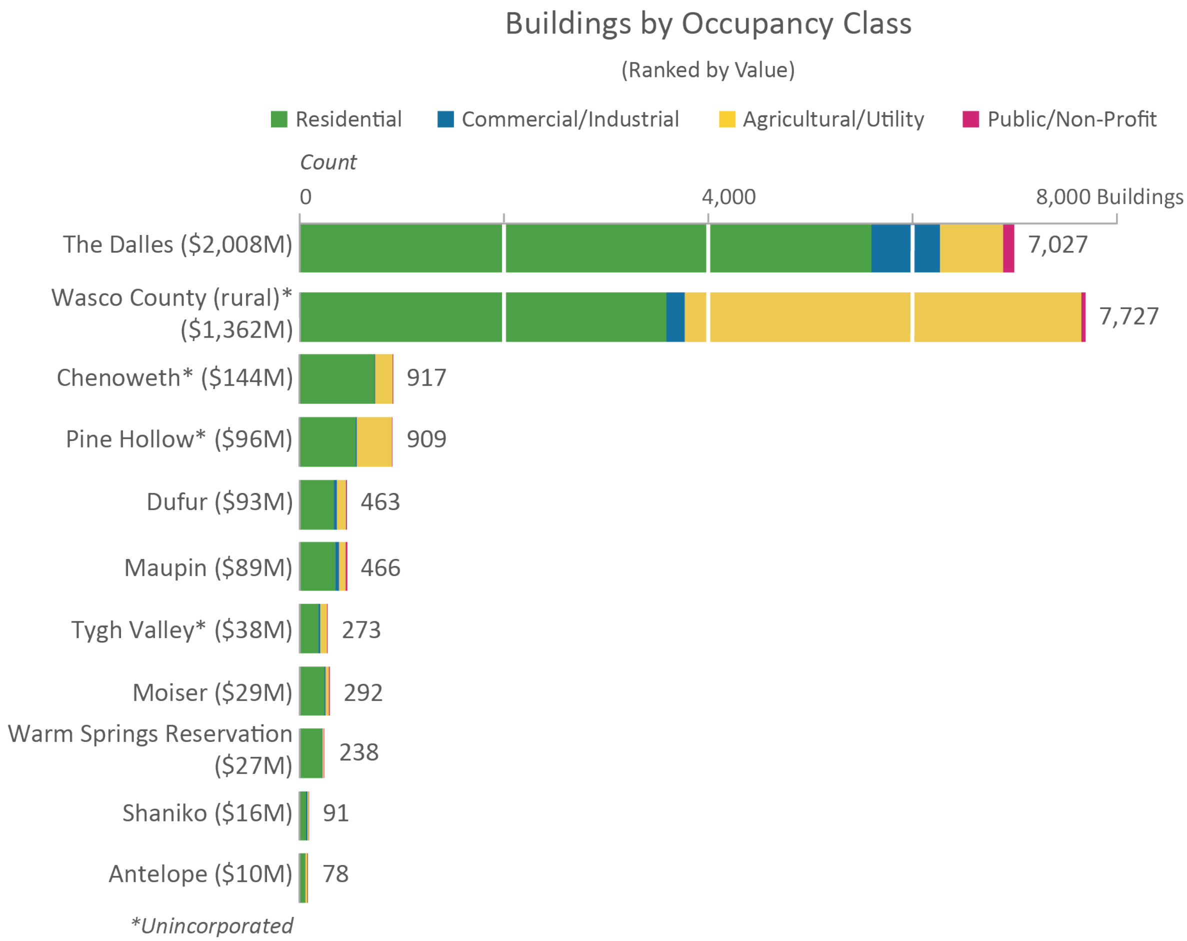
Community	Total Number of Buildings	Percentage of Buildings of Wasco County	Total Estimated Building Value ($)	Percentage of Building Value of Wasco County
Unincorporated County (rural)	7,727	42%	1,362,428,000	35%
Chenoweth	917	5.0%	143,595,000	3.7%
Pine Hollow	909	4.9%	95,521,000	2.4%
Tygh Valley	273	1.5%	37,496,000	1.0%
Warm Springs Reservation	238	1.3%	27,243,000	0.7%
Total Unincorporated County*	10,064	55%	1,666,283,000	43%
Antelope	78	0.4%	9,525,000	0.2%
Dufur	463	2.5%	92,824,000	2.4%
Maupin	466	2.5%	88,581,000	2.3%
Mosier	292	1.6%	28,875,000	0.7%
Shaniko	91	0.5%	15,581,000	0.4%
The Dalles	7,027	38%	2,007,625,000	51%
Total Wasco County	18,481	100%	3,909,294,000	100%

*Total includes portion of Warm Springs Reservation in Wasco County.

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 2015 (Wasco, Oregon Lidar Consortium; 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 18,481.

Wasco County supplied assessor data that we formatted for use in the risk assessment. The assessor data contain an array of information about each improvement (i.e., building). Tax lot data, which contain property boundaries and other information regarding the property, were obtained from the county assessor and were 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 assessment for both loss estimation and exposure analysis. **Figure 2-4** illustrates the building value and occupancy class across the communities of Wasco County.

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



Note that "Wasco County (rural)" excludes the Warm Springs Reservation, incorporated communities, Chenoweth, Tygh Valley, and Pine Hollow.

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. Wasco County critical facilities inventory.

	Hospital & Clinic		School		Police/Fire		Emergency Services		Military		Other*		Total	
Community	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)
(all dollar amounts in thousands)														
Unincorp. County (rural)	0	0	0	0	1	127	0	0	0	0	5	42,691	6	42,819
Chenoweth	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pine Hollow	0	0	0	0	1	1,361	0	0	0	0	0	0	1	1,361
Tygh Valley	0	0	0	0	1	452	0	0	0	0	0	0	1	452
Warm Springs Reservation	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Unincorp. County**	0	0	0	0	3	1,940	0	0	0	0	5	42,907	8	44,632
Antelope	0	0	0	0	1	153	0	0	0	0	1	747	2	899
Dufur	0	0	1	20,133	0	0	0	0	0	0	1	529	2	20,662
Maupin	0	0	2	12,798	1	1,215	0	0	0	0	2	383	5	14,396
Mosier	0	0	0	0	1	220	0	0	0	0	1	79	2	299
Shaniko	0	0	0	0	1	128	0	0	0	0	1	216	2	344
The Dalles	1	26,465	6	79,377	3	9,789	2	4,394	1	6,533	8	29,440	21	155,997
Total Wasco County	1	26,465	9	112,308	10	13,445	2	4,394	1	6,533	19	74,085	42	237,229

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).

**Total includes Warm Springs Reservation.

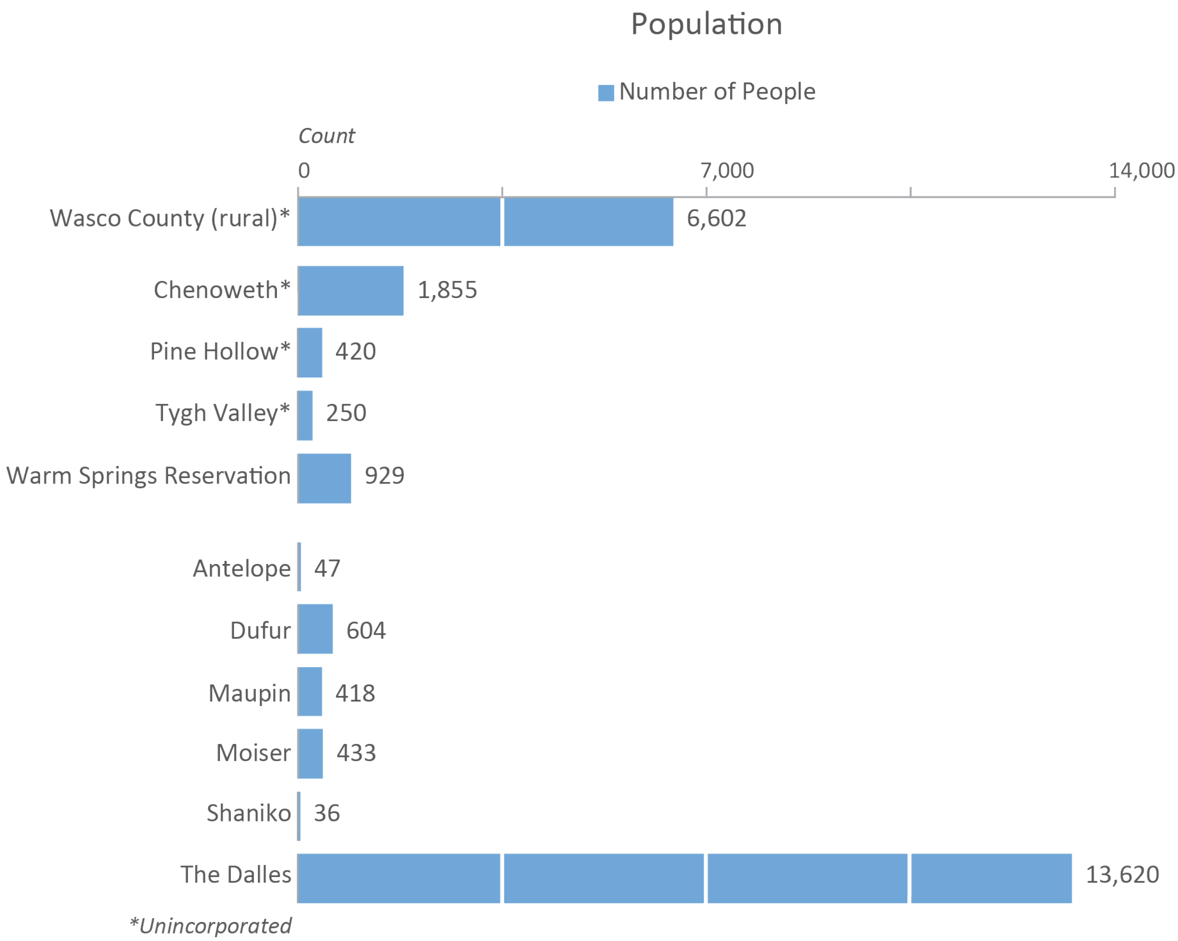
2.4 Population

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 for this report the impacts from natural hazards to non-permanent populations (e.g., tourists), whose total numbers fluctuate seasonally. Due to lack of information within the assessor and census databases, the distribution also includes vacation homes. From information reported in the 2010 U.S.

Census, American FactFinder regarding vacation rentals within the county (including incorporated communities), it is estimated that approximately 6% of residential buildings are vacation rentals in Wasco County (U.S. Census Bureau, 2010b).

From the census data, we analyzed the 25,213 residents within the study area who could be affected by a natural hazard scenario. For each natural hazard, with the exception of the 2,500-year probabilistic earthquake scenario, a simple exposure analysis was used to find the number of potentially displaced residents within a hazard zone. For the 2,500-year probabilistic earthquake scenario the number of potentially displaced residents was based on those in buildings estimated to be significantly damaged by the earthquake.

Figure 2-5. Population by Wasco County community.



3.0 ASSESSMENT OVERVIEW AND RESULTS

This risk assessment considers four natural hazards (earthquake, flood, landslide, and wildfire) that pose a risk to Wasco 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, tribal lands, unincorporated communities, and cities within Wasco 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, liquefaction, and landslide factors.

3.2.1 Data sources

Hazus-MH offers two scenario methods for estimating loss from earthquake, probabilistic and deterministic (FEMA Hazus-MH, 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.

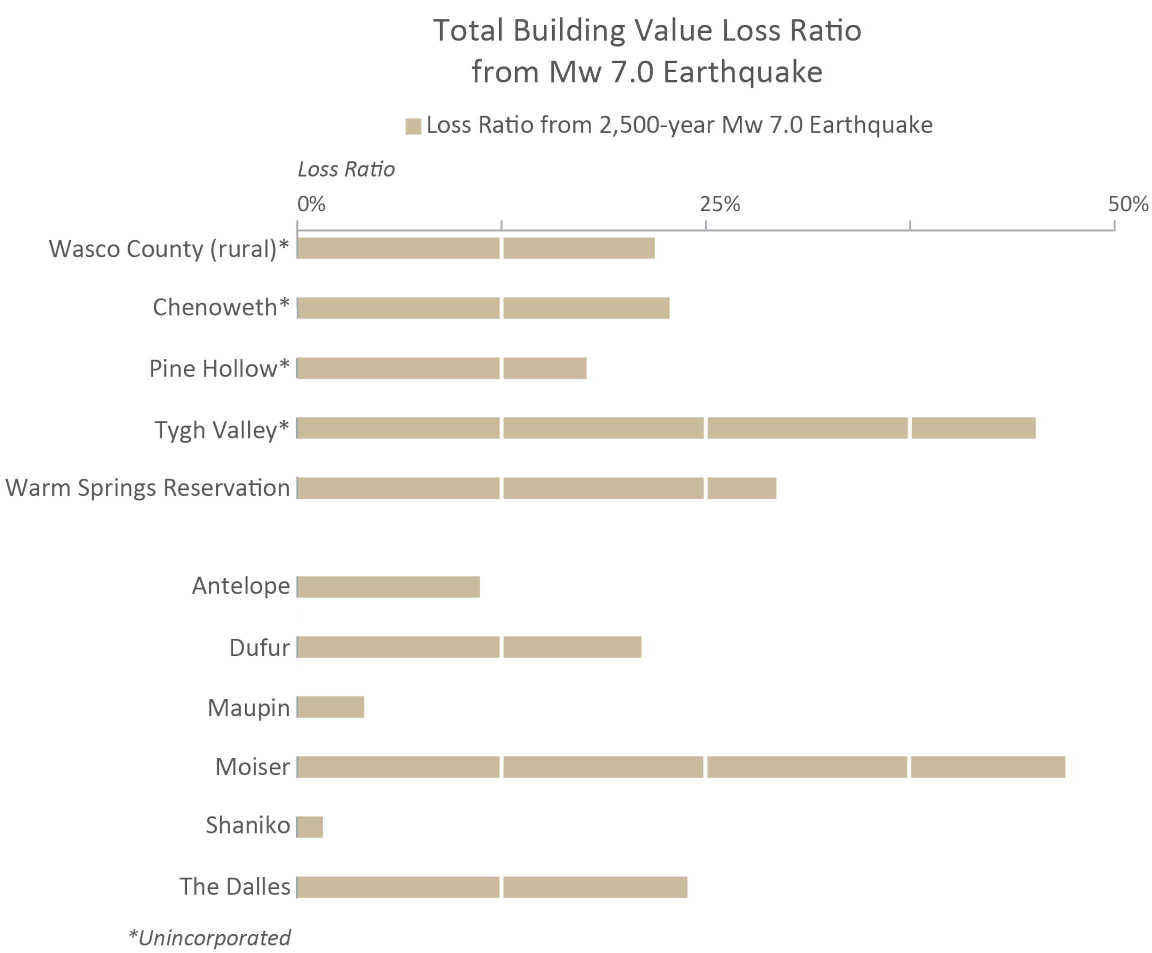
The 2% in 50 years or 2,500-year (actually 2,475-year) probabilistic shaking map of Madin and others (2021) was selected as the most appropriate for communicating earthquake risk for Wasco County. We based this decision on several factors such as previous Hazus-MH earthquake analyses in the region, available 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 Wasco 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 to each of the five damage state percentages (none, low, moderate, extensive, and complete). These damage states are correlated to loss ratios which are multiplied by the building dollar value resulting in a loss estimate (FEMA Hazus-MH, 2012b). **Figure 3-1** shows the loss estimates by community for Wasco County from an earthquake scenario described in this report.

Figure 3-1. Earthquake loss ratio by Wasco 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.

Wasco countywide 2,500-year probabilistic Mw 7.0 earthquake results:

- Number of red-tagged buildings: 1,104
- Number of yellow-tagged buildings: 2,118
- Loss estimate: $870,172,000
- Loss ratio: 22%
- Non-functioning critical facilities: 18
- Potentially displaced population: 1,888

The results indicate that Wasco County would incur significant losses (22%) due to the earthquakes represented in the probabilistic shaking map. These results are strongly influenced by ground deformation from liquefaction. High liquefaction and high landslide susceptibility exist in inhabited parts of the county, which increases the risk from earthquake. Developed areas in the communities of Chenoweth, Dufur, and the north and west parts of The Dalles have high estimates of damage due to liquefaction.

Although damage caused by coseismic landslides was not specifically looked at in this report, it likely contributes a moderate amount of the estimated damage from the earthquake hazard in Wasco County. Landslide exposure results show that 27% of buildings in Wasco 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. Developed areas in the communities of Mosier, Tygh Valley, and the south and east parts of The Dalles have may see losses due to coseismic landslide.

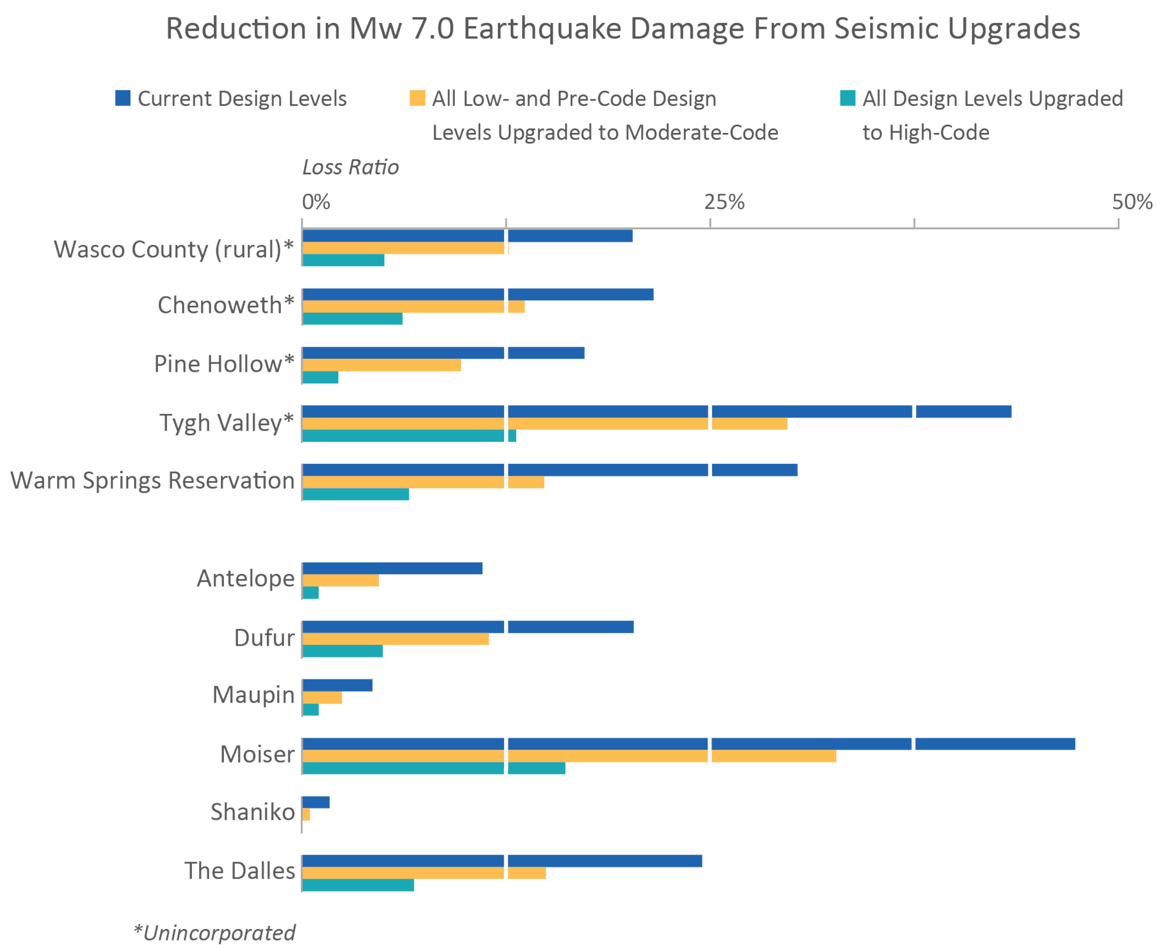
Building vulnerabilities such as the age of the building stock and occupancy type are also contributing factors in damage estimates. The first seismic buildings codes were implemented in Oregon in the 1970s (Judson, 2012) and by the 1990s, modern seismic building codes were being enforced. Nearly 85% of Wasco 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.

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.

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 22% to 14%, 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.

Figure 3-2. 2,500-year probabilistic Mw 7.0 earthquake loss ratio in Wasco 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 Chenoweth, Dufur, and the north and west parts of The Dalles which increases the likelihood of substantial ground deformation and building damage from an earthquake.
- High and very high landslide hazard areas in Mosier, Tygh Valley, and the south and east parts of The Dalles 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 throughout the county are older and less likely to meet modern building design standards. Older buildings may be more vulnerable to substantial damage during an earthquake.
- 18 of the 42 critical facilities in the study area are estimated to be nonfunctioning 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 Wasco 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 Columbia, Deschutes, John Day, Warm Springs, and White rivers and Fifteenmile, Grub Hollow, Mosier, Mill, Rock, Threemile creeks. All the listed streams are subject to flooding and can cause damage to buildings within the floodplain.

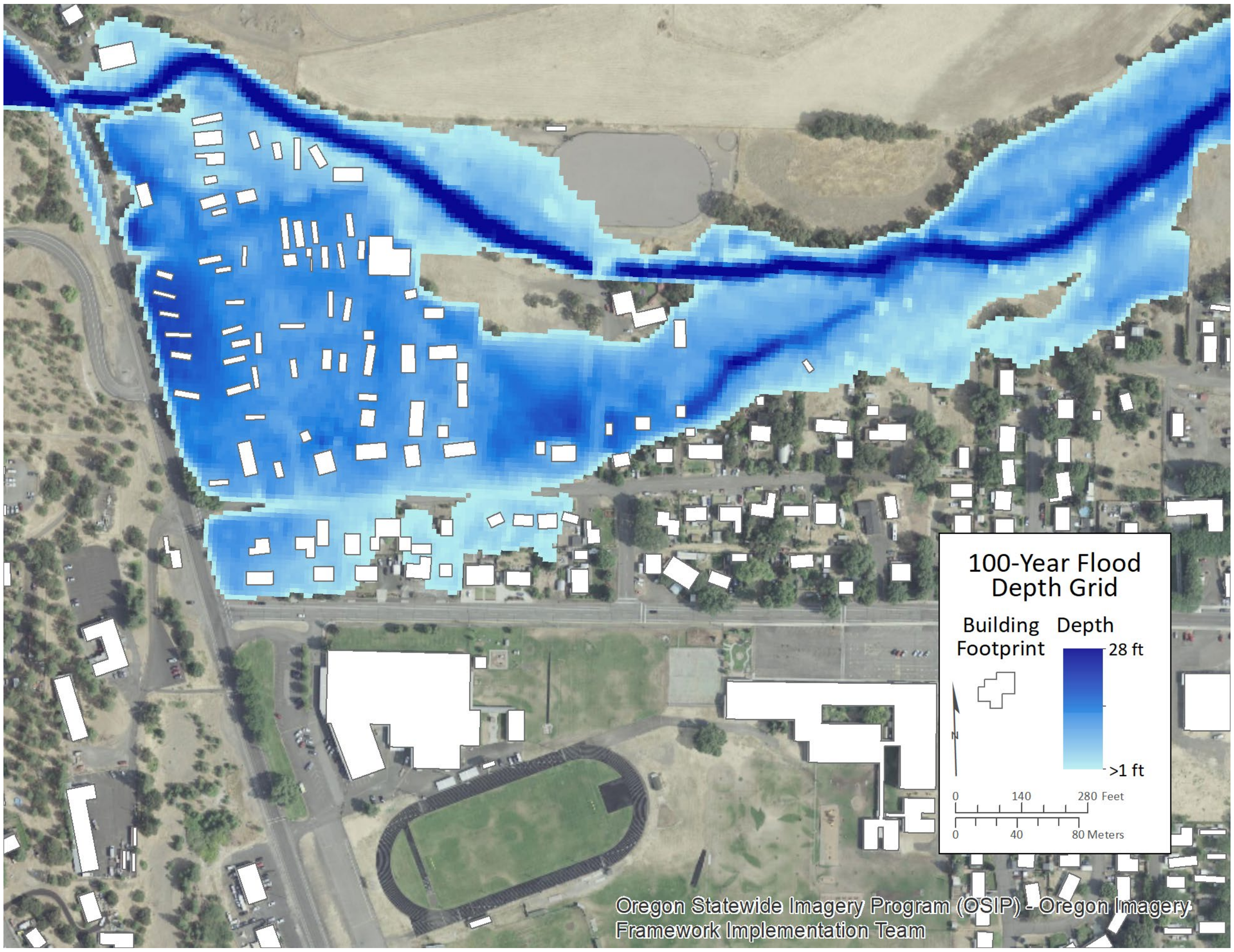
The impacts of flooding are determined by adverse effects to human activities within the natural and built environment. Through strategies such as flood hazard mitigation these adverse impacts can be reduced. Examples of common mitigating activities are elevating structures above the expected level of 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 Wasco 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 grid 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 City of The Dalles.



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 Wasco County, occupancy type was inferred from land use and zoning data. Basement presence attributes were derived from oblique imagery and street level imagery to estimate this important building attribute. 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 5**). 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 (FEMA, 2013). See **Appendix B, Table B-4** for multi-scenario cumulative results.

Wasco countywide 100-year flood loss:

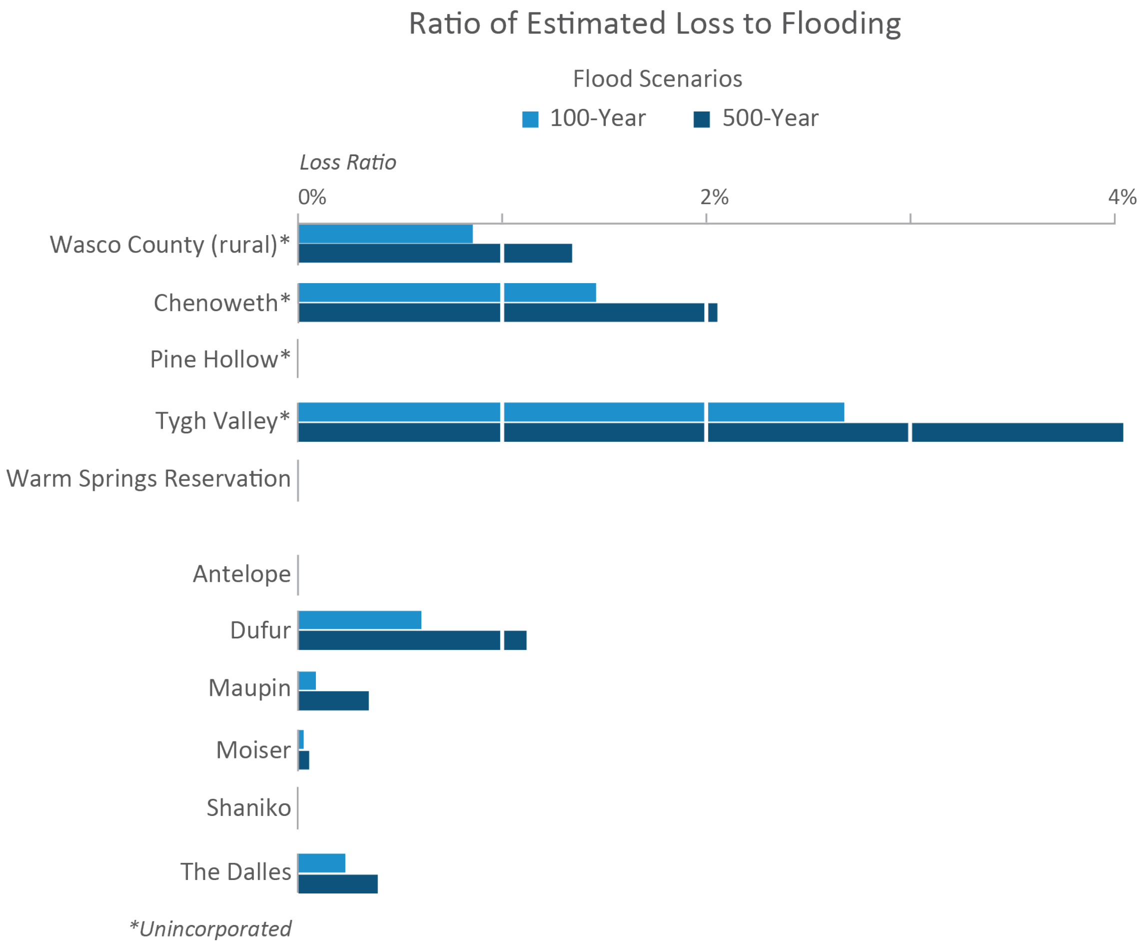
- Number of buildings damaged: 560
- Loss estimate: $19,867,000
- Loss ratio: 0.5%
- Damaged critical facilities: 1
- Potentially displaced population: 540

3.3.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario for the entire county is nearly $20 million. While the overall loss ratio for flood damage in Wasco County is only 0.5%, 100-year flooding has a significant impact to Sherman 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 in Wasco County are in the communities of Chenoweth, Tygh Valley, The Dalles, and Dufur. Flooding from streams that flow through these communities can flood and cause damage to nearby buildings. The loss estimate of the 100-year flood scenario for the entire county is nearly $20 million (**Figure 3-4**). Throughout the unincorporated parts of the county there are buildings along mapped streams that are estimated to be damaged by a 100-year flood.

Figure 3-4. Ratio of flood loss estimates by Wasco 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 undamaged buildings from Hazus-MH with the number of exposed buildings in the flood zone. Many of Wasco County's buildings were found to be within designated flood zones. Of the 586 buildings that are exposed to flooding, we estimate that only 26 are above the height of the 100-year flood. This evaluation also estimates that 540 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:

- Buildings along Chenoweth Creek in the community of Chenoweth and The City of The Dalles are at high risk from flooding.
- Buildings along Tygh Creek in the community of Tygh Valley are at high risk to flooding.
- Buildings along Fifteenmile Creek in the community of Dufur are at high risk to flooding.

- Approximately 9% of the residents in Dufur and Tygh Valley could potentially be displaced from a 100-year flood.

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 Wasco 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. Most of the landslide inventory mapping for Wasco County was done in the early 1970s. Some lidar-based mapping was done in 2012 in a rural unincorporated area east of Toledo as part of a water quality evaluation.

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.

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

Nearly all of Wasco County communities have some exposure to landslide hazard. Communities that developed in terrain with moderate to steep slopes or at the base of steep hillsides may be at risk to landslides. Some developed areas in Mosier and Tygh Valley, also areas in the Warm Springs Reservation, are highly susceptible to landslide hazard. While these areas are highly susceptible to landslides, most of the populated areas are not within these zones. The percentage of building value exposed to very high and high landslide susceptibility is approximately 13% 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 accurately depict the level of landslide risk to communities. The high and very high susceptibility zones represent areas most susceptible to landslides and with the highest impact to the community.

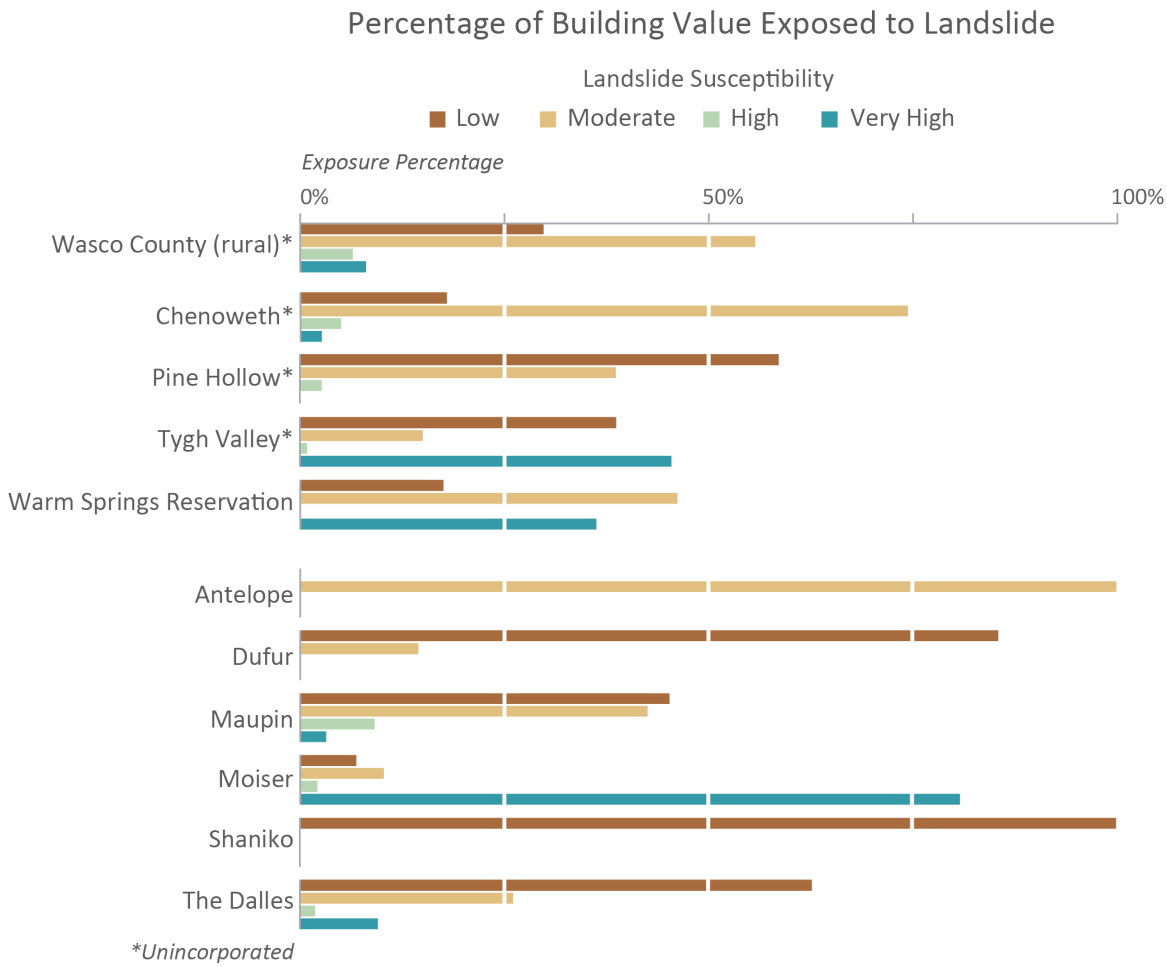
For this risk assessment we compared building locations to geographic extents of the landslide susceptibility zones (**Figure 3-5**). The exposure results shown below are for the high and very high susceptibility zones. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Wasco countywide landslide exposure (High and Very High susceptibility):

- Number of buildings: 3,013
- Value of exposed buildings: $498,607,000
- Percentage of exposure value: 13%
- Critical facilities exposed: 4
- Potentially displaced population: 4,338

The majority of buildings in Wasco County corresponds to the gentle terrain found near The Dalles and in the central part of the county along the White River, which are typically low susceptibility landslide zones. Despite this development pattern, there is a significant 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 the county.

Figure 3-5. Landslide susceptibility exposure by Wasco 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 Mosier and Tygh Valley 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 Mosier and Tygh Valley.
- The hilly portions in the central and eastern part of The Dalles are very highly susceptible to landslides.
- A large area of very high landslide hazard is present just to the south of the community of Chenoweth, where development has occurred and is likely to occur in the future.

3.5 Wildfire

Wildfires are a natural part of the ecosystem in Oregon. However, wildfires can present a substantial hazard to life and property in growing communities, because communities often grow in 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 Wasco County. Forests and grasslands cover a significant portion of Wasco County. “Conditions throughout the county are conducive to large and destructive wildfires” (Hulbert, 2005, p. 5). To limit exposure to wildfire, the Wasco County Land Use and Development Ordinance (WLUDO) requires a 100-foot (30-meter) setback from property lines to reduce the fire risk between residences and potential resource use on adjacent parcels (Wasco County Planning Department, 2016). Contact the Wasco County Planning Department 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 Wasco County.

Using guidance from ODF, we categorized the FRI into low, moderate, and high hazard zones for the wildfire exposure analysis. The 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-6**). The total dollar value of exposed buildings 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

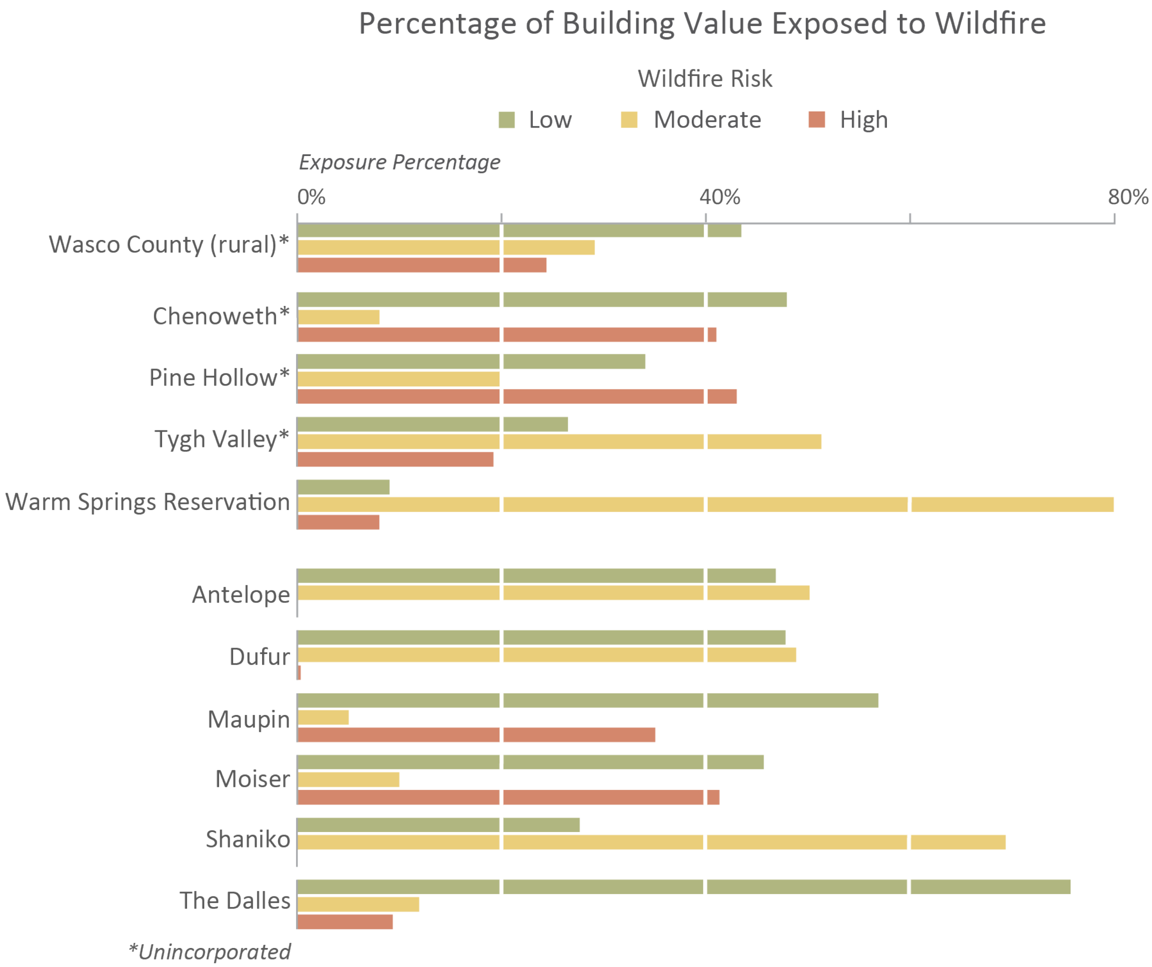
The high hazard category was chosen as the primary scenario for this report because that category represents areas that have the highest potential for losses. However, a large amount of loss would occur if the moderate hazard areas were to burn, as almost every community has at least 50% of exposure to moderate wildfire hazard. Still, the focus of this section is on high hazard areas within Wasco County to emphasize the areas where lives and property are most threatened.

Wasco countywide wildfire exposure (High hazard):

- Number of buildings: 4,057
- Value of exposed buildings: $693,559,000
- Percentage of total county value exposed: 18%
- Critical facilities exposed: 10
- Potentially displaced population: 5,125

For this risk assessment, building locations were compared to the geographic extent of the wildfire hazard categories. We found that many of the communities in Wasco County have a significant amount of high-risk exposure to wildfire. The primary areas of exposure to this hazard are in the forested areas along the eastern slopes of the Cascade Range, the Deschutes River valley, and many areas within the Warm Springs Reservation (see **Appendix E, Plate 6**). The communities of Pine Hollow, Mosier, Chenoweth, and Maupin are at a higher risk to wildfire than other communities in the study area. **Figure 3-6** illustrates the distribution of losses due to wildfire with the different communities of Wasco County. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Figure 3-6. Wildfire hazard exposure by Wasco 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:

- Wildfire risk is high for many homes in the WUI around the community of Maupin.
- A residential area south of the Pine Hollow Reservoir is designated a high wildfire risk area.
- A very large area (~30 square miles or 48 square kilometers) between Mosier and Chenoweth is a high wildfire risk.

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 accomplish this by using the latest natural hazard mapping and loss estimation tools to quantify expected damage to buildings and potential displacement of permanent residents. The comprehensive and fine-grained 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:

- **Moderate 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 Wasco County will experience significant impact and disruption. Results show that an earthquake can cause building losses of 20% to 40% to several communities in the study area. Some communities like Chenoweth, Dufur, and parts of The Dalles can expect a high percentage of losses due to ground deformation related to liquefaction. Some communities like Mosier, Tygh Valley, and parts of The Dalles may have a high percentage of losses due to coseismic landslides. The vulnerability of the building inventory (building age and occupancy type) also contributes 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 by Hazus-MH. 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 CSZ 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 22% to 14%. We found further reduction in estimated loss in our simulation to 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 Tygh Valley, where a significant loss reduction (from 43% to 29%) could occur by retrofitting all buildings to at least moderate code. While seismic retrofits are an effective strategy for reducing earthquake shaking damage, it should be noted that 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 decisionmakers.
- **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 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 from flooding. Another consideration is that flood is one of the most frequently occurring natural hazard. An average of 17% 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 residential buildings in Chenoweth, Dufur, Tygh Valley, and northeastern The Dalles along local streams.

- **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 unincorporated county 10% of the buildings exposed to flooding are elevated above the base flood elevation. Based on the number of buildings exposed to flooding several communities would benefit from elevating above the level of flooding.
- **New landslide mapping would increase the accuracy of future risk assessments**—The landslide hazard data used in this risk assessment were created before 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 a widespread hazard and is present for some communities within the county. The communities of Mosier and Tygh Valley have high levels of exposure to landslide hazard and residences within the Warm Springs Reservation are in areas that are highly susceptible to landslides.
- **Wildfire risk is significant for the overall study area**—Exposure analysis shows that buildings along the Columbia River and areas between and around the communities of Mosier and Chenoweth are very vulnerable to wildfire hazard. Additional highly vulnerable areas within the county are along the Deschutes River. Despite these concentrations of vulnerability, high wildfire hazard is present throughout the county. The communities of Pine Hollow, Maupin, and Tygh Valley, as well as the unincorporated county, have a 20% to 44% exposure to high wildfire hazard.
- **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 43% (18 of 42) of Wasco County's critical facilities will be non-functioning after an earthquake like one simulated in this report. In comparison, 24% (10 of 42) of critical facilities are at risk to wildfire hazard. A small number of critical facilities are at risk to flooding (1 of 42) and landslide (4 of 42) hazards.
- **The biggest causes of displacement to population are wildfire and landslide hazards**—Displacement of permanent residents from natural hazards was quantified within this report. We estimated that 20% of the population in the county are at risk to displacement due to wildfire hazard. Landslide hazard is a potential threat to 17% of permanent residents and 7% from earthquake hazard. A small percentage of residents are at risk to displacement from flood.
- **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 between communities and impacts from each natural hazard. In using Hazus-MH and exposure analysis, these results 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. Hazus-MH does not provide a site-specific analysis. 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 Sherman 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 underestimating the number of people that may be at risk to hazards, especially during periods of high temporary population.
- **Data accuracy and completeness—**Some datasets in our risk assessment had incomplete coverage or no 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 attributes derived from the assessor database, 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 decisionmakers 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 reevaluate 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 increase 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, 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.

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9.0 APPENDICES

APPENDIX A. COMMUNITY RISK PROFILES

A hazard 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 Wasco County (Rural)

Table A-1. Unincorporated Wasco County hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Unincorporated Wasco County		6,602	7,727		6	1,362,428,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	234	3.5%	308	0	11,184,000	0.8%
Earthquake	EQ Scenario	359	5.4%	1,150	2	273,499,000	20%
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	1,477	22%	1,343	0	196,958,000	14%
Wildfire	High Risk	2,824	43%	2,474	3	342,676,000	25%

[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 Wasco County critical facilities.

Critical Facilities by Community	**Flood 1% Annual Chance Exposed**	**Earthquake Moderate to Complete Damage >50% Prob.**	**Landslide High and Very High Susceptibility Exposed**	**Wildfire High Hazard Exposed**
BPA Big Eddy Substation				X
BPA Celilo Substation				
Juniper Flats Rural Fire Protection				
The Dalles Dam - Offices				X
Washington Family Ranch Airstrip		X		
Wicks Water Treatment Plant		X		X

A.2 Unincorporated Community of Chenoweth

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

Community Overview

Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Chenoweth	1,855	917	0	143,595,000

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	171	9.2%	97	0	2,177,000	1.5%
Earthquake	EQ Scenario	140	7.5%	184	0	30,657,000	21%

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	105	5.7%	70	0	10,911,000	7.6%
Wildfire	High Risk	806	43%	402	0	60,730,000	42%

[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).

A.3 Unincorporated Community of Pine Hollow

Table A-4. Unincorporated community of Pine Hollow hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Pine Hollow		420	909		1	95,521,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake	EQ Scenario	1	0.3%	70	0	16,387,000	17%
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	11	2.7%	18	0	2,535,000	2.7%
Wildfire	High Risk	212	50%	417	1	42,379,000	44%

[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-5. Unincorporated community of Pine Hollow critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Wamic Rural Fire Department				X

A.4 Unincorporated Community of Tygh Valley

Table A-6. Unincorporated community of Tygh Valley hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Tygh Valley		250	273		1	37,496,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	23	9.1%	38	1	1,044,000	2.8%
Earthquake	EQ Scenario	47	19%	131	1	16,153,000	43%
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	153	61%	142	1	17,364,000	46%
Wildfire	High Risk	64	26%	62	1	7,420,000	20%

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

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

Table A-7. Unincorporated community of Tygh Valley critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High Hazard**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Tygh Valley Rural Fire Protection District	X	X	X	X

A.5 Warm Springs Reservation*

Table A-8. Warm Springs Reservation hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Warm Springs Reservation	929	238	0	27,243,000

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	EQ Scenario	38	4.1%	28	0	8,198,000	30%

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	133	14%	26	0	9,883,000	36%
Wildfire	High Risk	108	12%	33	0	2,257,000	8.3%

*Information presented in table for portion of Warm Springs Reservation within Wasco County.

[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).

A.6 City of Antelope

Table A-9. City of Antelope hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Antelope	47	78	2	9,525,000

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	EQ Scenario	0	0.0%	2	0	1,044,000	11%

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%

[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 Antelope critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Antelope Community Center				
Antelope Fire Department				

A.7 City of Dufur

Table A-11. City of Dufur hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Dufur	604	463	2	92,824,000	

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	26	4.4%	27	0	580,000	0.6%
Earthquake	EQ Scenario	29	4.8%	82	1	18,696,000	20%

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	4	0.7%	5	0	341,000	0.4%

[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 Dufur critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High Hazard**
Critical Facilities by Community*	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Dufur City Hall				
Dufur High School		X		

A.8 City of Maupin

Table A-13. City of Maupin hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Maupin	418	466	5	88,581,000	

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%	3	0	77,000	0.1%
Earthquake	EQ Scenario	2	0.4%	13	0	3,787,000	4.3%

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	49	12%	67	0	10,833,000	12%
Wildfire	High Risk	162	39%	174	1	32,019,000	36%

[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-14. City of Maupin critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Maupin City Hall				
Maupin Fire Department				
Maupin Grade School				X
Maupin Wastewater Treatment				
South Wasco High School				

A.9 City of Mosier

Table A-15. City of Mosier hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Mosier	433	292	3	28,875,000

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	1	0.2%	1	0	8,000	0.0%
Earthquake	EQ Scenario	118	27%	124	3	13,559,000	47%

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	336	78%	223	2	23,943,000	83%
Wildfire	High Risk	164	38%	114	0	12,307,000	43%

[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-16. City of Mosier critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Mosier City Hall		X	X	
Mosier Community School		X	X	X
Mosier Fire Department		X	X	

A.10 City of Shaniko

Table A-17. City of Shaniko hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Shaniko		36	91		2		15,581,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake	EQ Scenario	0	0.0%	0	0	261,000	1.7%
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%

[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-18. City of Shaniko critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High Hazard**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Shaniko Fire House				
Shaniko Historic City Hall				

A.11 City of The Dalles

Table A-19. City of The Dalles hazard profile.

Community Overview

Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
The Dalles	13,620	7,027	21	2,007,625,000

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	84	0.6%	86	0	4,797,000	0.2%
Earthquake	EQ Scenario	1,155	8.5%	1,436	11	487,930,000	24%

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	2,074	15%	1,124	1	226,180,000	11%
Wildfire	High Risk	780	5.7%	376	4	193,429,000	9.6%

[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-20. City of The Dalles critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Risk
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Chenowith Elementary School		X		X
Chenowith Water PUD		X		
Colonel Wright Elementary School				
Dry Hollow Elementary School				X
Mid-Columbia Fire and Rescue		X		
Mid-Columbia Fire Station No. 2				
Mid-Columbia Medical Center		X	X	X
Northern Wasco County PUD				
Oregon Natl Guard - Fort Dalles Readiness Center				
Port of the Dalles				
Road Department				X
The Dalles City Hall		X		
The Dalles High School		X		
The Dalles Middle School				
The Dalles Police Department		X		
The Dalles Public Works				
The Dalles Wastewater Treatment		X		
Wahtonka High School		X		
Wasco County Emergency Management		X		
Wasco County Public Works		X		
Wasco County Sheriff's Office				

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

Table B-1. Wasco County building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Non-Profit			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)	3,605	454,349	33%	182	117,753	8.6%	3,901	737,124	54%	39	53,202	3.9%	7,727	42%	1,362,428	35%
Chenoweth	735	104,991	73%	5	697	0.5%	172	24,313	17%	5	13,594	9.5%	917	5.0%	143,595	3.7%
Pine Hollow	548	45,646	48%	10	2,256	2.4%	348	46,162	48%	3	1,456	1.5%	909	4.9%	95,521	2.4%
Tygh Valley	182	20,709	55%	16	3,200	8.5%	69	10,467	28%	6	3,120	8.3%	273	1.5%	37,496	1.0%
Warm Springs Reservation	214	13,033	48%	8	13,220	49%	14	840	3.1%	2	150	0.5%	238	1.3%	27,243	0.7%
Total Unincorporated County	5,284	638,728	38%	221	137,126	8.2%	4,504	818,906	49%	55	71,522	4.3%	10,064	55%	1,666,283	43%
Antelope	53	5,253	55%	1	224	2.4%	20	2,484	26%	4	1,563	16%	78	0.4%	9,525	0.2%
Dufur	334	46,961	51%	32	9,175	10%	88	13,175	14%	9	23,512	25%	463	2.5%	92,824	2.4%
Maupin	347	51,122	58%	38	12,799	14%	67	8,305	9.4%	14	16,355	18%	466	2.5%	88,581	2.3%
Mosier	242	19,077	66%	11	3,326	12%	31	3,081	11%	8	3,391	12%	292	1.6%	28,875	0.7%
Shaniko	62	6,362	41%	10	1,563	10%	15	6,433	41%	4	1,223	7.8%	91	0.5%	15,581	0.4%
The Dalles	5,623	1,024,453	51%	674	719,613	36%	621	64,227	3.2%	109	199,332	10%	7,027	38%	2,007,625	51%
Total Wasco County	11,945	1,791,956	46%	987	883,826	23%	5,346	916,611	23%	203	316,898	8.1%	18,481	100%	3,909,294	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)	7,727	1,362,428	805	345	273,499	20%	599	125	171,035	13%
Chenoweth	917	143,595	115	70	30,657	21%	108	22	19,409	14%
Pine Hollow	909	95,521	68	2	16,387	17%	11	0	9,223	10%
Tygh Valley	273	37,496	81	50	16,153	43%	72	13	11,054	29%
Warm Springs Reservation	238	27,243	23	6	8,198	30%	10	2	4,008	15%
Total Unincorporated County	10,064	1,666,283	1,092	473	344,894	21%	800	162	214,729	13%
Antelope	78	9,525	2	0	1,044	11%	0	0	444	4.7%
Dufur	463	92,824	61	22	18,696	20%	48	10	10,534	11%
Maupin	466	88,581	10	3	3,787	4.3%	9	2	2,148	2.4%
Mosier	292	28,875	60	64	13,559	47%	76	15	9,365	32%
Shaniko	91	15,581	0	0	261	1.7%	0	0	73	0.5%
The Dalles	7,027	2,007,625	893	543	487,930	24%	855	182	297,325	15%
Total Wasco County	18,481	3,909,294	2,118	1,105	870,171	22%	1,788	371	534,618	14%

Table B-3. Flood loss estimates.

			(all dollar amounts in thousands)					
			1% (100-yr)			**0.2% (500-yr)**		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**
Unincorporated County (rural)	7,727	1,362,428	308	11,184	0.8%	364	18,120	1.3%
Chenoweth	917	143,595	97	2,177	1.5%	102	3,082	2.1%
Pine Hollow	909	95,521	0	0	0.0%	0	0	0.0%
Tygh Valley	273	37,496	38	1,044	2.8%	40	1,573	4.2%
Warm Springs Reservation	238	27,243	0	0	0.0%	0	0	0.0%
Total Unincorporated County	10,064	1,666,283	443	14,405	0.9%	506	22,775	1.4%
Antelope	78	9,525	0	0	0.0%	0	0	0.0%
Dufur	463	92,824	27	580	0.6%	35	1,079	1.2%
Maupin	466	88,581	3	77	0.1%	12	317	0.4%
Mosier	292	28,875	1	8	0.0%	1	16	0.1%
Shaniko	91	15,581	0	0	0.0%	0	0	0.0%
The Dalles	7,027	2,007,625	86	4,797	0.2%	134	8,002	0.4%
Total Wasco County	18,481	3,909,294	560	19,867	0.5%	688	32,189	0.8%

Table B-4. Flood exposure.

			1% (100-yr)				
Community	**Total Number of Buildings**	**Total Population**	**Potentially Displaced Residents from Flood Exposure**	**% Potentially Displaced Residents from flood Exposure**	**Number of Flood Exposed Buildings**	**% of Flood Exposed Buildings**	**Number of Flood Exposed Buildings Without Damage**
Unincorporated County (rural)	7,727	6,602	303	4.6%	399	5.2%	38
Chenoweth	917	1,855	171	9.2%	97	11%	1
Pine Hollow	909	420	0	0.0%	0	0.0%	0
Tygh Valley	273	250	23	9.1%	40	14.7%	2
Warm Springs Reservation	238	929	0	0.0%	0	0.0%	0
Total Unincorporated County	10,064	10,056	497	4.9%	536	5.3%	41
Antelope	78	47	0	0.0%	0	0.0%	0
Dufur	463	604	26	4.4%	28	6.0%	1
Maupin	466	418	0	0%	3	1%	0
Mosier	292	433	1	0%	1	0%	0
Shaniko	91	36	0	0%	0	0%	0
The Dalles	7,027	13,620	85	1%	88	1%	1
Total Wasco County	18,481	25,214	609	2%	656	4%	43

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)	7,727	1,362,428	745	109,521	8.0%	598	87,436	6.4%	4,227	759,629	56%
Chenoweth	917	143,595	25	3,756	2.6%	45	7,155	5.0%	584	106,916	74%
Pine Hollow	909	95,521	0	0	0.0%	18	2,535	2.7%	392	36,966	39%
Tygh Valley	273	37,496	138	17,058	45%	4	306	0.8%	32	5,621	15%
Warm Springs Reservation	238	27,243	26	9,883	36.3%	0	0	0.0%	101	12,584	46%
Total Unincorporated County	10,064	1,666,283	934	140,218	8%	665	97,432	5.8%	5,336	921,716	55%
Antelope	78	9,525	0	0	0.0%	0	0	0.0%	78	9,525	100%
Dufur	463	92,824	0	0	0.0%	0	0	0.0%	74	13,427	14%
Maupin	466	88,581	11	2,789	3.1%	56	8,044	9.1%	237	37,677	43%
Mosier	292	28,875	214	23,345	81%	9	598	2.1%	37	2,951	10%
Shaniko	91	15,581	0	0	0.0%	0	0	0.0%	0	0	0%
The Dalles	7,027	2,007,625	972	190,503	9.5%	152	35,677	1.8%	2,232	523,387	26%
Total Wasco County	18,481	3,909,294	2,131	356,855	9.1%	882	141,751	3.6%	7,994	1,508,683	39%

Table B-6. Wildfire exposure.

			(all dollar amounts in thousands)					
			High Risk			**Moderate Risk**		
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)	7,727	1,362,428	2,474	342,676	25%	2,420	409,052	30%
Chenoweth	917	143,595	402	60,730	42%	67	11,910	8.3%
Pine Hollow	909	95,521	417	42,379	44%	179	19,569	20%
Tygh Valley	273	37,496	62	7,420	20%	133	19,832	53%
Warm Springs Reservation	238	27,243	33	2,257	8.3%	149	22,447	82%
Total Unincorporated County	10,064	1,666,283	3,388	455,462	27%	2,943	482,810	29%
Antelope	78	9,525	0	0	0.0%	40	4,925	52%
Dufur	463	92,824	5	341	0.4%	194	46,740	50%
Maupin	466	88,581	174	32,019	36%	25	4,609	5.2%
Mosier	292	28,875	114	12,307	43%	38	2,972	10%
Shaniko	91	15,581	0	0	0.0%	59	11,139	71%
The Dalles	7,027	2,007,625	376	193,429	9.6%	959	247,094	12%
Total Wasco County	18,481	3,909,294	4,057	693,558	18%	4,263	800,289	20%

APPENDIX C. HAZUS-MH METHODOLOGY

C.1 Software

We performed all loss estimations using Hazus®-MH 3.0 and ArcGIS® Desktop® 10.7.

C.2 User-Defined Facilities (UDF) Database

We compiled a UDF database for all buildings in Wasco County for use in both flood and earthquake modules of Hazus-MH. We used the Wasco County assessor database (acquired in 2015) 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

We used the existing DOGAMI 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, we used the centroid of the tax lot; for tax lots larger than 10 acres the building centroid was corrected by using orthoimagery. Extra effort was spent to locate building points along the 1% and 0.2% annual chance inundation fringe. For buildings partially within the inundation zone, we moved the building point to the centroid of the portion of the building within the inundation zone. We used an iterative approach 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 digital elevation model to ensure an accurate first-floor height.

C.2.2 Attributing building points

We populated the required attributes for Hazus-MH through a variety of approaches. We used the Wasco County assessor database wherever 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 positions 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 Wasco County assessor database. Where data were not available, the default value of RES1 was applied throughout.
- **Cost** – The cost of an individual UDF. Loss ratio is derived from this value. The value was obtained from the Wasco County assessor database. Where not available, cost was based on the square

footage of the building footprint or from the square footage found in the Wasco County assessor database. When multiple UDFs occupied a single tax lot, the overall cost of the tax lot was distributed to the UDFs based on square footage.

- **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 Wasco County assessor database. Where not available the year of "1900" was applied (7.8% of the UDFs).
- **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 Wasco 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 Wasco County assessor database where available. For UDFs without assessor information for number of stories that are within the flood zone, closer inspection using the Google Street View™ mapping service 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, 2012c]). 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 Wasco County assessor database where available. For UDFs without assessor information for basements that are within the flood zone, closer inspection using Google Street View™ mapping service or available oblique imagery was used to ascertain basement presence.
- **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: Hazus-MH overlays a UDF location on a depth grid and by using the **First floor height** determines the level of flooding occurring to a building. The **First floor height** is derived from the **Foundation type** attribute (Wasco County assessor data) or observation via oblique imagery or the 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 to estimate earthquake losses by determining which damage function will be applied. This information was not in the Wasco County assessor data, so instead Building type 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. (see "Seismic Building Codes" section below for more informatio*n*). This information is derived from the **Year built** attribute (Wasco Assessor) and state 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 number of people affected by a given hazard. This attribute is derived from the default Hazus-MH 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 Wasco County. **Table C-1** outlines the benchmark years that apply to buildings within Wasco County.

Table C-1. Wasco County seismic design level benchmark years.

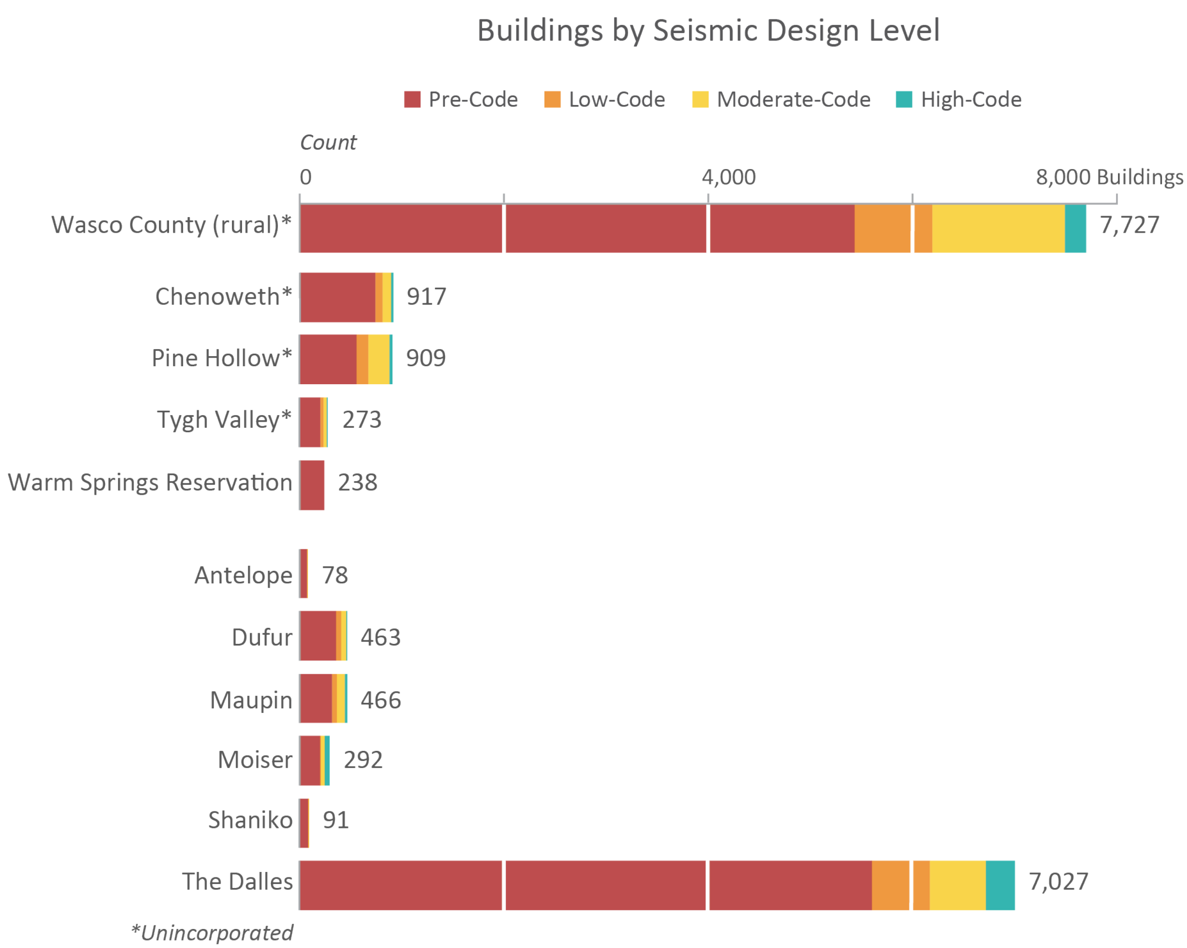
Building Type	Year Built	Design Level	Basis
Single-Family Dwelling (includes Duplexes)	prior to 1976	Pre Code	Interpretation of Judson (Judson, 2012)
	1976–1991	Low Code	
	1992–2003	Moderate Code	
	2004–2016	High Code	
Manufactured Housing	prior to 2003	Pre Code	Interpretation of OR BCD 2002 Manufactured 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 Wasco 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)	7,727	5,452	71%	765	10%	1,304	17%	206	2.7%
Chenoweth	917	742	81%	71	7.7%	84	9.2%	20	2.2%
Pine Hollow	909	556	61%	116	13%	208	23%	29	3.2%
Tygh Valley	273	202	74%	31	11%	31	11%	9	3.3%
Warm Springs Reservation	238	238	100%	0	0.0%	0	0.0%	0	0.0%
Total Unincorporated County	10,064	7,190	72%	983	10%	1,627	16%	264	2.6%
Antelope	78	70	90%	4	5.1%	4	5.1%	0	0.0%
Dufur	463	355	77%	50	11%	51	11%	7	1.5%
Maupin	466	315	68%	47	10%	79	17%	25	5.4%
Mosier	292	198	68%	8	2.7%	36	12%	50	17%
Shaniko	91	80	88%	5	5.5%	6	6.6%	0	0.0%
The Dalles	7,027	5,622	80%	569	8.1%	552	7.9%	284	4.0%
Total Wasco County	18,481	13,830	75%	1,666	9.0%	2,355	13%	630	3.4%

Figure C-1. Seismic design level by Wasco County community.



C.3 Flood Hazard Data

FEMA developed flood hazard data in 2020 for a revision of the Wasco 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 10-, 50-, 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): NEHRP soil classification, PGA, PGV, SA10, 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 tax lot 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
RFPD	Rural Fire Protection District
Risk MAP	Risk Mapping, Assessment, and Planning
SHMO	State Hazard Mitigation Officer
SLIDO	State Landslide Information Layer for Oregon
SLR	Sea level rise
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.

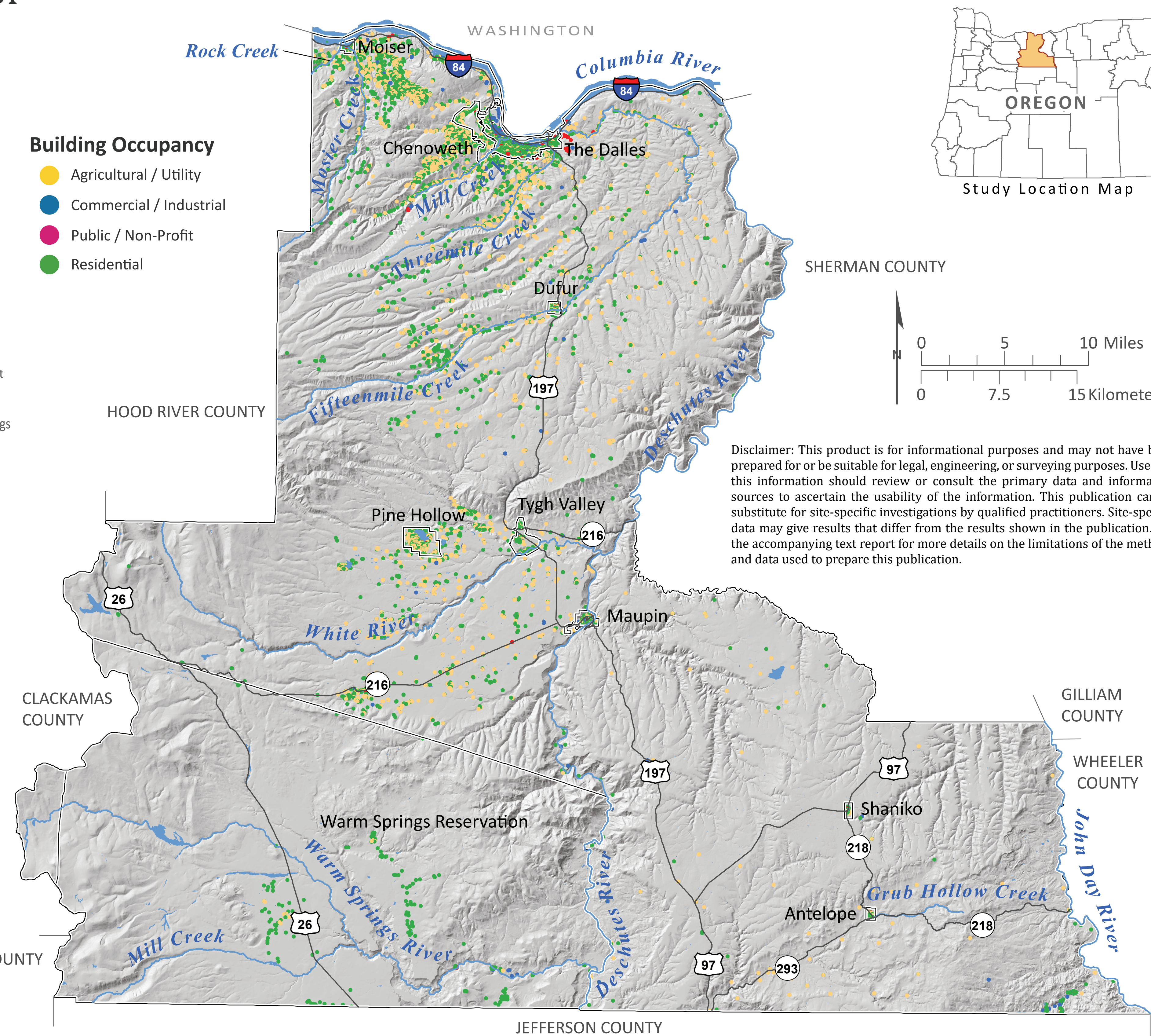
Vulnerability – Characteristics that make people or assets more susceptible to a natural hazard.

APPENDIX E. MAP PLATES

See appendix folder for individual map PDFs.

Building Distribution Map of Wasco County, Oregon

PLATE 1



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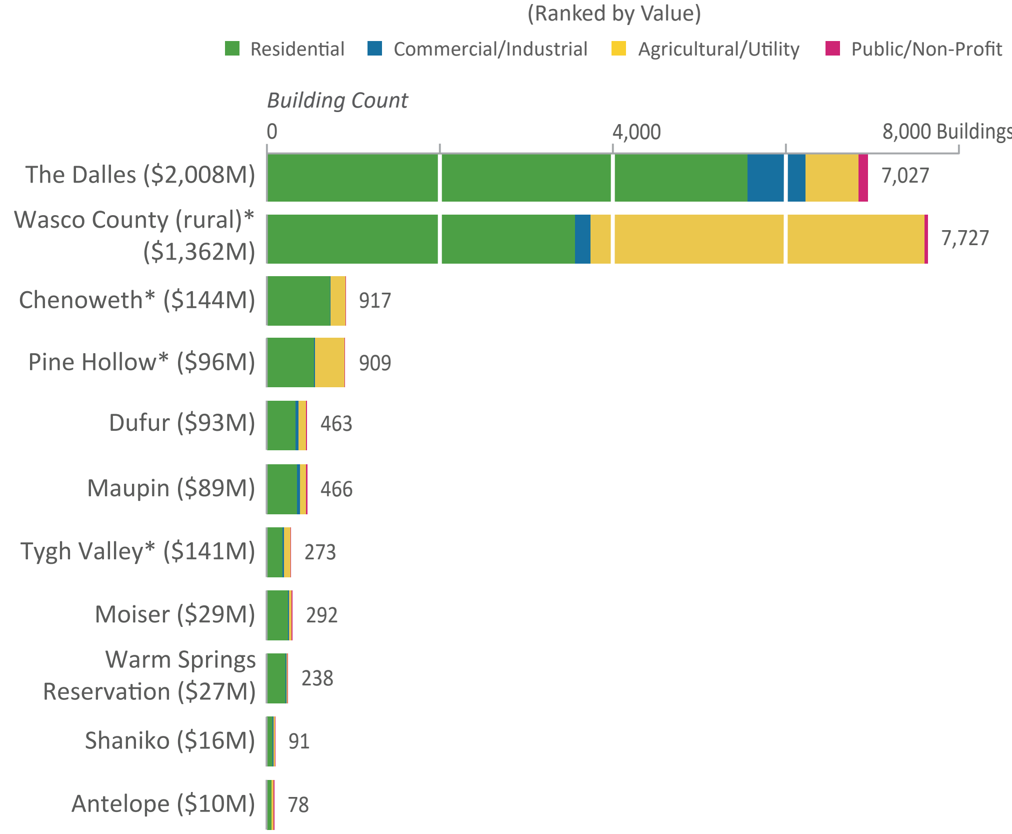
Buildings by Occupancy Class
(Ranked by Value)



*Unincorporated

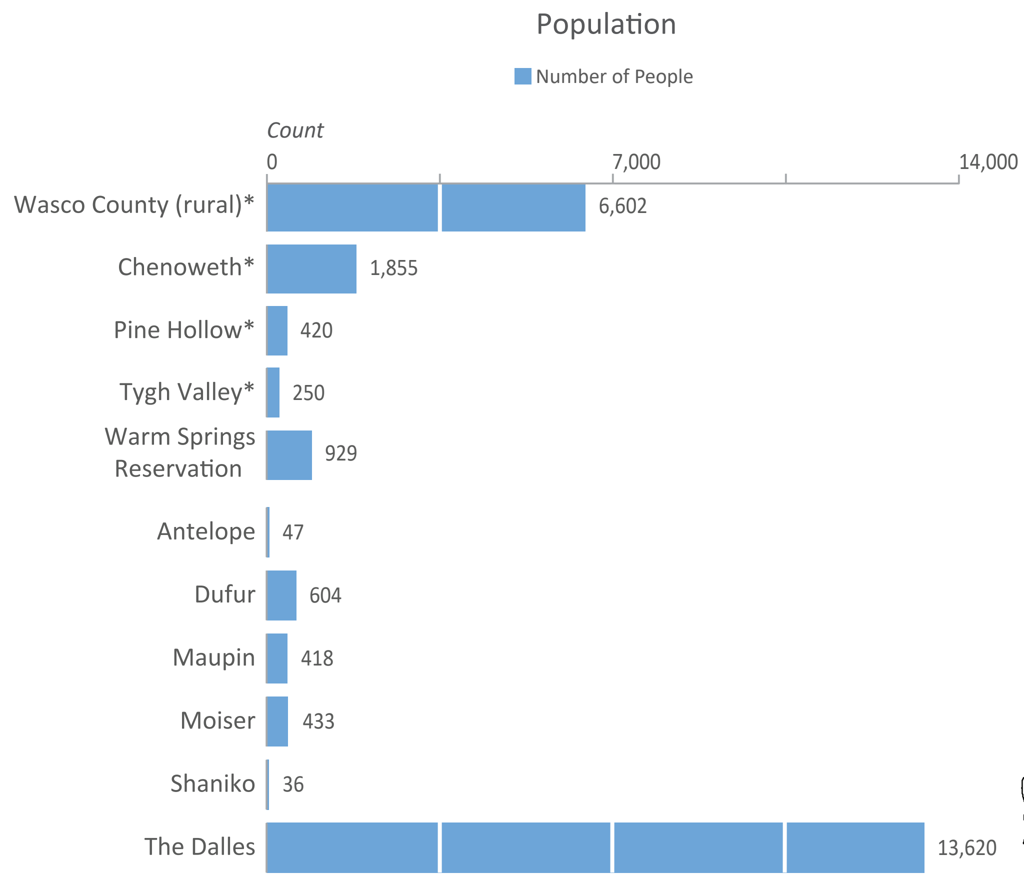
Data Sources:
Building footprints: Oregon Department of Geology and Mineral Industries (2016)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: 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

Population Density Map of Wasco County, Oregon

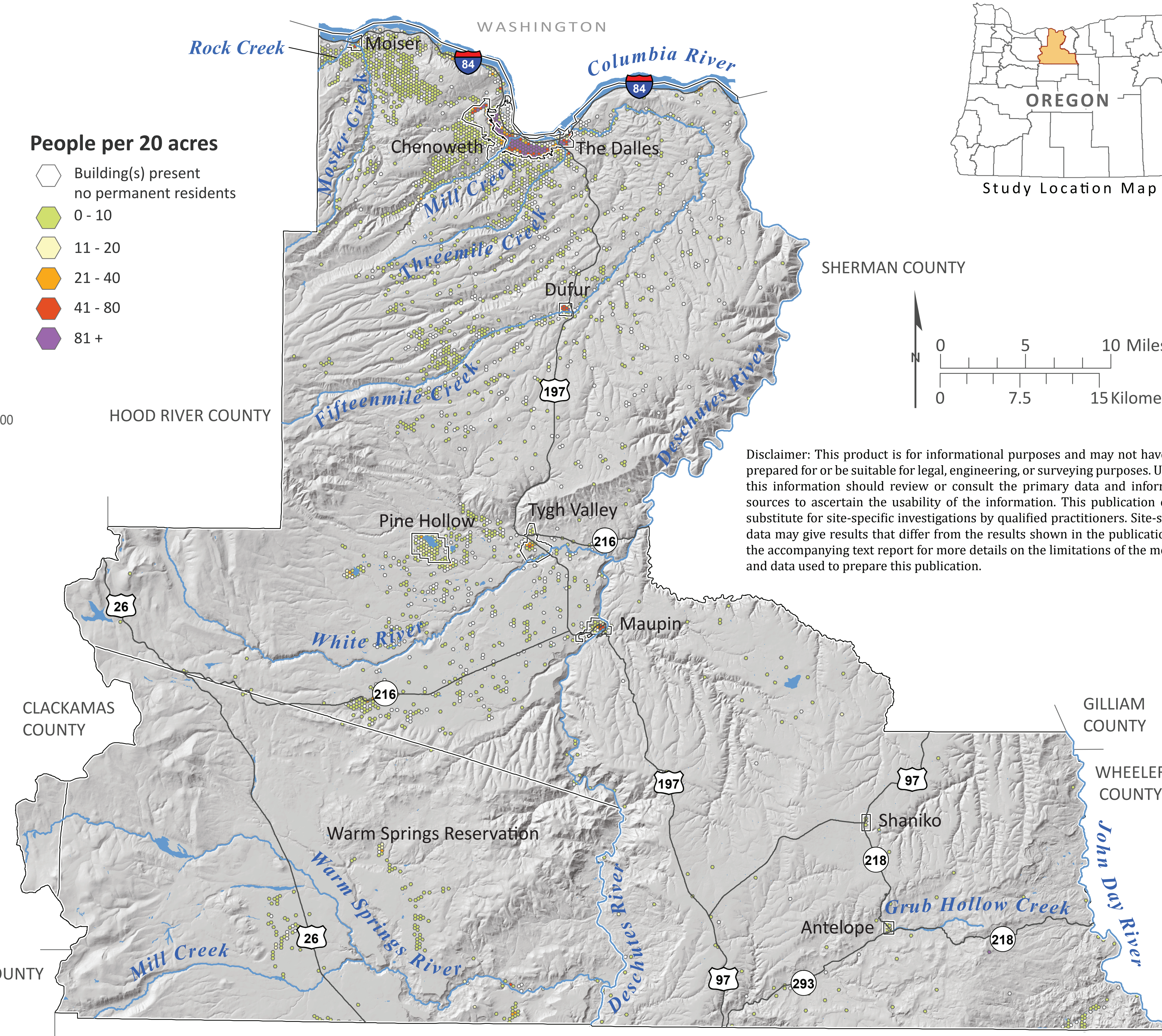
PLATE 2



*Unincorporated

People per 20 acres

- Building(s) present no permanent residents
- 0 - 10
- 11 - 20
- 21 - 40
- 41 - 80
- 81 +



OREGON

Study Location Map

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Data Sources:
Population data: U.S. Census (2010)
Roads: Oregon Department of Transportation Signed Routes (2013)
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

PLATE 3

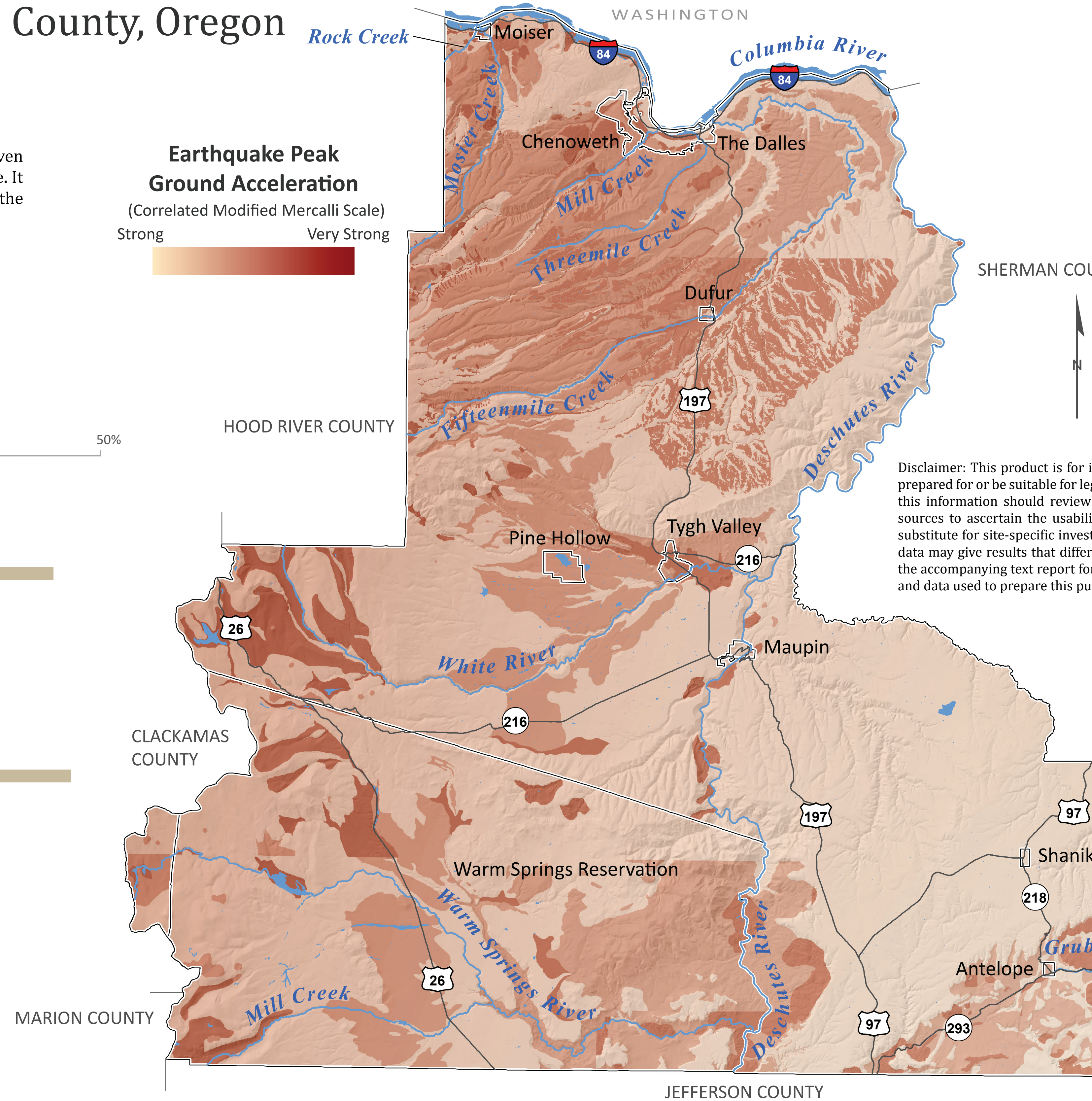
2,500-year Probabilistic Earthquake Shaking Map of Wasco County, Oregon

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.

Earthquake Peak Ground Acceleration

(Correlated Modified Mercalli Scale)

Strong — Very Strong



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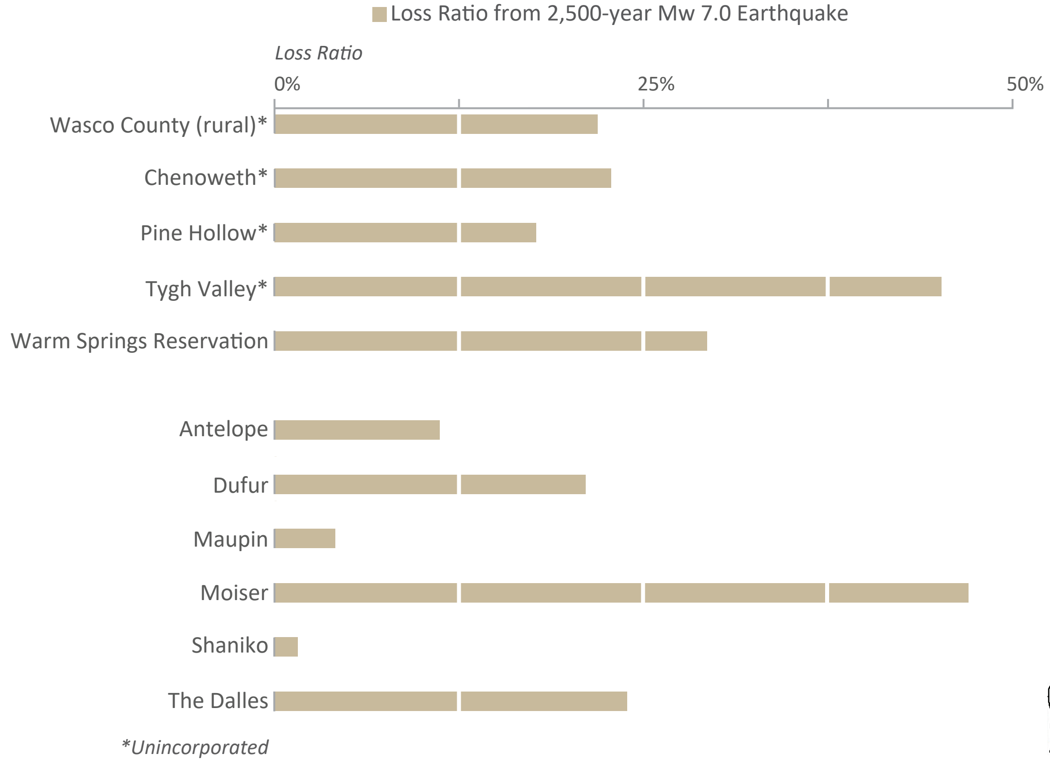
Total Building Value Loss Ratio from Mw 7.0 Earthquake



*Unincorporated

Data Sources:
2,475-year probabilistic PGA: Oregon Seismic Hazard Database, Madin and others (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
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)

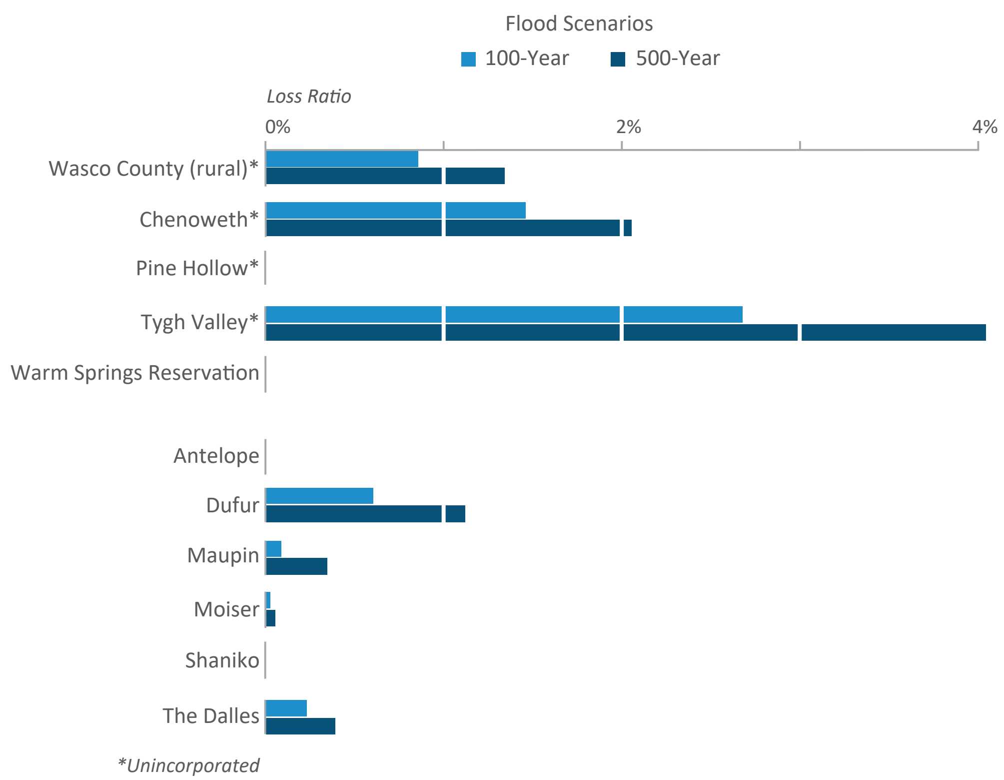
Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

PLATE 4

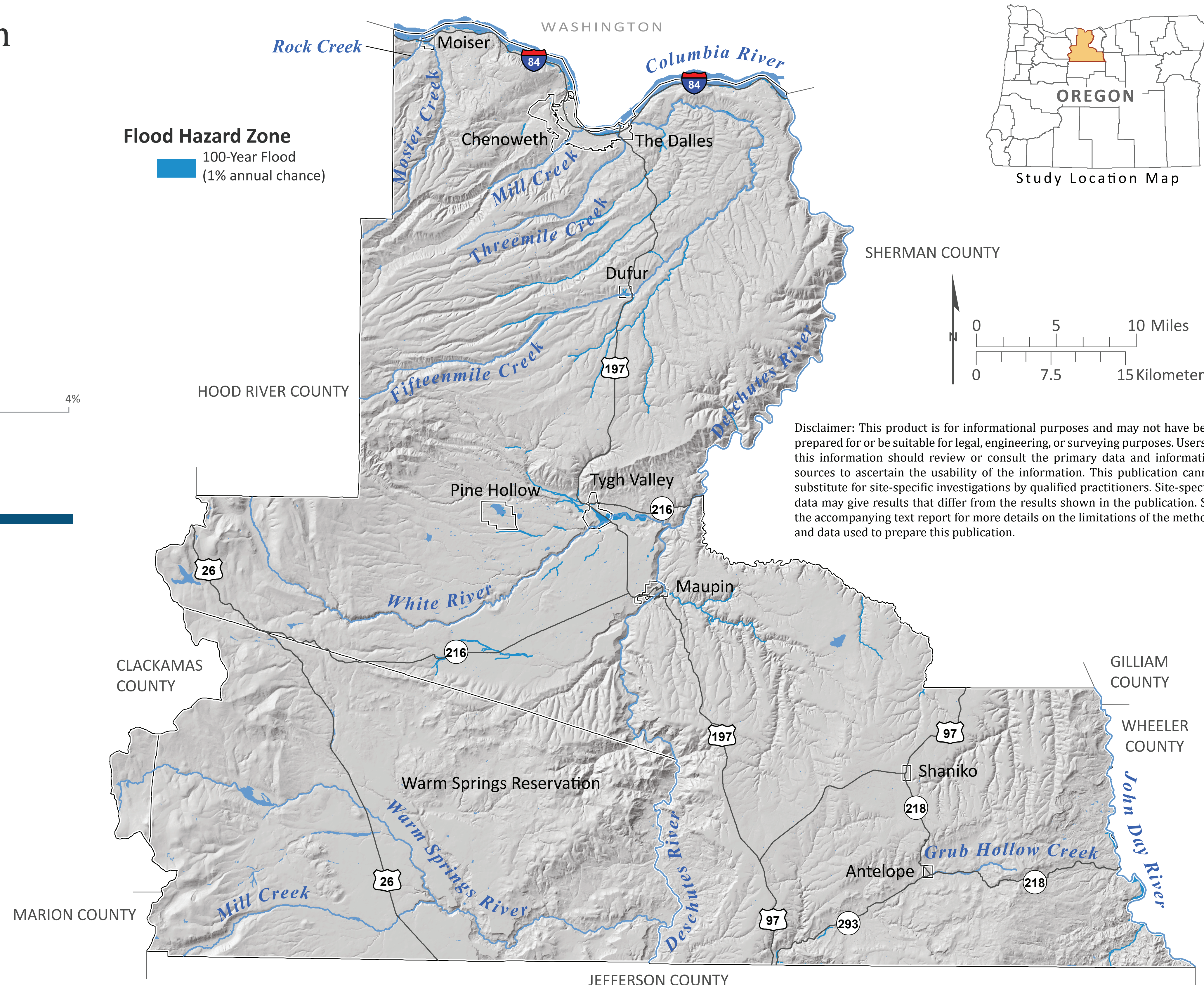
Flood Hazard Map of Wasco County, Oregon

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



Flood Hazard Zone

100-Year Flood (1% annual chance)



Study Location Map

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Data Sources:
Flood hazard zone (100-year): DOGAMI (2013)
Roads: Oregon Department of Transportation Signed Routes (2013)
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

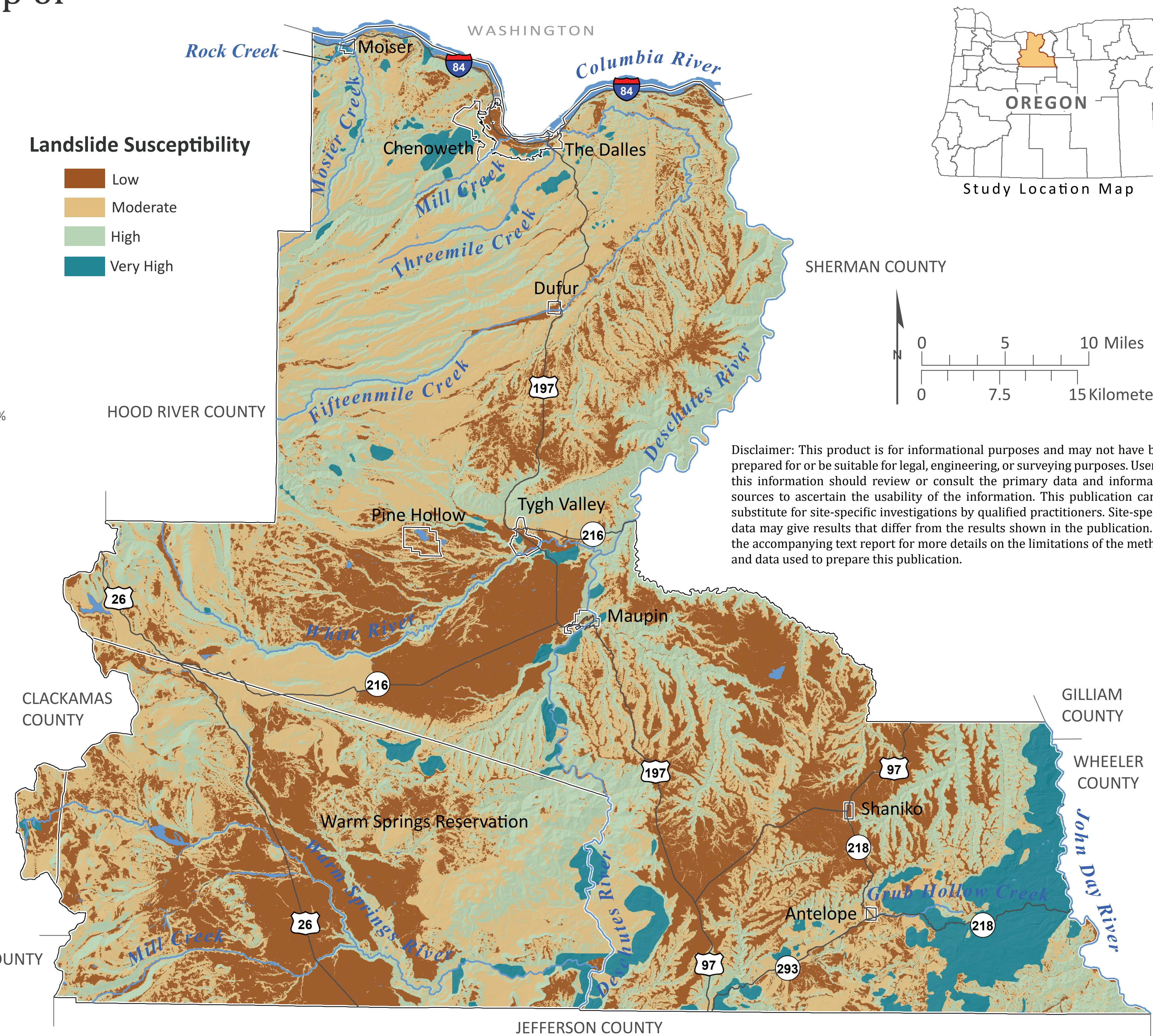
PLATE 5

Landslide Susceptibility Map of Wasco County, Oregon

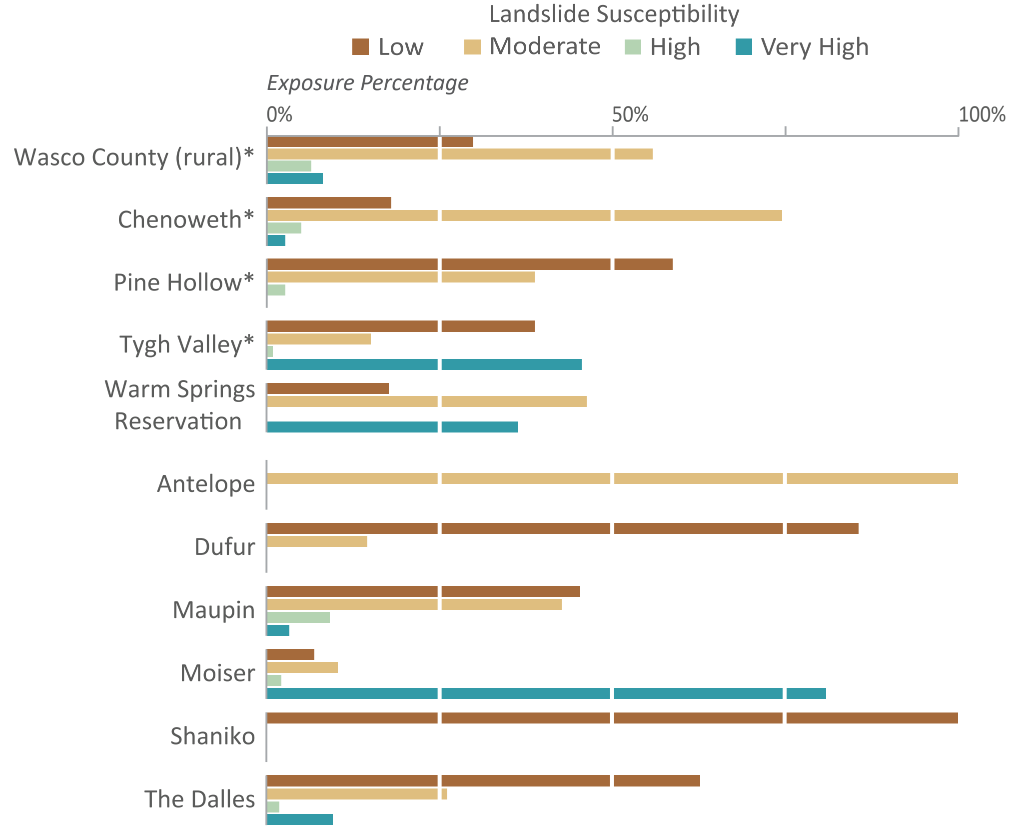
Landslide susceptibility is categorized as Low, Moderate, High, and Very High which describes the general level of susceptibility to landslide hazard. The dataset is an aggregation of three primary sources: landslide inventory (SLIDO), generalized geology, and slope.

Landslide Susceptibility

- Low
- Moderate
- High
- Very High



Percentage of Building Value Exposed to Landslide



*Unincorporated

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Data Sources:
Landslide susceptibility: Burns and others (2016)
Roads: Oregon Department of Transportation Signed Routes (2013)
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)

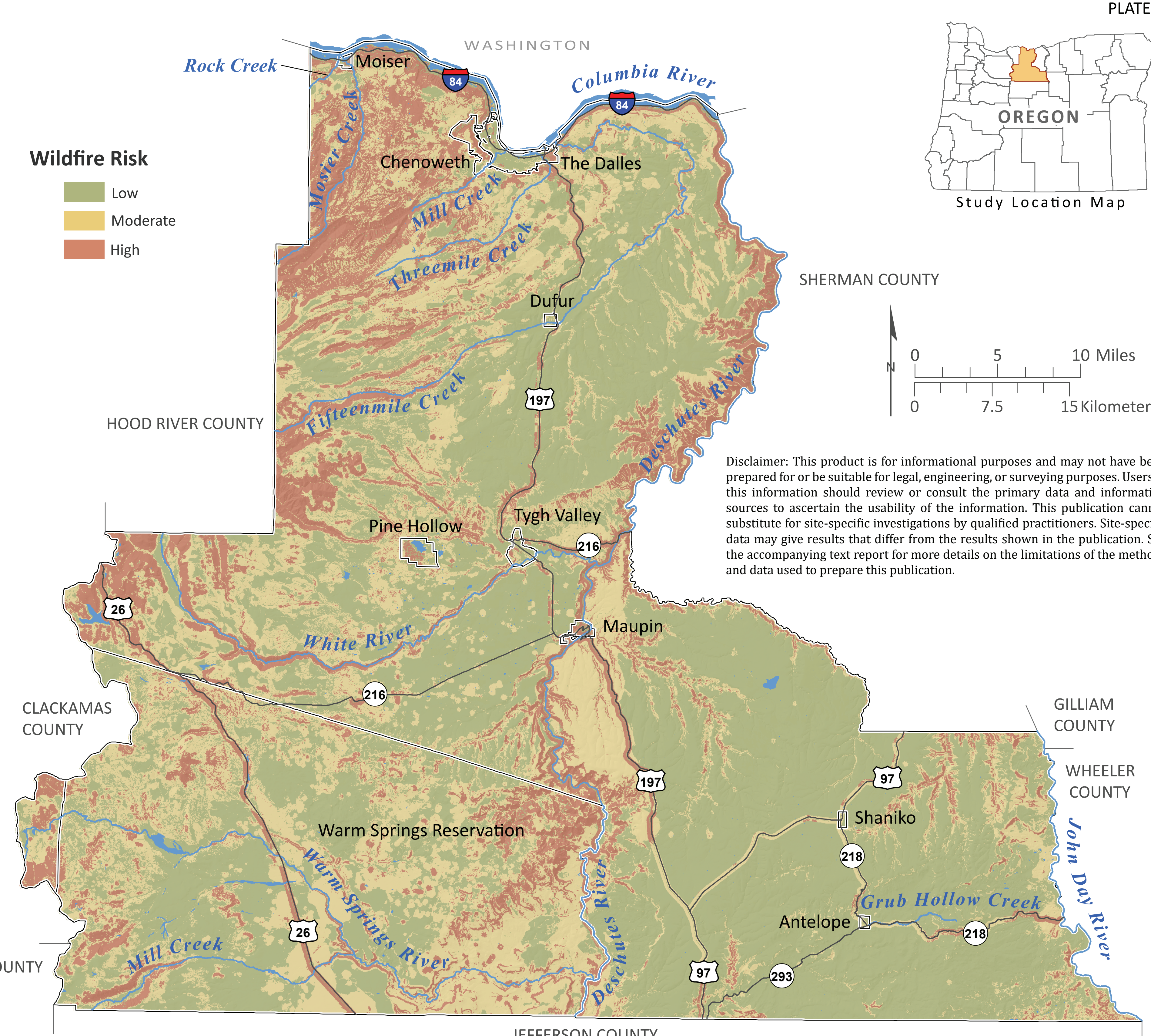
Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

Wildfire Risk Map of Wasco County, Oregon

PLATE 6

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).



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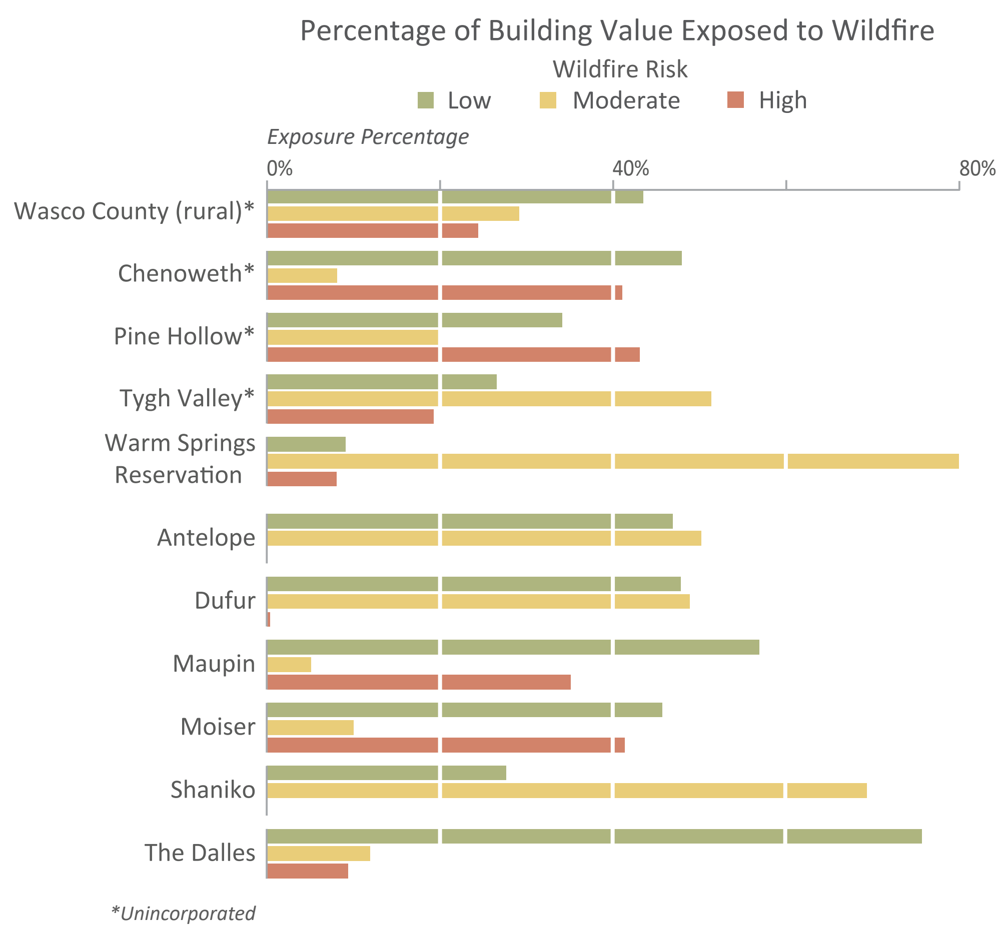

Data Sources:
Wildfire risk data: Oregon Department of Forestry (2013)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey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

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

Cartography by: Lowell Anthony, 2018