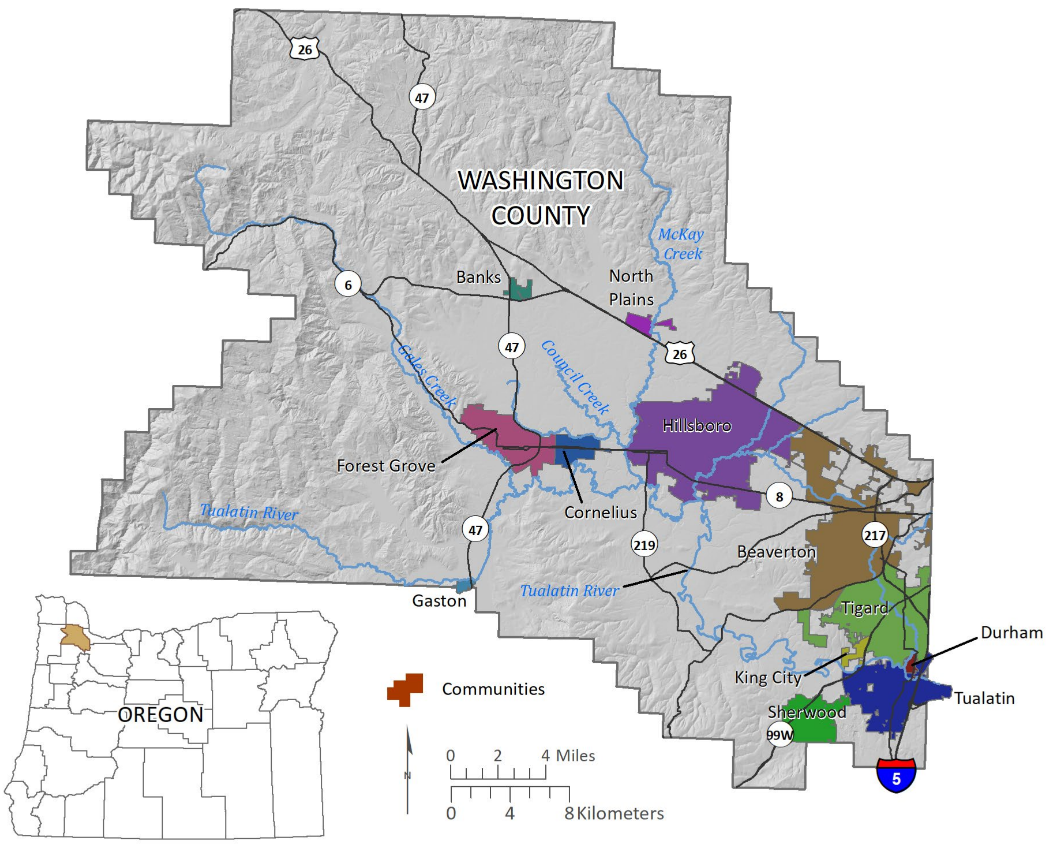
State of Oregon
Oregon Department of Geology and Mineral Industries
Ruarri Day-Stirrat, State Geologist

OPEN-FILE REPORT O-22-04

NATURAL HAZARD RISK REPORT FOR WASHINGTON COUNTY, OREGON

INCLUDING THE CITIES OF BANKS, BEAVERTON, CORNELIUS, DURHAM, FOREST GROVE, GASTON, HILLSBORO, KING CITY, NORTH PLAINS, SHERWOOD, TIGARD, AND TUALATIN



by Matt C. Williams and William J. Burns

2022

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

WHAT IS IN THIS REPORT?

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

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GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

See the digital publication folder for files.
Geodatabase is Esri® version 10.7 format. Metadata are embedded in the geodatabase and are also provided as separate .xml format files.

Washington_County_Risk_Report_Data.gdb

Feature dataset: Asset_Data
feature classes:
Building_footprints (polygons)
Communities (polygons)
UDF_points (points)

Washington_County_Depth_Grids:

Raster datasets:
FL_Depth_10
FL_Depth_50
FL_Depth_100
FL_Depth_500

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

We arrived at our findings and conclusions by completing three main tasks for each community: compiling an asset database, identifying and using the 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 vulnerabilities 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 and were produced using high-resolution, lidar topographic data. Although not all the data sources used in the report provide complete, countywide information, each hazard dataset used was the best available at the time of the analysis.
- In the third task, we performed risk assessments using Esri® ArcGIS Desktop® software. We took two risk assessment approaches: (1) estimated loss (in dollars) to buildings from flood (recurrence intervals) and earthquake scenarios using the 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, wildfire, and channel migration.

The findings and conclusions of this report show the potential impacts of hazards in communities within Washington County. Although earthquake damage will occur throughout the entire county, extensive damage and losses are more probable in the area near the Gales Creek Fault, such as the city of Forest Grove, and areas with liquefaction-prone soils. Our findings indicate that most of the critical facilities in the study area are at high risk from an earthquake. We used multiple Hazus-MH earthquake simulations to illustrate the potential reduction in earthquake damage through seismic retrofits. Some communities in the study area have moderate risk from flooding and we found a small percentage (<1%) of flood exposed buildings were elevated above the 100-year flood elevation. Our analysis shows that areas with moderate to steep slopes or at the base of steep hillsides are at greatest risk to landslide hazards, such as the west side of the Portland Hills and the southwestern portions of Beaverton and Tigard. Nearly 300 buildings in the unincorporated county were exposed to channel migration hazard located along the streams within the Tualatin River Watershed. Wildfire exposure analysis show a higher risk for buildings within the wildland-urban interface (WUI) portions of the county. We found that population is most at risk of displacement from landslide hazards.

The information presented in this report is designed to increase awareness of natural hazard risk, to support public outreach efforts, and to aid local decision-makers in developing comprehensive plans and natural hazard mitigation plans. This study can help emergency managers identify vulnerable critical facilities and develop contingencies in their response plans. The results of this study are designed to be used to help communities identify and prioritize mitigation actions that will improve community resilience.

Results were broken out for the following geographic areas:

- Unincorporated Washington County (rural)*
- City of Beaverton
- City of Durham
- City of Gaston
- City of King City
- City of Sherwood
- City of Tualatin
- City of Banks
- City of Cornelius
- City of Forest Grove
- City of Hillsboro
- City of North Plains
- City of Tigard

*Small portions of the cities of Lake Oswego, Portland, Rivergrove, and Wilsonville that were within Washington County were not individually examined in this report. However, building data within these portions were included within the "Unincorporated Washington County (rural)" jurisdiction.

Selected countywide results
Total buildings: 213,901
Total estimated building value: $75 billion

Gales Creek Fault Magnitude-6.7 Earthquake Scenario
Red-tagged buildings[a]: 1,807
Yellow-tagged buildings[b]: 6,049
Loss estimate: $2 billion

Landslide Exposure (High and Very High Susceptibility)
Number of buildings exposed: 8,997
Exposed building value: $2.7 billion

Wildfire Exposure (High and Moderate Risk):
Number of buildings exposed: 2,297
Exposed building value: $590 million

100-year Flood Scenario
Number of buildings damaged: 1,323
Loss estimate: $60 million

Channel Migration Zone (Erosion Hazard Area – 30-year):
Number of buildings exposed: 886
Exposed building value: $271 million

[a]Red-tagged buildings are considered uninhabitable due to complete damage
[b]Yellow-tagged buildings are considered limited habitability due to extensive damage

1.0 INTRODUCTION

A natural hazard is an environmental phenomenon that can negatively impact humans, and risk is the likelihood that a hazard will result in harm. A natural hazard risk assessment analyzes and quantifies how different types of hazards could affect the built environment, population, and the cost of recovery, and identifies potential risk. Risk

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.

assessments are one basis for developing mitigation plans, strategies, and actions, so that steps can be taken to prepare for a potential hazard event.

This report is a multi-hazard risk assessment analyzing individual buildings and the resident population in Washington County. Washington County is situated in the northwestern part of Oregon, between the Tualatin Mountains and the Oregon Coast Range, and is subject to many natural hazards, including earthquakes, riverine flooding, landslides, channel migration, and wildfire. This report provides a detailed and comprehensive analysis of these natural hazards and provides a comparative perspective not previously available. In this report, we describe our assessment results, which quantify the various levels of risk that each hazard presents to Washington County communities.

1.1 Purpose

The purpose of this project is to help communities in the study area better understand their risk and increase resilience to earthquakes (including liquefaction and site amplification), riverine flooding, landslides, channel migration, and wildfire natural hazards that are present in their communities. This is accomplished by the best available, most accurate and detailed information about these hazards to assess 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 our methods and results. Two primary methods (Hazus-MH or exposure), depending on the type of hazard, were used to assess risk. Results for each hazard type are reported on a countywide basis within each hazard section, and community-based results are reported in detail in **Appendix A: Community Risk Profiles**. **Appendix B** contains detailed risk assessment tables. **Appendix C** is a more detailed explanation of the Hazus-MH methodology. **Appendix D** lists acronyms and definitions of terms used in this report. **Appendix E** contains tabloid-size maps showing countywide hazard maps.

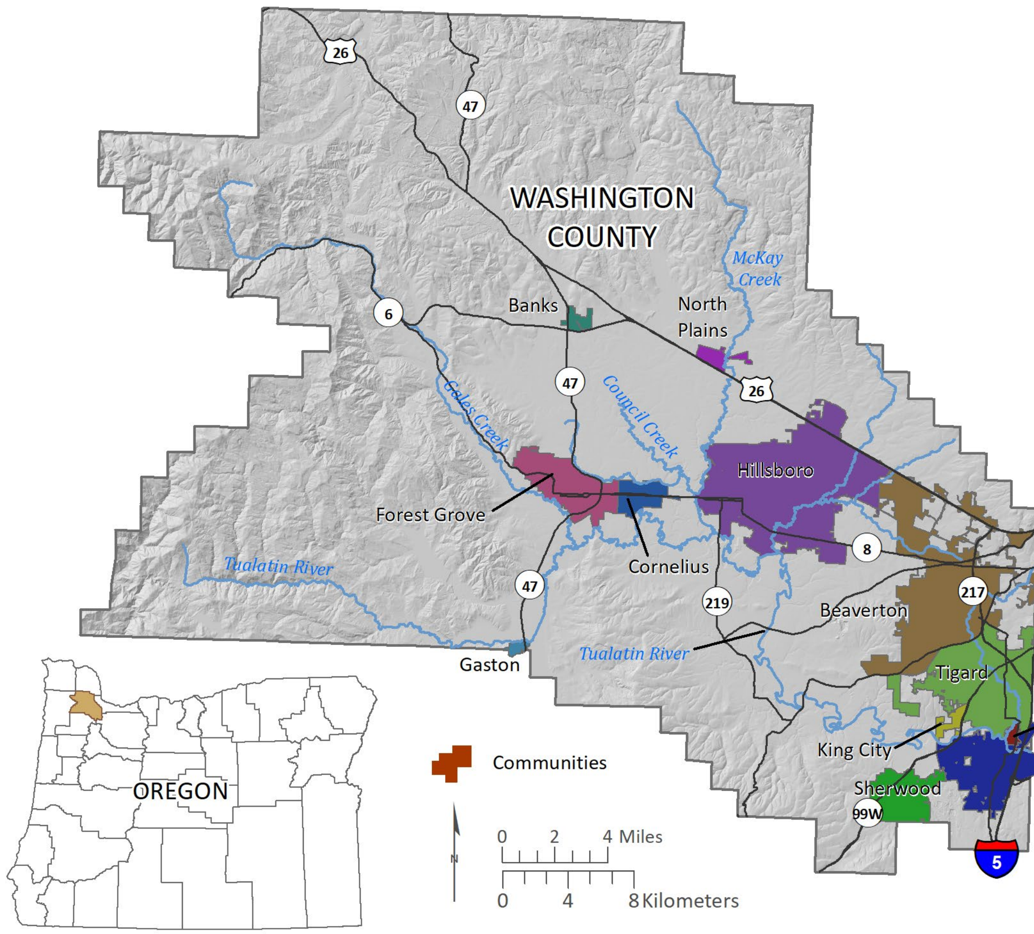
1.2 Study Area

The study area for this project includes the entirety of Washington County, Oregon. To make the report more functional, the study extent was expanded to include portions of the cities of Gaston and Tualatin that extend into neighboring counties (**Figure 1-1**). Small portions of the cities of Lake Oswego, Portland, Rivergrove, and Wilsonville that are within Washington County were not individually examined for this report. Building information within these communities was included within the Unincorporated Washington County (rural) jurisdiction. The study area is located in the northwestern portion of the state; the county is bordered by Columbia County to the north, Tillamook County to the west, Yamhill County to the south, and Clackamas and Multnomah Counties to the east. The study area covers approximately 1,890 square kilometers (730 square miles). Starting in the west, the study area transitions from timberland, to farmland, to suburbs, and then to urban development in the east.

"The county centers around the Tualatin Valley, which is bounded by the Tualatin Mountains (Portland Hills) along the north and east side of the county and the Oregon Coast Range along the west and south sides of the county. The central valley is characterized by suburbs and more densely populated urban areas. Much of the northwestern half of the county is heavily forested, rugged terrain and the central and southeastern sections of the county are urbanized or commonly used for agricultural purposes. The highest peak within the county is South Saddle Mountain at 1,056 meters (3,464 feet) above sea level" (Appleby and others, 2021, p. 18).

The population of the study area is 608,559 based on an estimated population for each community in 2020 from the Portland State University (PSU) Population Research Center https://www.pdx.edu/population-research/population-estimate-reports. The study area's two largest communities are Beaverton and Hillsboro, each with a population near 100,000. Most of the residents in the study area reside in the eastern half of the county. The incorporated communities of the study area are Banks, Beaverton, Cornelius, Durham, Forest Grove, Gaston, Hillsboro, King City, North Plains, Sherwood, Tigard, and Tualatin (**Figure 1-1**). No unincorporated communities were individually examined in this study.

Figure 1-1. Study area: Washington County with communities in this study identified.



1.3 Project Scope

For this risk assessment, we limited the project scope to buildings and population because of data availability, the strengths and limitations of the risk assessment methodology, and funding availability. We did not analyze impacts to the local economy, land values, infrastructure (transportation, power, water, gas, communication, and sewage), 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, in which 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) was used to distribute people into residential structures on a census block basis. Permanent resident counts were then adjusted to current estimates from the PSU Population Research Center.

A critical component of this risk assessment is a countywide building inventory developed from building footprint data and the Washington County tax assessor database (acquired 2021). 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 based on expert knowledge of the datasets; most datasets are DOGAMI publications. In addition to geologic hazards, we included wildfire hazard in this risk assessment. The Oregon Department of Forestry (ODF) provided recommendations on the use of wildfire datasets for risk analysis. 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 Gales Creek Fault magnitude (Mw) 6.7 scenario. Includes earthquake-induced or “coseismic” liquefaction, soil amplification class, and landslides.

Flood Risk Assessment

- Hazus-MH loss estimation to four recurrence intervals (10%, 2%, 1%, and 0.2% annual chance)
- Exposure to 1% annual chance recurrence interval

Landslide Risk Assessment

- Exposure based on Landslide Susceptibility Index (Low to Very High) and updated Washington County landslide mapping.

Wildfire Risk Assessment

- Exposure based on Fire Risk Index (Low to High)

Channel Migration Risk Assessment

- Exposure based on the erosion hazard area – 30-year (exposed, not exposed)

Table 1-1. Hazard data sources for Washington County.

Hazard	Scenario or Classes	Scale/Level of Detail	Data Source
Earthquake	Gales Creek Fault Mw 6.7	Countywide	USGS (Parsonius and Haller, 2017) accessed via Hazus fault database
-Coseismic landslide	Susceptibility – wet (3-10 hazard classes)	Statewide	DOGAMI (Appleby and others, 2019)
- Coseismic liquefaction	Susceptibility (1-5 classes)	"	"
- Coseismic soil amplification class	NEHRP (A-F classes)	"	"
Flood	Depth Grids: 10% (10-yr) 2% (50-yr) 1% (100-yr) 0.2% (500-yr)	Countywide	DOGAMI – derived from FEMA (2018) data, included in GIS data for this report
Landslide	Susceptibility (Low, Moderate, High, Very High)	Statewide	DOGAMI (Burns and others, 2016), DOGAMI (Hairston-Porter and others, 2021)
Channel Migration	Erosion Hazard Area – 30-year (Not Exposed, Exposed)	Streams in the Tualatin River Watershed	DOGAMI (Appleby and others, 2021)
Wildfire	Integrated Hazard (Low, Moderate, High)	Regional (Pacific Northwest, US)	ODF (Gilbertson-Day and others, 2018), OSU and Wildland Associates (Rau and others, 2021)

1.4 Previous Studies

Wang (1998) used Hazus-MH to estimate the impact from a Mw 8.5 Cascade Subduction Zone (CSZ) earthquake scenario on the state of Oregon. The results of that study were arranged into individual counties. Washington County was estimated to experience a 3% loss ratio in the Mw 8.5 CSZ scenario (Wang, 1998). We did not compare the results of this project with the results of the previous study because the studies used very different methodologies.

Bauer and others (2018) studied the impacts from a Mw 9.0 CSZ earthquake and a Portland Hills Fault Mw 6.8 earthquake for counties (Clackamas, Multnomah, and Washington) within the Portland Metro area. The report discussed the findings from a Hazus-MH earthquake analysis using detailed building data information and the best available seismic and ground deformation information. These findings included scenarios of wet and dry landslide hazard, day and night casualties, and a seismic building code analysis. The report also discussed post-earthquake debris estimations and impacts to infrastructure. The report, "Earthquake regional impact analysis for Clackamas, Multnomah, and Washington counties," is accessible from https://www.oregongeology.org/pubs/ofr/p-O-18-02.htm.

We did not compare the results of this project with the results of these previous studies, because the previous Wang (1998) study utilized a much lower level of detailed building information and site-specific earthquake hazard inputs. Additionally, this study analyzed a different earthquake scenario from the previous studies. Comparative analysis was not part of the scope of this project.

2.0 METHODS

Where there is interaction between people and natural hazards there is risk. We used a quantitative approach through two modes of analysis, Hazus-MH loss estimation and exposure, to assess the level of risk to buildings and people from natural hazards.

2.1 Hazus-MH Loss Estimation

Key Terms:

- *Loss estimation:* Damage in terms of value that occurs to a building in an earthquake or flood scenario, as modeled with Hazus-MH methodology. This is measured as the cost to repair or replace the damaged building in US dollars.
- *Loss ratio:* Percentage of estimated loss relative to the total value.

We wanted to find the estimated loss that buildings could potentially incur from earthquake and flood hazards for Washington County. To accomplish this, we used Hazus-MH because it is the national standard for loss estimation for earthquake, flood, hurricane, and tsunami hazards.

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."

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 determined using a method called RSMeans valuation (Charest, 2017) and is calculated by multiplying the building area (in square feet) 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. We estimated damage and loss by intersecting building locations with natural hazard layers and applying damage functions based on the hazard severity (e.g., depth of flooding) and building characteristics (e.g., first-floor height). **Figure 2-1** illustrates the range of building loss estimates from Hazus-MH flood analysis by showing the percentage of building loss from flood and in some cases (in yellow) where a building's first-floor height is above the level of flooding.

We used Hazus-MH version 4.2, 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 city of Beaverton, Oregon.

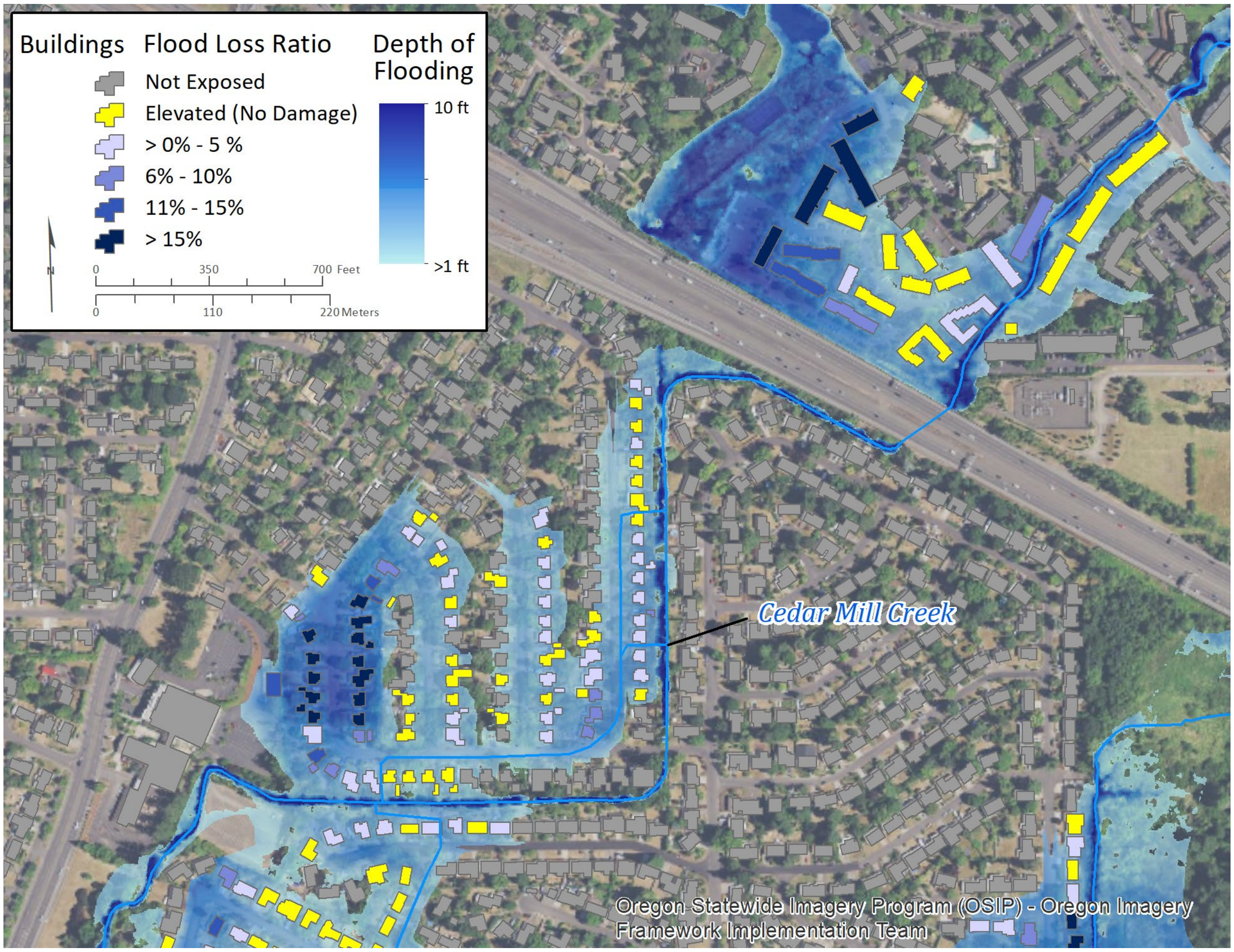


Image source: Oregon Statewide Imagery Program, 2018

Depth grid: Derived from the effective FEMA Flood Insurance Rate Map data for Washington County, 2017

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.

Since loss estimation using Hazus-MH is not available for all types of hazards, we used exposure analysis to assess the level risk for Washington County for landslide, channel migration, and wildfire hazards. 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 available damage models like those in Hazus. 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. For example, **Figure 2-2** shows buildings that are exposed to different areas of landslide susceptibility where building footprints are colored based on what susceptibility zone the center of the building is within.

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

Figure 2-2. Landslide susceptibility areas and building exposure in Beaverton, Oregon.

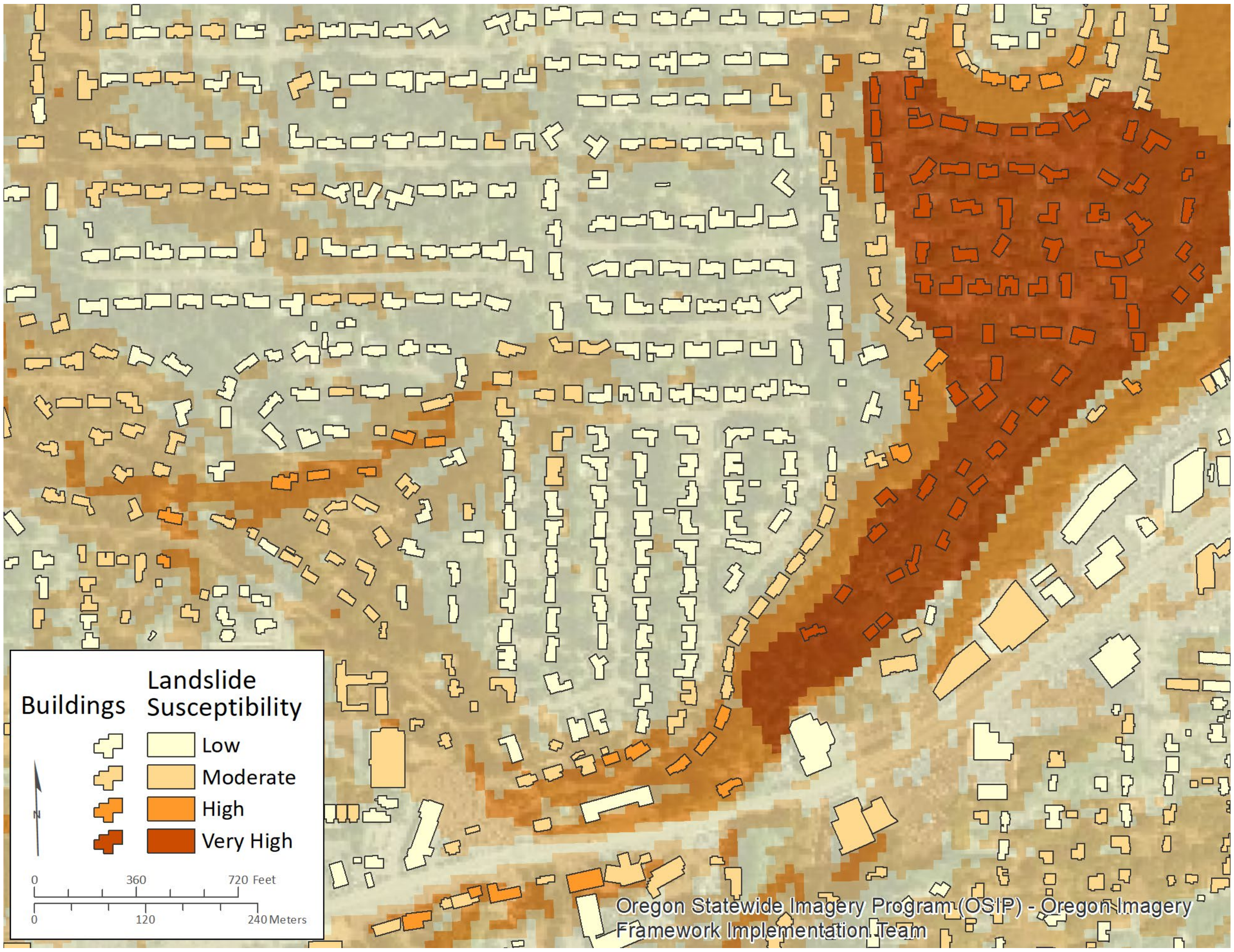


Image source: Oregon Statewide Imagery Program, 2018

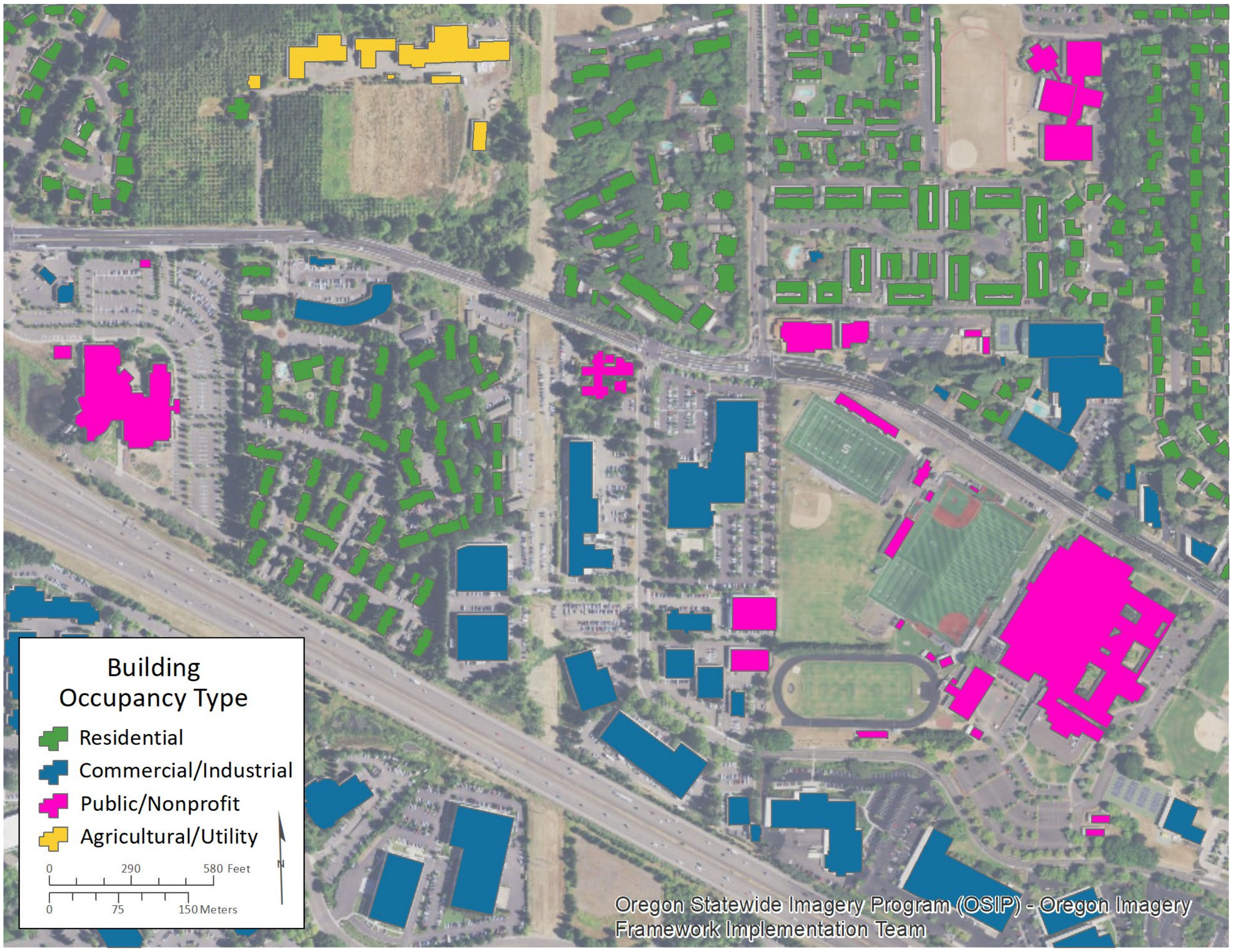
Landslide data source: Landslide susceptibility overview map of Oregon, (Burns and others, 2016)

2.3 Building Inventory

A key piece of the risk assessment is the countywide building inventory. This inventory consists of all buildings larger than 19 square meters (100 square feet), as determined from existing building footprints (Williams, 2021). **Figure 2-3** shows an example of building inventory occupancy types used in the Hazus-MH and exposure analyses in Washington County. See also **Appendix B: Table B-1** and **Appendix E: Plate 1** and **Plate 2.**

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

Figure 2-3. Building occupancy types, city of Beaverton, Oregon.



The distribution of building count and value per community in Washington County ranges from 322 buildings and $81 million for Gaston to 37,513 buildings and $15 billion for Hillsboro (**Table 2-1**). A table detailing the occupancy class distribution by community is included in **Appendix B: Detailed Risk Assessment Tables**.

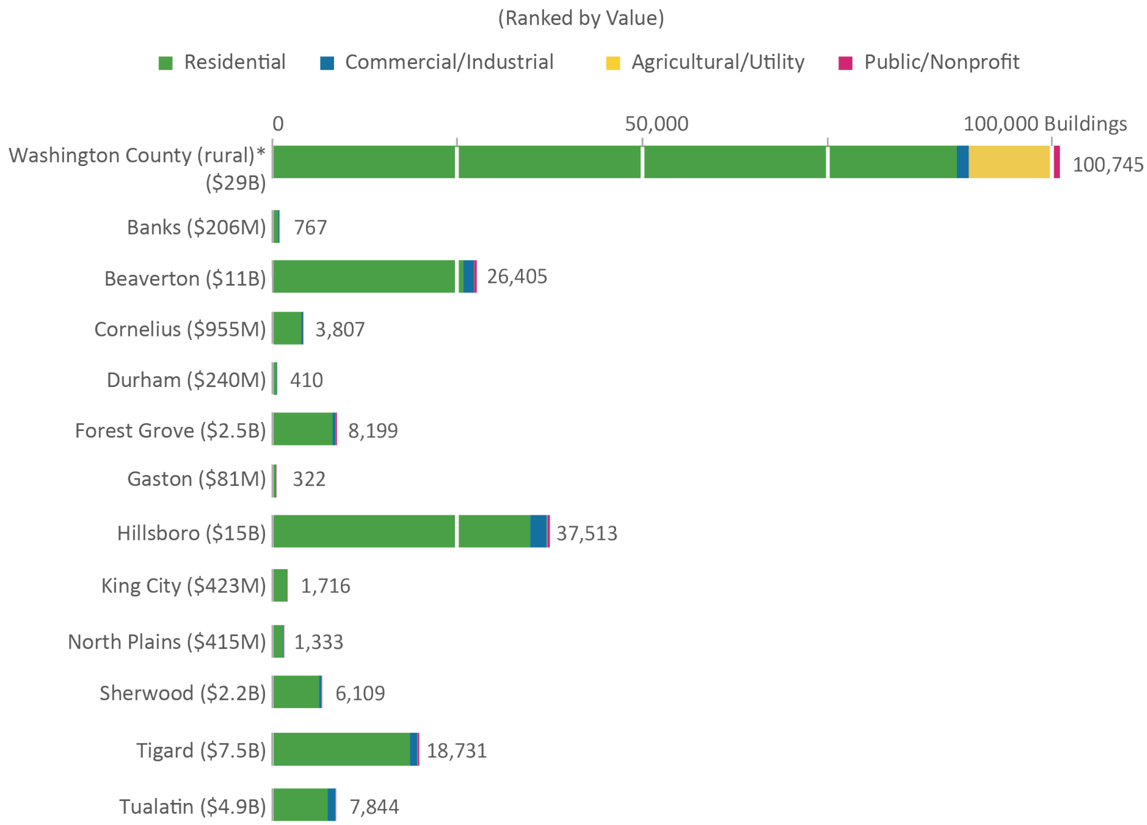
Table 2-1. Washington County building inventory.

Community	Total Number of Buildings	Percentage of Total Buildings	Estimated Total Building Value ($)	Percentage of Total Building Value
Unincorp. Washington Co (rural)	100,745	47%	28,760,104,000	38%
Banks	767	0.4%	205,773,000	0.3%
Beaverton	26,405	12%	11,283,939,000	15%
Cornelius	3,807	1.8%	954,752,000	1.3%
Durham	410	0.2%	240,089,000	0.3%
Forest Grove	8,199	3.8%	2,525,502,000	3.4%
Gaston	322	0.2%	81,440,000	0.1%
Hillsboro	37,513	18%	15,487,612,000	21%
King City	1,716	0.8%	423,075,000	0.6%
North Plains	1,333	0.6%	414,606,000	0.6%
Sherwood	6,109	2.9%	2,194,018,000	2.9%
Tigard	18,731	8.8%	7,526,469,000	10%
Tualatin	7,844	3.7%	4,964,016,000	6.6%
Total Study Area	213,901	100%	75,061,395,000	100%

The building inventory was developed from a statewide building footprints dataset developed in 2021 called the Statewide Building Footprints for Oregon, release 1 (SBFO-1) (Williams, 2021). The SBFO-1 data of Washington County was modified from a building footprints dataset maintained by Metro Regional Land Information System (http://rlisdiscovery.oregonmetro.gov/, downloaded June 2020). The building footprints provide a spatial location and 2D representation of a structure. The total number of buildings within the study area was 213,901.

Washington County supplied assessor data and we formatted it for use in the risk assessment. The assessor data contains an array of information about each improvement (i.e., building). Tax lot data, which contains property boundaries and other information regarding the property, was obtained from the county assessor and was used to link the buildings with assessor data. The linkage between the two datasets resulted in a database of UDF points that contain attributes for each building. These points are used in the risk assessments for both loss estimation and exposure analysis. The majority of buildings are within the jurisdictions of the unincorporated county, Beaverton, Hillsboro, and Tigard and the most common building usage in the study area is residential (**Figure 2-4**).

Figure 2-4. Community building value and count in Washington County by occupancy class.



Note that "Washington County (rural)" includes small portions of Lake Oswego, Portland, Rivergrove, and Wilsonville.

Critical facilities are important to note because these facilities play a crucial role in emergency response efforts. We embedded identifying characteristics into the critical facilities in the UDF database so 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 identified include hospitals, schools, fire stations, police stations, emergency operations, and military facilities. In addition, we included other buildings based on specific community input and structures that would be essential during a natural hazard event, such as public works and water treatment facilities. 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. Critical facilities are present throughout the county with most in the incorporated county and Beaverton (**Table 2-2**). Critical facilities are listed for each community in **Appendix A**.

Table 2-2. Washington County critical facilities inventory.

Community	Hospital & Clinic		School		Police/Fire		Emergency Services		Military		Other*		Total	
	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)
(all dollar amounts in thousands)														
Unincorp. Washington Co (rural)	3	880,708	50	576,075	13	41,337	0	0	0	0	5	117,189	71	1,615,309
Banks	0	0	3	39,172	0	0	0	0	0	0	0	0	3	39,172
Beaverton	3	15,526	43	749,637	10	22,831	1	2,236	0	0	2	13,661	59	803,891
Cornelius	1	5,281	3	30,235	2	5,046	0	0	0	0	1	1,784	7	42,345
Durham	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest Grove	3	16,869	8	179,814	3	9,995	0	0	1	7,170	3	8,322	18	222,170
Gaston	0	0	2	3,490	2	4,197	0	0	0	0	0	0	4	7,687
Hillsboro	9	63,665	29	517,547	10	197,713	0	0	1	2,391	4	249,641	53	1,030,957
King City	0	0	1	14,129	2	1,512	0	0	0	0	0	0	3	15,641
North Plains	0	0	1	9,962	2	5,006	0	0	0	0	0	0	3	14,968
Sherwood	0	0	11	130,646	2	7,464	0	0	0	0	1	5,758	14	143,868
Tigard	1	2,959	14	199,343	3	13,514	0	0	0	0	2	18,869	20	234,685
Tualatin	3	147,053	7	111,660	2	8,060	1	2,378	0	0	1	1,686	14	270,837
Total Study Area	23	1,132,061	172	2,561,710	51	316,675	2	4,614	2	9,561	19	416,910	269	4,441,531

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

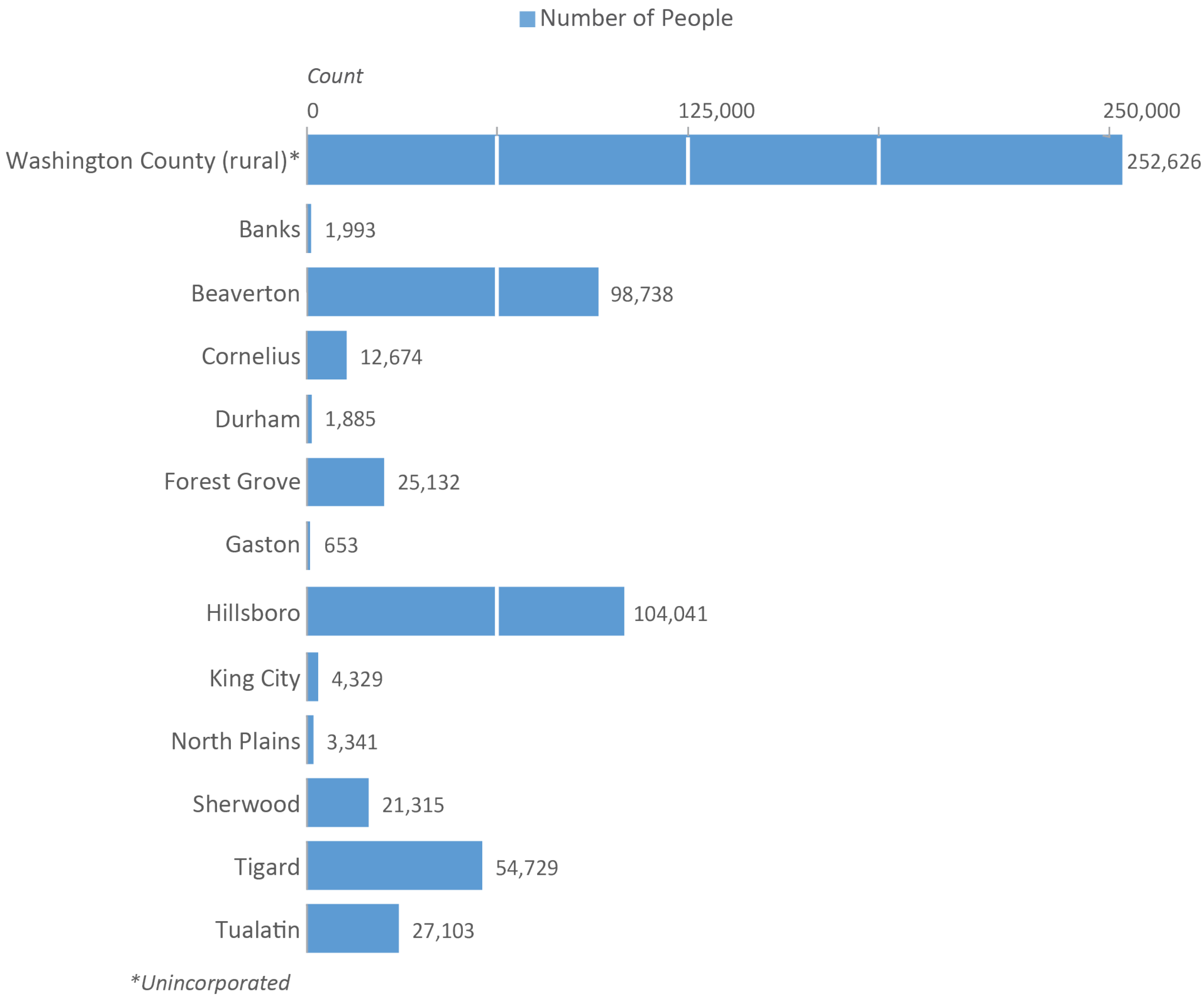
* Category includes buildings that are not traditional (emergency response) critical facilities but considered critical during an emergency based on input from local stakeholders (e.g., water treatment facilities or airports).

2.4 Population

One purpose of the UDF database design was so that we could estimate the number of people at risk from natural hazards. Within the UDF database, the population of permanent residents reported per census block was distributed among residential buildings and pro-rated based on building area gleaned from 2010 U.S. Census data. This census block-based distribution was further adjusted with the PSU Population Research Center estimates for 2021 (**Figure 2-5**). We did not examine the impacts of natural hazards on nonpermanent populations (e.g., tourists), whose total numbers fluctuate seasonally. Due to lack of information within the assessor and census databases, the distribution includes vacation homes, which in many communities make up a small portion of the residential building stock. From information reported in the 2010 U.S. Census regarding vacation rentals within the county, it is estimated that approximately 5% of residential buildings are vacation rentals in Washington County (U.S. Census Bureau, 2010b).

From the Census and PSU Population Research Center data, we assessed the risk of the 608,559 residents within the study area that could be affected by a natural hazard. For each natural hazard, except for the earthquake scenario, a simple exposure analysis was used to find the number of potentially displaced residents within a hazard zone. For the earthquake scenario, the number of potentially displaced residents was based on residents in buildings estimated to be significantly damaged by the earthquake.

Figure 2-5. Population distribution by Washington County community.



3.0 ASSESSMENT OVERVIEW AND RESULTS

In these risk assessments, we considered five natural hazards (earthquake, flood, landslide, channel migration, and wildfire) that pose a risk to Washington County. The assessment describes both localized vulnerabilities and the widespread challenges that impact all communities. While results of this risk assessment do not typically represent singular hazard events, they do quantify the potential overall level of risk present for assets and residents. 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 become more resilient to future disasters by utilizing the results in plan updates and developing future action items for risk reduction.

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

3.1 Earthquake

An earthquake is a sudden movement of rock on each side of a fault in the earth's crust, which abruptly releases strain that has accumulated. The movement along the fault produces waves of 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, also called coseismic hazards, are liquefaction and landslides. Liquefaction occurs when saturated soils substantially lose bearing capacity due to ground shaking, causing the soil to behave like a liquid; this action can be a source of tremendous damage. Coseismic landslides are mass movement of rock, debris, or soil induced by ground shaking. All earthquake damages in this report include damages derived from shaking and from liquefaction and landslide factors.

Washington County is at risk from several fault systems including Cascadia Subduction Zone, Portland Hills fault, and Gales Creek Fault. Because the impacts of a Cascadia Subduction Zone and Portland Hills fault have been recently modeled in a study by Bauer and others (2018), we did not include these scenarios in this study and instead present the results from the Gales Creek Fault.

3.1.1 Data sources

Hazus-MH offers two methods for estimating loss from earthquake, probabilistic and deterministic (FEMA Hazus-MH, 2012b). A probabilistic method 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 method uses a specific seismic scenario event, such as a CSZ Mw 9.0 event. We used the deterministic scenario method for this study along with the UDF database so that loss estimates could be calculated on a building-by-building basis.

Bauer and others (2020) recently completed detailed earthquake risk analysis of the Portland region, which included all of Washington County. Their analysis included two earthquake scenarios: a regional magnitude-9.0 CSZ earthquake, and a magnitude-6.8 earthquake on the Portland Hills Fault, a local crustal fault situated at the foot of the Tualatin Mountains (eastern portion of Washington County). The results of that analysis can be accessed here https://www.oregongeology.org/pubs/ofr/p-O-20-01.htm. Because this analysis followed a very similar method, was recently completed (published 2 years ago), covered all of Washington County, and is readily available, we decided to not replicate these two earthquake scenarios and instead selected another likely local crustal fault scenario on the Gales Creek Fault located in western Washington County.

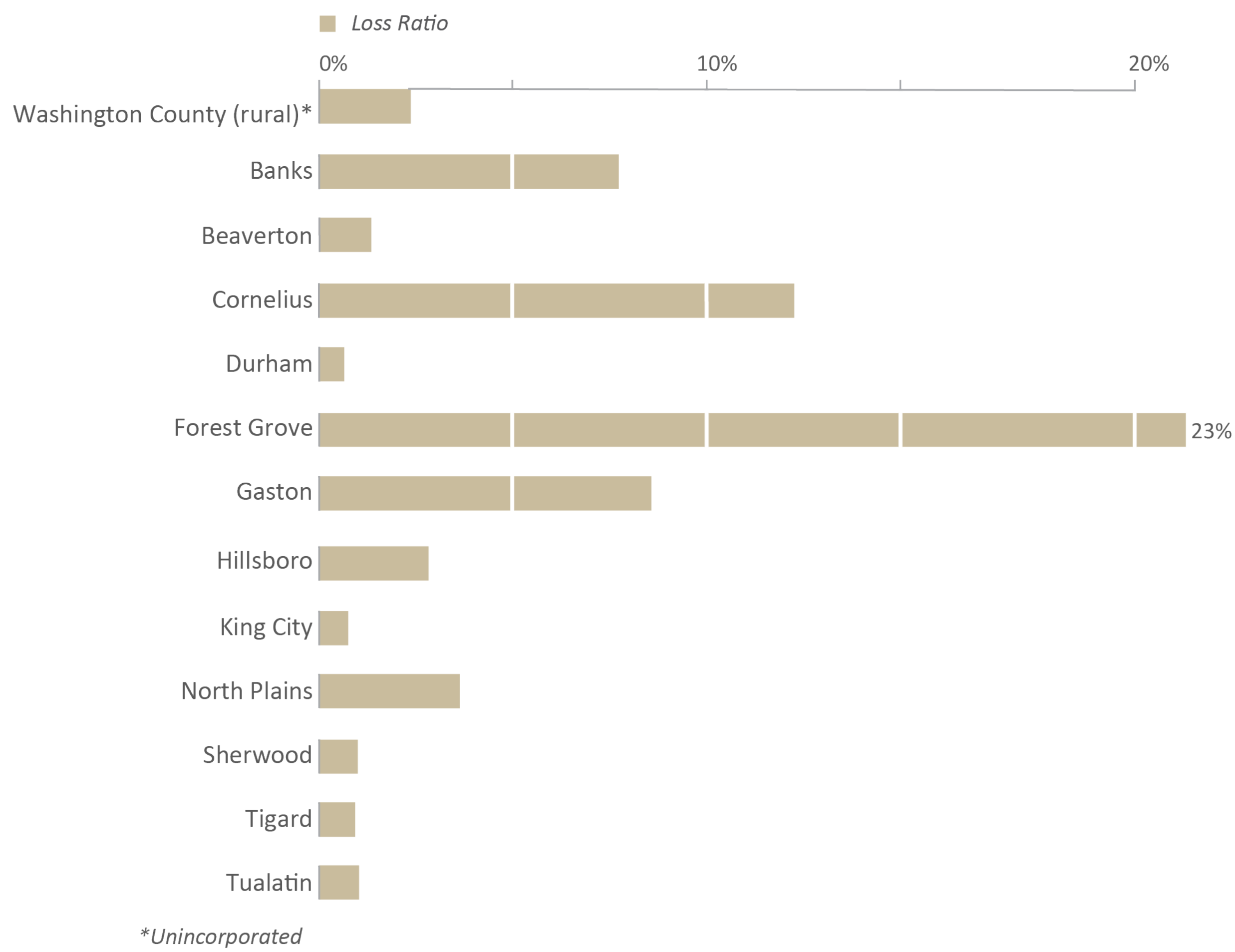
The Gales Creek Fault deterministic scenario with a magnitude of 6.7 was selected as the most appropriate for communicating additional earthquake risk for Washington County. The default Hazus-MH earthquake scenario database contained the location and orientation of the fault and provided a recommended magnitude for use in a simulated earthquake event.

The following hazard layers used for our loss estimation are derived from work conducted by Appleby and others (2019) and acquired through the Oregon Seismic Hazard Database, release 1.0 by Madin and others (2021): National Earthquake Hazard Reduction Program (NEHRP) soil amplification class, landslide susceptibility (wet), and liquefaction susceptibility. The liquefaction and landslide susceptibility layers were used by the Hazus-MH tool to calculate the probability and magnitude of permanent ground deformation caused by these factors. Hazus-MH uses a characteristic magnitude value to calculate the impacts of liquefaction and landslides. For this study, we followed the details provided in the default Hazus-MH database and used Mw 6.7 as the characteristic event.

3.1.2 Countywide results

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

Figure 3-1. Earthquake loss ratio from Gales Creek Fault Mw 6.7 by Washington 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).

We considered critical facilities nonfunctioning 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 probability of damage state was determined by Hazus-MH earthquake analysis and we reviewed the damage states in the results. The number of potentially displaced residents from an earthquake scenario described in this report was based on the formula (FEMA, 2012b): Displaced Residents = ([Number of Occupants] * [Probability of Complete Damage]) + (0.9 * [Number of Occupants] * [Probability of Extensive Damage]).

The results indicate that Washington County will incur losses of approximately $2 billion or 2.7% of their total building assets should a Gales Creek Fault Mw 6.7 earthquake strike. These results are strongly influenced by proximity to the Gales Creek Fault and ground deformation from liquefaction. Moderate to high liquefaction susceptibility exists throughout the county, which increases the risk from an earthquake. There are some developed areas in the communities of Forest Grove and Hillsboro that are built on highly liquefiable soils and therefore have higher estimates of damage from this earthquake scenario than other communities in the study area.

Washington County Gales Creek Fault Mw 6.7 earthquake results:

- Number of red-tagged buildings: 1,807
- Number of yellow-tagged buildings: 6,049
- Loss estimate: $2,018,269,000
- Loss ratio: 2.7%
- Nonfunctioning critical facilities: 31
- Potentially displaced population: 6,160

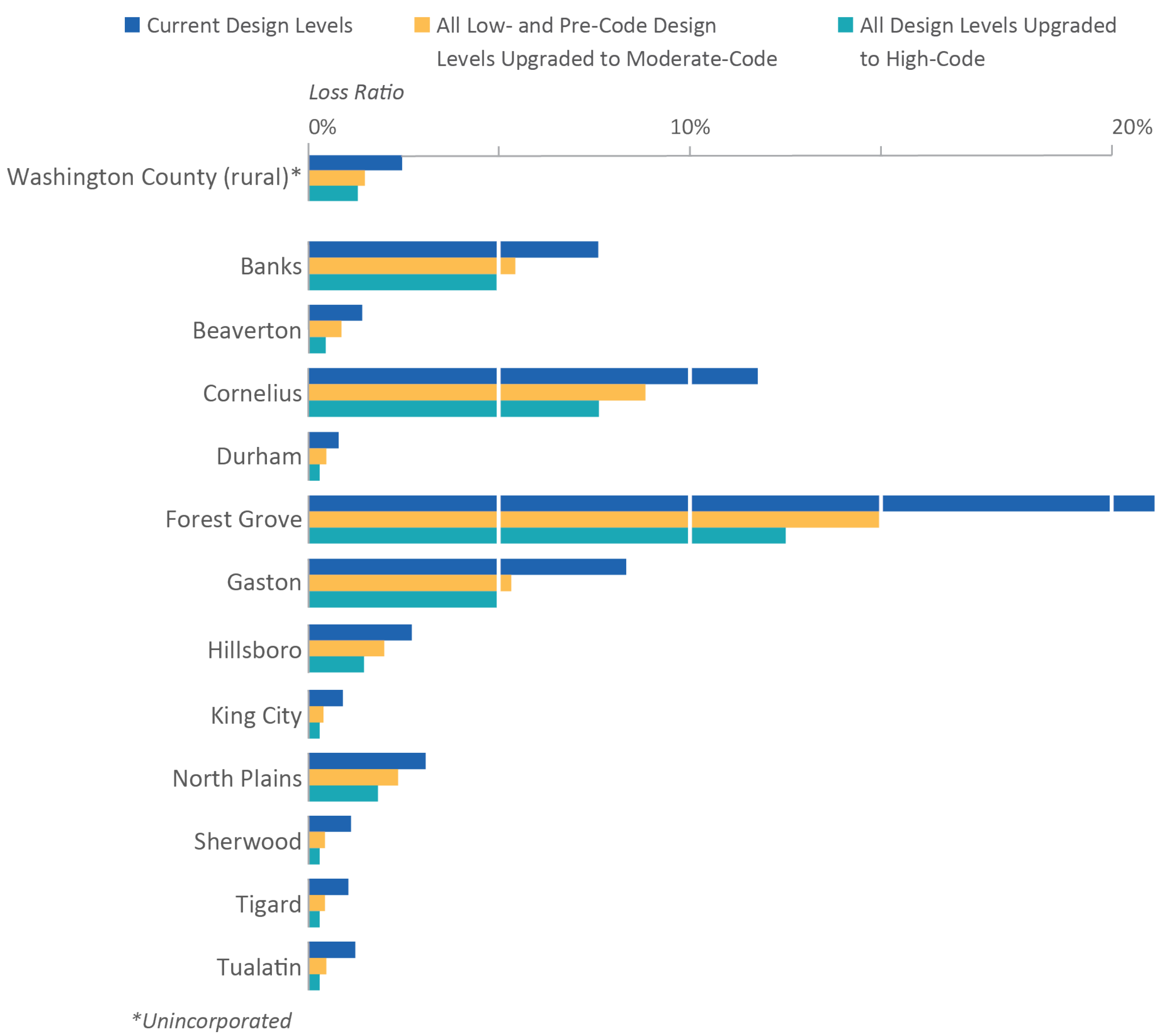
Although the impacts of coseismic landslides were included in the Hazus earthquake results, we did not perform an analysis that specifically isolated damage caused by coseismic landslides. It is worth noting that coseismic landslides likely contribute a small percentage of the overall estimated damage from the earthquake hazard in Washington County. Landslides exist in the northern portion of Washington County where coseismic landslides are more likely to occur.

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 70% of Washington County's buildings were built before the 1990's. Certain building types are known to be more vulnerable than others in earthquakes, such as the manufactured homes. In Hazus-MH, manufactured homes are one occupancy type that performs poorly in earthquake damage modeling. Communities that are composed of an older building stock and more vulnerable occupancy types are expected to experience more damage from earthquake than communities with fewer of these vulnerabilities.

If buildings could be seismically retrofitted to moderate or high code standards, earthquake risk would be greatly reduced. In this study, a simulation in Hazus-MH earthquake analysis shows that the number of red-tagged buildings drop from 1,807 to 1,029, 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 reduce risk. Two simulations of a deterministic Mw 6.7 earthquake where all buildings are upgraded to moderate code standards or to high code standards show a reduction in loss estimates (**Figure 3-2**).

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

Figure 3-2. Gales Creek Fault Mw 6.7 earthquake loss ratio in Washington County, with simulated seismic building code upgrades.



3.1.3 Areas of significant risk

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

- Areas near the epicenter of the simulated earthquake scenario are likely to incur a significant amount of damage. The communities of Banks, Cornelius, Forest Grove, and Gaston have higher estimated loss ratios compared to other communities in the study due to the level of shaking likely to occur.
- Buildings in relatively high liquefaction susceptible areas along Dairy Creek, Gales Creek, and the Tualatin River are at higher risk to damage from coseismic liquefaction induced ground deformation.
- Unreinforced masonry buildings in the older downtown portions of Forest Grove and Hillsboro are more vulnerable to potentially substantial damage during an earthquake compared to other nearby structures built to modern standards.
- 28 of the 269 critical facilities in the study area are estimated to be nonfunctioning due to an earthquake like the one simulated in this study.

3.2 Flooding

The frequency and severity of flooding may change over time due to changes in climate and precipitation patterns, land use, and how we manage our waterways. This study represents our current understanding of flood hazards and flood risk, but we recognize that flood models and risk assessments will need to be updated with time and changing conditions.

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 Washington 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 such as 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 and impact of flooding. The annual probabilities calculated for flood hazard used in this report are 10%, 2%, 1%, and 0.2%, henceforth referred to as 10-year, 50-year, 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 largest river within the county is the Tualatin River. The major streams within the basin are Beaverton Creek, Bronson Creek, Council Creek, Dairy Creek, Fanno Creek, Gales Creek, McKay Creek, and Rock Creek North. All the listed streams are subject to flooding and damaging buildings within the floodplain. The Tualatin River reached record flooding in 1996, which caused widespread damage totaling in the millions of dollars (Appleby and others, 2021). Due to the level of damages in Tualatin and the surrounding areas, the event received a Presidential Disaster Declaration (Washington County Emergency Management, 2017).

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.

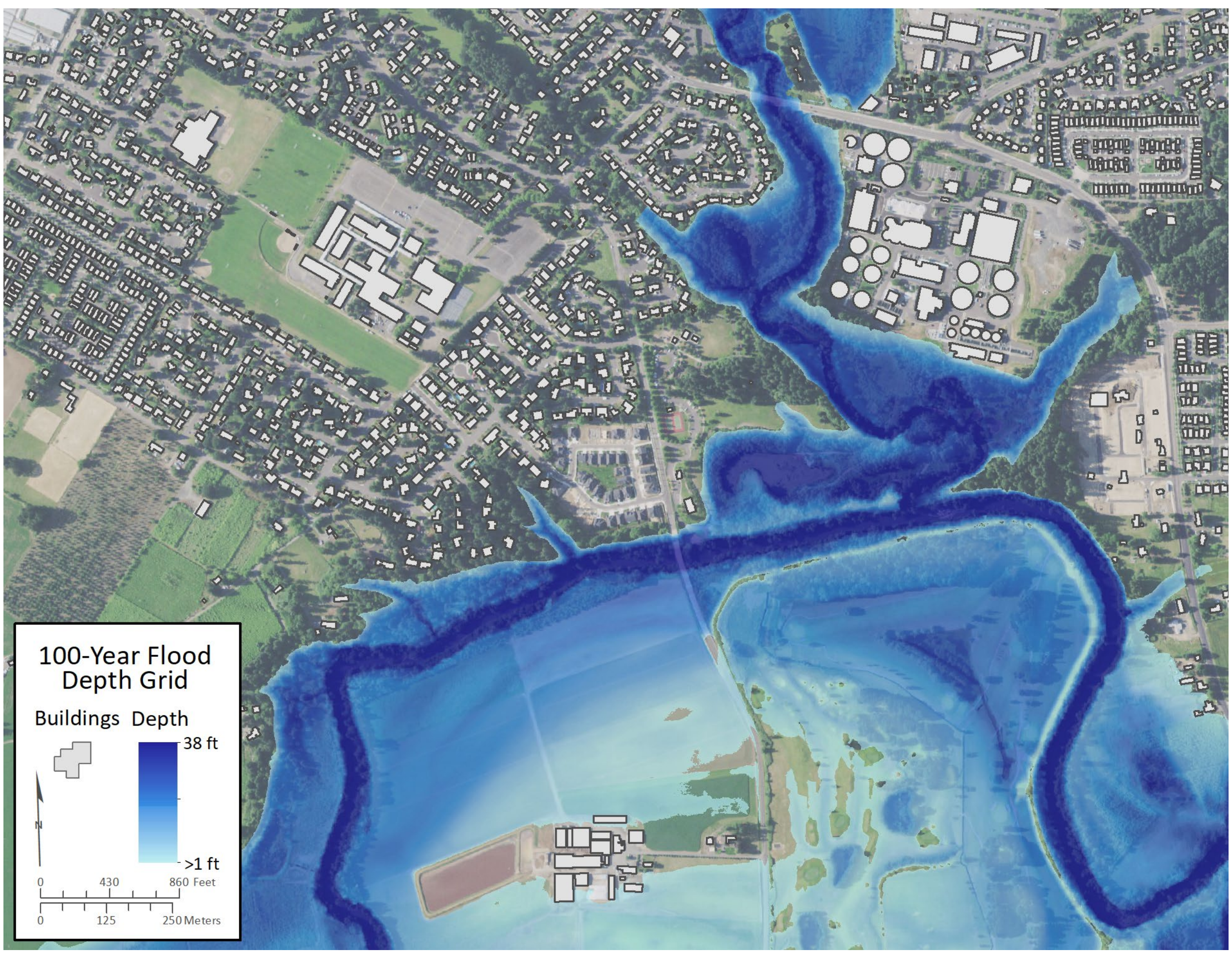
3.2.1 Data sources

The Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) for the study area were updated and made effective in 2018 (FEMA, 2018); these were the primary data sources for the flood risk assessment. Further information regarding NFIP related statistics can be found at FEMA's website: https://www.fema.gov/policy-claim-statistics-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.

Depth grids for "Zone A" designated flood zones, or approximate 100-year flood zones, were developed by the Strategic Alliance for Risk Reduction (STARR) in 2015 to revise the Washington County FIRMs (FEMA, 2018). DOGAMI developed the 10-, 50-, 100-, and 500-year depth grids from detailed stream model information within the study area. DOGAMI used high-resolution lidar collected in 2014 to create the depth grids (Metro 2014 project, Oregon Lidar Consortium; see http://www.oregongeology.org/lidar/collectinglidar.htm) . Both sets of depth grids 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**). Depth grids for four riverine flooding scenarios (10-, 50-, 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 Hillsboro, Oregon.



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 Washington County, occupancy type and basement presence attributes were available from the assessor database for most buildings. Where individual building information was not available from assessor data, we used oblique imagery and street-level imagery to estimate these important building attributes. Only buildings in a flood zone or within 152 meters (500 feet) 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.

3.2.2 Countywide results

For this risk assessment, we imported the countywide UDF data and depth grids into Hazus-MH and ran a flood analysis for four flood scenarios (10-, 50-, 100-, and 500-year). We used the 100-year flood scenario as the primary scenario for reporting flood results (also see Appendix E: **Plate 7**). The 100-year flood has traditionally been used as a reference level for flooding and is the standard probability that FEMA uses for regulatory purposes. See **Table B-4** for multiscenario cumulative results.

Washington countywide 100-year flood loss:

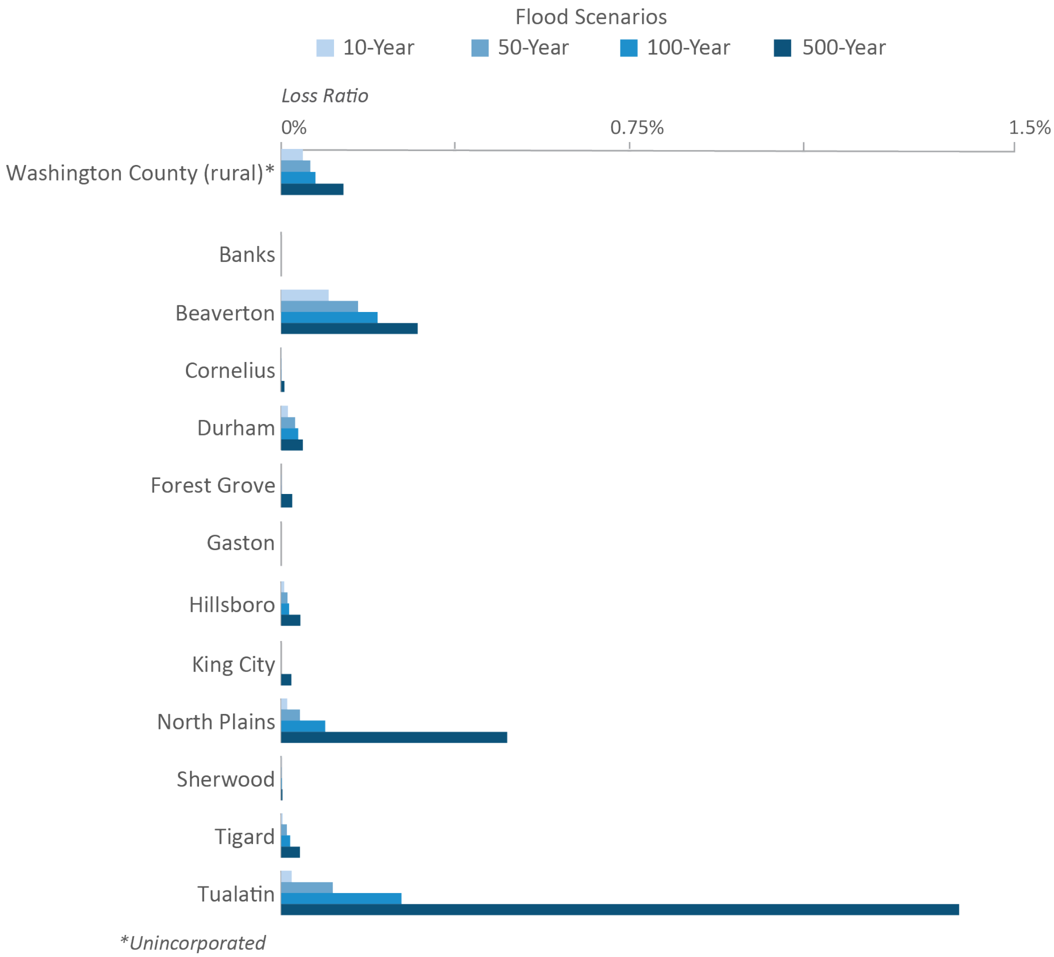
- Number of buildings damaged: 1,323
- Loss estimate: $60,414,000
- Loss ratio: 0.08%
- Damaged critical facilities: 2
- Potentially displaced population: 4,161

3.2.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario for the entire county is more than $60 million. While the loss ratio of flood damage for the entirety of Washington County is only 0.08%, the impact to areas of development near flood-prone streams is significant. (**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 and impact from flooding. The Hazus-MH analysis also provides useful flood data on individual communities so that planners can identify problems and consider which mitigating activities will provide the greatest resilience to flooding.

The main flooding problems within Washington County are within Tualatin floodplain areas in the unincorporated county and many commercial areas in Beaverton along Beaverton Creek and Fanno Creek and in a significant portion of commercial areas in the city of Tualatin. Many other communities in Washington County have little to no risk from flooding (**Figure 3-4**). There are few areas of concentrated flood damage in the study area. The small amount of damage that is estimated is scattered across the county at various places along the mapped streams.

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



3.2.4 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 nondamaged buildings from Hazus-MH with the number of exposed buildings in the flood zone. A small proportion (0.8%) of Washington County's buildings were found to be within designated flood zones. Of the 1,625 buildings that are exposed to flooding, we estimate that 302 are above the height of the 100-year flood. This evaluation also estimates that 4,161 residents might have mobility or access issues due to surrounding water. See **Appendix B: Table B-5** for community-based results of flood exposure.

3.2.5 Areas of significant risk

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

- Commercial areas in the city of Tualatin along Hedges Creek are at risk of flooding.
- Commercial areas in Tigard along Fanno Creek are at risk of flooding.
- Commercial areas in Beaverton along Beaverton Creek are at risk of flooding.
- Residential and commercial buildings along tributaries to Beaverton Creek throughout the city of Beaverton are at risk of flooding from a 100-year flood.

- Several residences and businesses in North Plain along a tributary to McKay Creek are at risk of flooding.
- Many residential structures are exposed to flooding in the vicinity of Highway 26 and Cedar Mill Creek and Johnston Creek.

3.3 Landslide Susceptibility

This study represents our current understanding of landslide susceptibility within this study area. However, changing climate, precipitation patterns, land use, wildfire events, and land and forest management strategies may increase or decrease the susceptibility to landslides.

Landslides are mass movements of rock, debris, or soil. There are many different types of landslides in Oregon. In Washington County, the most common are debris flows and shallow and deep 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. Factors that influence landslide type include slope steepness, water content, and geology. Many triggers can cause a landslide: intense rainfall, earthquakes, or human-induced factors like water concentration, 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).

3.3.1 Data sources

The Statewide Landslide Information Layer for Oregon (SLIDO), release 4.0 (Franczyk and others, 2019) is a compilation of data about landslide hazards in the state of Oregon. One of the datasets in SLIDO is a compilation of landslide inventories from 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 inventory data vary greatly in scale, scope, and focus and thus in accuracy and resolution across the state. Washington County landslide mapping studies that were compiled into SLIDO using less accurate methods:

- Regional Landslide Hazard Maps of the Southwest Quarter of the Beaverton Quadrangle, West Bull Mountain Planning Area, Washington County (Burns, 2008)
- Regional Landslide Hazard Maps of the Western half of The Linnton Quadrangle (Burns and Mickelson, unpublished 2009)

Burns and others (2016) used SLIDO 3.2 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. Landslide inventory data directly define the Very High landslide susceptibility zone, whereas the landslide inventory 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.

Recent landslide inventory mapping in Washington County by Hairston-Porter and others in 2021 (thus not included in Burns and others [2016]) following methods outlined in DOGAMI Special Paper 42 (SP-42: Burns and Madin, 2009). To use the best available landslide data for this risk assessment, we added this new landslide inventory data (Hairston-Porter and others, 2021) to the Statewide Landslide Susceptibility Map (Burns and others, 2016). The new landslide inventory data are equivalent to the very high susceptibility zone. Therefore, we simply "stamped in" the new inventory, replacing the existing susceptibility zones in the Statewide Landslide Susceptibility Map (Burns and others, 2016). The landslide deposits mapped by Hairston-Porter and others (2021) were "stamped in" to the landslide susceptibility dataset and superseded the previous Very High zones. Previously mapped Very High zones within the Hairston-Porter and others (2021) study area were converted to High zones.

Figure 3-5. Recent landslide mapping in Washington County.

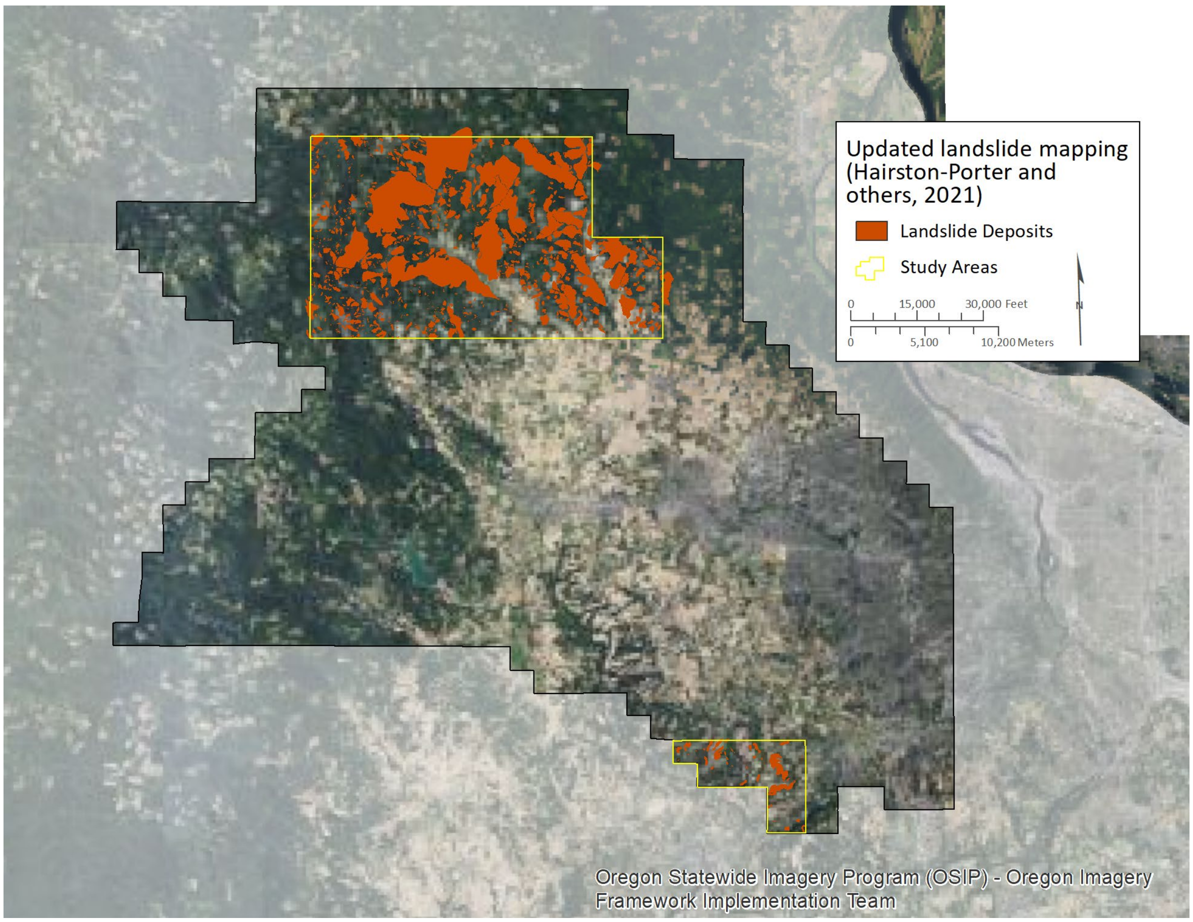


Image source: Oregon Statewide Imagery Program, 2018

We overlaid building and critical facilities data on the new landslide susceptibility map for Washington County to assess the landslide susceptibility 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 in the following section. 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.

3.3.2 Countywide results

We found that portions of Beaverton, Tigard, Hillsboro, Forest Grove, and the unincorporated county are exposed to landslide hazards. Areas in terrain with moderate to steep slopes or at the base of steep hillsides may be exposed to landslides. While these areas are highly prone to landslides, most of the populated areas are outside these zones because most of the buildings are on the relatively flat ground toward the center of the Tualatin Valley. The percentage of building value exposed to Very High and High landslide susceptibility is approximately 3.6%, which equates to nearly 9,000 buildings with a value of nearly $2.7 billion.

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 8**). It was useful to combine exposure for both susceptibility zones to best communicate the level of landslide risk to communities. These susceptibility zones represent areas most susceptible to landslides with the highest impact to the community.

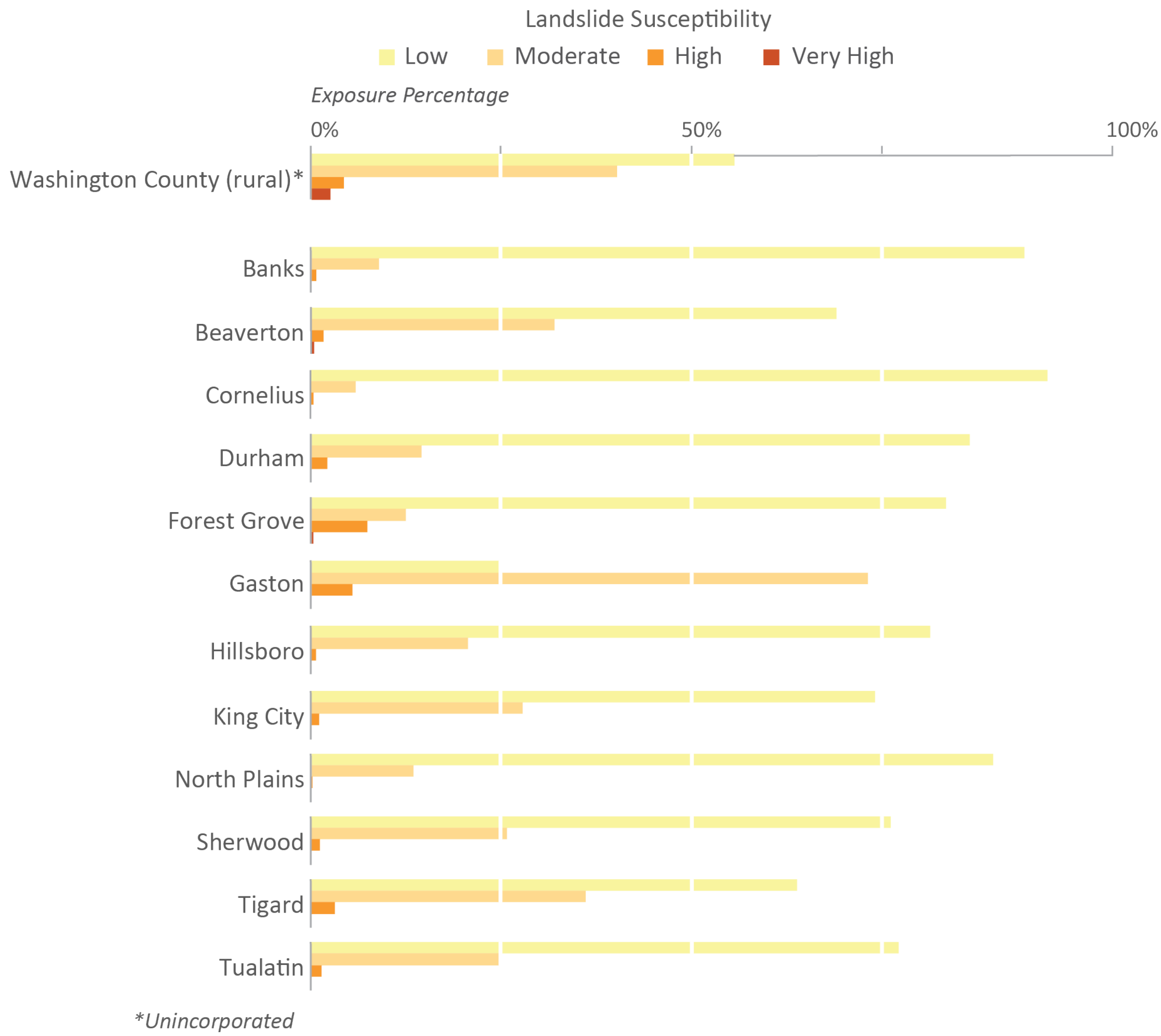
For this risk assessment we compared building locations to geographic extents of the landslide susceptibility zones (**Figure 3-6**). The exposure results shown below are for the High and Very High susceptibility zones. See **Appendix B: Detailed Risk Assessment Tables** for multiscenario analysis results.

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

- Number of buildings: 8,997
- Value of exposed buildings: $2,689,627,000
- Percentage of total county value exposed: 3.6%
- Critical facilities exposed: 1
- Potentially displaced population: 20,383

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

Figure 3-6. Landslide susceptibility exposure by Washington County community.



3.3.3 Areas of significant risk

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

- Residential structures along the west side of the Portland Hills are generally at a higher risk of damage from landslides.
- The southern, western, and northern rural areas of Washington County with steep slopes have increased risk of damage from landslides.
- Many areas in the southwestern portions of Beaverton and Tigard are highly susceptible to damage from landslides.
- Buildings built along Rock Creek in Hillsboro are at higher risk of damage from landslides than other adjacent areas.
- The northwestern portion of Forest Grove is highly susceptible to damage from landslides.

3.4 Channel Migration

The frequency and severity of channel migration may change over time due to changes in climate and precipitation patterns, land use, and how we manage our waterways. This study represents our current understanding of channel migration hazards and risk, but we recognize that channel migration mapping and risk assessments will need to be updated with time and changing conditions.

Channel migration is a dynamic process by which a stream's location changes over time. This process includes channel bed and bank erosion, sediment deposition, and channel avulsion, a process in which the stream abruptly moves to a new location on the floodplain. Many factors influence channel movement, including the local geology, size, and quantity of sediment within the river, discharge of water, vegetation, channel shape, and slope. Human changes to the channel, such as the construction of dams and levees, also has a major impact on how a channel changes its course. In combination, these factors affect how a river's energy and erosive power is dispersed. Straight, steep streams have highly concentrated erosive power; by contrast, curving channels that flow across wide and flat floodplains allow the river to dissipate its energy over a wider area and for sediment to be deposited (Rapp and Abbe, 2003).

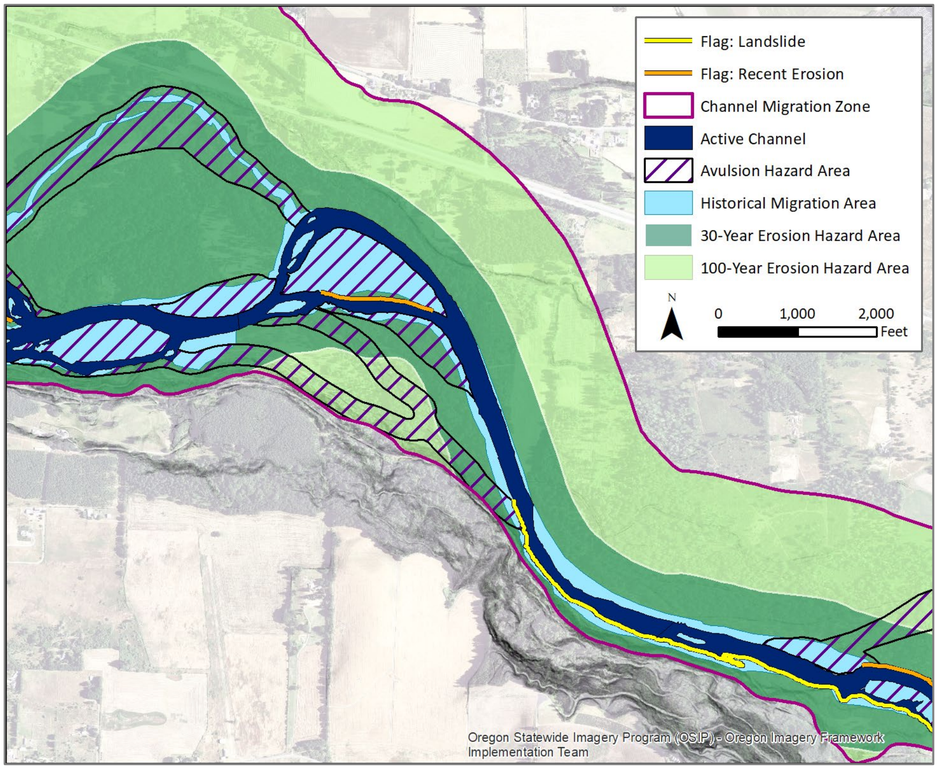
The area in which a stream channel moves laterally over a given time is known as a channel migration zone (CMZ). In places where development has occurred within the CMZ, structures are at risk for severe damage to foundations and infrastructure. The CMZ typically extends beyond the limits of the regulatory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

3.4.1 Data sources

The channel migration zones used for this report were developed by Appleby and others (2021) for the mainstem of the Tualatin River, seven tributaries to the Tualatin River (Beaver Creek, Beaverton Creek, Dairy Creek, Fanno Creek, Gales Creek, McKay Creek, and Rock Creek) and two tributaries to Dairy Creek (East Fork and West Fork Dairy Creek). The CMZ includes the areas of historical channel migration, potential erosion, and channel avulsion; these areas are mapped based on geology, historical aerial imagery, lidar topography, limited field work, and measured rates of historical channel migration. The methodology for developing the related zones and how they are combined are described in Appleby and others (2021). The CMZ is subdivided into seven subcomponents: the active channel, historical migration area, 30-year and 100-year erosion hazard areas, the avulsion hazard area, and flagged streambanks that are actively eroding or adjacent to landslides (**Figure 3-7**).

To assess the exposure within each community, we overlaid buildings and critical facilities on the 30-year erosion hazard area within the CMZ. While there is risk throughout the CMZ, we chose to examine the structures within the 30-year erosion hazard area, because it represents the area of greatest probability of being at risk from channel migration during the next 30 years. We estimated the total dollar value of exposed buildings and the number of people potentially displaced from the 30-year CMZ and reported these values in the following section. Land value losses due to CMZ were not examined for this report.

Figure 3-7. Example diagram of the components of a CMZ map, including the active channel (AC) in dark blue, historical migration area (HMA) in light blue, avulsion hazard area (AHA) with hatched lines, 30-year and 100-year erosion hazard areas (EHA) in dark and light green, flagged streambanks with yellow and orange lines, and channel migration zone (CMZ) boundary outlined in magenta (from Appleby and others, 2021).



3.4.2 Countywide results

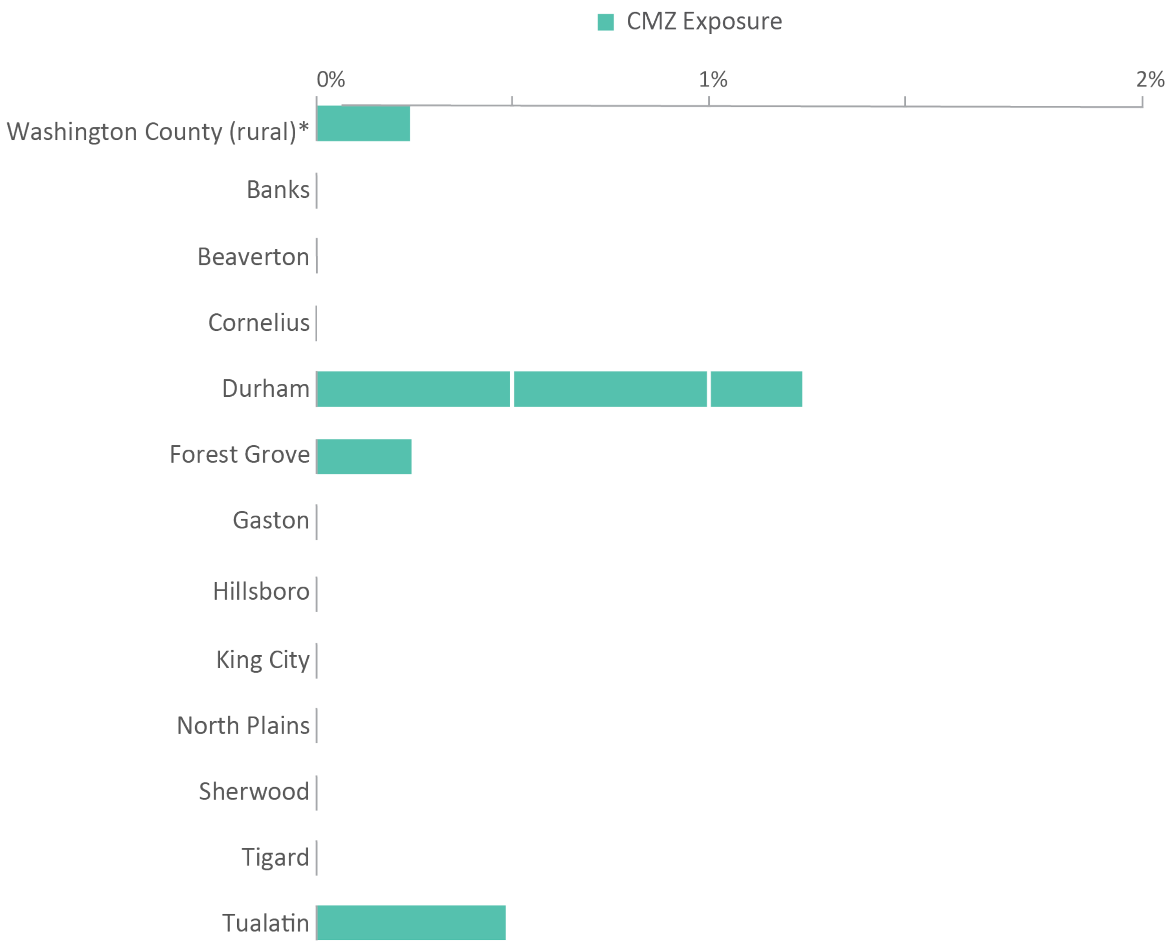
While channel migration areas have been mapped along many of the creeks and rivers that comprise the Tualatin River Watershed, there is very little overall building exposure to this hazard. To quantify risk, the exposure analysis was conducted by determining which buildings were within or outside of the CMZ (see **Appendix E: Plate 9**). Areas where shifting channel patterns in these streams occur, presents a minor risk from channel migration hazard compared to other hazards in the county. In Washington County, the areas in the 30-year erosion hazard area are composed of urban, forested, and agricultural land, that include bridges, and roads, but few buildings are exposed. The areas that have experienced the greatest historical migration and thus have the widest CMZs are along Gales Creek and the upper Tualatin River.

Washington countywide channel migration exposure (30-year Erosion Hazard Area):

- Number of buildings: 332
- Value of exposed buildings: $106,312,000
- Percentage of total county value exposed: 0.1%
- Critical facilities exposed: 0
- Potentially displaced population: 578

Several apartment buildings along the Tualatin River in the Cities of Durham and Tualatin are within of the channel migration hazard areas. **Figure 3-8** illustrates the distribution of exposed building value due to channel migration with the different communities of Washington County. See **Appendix B: Detailed Risk Assessment Tables** for complete analysis results.

Figure 3-8. Channel migration exposure by Washington County community.



3.4.3 Areas of significant risk

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

- Channel migration building exposure is present in areas in the upper reaches of East Fork Dairy Creek and Gales Creek in the rural portions of the county.
- Several apartment buildings in the Cities of Durham and Tualatin along the Tualatin River are exposed to channel migration hazard.

3.5 Wildfire

The frequency, intensity, and severity of wildfires may change over time due to changes in climate, drought conditions, urbanization, and how we manage our forested lands. This study represents our current understanding of wildfire hazards and wildfire risk, but we recognize that wildfire models and risk assessments will need to be updated with time and changing conditions.

Wildfires are a natural part of the ecosystem in Oregon. However, wildfires can present a substantial hazard to life and property in growing communities. 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 (Gilbertson-Day and others., 2018). Post-wildfire geologic hazards can also present risk. These usually include flood, debris flows, and landslides. Post-wildfire geologic hazards were not evaluated in this project.

The Washington County Community Wildfire Protection Plan (WCCWPP), published in 2007, recommended that the county develop policies that address fire restriction enforcement, wildland-urban interface standards, and building code enforcement related to emergency access. Forests cover approximately 40% of the study area and play an important role in the local economy, but also surround homes and businesses (WCCWPP, 2007). Contact the Washington County Planning and Development Services for specific requirements related to the county's comprehensive plan.

3.5.1 Data sources

The Pacific Northwest Quantitative Wildfire Risk Assessment (PNRA): Methods and Results (Gilbertson-Day and others, 2018) is a comprehensive report that includes a database of spatial information related to wildfire hazard developed by the United States Forest Service (USFS) for the states of Oregon and Washington. 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 a dataset was derived from the PNRA database and was used to measure the risk to communities in Washington County.

We used a dataset called "Integrated Hazard" that was prepared by the Oregon State University – Extension Service Fire Program and Wildland Fire Associates, which we categorized into low, moderate, and high hazard zones for the wildfire exposure analysis. The Integrated Hazard dataset was developed by combining the conditional flame length and burn probability data from the PNRA (Rau and others, 2021). Conditional flame length is a measurement of fire intensity or the predicted level of severity of a simulated wildfire. Burn probability is derived from simulations using many elements including weather, ignition frequency, ignition density, and fire modeling landscape (Gilbertson-Day and others, 2018).

Burn probabilities were grouped into three hazard categories (mean annual probabilities):

- Low wildfire hazard (0.0001 – 0.0002 or 1/10,000 – 1/5,000)
- Moderate wildfire hazard (0.0002 – 0.002 or 1/5,000 – 1/500)
- High wildfire hazard (0.002 – 0.04 or 1/500 – 1/25)

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

3.5.2 Countywide results

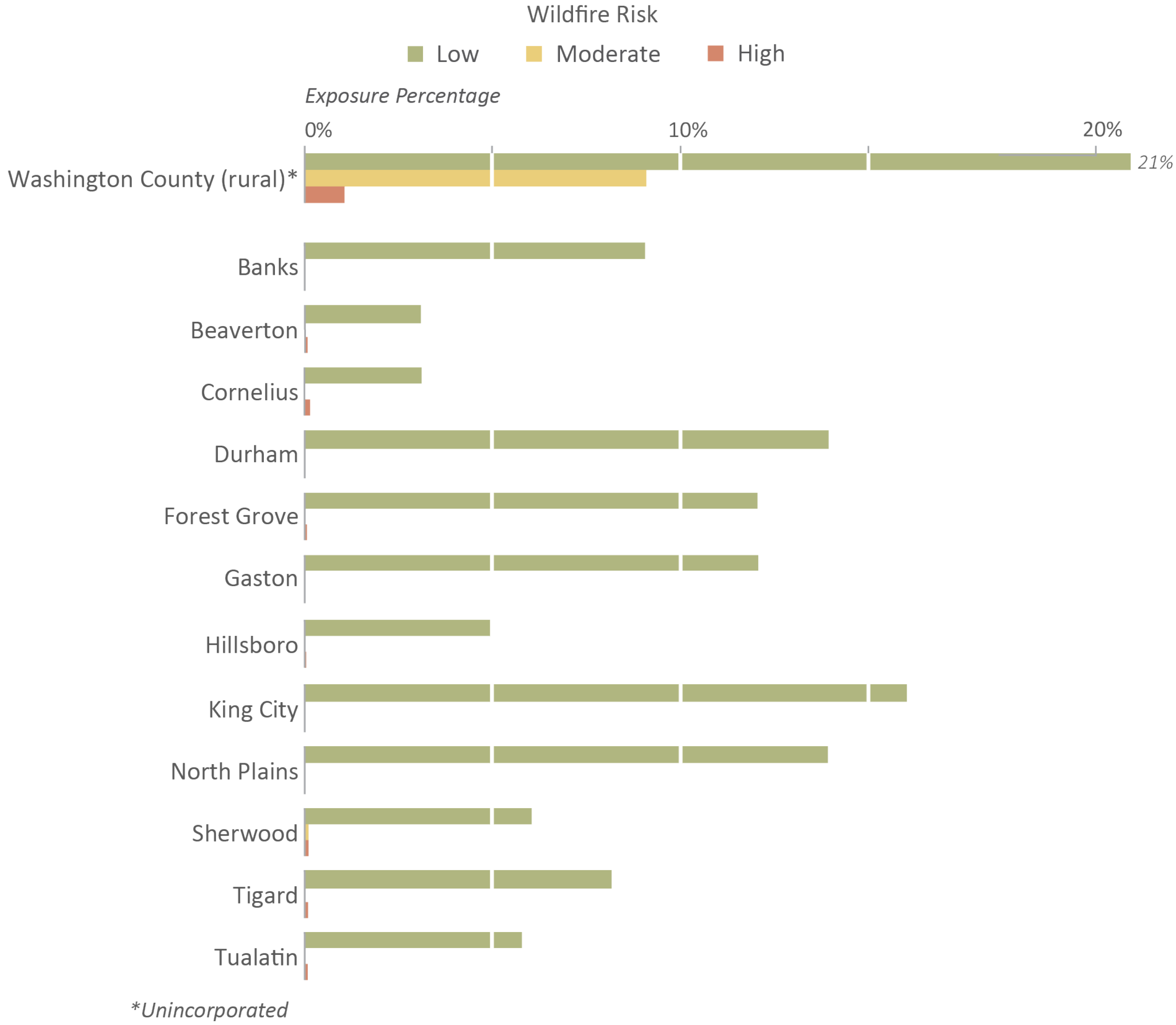
The High and Moderate hazard categories were chosen as the primary risk scenario for this report because these categories represent areas that have the highest potential for losses. However, Low hazard is not the same as no hazard. Moderate wildfire risk is included with High Risk in the assessment of exposure to wildfire, because under certain conditions Moderate Risk zones can be very susceptible to burn. In combining the High and Moderate risk categories within Washington County, we can emphasize areas where lives and property are most at risk.

Washington countywide wildfire exposure (High or Moderate Risk):

- Number of buildings: 2,297
- Value of exposed buildings: $589,719,000
- Percentage of total county value exposed: 0.8%
- Critical facilities exposed: 0
- Potentially displaced population: 3,309

For this risk assessment, the building locations were compared to the geographic extent of the wildfire hazard categories. A total of 2,111 buildings in Unincorporated Washington County (rural) are exposed to High or Moderate wildfire hazard, whereas the incorporated communities have very little exposure. The primary areas of exposure to this hazard are in the forested unincorporated areas in the northern and western portions of the county (see **Appendix E: Plate 10**). The incorporated communities of Forest Grove, North Plains, and Sherwood have the highest percentage of exposure to Moderate wildfire hazard within the study area. **Figure 3-9** illustrates the level of risk from wildfire for the different communities of Washington County. See **Appendix B: Detailed Risk Assessment Tables** for multiscenario analysis results.

Figure 3-9. Wildfire risk exposure by Washington 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:

- Much of the forested portions of the rural unincorporated county have elevated levels of wildfire risk. These areas are considered within the Wildland-Urban Interface in the southern, western, and northern fringes of Washington County.

4.0 CONCLUSIONS

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

- **Extensive damage and losses for some areas in Washington County can occur from an earthquake**– Based on the results of a Gales Creek Fault Mw 6.7 earthquake, some communities in Washington County will experience at least some impact and disruption from such an event. Results show that this earthquake could cause building value losses at approximately 20% for buildings within and near Forest Grove. Some communities like Forest Grove and Hillsboro can expect earthquake damage due to ground shaking. The damages in this part of the county are primarily from earthquake shaking. Other buildings along floodplains could experience losses due to ground deformation related to liquefaction. High vulnerability within the building inventory (unreinforced masonry) also contributed to losses expected in the county.
- **Retrofitting buildings to modern seismic building codes can reduce damages and losses from earthquake shaking** – Seismic building codes have a major influence on earthquake shaking damage estimated in this study. We found that retrofitting to at least moderate code was the most efficient 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 2.7% to 1.6%. Communities with older buildings that were constructed below the moderate seismic code standards are both the most vulnerable and have the greatest potential for risk reduction. For example, the city of Forest Grove could reduce losses from 23% to 15% by retrofitting all buildings to at least moderate code. Although seismic retrofits are an effective strategy for reducing earthquake shaking damage, it should be noted that earthquake-induced landslide and liquefaction hazards will also be present in areas along Dairy Creek, Gales Creek and the Tualatin River, and these hazards require different geotechnical mitigation strategies.
- **Some communities in the study area are at moderate risk from flooding** – Many buildings within the floodplain are vulnerable to significant damage from flooding. At first glance, Hazus-MH flood loss estimates may give a false impression of lower risk because they show lower damages within individual communities relative to the other hazards we examined. This is due to the difference between the type of results from loss estimation and exposure analysis, as well as the limited area impacted by flooding. Another consideration is that flood is one of the most frequently occurring natural hazards. We estimate that buildings within the 100-year flood zone will see an average value loss of 8.9%. The areas that are most vulnerable to flood hazard within the study are some commercial areas along streams in Beaverton (Beaverton Creek), Tualatin (Hedges Creek), and Tigard (Fanno Creek) and residential buildings in Beaverton (tributaries to Beaverton Creek), North Plain (McKay Creek), and areas near Highway 26 and Cedar Mill Creek and Johnston Creek.
- **Elevating structures in the flood zone reduces vulnerability** – We used flood exposure analysis in addition to Hazus-MH loss estimation to identify buildings that were not damaged but 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, the in the unincorporated county has 214 buildings that are estimated to be elevated above the base flood elevation (BFE). Based on the number of buildings exposed to flooding in Beaverton, Hillsboro, and Tualatin, these communities would benefit from elevating above the level of flooding.

- **Landslide hazard is significant for steeper areas in the county** – The recent landslide mapping used in this study was created using lidar and modern mapping methods to develop accurate landslide hazard maps. We used exposure analysis to assess the threat from landslide hazards. The developed areas along the west side of the Portland Hills and steeper areas in rural parts of the county are highly susceptible to landslides. Buildings in southern portions of Beaverton and Tigard, as well as along Rock Creek in Hillsboro are at risk of damage from landslides. More than 7% of the buildings in Forest Grove are exposed to Very High or High landslide hazard.
- **Exposure analysis show that buildings in the riverine valleys of the study area are at risk due to channel migration hazard** – Channel migration hazard has been mapped throughout the county along the Tualatin River and its major tributaries. Exposure analysis shows that channel migration is a threat to communities and buildings along East Fork Dairy Creek and Gales Creek. Residential areas in the Cities of Durham and Tualatin have very high risk from channel migration.
- **Wildfire risk is higher in the wildland-urban interface portions of the county** – Exposure analysis shows that buildings in rural portions of the county are at higher risk from wildfire than other areas in the county. The forested and less populated western and northern portions of the county correspond to high and moderate wildfire hazard. A total of 2% of the buildings in the unincorporated county are within areas of high or moderate wildfire hazard.
- **Most of the study area's critical facilities are at greatest risk from earthquake hazard relative to other hazards in the study area** – Because of their importance during and after a natural disaster, we identified and examined critical facilities. We estimated that 12% (31 of 269) of Washington County's critical facilities will be nonfunctioning after a Gales Creek Fault Mw 6.7 earthquake. We found little to no exposure of critical facilities to flood, landslide, channel migration, or wildfire.
- **Of the hazards examined in this study, landslide is the greatest risk to people within the study** – Potential displacement of permanent residents from natural hazards was estimated within this report. We estimated that 3% of the population in the county are within areas deemed Very High to High risk from landslide. We also estimated that 1% of the population could be displaced from an earthquake similar to the one simulated in this study. A small percentage of residents are vulnerable to displacement from flood, channel migration, and wildfire hazards.
- **The results allow communities the ability to compare across hazards and prioritize their needs** – Each community within the study area was assessed for natural hazard exposure and loss. This allowed for comparison of risk for a specific hazard between communities. It also allows for a comparison between different hazards, though care must be taken to distinguish loss estimates and exposure results. The loss estimates and exposure analyses can assist in developing plans that address the concerns for those individual communities.

5.0 LIMITATIONS

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

- **Spatial and temporal variability of natural hazard occurrence** – Flood, landslide, channel migration, and wildfire are extremely unlikely to occur across the fully mapped extent of the hazard zones, the exception is earthquake hazard. For example, areas mapped in the 100-year 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. Although 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. This is an important factor when considering the loss ratio of an individual building. On-the-ground mitigation, such as elevating buildings to avoid flood losses, has been only minimally captured. Also, due to a lack of building material information, assumptions were made about the distribution of wood, steel, and unreinforced 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 is different than results in building loss produced by Hazus analysis.. 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 Washington 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 (United States Census Bureau, 2010b) and are adjusted for population growth based on PSU Population Research Center data. As a result, we are slightly underestimating the number of people that may be in harm’s way on a summer weekend.

  Data accuracy and completeness – Some datasets in our risk assessments had incomplete coverage or lacked high-resolution data within the study area. We used lower-resolution data where there was incomplete coverage or where high-resolution data were not available. We made assumptions to amend areas of incomplete data coverage based on reasonable methods described within this report. Data layers in which assumptions were made to fill gaps are building footprints, population, some building specific attributes, and landslide susceptibility. Many of the datasets included known or suspected artifacts, omissions and errors, however repairing these problems was beyond the scope of the project and are areas needing additional research. We are aware that some uncertainty has been introduced from these data amendments at an individual building scale, but at community-wide scales the effects of the uncertainties are slight.

6.0 RECOMMENDATIONS

The following areas of implementation are needed to better manage natural hazards and reduce communities’ risk through mitigation planning. These implementation areas, although 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 reducing 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 becomes a 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 after a disaster—this ability is commonly referred to as "resilience."

This report is intended to provide local officials with 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 and local community organizations that partner with local officials in the development of additional effective resources could help this information reach a wider audience.

6.2 Planning

Local decision-makers can make plans based on the geohazard and risk information presented in this report. The primary framework for accomplishing this is through the comprehensive planning process. A 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. The information presented in this report is a key resource because it directly informs 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 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 nonbuilding structures and to different considerations about emergency response during and after a disaster.

6.3 Emergency Response

Critical facilities 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 assist with early warning.

The building database that accompanies this report can guide predisaster mitigation, emergency response, and community resilience improvements. Vulnerable areas can be identified and supported through awareness campaigns. These campaigns can be aimed at predisaster mitigation actions, such as seismic retrofitting. 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. Reduction of the magnitude of the disaster, emergency planning, and improved response time contribute to a community's natural hazard resilience.

6.4 Mitigation Funding Opportunities

Several funding sources 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 three programs that assist states, local communities, tribes, and territories with natural hazard mitigation funding: Hazard Mitigation Grant Program (HMGP), Building Resilient Infrastructure and Communities (BRIC), and Pre-Disaster Mitigation (PDM) Grant Program. FEMA also has a grant program specifically for flooding called Flood Mitigation Assistance (FMA). The SHMO can help with finding further opportunities for earthquake and tsunami assistance and funding.

6.5 Hazard-Specific Risk Reduction Actions

6.5.1 Earthquake

- Evaluate critical facilities for seismic preparedness by identifying structural deficiencies and vulnerabilities to dependent systems (e.g., water, fuel, power).
- Evaluate vulnerabilities of critical facilities. We estimate that 12% of critical facilities (**Appendix A: Community Risk Profiles**) will be damaged by an earthquake scenario described in this report, which will have many direct and indirect negative effects on first-response and recovery efforts.
- Identify communities and buildings that would benefit from seismic upgrades.

6.5.2 Flood

- Map areas of potential floodwater storage areas.
- Identify structures that have repeatedly flooded in the past and would be eligible for FEMA's "buyout" program.
- Additional risk reduction strategies may be found on FEMA's website at https://www.ready.gov/floods.

6.5.3 Landslide

- Create modern landslide inventory and susceptibility maps.
- Monitor ground movement in high susceptibility areas.
- Evaluate risks to transportation networks and land value losses due to landslide in future risk assessments.
- Study the risk from landslides that are experience channel erosion at the toe of the landslide.
- Additional risk reduction strategies may be found on FEMA's website at https://www.ready.gov/landslides-debris-flow.

6.5.4 Channel migration

- Future development in areas with the largest CMZs, particularly Gales Creek and the upper Tualatin River, should include CMZ mitigation strategies into plans and designs.
- Evaluate the losses in land value or productivity due to channel migration.
- Evaluate risks to transportation networks and bridges due to channel migration.
- Identify areas suitable for conservation corridors along rivers that are at risk from channel migration. These can be multipurpose and include areas that provide or improve floodwater storage, riparian and aquatic habitat restoration, climate change resilience, and water quality.

6.5.5 Wildfire-related geologic hazards

- Evaluate post-wildfire geologic hazards including flood, debris flows, and landslides.
- Additional risk reduction strategies may be found on FEMA's website at https://www.ready.gov/wildfires.

7.0 ACKNOWLEDGMENTS

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Many people contributed to this report at different points during the analysis phase and during the writing phase and at various levels. We are grateful to everyone who contributed, especially the following from DOGAMI: William Burns, Christina Appleby, and Robert Hairston-Porter.

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8.0 REFERENCES

Appleby, C. A., Burns, W. J., Hairston-Porter, R. W., and Bauer, J. M., 2019, Coseismic landslide susceptibility, liquefaction susceptibility, and soil amplification class maps, Clackamas, Columbia, Multnomah, and Washington Counties, Oregon: For us in Hazus: FEMA's methodology for estimating potential losses from disasters: Oregon Department of Geology and Mineral Industries Open-File Report O-19-09, 50 p. https://www.oregongeology.org/pubs/ofr/p-O-19-09.htm

Appleby, C. A., Williams, M. C., Anthony, L. H., and Madin, I. P., 2021, Flood depth and channel migration zone maps, Benton, Marion, Morrow, and Washington Counties, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-21-15, 72 p. https://www.oregongeology.org/pubs/ofr/o-21-15/o-21-15.htm

Applied Technology Council, 2015, Rapid visual screening of buildings for potential seismic hazards: A handbook (3rd ed.): Redwood City, Calif., FEMA Publication 154. https://www.fema.gov/sites/default/files/2020-07/fema_earthquakes_rapid-visual-screening-of-buildings-for-potential-seismic-hazards-a-handbook-third-edition-fema-p-154.pdf

Bauer, J. M., 2018, ArcGIS Python script alternative to the Hazus-MH Flood Model for User-Defined Facilities: Oregon Department of Geology and Mineral Industries Open-File Report O-18-04, 28 p. https://www.oregongeology.org/pubs/ofr/p-O-18-04.htm

Bauer, J. M., Burns, W. J., and Madin, I. P., 2018, Earthquake regional impact analysis for Clackamas, Multnomah, and Washington Counties, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-18-02, 96 p. https://www.oregongeology.org/pubs/ofr/p-O-18-02.htm

Burns, W.J., 2008. Regional Landslide Hazard Maps of the Southwest Quarter of the Beaverton Quadrangle, West Bull Mountain Planning Area, Washington County, Oregon. Oregon Department of Geology and Mineral Industries, Open File Report O-08-09. https://www.oregongeology.org/pubs/ofr/O-08-09.zip

Burns, W.J. and Mickelson, K.A., unpublished 2009. Regional Landslide Hazard Maps of the Western half of The Linnton Quadrangle, Washington and Multnomah Counties, Oregon, Oregon Department of Geology and Mineral Industries, https://www.co.washington.or.us/lut/planningprojects/bethany/upload/large_fs5_attach1_dogami report.pdf

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

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

Business Oregon, 2015, Oregon benefit-cost analysis tool for evaluation of seismic rehabilitation grant program applications: User's guide: Salem, Oreg., Infrastructure Finance Authority Division, 34 p. https://www.oregon.gov/biz/Publications/SRGP%20Application%20Documents/UserGuide.pdf

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

Federal Emergency Management Agency, 2012a, Hazus®-MH 2.1 User manual, Flood model: Washington, D.C., 382 p. https://www.fema.gov/flood-maps/tools-resources/flood-map-products/hazus/user-technical-manuals

Federal Emergency Management Agency, 2012b, Hazus®-MH 2.1 Technical manual, Earthquake model: Washington, D.C., 718 p. https://www.fema.gov/flood-maps/tools-resources/flood-map-products/hazus/user-technical-manuals

Federal Emergency Management Agency, 2012c, Hazus®-MH 2.1, Technical manual, Flood model: Washington, D.C., 569 p. https://www.fema.gov/flood-maps/tools-resources/flood-map-products/hazus/user-technical-manuals

Federal Emergency Management Agency, 2018, Flood insurance study: Washington County, Oregon and incorporated areas: Washington D.C., Flood Insurance Study Number 41067CV001B, v. 1, 105 p. https://map1.msc.fema.gov/data/41/S/PDF/41067CV001B.pdf?LOC=2b7d5898bd921ba5ea9900b4b125557f

Franczyk, J. J., Burns, W. J., and Calhoun, N. C., 2019, Statewide landslide information layer for Oregon, release 4 [SLIDO-4.0]: Oregon Department of Geology and Mineral Industries, 54 p., 1:750,000, geodatabase https://www.oregongeology.org/pubs/dds/p-slido4.htm

Gilbertson-Day, J. W., Stratton, R. D., Scott, J. H., Vogler, K. C., and Brough, A., 2018, Pacific Northwest Quantitative Wildfire Risk Assessment: Methods and Results, final report, report to Oregon Department of Forestry and others, 86 p. http://oe.oregonexplorer.info/externalcontent/wildfire/reports/20170428_PNW_Quantitative_Wildfire_Risk_Assessment_Report.pdf

Hairston-Porter, R. W., Madin, I. P., Burns, W. J., and Appleby, C. A., 2021, Landslide, coseismic liquefaction susceptibility, and coseismic soil amplification class maps, Benton, Marion, Morrow, and Washington Counties, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-21-14, 49 p. https://www.oregongeology.org/pubs/ofr/o-21-14/o-21-14.htm

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

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

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

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

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

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

Parsonius, S. F., and Haller, K. M., compilers, 2017, Fault number 718, Gales Creek fault zone, in Quaternary fault and fold database of the United States, U. S. Geological Survey website, https://earthquake.usgs.gov/cfusion/qfault/show_report_AB_archive.cfm?fault_id=718&section_id

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

Rau, A., Groth, A., and Beasley, M., 2021, Tualatin Basin Quantitative Wildfire Risk Assessment and Recommendations: Oregon State University – Extension Service Fire Program and Wildland Fire Associates, 97 p.

U.S. Census Bureau, 2010a, Master Address File/Topologically Integrated Geographic Encoding and Referencing system or database: Oregon census block: United States Census Bureau. https://www2.census.gov/geo/tiger/TIGER2010/TABBLOCK/2010/

U.S. Census Bureau, 2010b, American FactFinder: Profile of General Population and Housing Characteristics: United States Census Bureau. Web. 10 November 2021. https://data.census.gov/cedsci/all?q=housing

U.S. Geological Survey, 2017, Earthquake hazards 101 — the basics. Retrieved from https://www.usgs.gov/programs/earthquake-hazards/science/earthquake-hazards-101-basics

Wang, Y., 1998, Earthquake damage and loss estimate for Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-98-3, 10 p. 2 app. https://www.oregongeology.org/pubs/ofr/O-98-03.pdfWang, Y., 1998, Earthquake damage and loss estimate for Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-98-3, 10 p. 2 app. https://www.oregongeology.org/pubs/ofr/O-98-03.pdf

Washington County Community Wildfire Protection Plan Planning Committee, 2007, Washington County Community Wildfire Protection Plan, 166 p. https://www.emcwc.org/sites/default/files/uploads/docs/WashCo_CWPP_Appendices_Final.pdf

Washington County Emergency Management, 2017, Washington County Emergency Operations Plan, version 3.0, 70 p., vol. 1. https://www.co.washington.or.us/EmergencyManagement/upload/WashCo_Basic-Plan-Update-9_2017.pdf

Williams, M. C., 2021, Statewide Building Footprints for Oregon, release 1.0: Oregon Department of Geology and Mineral Industries Digital Data Series SBFO-1. https://www.oregongeology.org/pubs/dds/p-SBFO-1.htm

9.0 APPENDICES

APPENDIX A. COMMUNITY RISK PROFILES

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

A.1 Unincorporated Washington County (Rural)

Table A-1. Unincorporated Washington County (rural) hazard profile.

Community Overview

Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Unincorporated Washington County (rural)	252,626	100,745	71	28,760,104,000

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	1,969	0.8%	651	0	20,649,000	0.1%
Earthquake	Gales Creek Fault Mw 6.7	898	0.4%	3,359	7	643,401,406	2.2%

Exposure Analysis Summary

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	12,441	4.9%	6,660	0	1,877,513,000	6.5%
Channel Migration	Channel migration zone	353	0.1%	299	0	71,147,000	0.2%
Wildfire	High or Moderate Risk	2,874	1.1%	2,111	0	536,138,000	1.9%

[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 Washington County (rural) critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
Critical Facilities by Community	Exposed	>50% Prob.	Exposed	Exposed	Exposed
Agia Sophia Academy	-	-	-	-	-
Aloha Senior High School	-	-	-	-	-
Aloha-Huber Park School	-	-	-	-	-
Apple Valley	-	-	-	-	-
Banks Christian Academy	-	-	-	-	-
Banks RFPD - Buxton Station	-	X	-	-	-
Banks RFPD - Timber Station	-	X	-	-	-
Barnes Elementary School	-	-	-	-	-
Beaver Acres Elementary School	-	-	-	-	-
Bethany Elementary School	-	-	-	-	-
Bethany Village Montessori School	-	-	-	-	-
Bonny Slope Elementary School	-	-	-	-	-
Butternut Creek Elementary School	-	-	-	-	-
Catlin Gabel School	-	-	-	-	-
Cedar Hills Coop Kindergarten	-	-	-	-	-
Cedar Hills Hospital	-	-	-	-	-
Cedar Mill Elementary School	-	-	-	-	-
Chiquitos School	-	-	-	-	-
Clean Water Services - Rock Creek	-	-	-	-	-
Coffee Creek Correctional Facility	-	-	-	-	-
Dilley Elementary School	-	X	-	-	-
Errol Hassell Elementary School	-	-	-	-	-
Faith Bible Christian School	-	-	-	-	-
Farmington View Elementary School	-	-	-	-	-
Findley Elementary School	-	-	-	-	-
Forest Grove Fire and Rescue - Gales Creek Station	-	X	-	-	-
Forest Hills Lutheran School	-	-	-	-	-
Gales Creek Elementary School	-	-	-	-	-
Groner Elementary School	-	-	-	-	-
Harvey's Acres	-	-	-	-	-
Hazeldale Elementary	-	-	-	-	-
Hillsboro Water Treatment Plant	-	-	-	-	-
Holy Trinity School	-	-	-	-	-
Indian Hills Elementary School	-	-	-	-	-
International School of Beaverton	-	-	-	-	-
Jacob Wismer Elementary School	-	-	-	-	-
Kinnaman Elementary School	-	-	-	-	-
LC Tobias Elementary School	-	-	-	-	-
Lenox Elementary School	-	-	-	-	-
Life Christian School	-	-	-	-	-
Little Stars Montessori at the Fantastic Umbrella	-	-	-	-	-

Meadow Park Middle School	-	-	-	-	-
Montessori School of Beaverton	-	-	-	-	-
Mountain View Middle School	-	-	-	-	-
Oak Hills Elementary School	-	-	-	-	-
OHSU Doernbecher Pediatrics - Westside at Bethany Village	-	-	-	-	-
Oregon Episcopal School	-	-	-	-	-
Providence St. Vincent Hospital	-	-	-	-	-
Raleigh Park Elementary School	-	-	-	-	-
Reedville Elementary School	-	-	-	-	-
Rock Creek Elementary School	-	-	-	-	-
Springville K-8 School	-	-	-	-	-
St Francis of Assisi School	-	-	-	-	-
St Pius X School	-	-	-	-	-
Stoller Middle School	-	-	-	-	-
Terra Linda Elementary School	-	-	-	-	-
The Goddard School – Portland	-	-	-	-	-
Tualatin Valley Fire and Rescue - Station 19	-	-	-	-	-
Tualatin Valley Fire and Rescue - Station 56	-	-	-	-	-
Tualatin Valley Fire and Rescue - Station 60	-	-	-	-	-
Tualatin Valley Fire and Rescue - Station 62 Command	-	-	-	-	-
Tualatin Valley Fire and Rescue - Station 64	-	-	-	-	-
Tualatin Valley Fire and Rescue - Station 65	-	-	-	-	-
Tualatin Valley Fire and Rescue - Station 68	-	-	-	-	-
Tualatin Valley Fire and Rescue - Station 69	-	-	-	-	-
Tualatin Valley Fire and Rescue - Training Center	-	-	-	-	-
Valley Catholic Middle School	-	-	-	-	-
Visitation Catholic School	-	X	-	-	-
Washington Co Sheriff's Office	-	-	-	-	-
West Tualatin View Elementary School	-	-	-	-	-
West Union Elementary School	-	-	-	-	-
Westview Senior High School	-	-	-	-	-

A.2 City of Banks

Table A-3. City of Banks hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Banks	1,993	767	3	205,773,000	

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	CSZ Mag 9.0 Deterministic	35	1.8%	73	2	16,085,089	7.8%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	21	1.0%	7	0	1,206,000	0.6%
Channel Migration	Channel migration zone	0	0%	0	0	0	0%
Wildfire	High or Moderate 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-4. City of Banks critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
	Exposed	>50% Prob.	Exposed	Exposed	Exposed
Banks Elementary School	-		-	-	-
Banks High School	-	X	-	-	-
Banks Junior High School	-	X	-	-	-

A.3 City of Beaverton

Table A-5. City of Beaverton hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Beaverton	98,738	26,405	59	11,283,939,000

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	1,376	1.4%	355	0	22,809,000	0.2%
Earthquake	CSZ M9.0 Deterministic	169	0.2%	92	0	109,754,657	1.0%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	1,932	2.0%	497	0	203,276,000	1.8%
Channel Migration	Channel migration zone	0	0%	0	0	0	0%
Wildfire	High or Moderate Risk	98	0.0%	49	0	13,521,000	0.1%

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

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

Table A-6. City of Beaverton 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	Channel Migration Zone Exposed	Wildfire High or Moderate Risk Exposed
Arco Iris Spanish Immersion School	-	-	-	-	-
Arts & Communication High School	-	-	-	-	-
Beaverton Emergency Management	-	-	-	-	-
Beaverton High School	-	-	-	-	-
Beaverton Operations	-	-	-	-	-
Beaverton Police Department	-	-	-	-	-
Cedar Park Middle School	-	-	-	-	-
Chehalem Elementary School	-	-	-	-	-
Clean Water Services	-	-	-	-	-
Conestoga Middle School	-	-	-	-	-
Cooper Mountain Elementary School	-	-	-	-	-
Cor Deo Christian Academy	-	-	-	-	-
Edison High School	-	-	-	-	-
Elmonica Elementary School	-	-	-	-	-
Fir Grove Elementary School	-	-	-	-	-
Five Oaks Middle School	-	-	-	-	-
German American School of Portland	-	-	-	-	-
Greenway Elementary School	-	-	-	-	-
Highland Park Middle School	-	-	-	-	-
Hiteon Elementary School	-	-	-	-	-
Jesuit High School	-	-	-	-	-
Living Wisdom School	-	-	-	-	-
McKay Elementary School	-	-	-	-	-
McKinley Elementary School	-	-	-	-	-
Merlo Station High School	-	-	-	-	-
Montclair Elementary School	-	-	-	-	-
Nancy Ryles Elementary School	-	-	-	-	-
Pacific Academy	-	-	-	-	-
Pilgrim Luthern School	-	-	-	-	-
Prince of Peace Luthern School	-	-	-	-	-
Providence Medical Group – Sunset	-	-	-	-	-
Providence St. Vincent Hospital - Northwest Gynecology Center	-	-	-	-	-
Providence St. Vincent Hospital - Westside Pediatric Clinic	-	-	-	-	-
Raleigh Hills Elementary School	-	-	-	-	-
Ridgewood Elementary School	-	-	-	-	-
Scholls Heights Elementary School	-	-	-	-	-
Sexton Mountain Elementary School	-	-	-	-	-
Southridge High School	-	-	-	-	-
Southwest Christian School	-	-	-	-	-
St Ceclia School	-	-	-	-	-

St Stephens Academy	-	-	-	-	-
Sunset High School	-	-	-	-	-
Sunshine Montessori Preschool and Kindergarten	-	-	-	-	-
TVF & R - North Division Office	-	-	-	-	-
TVF & R - Station 53 Progress	-	-	-	-	-
TVF & R - Station 61 Butner Rd	-	-	-	-	-
TVF & R - Station 65 West Slope	-	-	-	-	-
TVF & R - Station 66 South Beaverton	-	-	-	-	-
TVF & R - Station 67 Farmington	-	-	-	-	-
TVF & R - Station 70	-	-	-	-	-
TVF & R - North Division Office	-	-	-	-	-
Valley Catholic High School	-	-	-	-	-
Vose Elementary School	-	-	-	-	-
Washington Co. Sheriff's Office – East Precinct	-	-	-	-	-
West Sylvan Middle School	-	-	-	-	-
Whitford Middle School	-	-	-	-	-
William Walker Elementary School	-	-	-	-	-
YMCA Kindergarten	-	-	-	-	-
Young Learners Preschool	-	-	-	-	-

A.4 City of Cornelius

Table A-7. City of Cornelius hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Cornelius	12,674	3,807	7	954,752,000

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	6	0.0%	1	0	8,000	0.0%
Earthquake	CSZ M9.0 Deterministic	636	5.0%	677	4	117,743,309	12.3%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	34	0.3%	13	0	2,659,000	0.3%
Channel Migration	Channel migration zone	0	0%	0	0	0	0%
Wildfire	High or Moderate Risk	27	0.2%	9	0	1,693,000	0.2%

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

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

Table A-8. City of Cornelius critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Cornelius Elementary School	-	X	-	-	-
Cornelius Fire Dept	-	-	-	-	-
Cornelius Police Dept	-	X	-	-	-
Cornelius Public Works	-	X	-	-	-
Echo Shaw Elementary School	-	X	-	-	-
Emmaus Christian School	-	-	-	-	-
Virginia Garcia Memorial Health Center	-	-	-	-	-

A.5 City of Durham

Table A-9. City of Durham hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Durham	1,885	410	0	240,089,000

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%	1	0	86,000	0.0%
Earthquake*	CSZ M9.0 Deterministic	1	0.0%	1	0	949,747	0.4%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	62	3.3%	17	0	4,897,000	2.0%
Channel Migration	Channel migration zone	107	5.7%	2	0	3,366,000	1.2%
Wildfire	High or Moderate 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).

A.6 City of Forest Grove

Table A-10. City of Forest Grove hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Forest Grove	25,132	8,199	18	2,525,502,000

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%	2	0	3,000	0.0%
Earthquake*	CSZ M9.0 Deterministic	3,307	13.2%	2,487	14	584,633,685	23.1%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	1,817	7.2%	591	1	182,597,000	7.2%
Channel Migration	Channel migration zone	0	0%	12	0	5,204,000	0.2%
Wildfire	High or Moderate Risk	1	0.0%	1	0	250,000	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-11. City of Forest Grove critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
	Exposed	>50% Prob.	Exposed	Exposed	Exposed
CWS – Forest Grove STP	-	X	-	-	-
Fern Hill Elementary School	-	-	-	-	-
Forest Grove Armory	-	X	-	-	-
Forest Grove Community School	-	X	-	-	-
Forest Grove/Cornelius Emergency Management	-	X	-	-	-
Forest Grove Fire & Rescue	-	-	-	-	-
Forest Grove High School	-	X	-	-	-
Forest Grove Police Dept	-	X	-	-	-
Forest Grove Public Works	-	X	-	-	-
Forest Grove Water Treatment	-	X	X	-	-
Geneva Urgent Care	-	-	-	-	-
Harvey Clarke Elementary School	-	X	-	-	-
Joseph Gale Elementary School	-	-	-	-	-
Maple Street Clinic	-	X	-	-	-
Neil Armstrong Middle School	-	X	-	-	-
Tom McCall Upper Elementary	-	X	-	-	-
Tuality Community Hospital - Forest Grove	-	X	-	-	-
Westside Christian School	-	X	-	-	-

A.7 City of Gaston

Table A-12. City of Gaston hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Gaston		653	322		4		81,440,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	2	0.3%	0	0	0	0.0%
Earthquake*	CSZ M9.0 Deterministic	8	1.3%	23	1	6,883,943	8.5%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	48	7.3%	15	0	4,202,000	5.2%
Channel Migration	Channel migration zone	0	0%	0	0	0	0%
Wildfire	High or Moderate 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-13. City of Gaston critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Channel Migration Zone**	**Wildfire High or Moderate Risk**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Gaston Elementary School	-	-	-	-	-
Gaston Jr/Sr High School	-	-	-	-	-
Gaston Police Dept	-	-	-	-	-
Gaston RFPD	-	X	-	-	-

A.8 City of Hillsboro

Table A-14. City of Hillsboro hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Hillsboro	104,041	37,513	53	15,487,612,000

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	203	0.2%	74	0	2,547,000	0.0%
Earthquake*	CSZ M9.0 Deterministic	1,017	1.0%	1,037	0	426,257,121	2.8%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	1,160	1.1%	360	0	91,965,000	0.6%
Channel Migration	Channel migration zone	10	0.0%	5	0	942,000	0.0%
Wildfire	High or Moderate Risk	166	0.2%	57	0	13,704,000	0.09%

[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-15. City of Hillsboro critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
	Exposed	>50% Prob.	Exposed	Exposed	Exposed
Brookwood Elementary School	-	-	-	-	-
Carden Cascade Academy	-	-	-	-	-
Century High School	-	-	-	-	-
City View Charter School	-	-	-	-	-
Eastwood Elementary School	-	-	-	-	-
Evergreen Jr High School	-	-	-	-	-
Faith Bible High School	-	-	-	-	-
Glencoe High School	-	-	-	-	-
Hillsboro Airport	-	-	-	-	-
Hillsboro Armory	-	-	-	-	-
Hillsboro Fire Dept – Brookwood	-	-	-	-	-
Hillsboro Fire Dept – Cherry Lane	-	-	-	-	-
Hillsboro Fire Dept – Jones Farm	-	-	-	-	-
Hillsboro Fire Dept – Logistics Division	-	-	-	-	-
Hillsboro Fire Dept – Main Station	-	-	-	-	-
Hillsboro Fire Dept – Ronier Acres	-	-	-	-	-
Hillsboro High School	-	-	-	-	-
Hillsboro Police Dept	-	-	-	-	-
Hillsboro Public Works Office	-	-	-	-	-
Hillsboro Sheriff – Jail	-	-	-	-	-
Hillsboro Urgent Medicine	-	-	-	-	-
Hillsboro Wastewater Treatment	-	-	-	-	-
Imlay Elementary School	-	-	-	-	-
J W Poynter Middle School	-	-	-	-	-
Jackson Elementary School	-	-	-	-	-
Ladd Acres Elementary School	-	-	-	-	-
Liberty High School	-	-	-	-	-
Lincoln St Elementary School	-	-	-	-	-
Minter Bridge Elementary School	-	-	-	-	-
Mooberry Elementary School	-	-	-	-	-
Orenco Elementary School	-	-	-	-	-
Paul L Patterson Elementary School	-	-	-	-	-
Peter Boscow Elementary School	-	-	-	-	-
Providence Medical - Orenco	-	-	-	-	-
Providence Medical - Tanasbourne	-	-	-	-	-
Quatama Elementary School	-	-	-	-	-
R A Brown Middle School	-	-	-	-	-
Rosedale Elementary School	-	-	-	-	-
St. Matthew Elementary School	-	-	-	-	-
Swallowtail School	-	-	-	-	-
The Goddard School	-	-	-	-	-

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Tuality Valley Jr Academy	-	-	-	-	-
Tuality Community Hospital - Hillsboro	-	-	-	-	-
Tuality Health Information Center	-	-	-	-	-
Tuality Healthplace	-	-	-	-	-
Tuality Orenco Station Medical Clinic	-	-	-	-	-
Tuality Urgent Care	-	-	-	-	-
Virginia Garcia Memorial Health Center	-	-	-	-	-
W L Henry Elementary School	-	-	-	-	-
W Verne McKinney Elementary School	-	-	-	-	-
Washington County Community Corrections	-	-	-	-	-
Washington County Road Department	-	-	-	-	-
Washington County Sheriff’s Office	-	-	-	-	-
Westside Medical Clinic	-	-	-	-	-
Witch Hazel Elementary School	-	-	-	-	-

A.9 City of King City

Table A-16. City of King City hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
King City		4,329	1,716		3		423,075,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake*	CSZ M9.0 Deterministic	2	0.0%	4	0	2,228,540	0.5%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	82	1.9%	7	0	4,414,000	1.0%
Channel Migration	Channel migration zone	0	0%	0	0	0	0%
Wildfire	High or Moderate 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-17. City of King City critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Deer Creek Elementary School	-	-	-	-	-
King City Police Dept	-	-	-	-	-
TVF & R - Station 35 King City	-	-	-	-	-

A.10 City of North Plains

Table A-18. City of North Plains hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
North Plains		3,341	1,333		3	414,606,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	22	0.7%	9	0	383,000	0.1%
Earthquake*	CSZ M9.0 Deterministic	21	0.6%	44	0	15,448,698	3.7%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	9	0.3%	2	0	378,000	0.1%
Channel Migration	Channel migration zone	0	0%	0	0	0	0%
Wildfire	High or Moderate 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-19. City of North Plains critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
North Plains Elementary School	-	-	-	-	-
North Plains Police Dept	-	-	-	-	-
Tualatin Valley Fire and Rescue – Station 17	-	-	-	-	-

A.11 City of Sherwood

Table A-20. City of Sherwood hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Sherwood		21,315	6,109		14		2,194,018,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	1	0	30,000	0.0%
Earthquake*	CSZ M9.0 Deterministic	9	0.0%	11	0	15,739,639	0.7%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	385	1.8%	83	0	24,118,000	1.1%
Channel Migration	Channel migration zone	0	0%	0	0	0	0%
Wildfire	High or Moderate Risk	39	0.0%	15	0	5,030,000	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-21. City of Sherwood critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Channel Migration Zone**	**Wildfire High or Moderate Risk**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Archer Glen Elementary School	-	-	-	-	-
Edy Ridge Elementary School	-	-	-	-	-
J Clyde Hopkins Elementary School	-	-	-	-	-
Middleton Elementary School	-	-	-	-	-
Sherwood Charter School	-	-	-	-	-
Sherwood Christian Montessori School	-	-	-	-	-
Sherwood High School	-	-	-	-	-
Sherwood Middle School	-	-	-	-	-
Sherwood Police Dept	-	-	-	-	-
Sherwood Public Works	-	-	-	-	-
Smockville Montessori School	-	-	-	-	-
St Francis School	-	-	-	-	-
St Paul Lutheran School	-	-	-	-	-
TVF & R - Station 33 Sherwood	-	-	-	-	-

A.12 City of Tigard

Table A-22. City of Tigard hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Tigard	54,729	18,731	20	7,526,469,000

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	173	0.3%	45	0	1,392,000	0.0%
Earthquake*	CSZ M9.0 Deterministic	32	0.1%	33	0	44,742,097	0.6%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	2,005	3.7%	635	0	228,061,000	3.0%
Channel Migration	Channel migration zone	0	0%	1	0	130,000	0.0%
Wildfire	High or Moderate Risk	94	0.0%	49	0	13,010,000	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-23. City of Tigard critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Alberta Rider Elementary School	-	-	-	-	-
Charles F Tigard Elementary School	-	-	-	-	-
Clean Water Services - Durham	-	-	-	-	-
Durham Elementary School	-	-	-	-	-
Gaarde Christian School	-	-	-	-	-
Islamic School of Met (Ismet)	-	-	-	-	-
James Templeton Elementary School	-	-	-	-	-
Mary Woodward Elementary School	-	-	-	-	-
Metzger Elementary School	-	-	-	-	-
Northwest Montessori School	-	-	-	-	-
Providence Medical Group - Scholls	-	-	-	-	-
St Anthony's School	-	-	-	-	-
Thomas R Fowler Middle School	-	-	-	-	-
Tigard High School	-	-	-	-	-
Tigard Police Dept	-	-	-	-	-
Tigard Public Works Office	-	-	-	-	-
TVF & R - Station 50	-	-	-	-	-
TVF & R - Station 51 Tigard	-	-	-	-	-
Twality Middle School	-	-	-	-	-
Westgate Christian School	-	-	-	-	-

A.13 City of Tualatin

Table A-24. City of Tualatin hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Tualatin		27,103	7,844		14		4,964,016,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	410	1.5%	184	0	12,507,000	0.3%
Earthquake*	CSZ M9.0 Deterministic	24	0.1%	16	0	34,401,043	0.7%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	388	1.4%	110	0	64,340,000	1.3%
Channel Migration	Channel migration zone	117	0.4%	18	0	26,464,000	0.5%
Wildfire	High or Moderate Risk	10	0.0%	6	0	6,374,000	0.1%

[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-25. City of Tualatin critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Channel Migration Zone**	**Wildfire High or Moderate Risk**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Bridgeport Elementary School	-	-	-	-	-
Edward Byrom Elementary School	-	-	-	-	-
Hazelbrook Middle School	-	-	-	-	-
Horizon Christian High School	-	-	-	-	-
Legacy Medical Group - Bridgeport	-	-	-	-	-
Legacy Medical Group - Tualatin	-	-	-	-	-
Legacy Meridian Park Hospital	-	-	-	-	-
Sunrise Montessori School	-	-	-	-	-
Tualatin Elementary School	-	-	-	-	-
Tualatin Emergency Management	-	-	-	-	-
Tualatin High School	-	-	-	-	-
Tualatin Police Department	-	-	-	-	-
Tualatin Public Works	-	-	-	-	-
TVF & R - Station 34 Tualatin	-	-	-	-	-

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

Table B-1. Washington County building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Nonprofit			All Buildings			
Community	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Number of Buildings per County Total	Building Value ($)	Value of Buildings per County Total
Unincorp. Washington Co (rural)	85,374	22,809,831	79%	1,527	3,005,968	11%	13,108	1,871,611	7%	736	1,072,693	3.7%	100,745	47%	28,760,104	38%
Banks	627	124,116	60%	54	32,140	16%	59	4,250	2.1%	27	45,266	22%	767	0.4%	205,773	0.3%
Beaverton	23,739	6,779,415	60%	1,320	3,408,172	30%	1,025	51,628	0.5%	321	1,044,724	9.3%	26,405	12%	11,283,939	15%
Cornelius	3,473	614,930	64%	177	255,414	27%	107	18,434	1.9%	50	65,975	6.9%	3,807	1.8%	954,752	1.3%
Durham	377	184,166	77%	29	55,706	23%	4	216	0.1%	0	0	0.0%	410	0.2%	240,089	0.3%
Forest Grove	7,415	1,644,998	65%	335	519,172	21%	303	35,839	1.4%	146	325,493	13%	8,199	3.8%	2,525,502	3.4%
Gaston	278	57,302	70%	15	9,223	11%	4	1,526	2%	25	13,390	16%	322	0.2%	81,440	0.1%
Hillsboro	32,073	7,218,215	47%	2,102	7,050,782	46%	3,015	131,769	0.9%	323	1,086,845	7.0%	37,513	18%	15,487,612	21%
King City	1,676	362,223	86%	27	42,554	10%	9	1,806	0%	4	16,492	3.9%	1,716	0.8%	423,075	0.6%
North Plains	1,148	248,220	60%	125	136,472	33%	45	9,113	2%	15	20,801	5.0%	1,333	0.6%	414,606	0.6%
Sherwood	5,701	1,449,523	66%	276	569,546	26%	61	4,835	0.2%	71	170,114	7.8%	6,109	2.9%	2,194,018	2.9%
Tigard	17,054	4,660,015	62%	930	2,467,239	33%	573	33,575	0%	174	365,639	4.9%	18,731	8.8%	7,526,469	10%
Tualatin	6,776	2,377,011	48%	945	2,397,518	48%	36	21,539	0%	87	167,948	3.4%	7,844	3.7%	4,964,016	6.6%
Total Study Area	185,711	48,529,965	65%	7,862	19,949,907	27%	18,349	2,186,141	3%	1,979	4,395,380	5.9%	213,901	100%	75,061,394	100%

Table B-2. Earthquake loss estimates.

			(all dollar amounts in thousands)							
			Total Earthquake Damage							
			Buildings Damaged				**All Buildings Changed to At Least Moderate Code**			
	Total Number of Buildings	**Total Estimated Building Value ($)**	**Yellow-Tagged Buildings**	**Red-Tagged Buildings**	**Sum of Economic Loss**	**Loss Ratio**	**Yellow-Tagged Buildings**	**Red-Tagged Buildings**	**Sum of Economic Loss**	**Loss Ratio**
Unincorp. Washington Co (rural)	100,745	28,760,104	2,542	817	643,401	2.2%	1733	443	408,892	1.4%
Banks	767	205,773	59	13	16,085	7.8%	44	10	11,549	5.6%
Beaverton	26,405	11,283,939	87	5	109,755	1.0%	22	3	46,196	0.4%
Cornelius	3,807	954,752	536	141	117,743	12%	389	86	82,890	8.7%
Durham	410	240,089	1	0	950	0.4%	0	0	436	0.2%
Forest Grove	8,199	2,525,502	1,819	668	584,634	23%	1347	355	375,860	15%
Gaston	322	81,440	18	5	6,884	8.5%	11	3	4,550	5.6%
Hillsboro	37,513	15,487,612	888	148	426,257	2.8%	558	121	246,854	1.6%
King City	1,716	423,075	4	0	2,229	0.5%	1	0	1,075	0.3%
North Plains	1,333	414,606	37	7	15,449	3.7%	26	6	9,546	2.3%
Sherwood	6,109	2,194,018	11	1	15,740	0.7%	3	0	7,727	0.4%
Tigard	18,731	7,526,469	31	2	44,742	0.6%	8	1	19,294	0.3%
Tualatin	7,844	4,964,016	15	1	34,401	0.7%	4	0	14,895	0.3%
Total Study Area	213,901	75,061,394	6,049	1,807	2,018,269	2.7%	4,148	1,029	1,229,765	1.6%

Table B-3. Flood loss estimates.

			(all dollar amounts in thousands)											
			10% (10-yr)			**2% (50-yr)**			**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**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**
Unincorp. Washington Co (rural)	100,745	28,760,104	398	13,022	0.0%	558	17,547	0.1%	651	20,649	0.1%	1,080	37,428	0.1%
Banks	767	205,773	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Beaverton	26,405	11,283,939	203	11,197	0.1%	310	18,191	0.2%	355	22,809	0.2%	429	32,268	0.3%
Cornelius	3,807	954,752	1	2	0.0%	1	7	0.0%	1	8	0.0%	5	64	0.0%
Durham	410	240,089	1	33	0.0%	1	69	0.0%	1	86	0.0%	1	108	0.0%
Forest Grove	8,199	2,525,502	1	0	0.0%	2	2	0.0%	2	3	0.0%	20	579	0.0%
Gaston	322	81,440	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Hillsboro	37,513	15,487,612	39	922	0.0%	66	1,995	0.0%	74	2,547	0.0%	141	6,173	0.0%
King City	1,716	423,075	0	0	0.0%	0	0	0.0%	0	0	0.0%	13	89	0.0%
North Plains	1,333	414,606	1	51	0.0%	4	162	0.0%	9	383	0.1%	58	1,963	0.5%
Sherwood	6,109	2,194,018	1	10	0.0%	1	20	0.0%	1	30	0.0%	1	50	0.0%
Tigard	18,731	7,526,469	15	213	0.0%	37	889	0.0%	45	1,392	0.0%	78	2,959	0.0%
Tualatin	7,844	4,964,016	18	1,071	0.0%	76	5,369	0.1%	184	12,507	0.3%	406	70,519	1.4%
Total Study Area	213,901	75,061,394	678	26,521	0.0%	1,056	44,252	0.1%	1,323	60,414	0.08%	2,232	152,200	0.2%

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**
Unincorp. Washington Co (rural)	100,745	252,626	1,969	0.8%	865	0.9%	214
Banks	767	1,993	0	0.0%	0	0.0%	0
Beaverton	26,405	98,738	1,376	1.4%	384	1.5%	29
Cornelius	3,807	12,674	6	0.0%	3	0.1%	2
Durham	410	1,885	0	0.0%	1	0.2%	0
Forest Grove	8,199	25,132	0	0.0%	2	0.0%	0
Gaston	322	653	2	0.3%	1	0.3%	1
Hillsboro	37,513	104,041	203	0.2%	99	0.3%	25
King City	1,716	4,329	0	0.0%	0	0.0%	0
North Plains	1,333	3,341	22	0.7%	15	1.1%	6
Sherwood	6,109	21,315	0	0.0%	1	0.0%	0
Tigard	18,731	54,729	173	0.3%	59	0.3%	14
Tualatin	7,844	27,103	410	1.5%	195	2.5%	11
Total Study Area	213,901	608,559	4,161	0.7%	1,625	0.8%	302

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**
Unincorp. Washington Co (rural)	100,745	28,760,104	2694	701,247	2.4%	3,966	1,176,240	4.1%	36,081	11,257,655	39%
Banks	767	205,773	0	0	0%	7	1,206	0.6%	84	17,623	8.6%
Beaverton	26,405	11,283,939	83	33,159	0.3%	414	170,117	1.5%	11,153	3,545,750	31%
Cornelius	3,807	954,752	0	0	0%	13	2,659	0.3%	285	54,328	5.7%
Durham	410	240,089	0	0	0%	17	4,897	2.0%	61	34,281	14%
Forest Grove	8,199	2,525,502	13	4,202	0.2%	578	178,395	7.1%	1,135	303,306	12%
Gaston	322	81,440	0	0	0%	15	4,202	5.2%	266	57,490	71%
Hillsboro	37,513	15,487,612	0	0	0%	360	91,965	0.6%	4,439	3,117,833	20%
King City	1,716	423,075	0	0	0%	7	4,414	1.0%	481	115,861	27%
North Plains	1,333	414,606	0	0	0%	2	378	0.1%	223	54,507	13%
Sherwood	6,109	2,194,018	0	0	0%	83	24,118	1.1%	1,972	539,597	25%
Tigard	18,731	7,526,469	0	0	0%	635	228,061	3.0%	8,352	2,608,886	35%
Tualatin	7,844	4,964,016	0	0	0%	110	64,340	1.3%	2,346	1,169,371	24%
Total Study Area	213,901	75,061,394	2,790	738,608	0.1%	6,207	1,950,992	2.6%	66,878	22,876,488	30%

Table B-6. Channel migration exposure.

(all dollar amounts in thousands)

Community	Total Number of Buildings	Total Population	Total Estimated Building Value ($)	Channel Migration Hazard: Potentially Displaced Residents from channel migration Exposure	% Potentially Displaced Residents from channel migration Exposure	Number of Buildings Exposed	Building Value ($)	Ratio of Exposure Value
Unincorp. Washington Co (rural)	100,745	252,626	28,760,104	353	0.1%	299	71,147	0.2%
Banks	767	1,993	205,773	0	0%	0	0	0%
Beaverton	26,405	98,738	11,283,939	0	0%	0	0	0%
Cornelius	3,807	12,674	954,752	0	0%	0	0	0%
Durham	410	1,885	240,089	107	5.7%	2	3,366	1.2%
Forest Grove	8,199	25,132	2,525,502	0	0%	12	5,204	0.2%
Gaston	322	653	81,440	0	0%	0	0	0%
Hillsboro	37,513	104,041	15,487,612	0	0%	0	0	0%
King City	1,716	4,329	423,075	0	0%	0	0	0%
North Plains	1,333	3,341	414,606	0	0%	0	0	0%
Sherwood	6,109	21,315	2,194,018	0	0%	0	0	0%
Tigard	18,731	54,729	7,526,469	0	0%	1	130	0.0%
Tualatin	7,844	27,103	4,964,016	117	0.4%	18	26,464	0.5%
Total Study Area	213,901	608,559	75,061,394	578	0.01%	332	106,312	0.1%

Table B-7. Wildfire exposure.

			(all dollar amounts in thousands)								
			High Risk			**Moderate Risk**			**Low 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 ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**
Unincorp. Washington Co (rural)	100,745	28,760,104	1,207	303,478	1.1%	904	232,660	0.8%	22,635	6,009,638	21%
Banks	767	205,773	0	0	0%	0	0	0%	103	19,434	9%
Beaverton	26,405	11,283,939	35	9,500	0.1%	14	4,021	0.0%	1,009	368,344	3%
Cornelius	3,807	954,752	9	1,693	0.2%	0	0	0%	118	27,278	3%
Durham	410	240,089	0	0	0%	0	0	0%	121	34,778	14%
Forest Grove	8,199	2,525,502	1	250	0.0%	0	0	0%	1,017	310,077	12%
Gaston	322	81,440	0	0	0%	0	0	0%	41	9,862	12%
Hillsboro	37,513	15,487,612	32	6,772	0.0%	25	6,932	0.0%	2,431	733,690	5%
King City	1,716	423,075	0	0	0%	0	0	0%	290	68,191	16%
North Plains	1,333	414,606	0	0	0%	0	0	0%	184	56,825	14%
Sherwood	6,109	2,194,018	12	3,241	0.1%	3	1,789	0.1%	327	123,245	6%
Tigard	18,731	7,526,469	33	9,706	0.1%	16	3,304	0.0%	1,768	569,993	8%
Tualatin	7,844	4,964,016	5	6,259	0.1%	1	115	0.0%	414	309,176	6%
Total Study Area	213,901	75,061,394	1,334	340,899	0.5%	963	248,820	0.3%	30,458	8,640,532	12%

APPENDIX C. HAZUS-MH METHODOLOGY

C.1 Software

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

C.2 User-Defined Facilities (UDF) Database

A UDF database was compiled for all buildings in Washington County for use in both the flood and earthquake modules of Hazus-MH. The Washington County assessor database (acquired in 2021) was used to determine which taxlots had improvements (i.e., buildings) and how many building points should be included in the UDF database.

C.2.1 Locating buildings points

The Oregon Department of Geology and Mineral Industries (DOGAMI) used the SBFO-1 (Williams, 2021) dataset to help precisely locate the centroid of each building. Extra effort was spent to locate building points along the 1% and 0.2% annual chance inundation fringe. When buildings were partially within the inundation zone, the building point was moved to the centroid of the portion of the building within the inundation zone. An iterative approach was used to further refine locations of building points for the flood module by generating results, reviewing the highest value buildings, and moving the building point over a representative elevation on the lidar digital elevation model to ensure an accurate first-floor height.

C.2.2 Attributing building points

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

- **Longitude** and **Latitude** – Location information that provides Hazus-MH the x and y-position of the UDF point. This allows for an overlay to occur between the UDF point and the flood or earthquake input data layers. The hazard model uses this spatial overlay to determine the correct hazard risk level that will be applied to the UDF point. The format of the attribute must be in decimal degrees. A simple geometric calculation using GIS software is done on the point to derive this value.
- **Occupancy class** – An alphanumeric attribute that indicates the use of the UDF (e.g., 'RES1' is a single-family dwelling). The alphanumeric code is composed of seven broad occupancy types (RES = residential, COM = commercial, IND = industrial, AGR = agricultural, GOV = public, REL = nonprofit/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 Washington County assessor database. When data was not available, the default value of RES1 was applied throughout.
- **Cost** – The replacement cost of an individual UDF. Loss ratio is derived from this value. Replacement cost is based on a method called RSMeans valuation (Charest, 2017) and is calculated by multiplying the building area by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus database.

- **Year built** – The year of construction that is used to attribute the Building Design Level field for the earthquake analysis (see "Building Design" below). The year a UDF was built is obtained from Washington County assessor database. When not available, the year of "1900" was applied.
- **Square feet** – The size of the UDF is used to pro-rate the total improvement value for taxlots with multiple UDFs. The value distribution method will ensure that UDFs with the highest area will be the most expensive on a given taxlot. 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 Washington 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 Washington County assessor database when available. For UDFs without assessor information for number of stories that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used for attribution.
- **Foundation type** – The UDF foundation type correlates with First-Floor Height values in feet (see Table 3.11 in the Hazus-MH Technical Manual for the Flood Model [FEMA Hazus-MH, 2012a]). It also functions within the flood model by indicating if a basement exists or not. UDFs with a basement have a different damage function from UDFs that do not have one. The value was obtained from the Washington County assessor database when available. For UDFs without assessor information for basements that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used to ascertain if one exists or not.
- **First-floor height** – The height in feet above grade for the lowest habitable floor. The height is factored during the depth of flooding analysis. The value is used directly by Hazus-MH, where Hazus-MH overlays a UDF location on a depth grid and using the **first-floor height** determines the level of flooding occurring to a building. It is derived from the Foundation Type attribute or observation via oblique imagery or Google Street View™ mapping service.
- **Building type** – This attribute determines the construction material and structural integrity of an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information was unavailable from the Washington County assessor data, so instead it was derived from a statistical distribution based on **Occupancy class**.
- **Building design level** – This attribute determines the seismic building code for an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information is derived from the **Year Built** attribute (Washington County Assessor) and state/regional Seismic Building Code benchmark years.
- **Number of people** – The estimated number of permanent residents living within an individual residential structure. It is used in the post-analysis phase to determine the amount of people affected by a given hazard. This attribute is derived from default Hazus database (United States Census Bureau, 2010a) of population per census block and distributed across Residential UDFs and adjusted based on population growth estimates from PSU Population Research Center.
- **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 Washington County. **Table C-1** outlines the benchmark years that apply to buildings within Washington County.

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

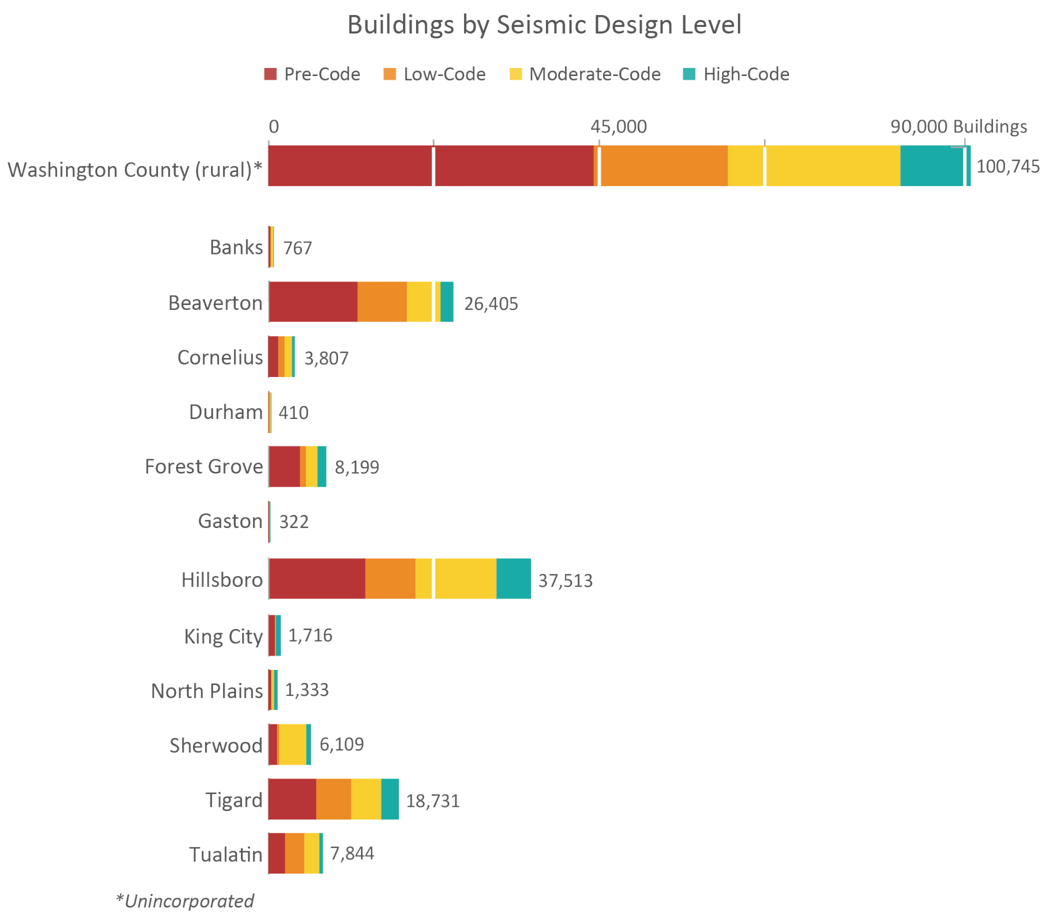
Building Type	Year Built	Design Level	Basis
Single-Family Dwelling (includes Duplexes)	prior to 1976	Pre Code	Interpretation of Judson (Judson, 2012)
	1976–1991	Low Code	
	1992–2003	Moderate Code	
	2004–2016	High Code	
Manufactured Housing	prior to 2003	Pre Code	Interpretation of OR BCD 2002 Manufactured 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 Washington 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
Unincorp. Washington Co (rural)	100,745	46,707	46%	19,187	19%	24,753	25%	10,098	10%
Banks	767	301	39%	56	7.3%	372	49%	38	5.0%
Beaverton	26,405	12,701	48%	7,075	27%	4,804	18%	1,825	6.9%
Cornelius	3,807	1,489	39%	886	23%	1,054	28%	378	9.9%
Durham	410	116	28%	180	44%	93	23%	21	5.1%
Forest Grove	8,199	4,452	54%	811	9.9%	1,654	20%	1,282	16%
Gaston	322	184	57%	52	16%	57	18%	29	9.0%
Hillsboro	37,513	13,774	37%	7,210	19%	11,562	31%	4,967	13%
King City	1,716	925	54%	54	3.1%	87	5.1%	650	38%
North Plains	1,333	404	30%	120	9.0%	330	25%	479	36%
Sherwood	6,109	1,219	20%	348	5.7%	3,844	63%	698	11%
Tigard	18,731	6,913	37%	4,997	27%	4,289	23%	2,532	14%
Tualatin	7,844	2,399	31%	2,831	36%	2,152	27%	462	5.9%
Total Study Area	213,901	91,584	43%	43,807	20%	55,051	26%	23,459	11%

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



C.3 Flood Hazard Data

Depth grids for "Zone A" designated flood zones, or approximate 100-year flood zones, were developed by the Strategic Alliance for Risk Reduction (STARR) in 2015 to revise the Washington County FIRMs (FEMA, 2018). DOGAMI developed depth grids from detailed stream model information within the study area. Both sets of depth grids were used in this risk assessment to determine the level to which buildings are impacted by flooding.

A study area-wide, 2-meter, 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 (Bauer, 2018). The analysis was then run for a given flood event, and the script cross-referenced a UDF location with the depth grid to find the depth of flooding. The script then applied a specific damage function, based on a UDF's Occupancy Class [OccCls], which was used to determine the loss ratio for a given amount of flood depth, relative to the UDF's first-floor height.

C.4 Earthquake Hazard Data

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): National Earthquake Hazard Reduction Program (NEHRP) soil classification, liquefaction susceptibility and wet landslide susceptibility. The liquefaction and landslide susceptibility layers together with NEHRP were used by the Hazus-MH tool to calculate ground motion layers and permanent ground deformation and associated probability.

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

C.5 Post-Analysis Quality Control

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

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

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

APPENDIX D. ACRONYMS AND DEFINITIONS

D.1 Acronyms

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

D.2 Definitions

1% annual chance flood – The flood elevation that has a 1% 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% chance of being equaled or exceeded each year. Sometimes referred to as the 500-year flood.

Base flood elevation (BFE) – Elevation of the 1% 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 SFHAs 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 Washington County, Oregon

PLATE 1

Building Occupancy

- Agricultural / Utility
- Commercial / Industrial
- Public / Nonprofit
- Residential

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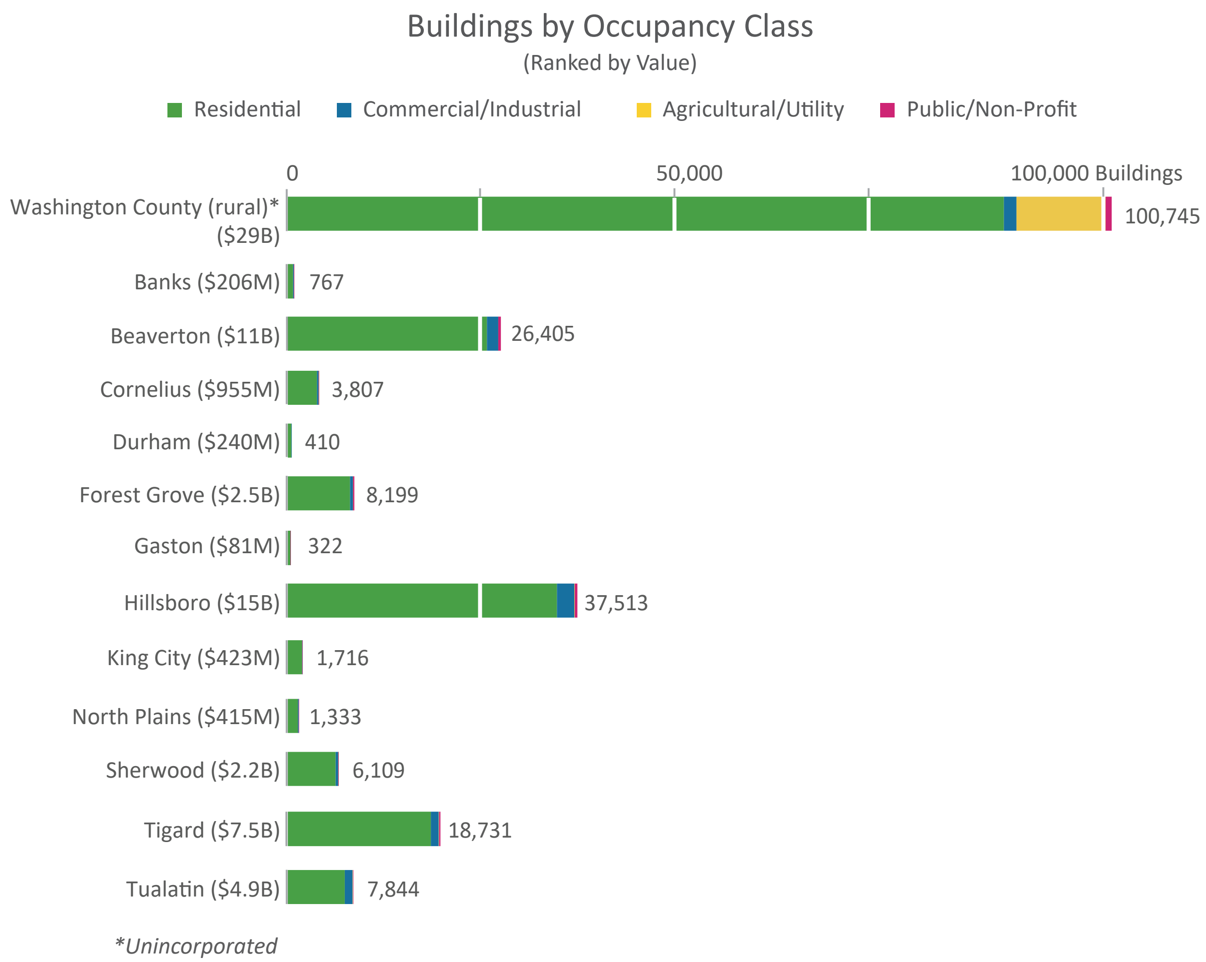

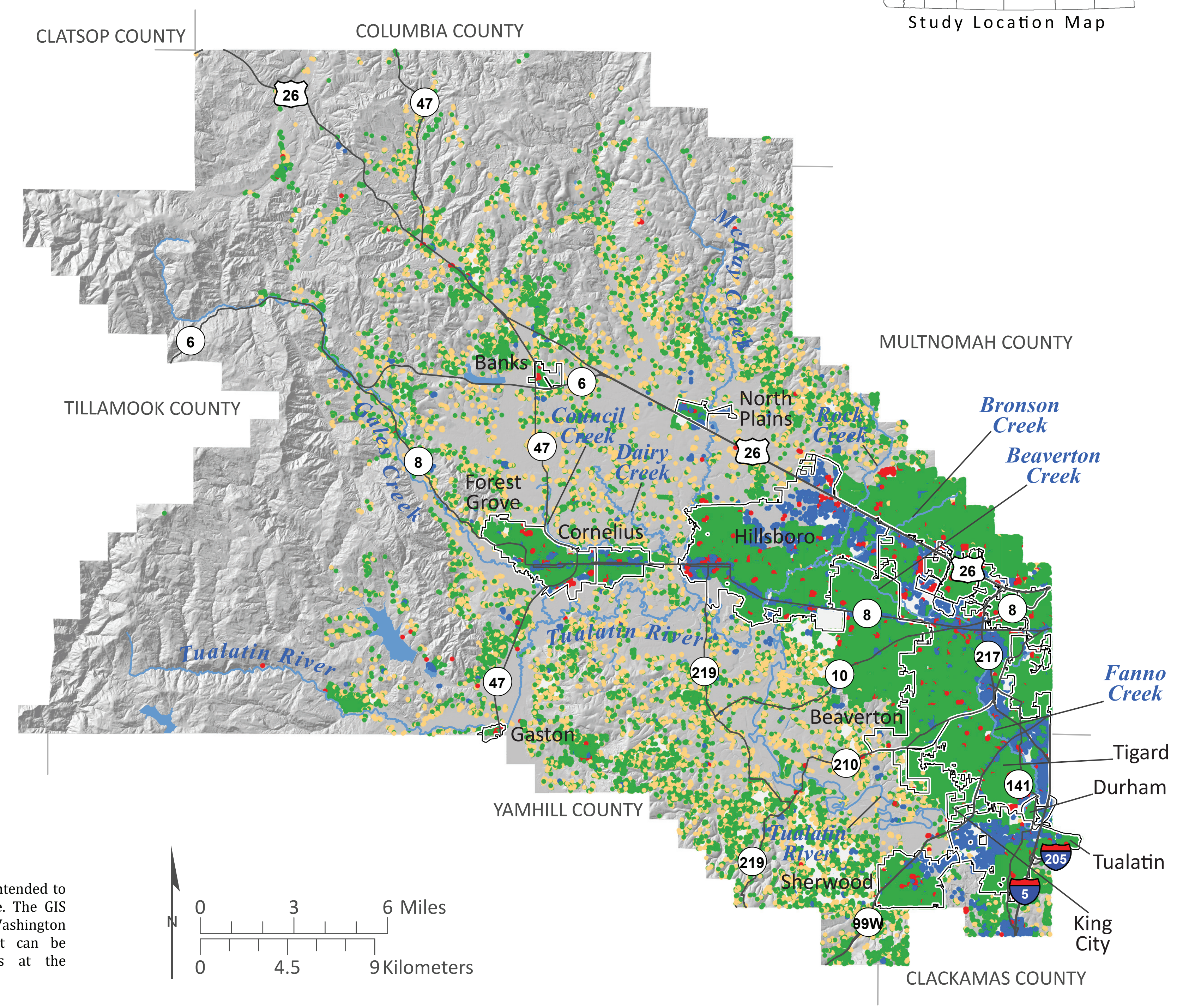

Data Sources:
Building footprints: Oregon Department of Geology and Mineral Industries (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by:Matt C. Williams, 2022

This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Washington County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

Population Density Map of Washington County, Oregon

PLATE 2

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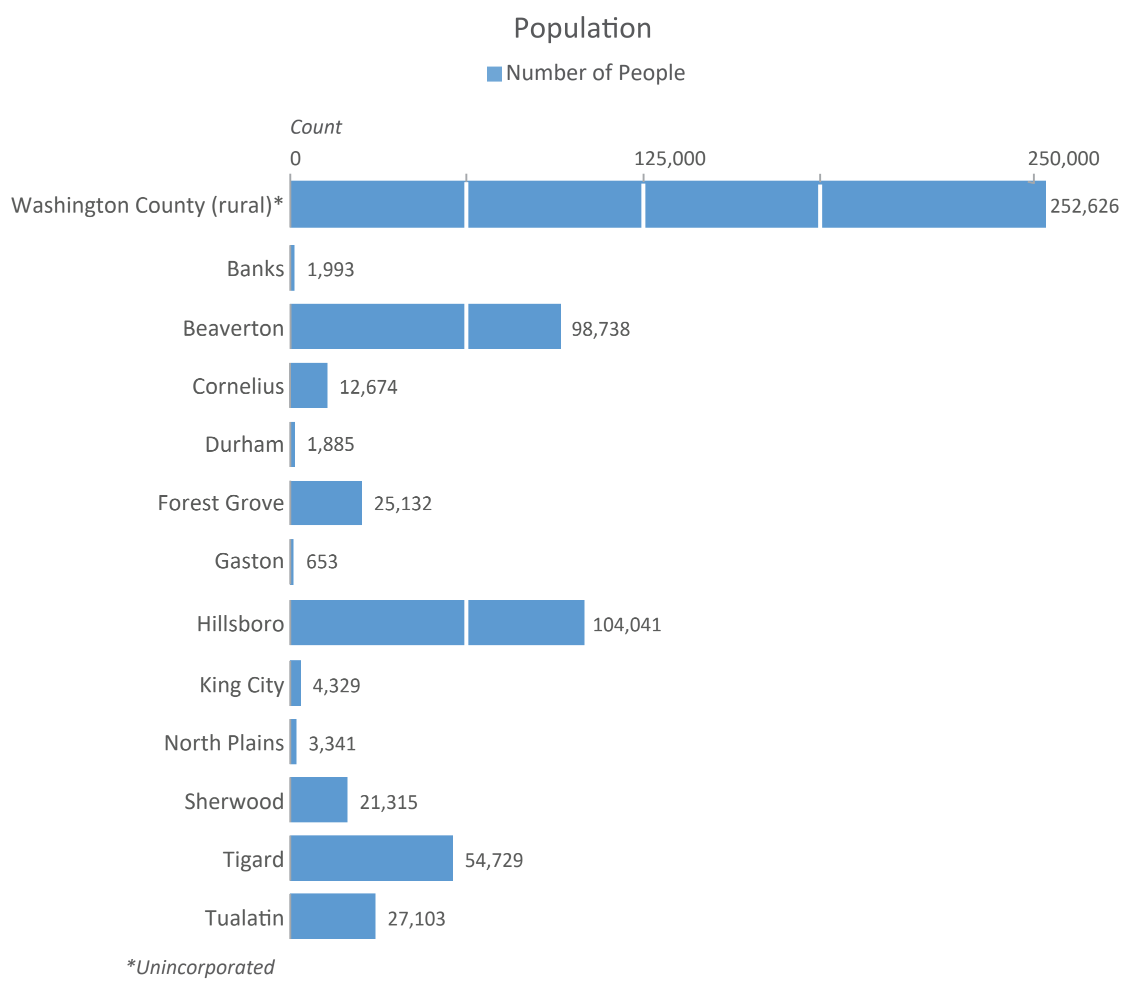
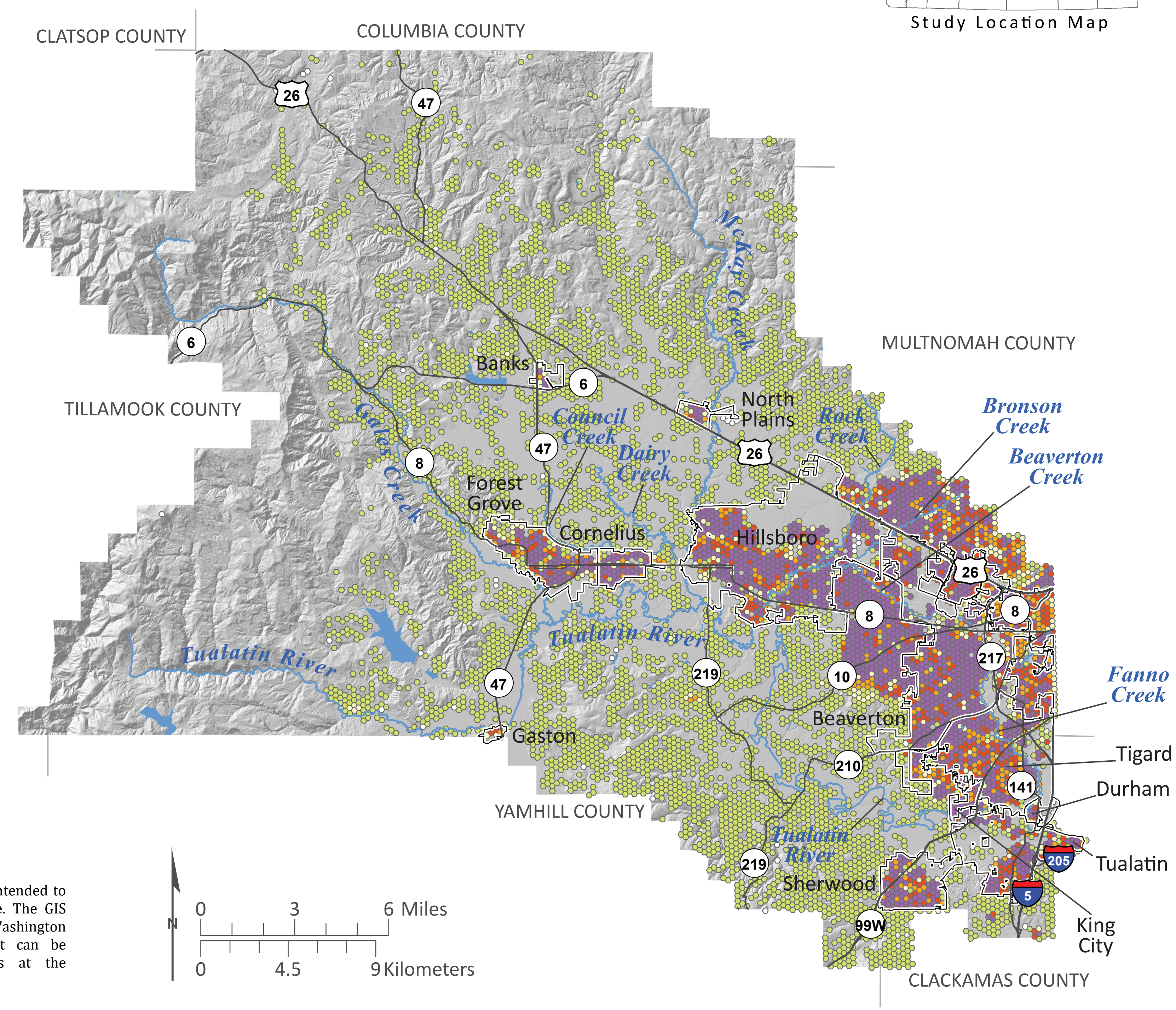
People per 20 acres

- Building(s) present no permanent residents
- 1 - 40
- 41 - 80
- 81 - 120
- 121 - 160
- 161 +





Data Sources:
Population data: PSU Population Research Center (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: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by: Matt C. Williams, 2022

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Gales Creek Magnitude 6.7 Earthquake Shaking Map of Washington County, Oregon

PLATE 3

Earthquake Peak Ground Acceleration

(Modified Mercalli Intensity Scale)

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.

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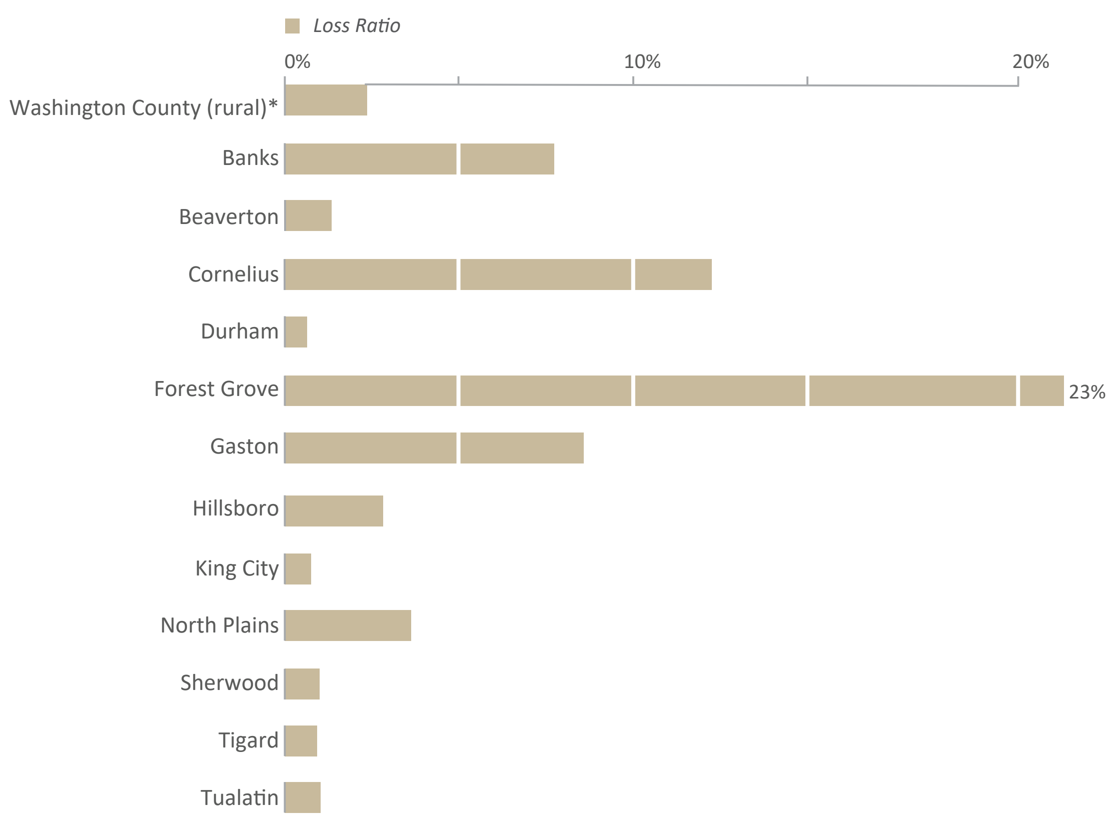
Total Building Value Loss Ratio
from Gales Creek Fault Mw 6.7 Earthquake



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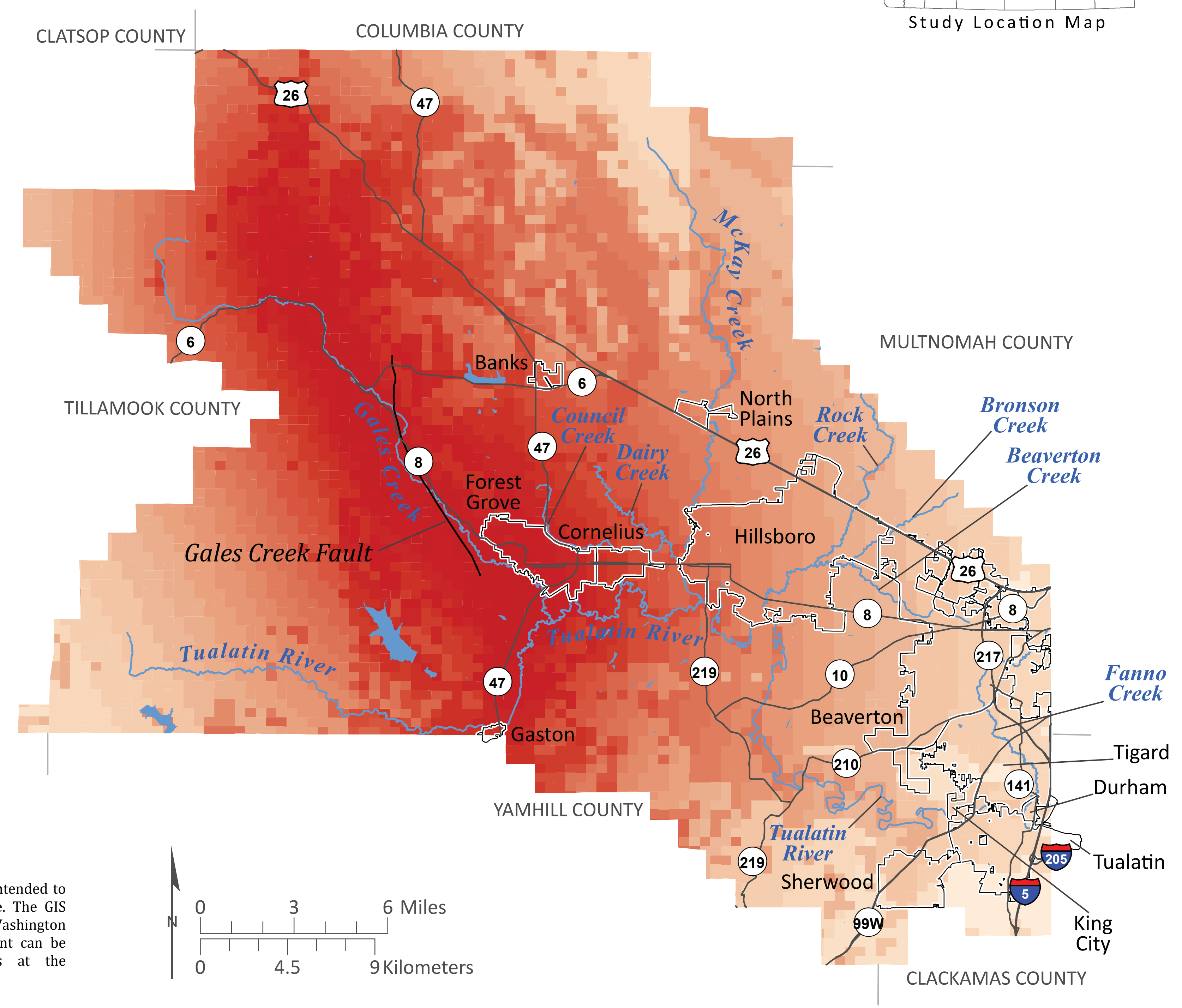


Data Sources:
Earthquake peak ground acceleration: Calculated in Hazus-MH 5.0 (2022)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by: Matt C. Williams, 2022

This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Washington County Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

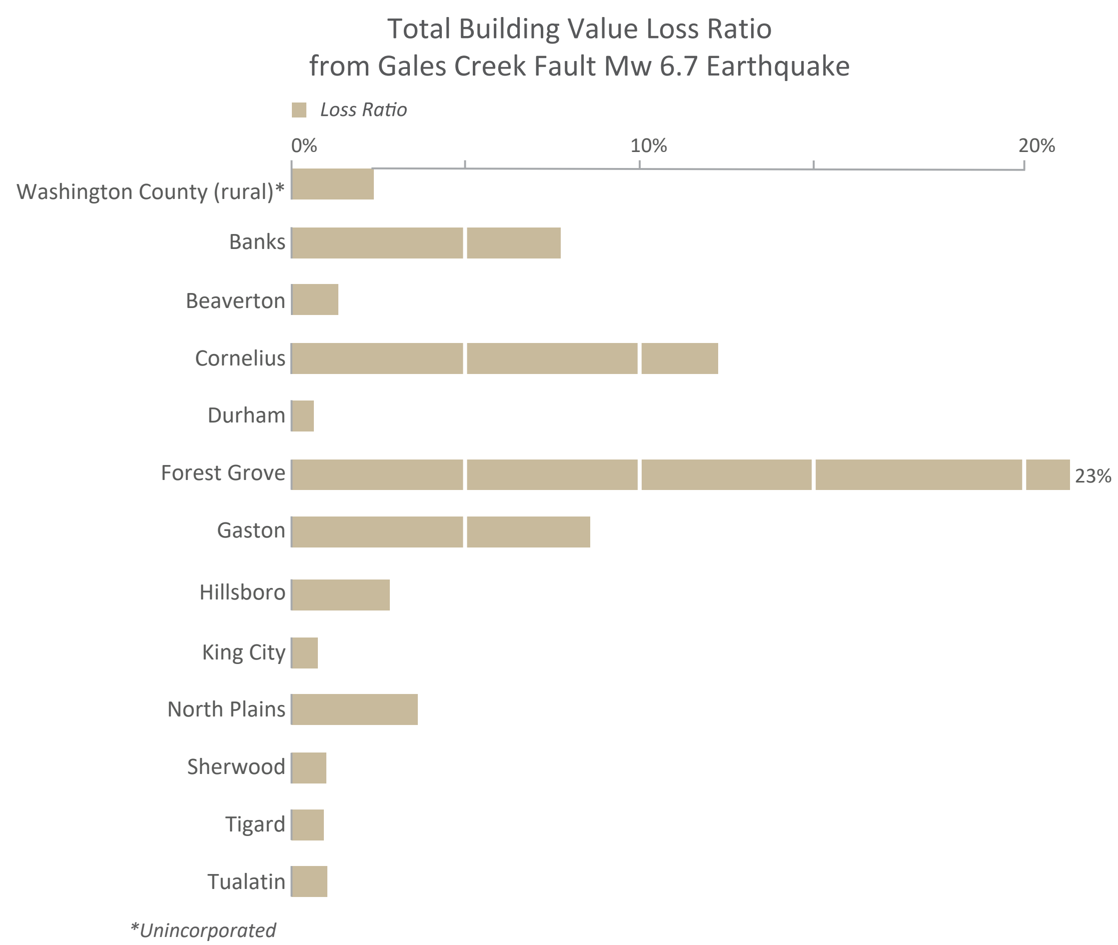
Liquefaction Susceptibility Map of Washington County, Oregon

PLATE 4

Liquefaction Susceptibility

- Low or None
- Moderate
- High
- Very High

Liquefaction is a type of ground deformation that occurs during an earthquake where saturated, non-cohesive soil contracts and liquefies. The ground that becomes liquefied can no longer support heavy structures that are built on top of it. Liquefaction is a significant factor in assessing the risk from earthquake hazard.



Data Sources:
Liquefaction: Oregon Department of Geology and Mineral Industries (2021)
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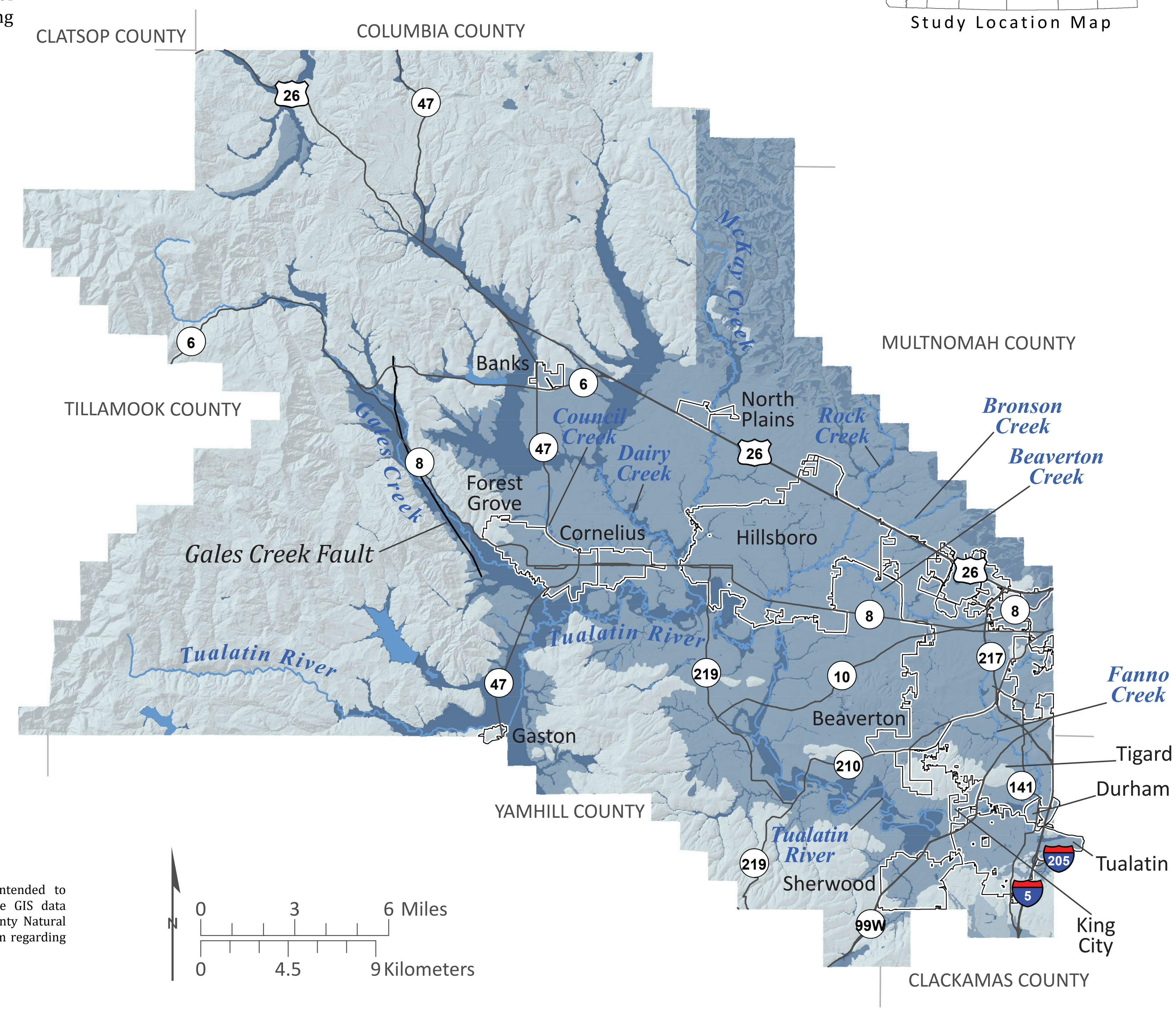
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by: Matt C. Williams, 2022



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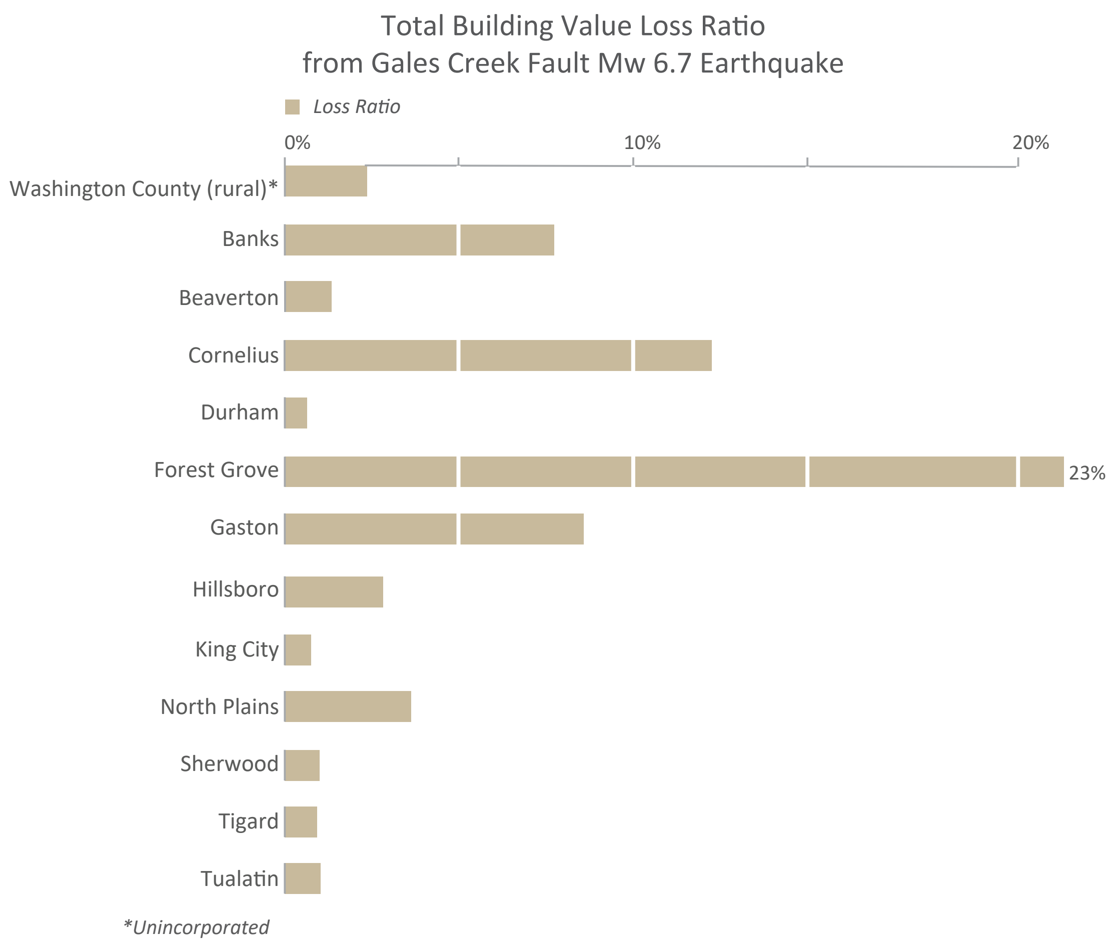
Site Amplification Class Map of Washington County, Oregon

PLATE 5

NEHRP Class

- B
- C
- D
- E, F

Site Amplification is the degree to which soil types attenuate (weaken) or amplify (strengthen) seismic waves produced from an earthquake. The National Earthquake Hazards Reduction Program (NEHRP) classifies these geologic units into soft rock (B), dense soil or soft rock (C), stiff soil (D), and soft clay or soil (E, F). NEHRP soils can significantly affect the level of shaking and amount of damage that occurs at a specific location during an earthquake



Data Sources:
Soil amplification: Oregon Department of Geology and Mineral Industries (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
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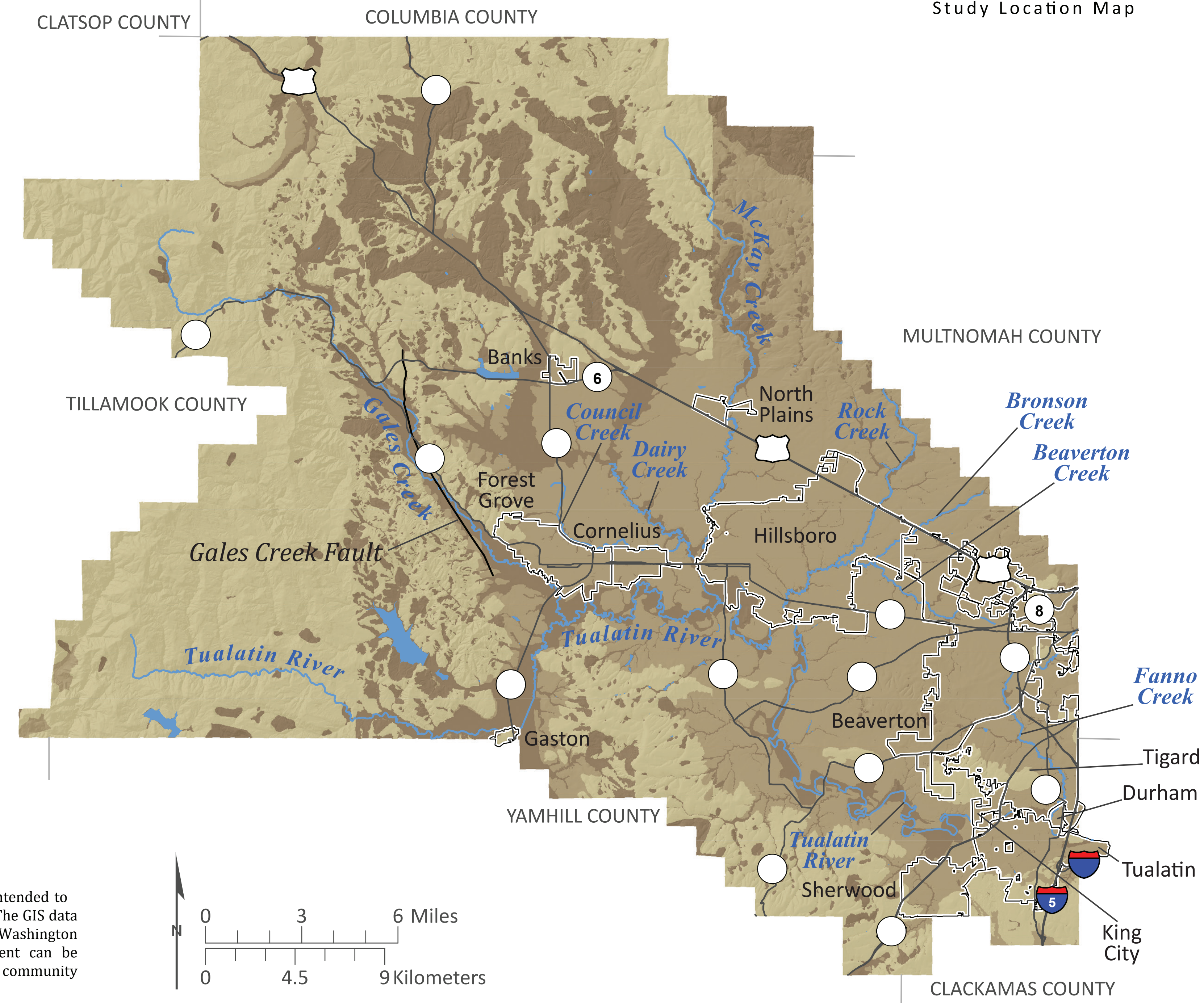
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by: Matt C. Williams, 2022



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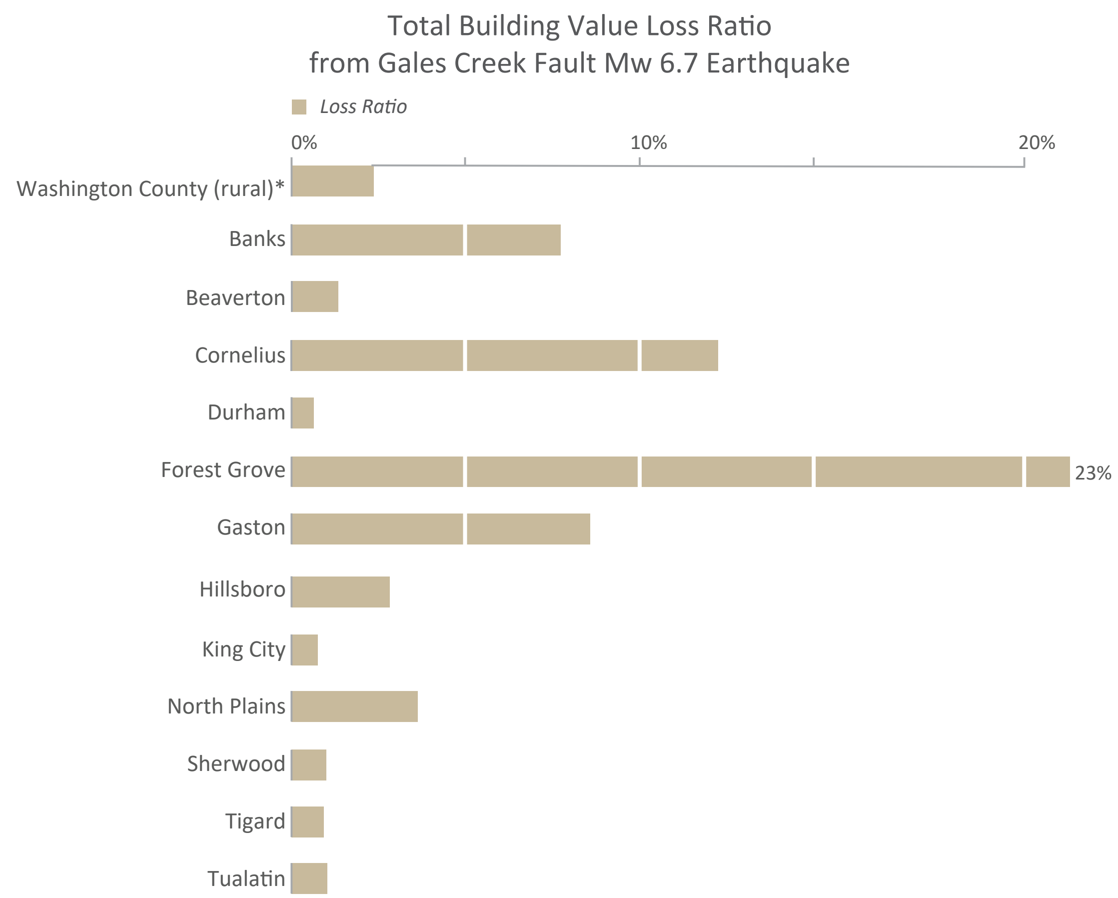
Coseismic Landslide Susceptibility (Wet) Map of Washington County, Oregon

PLATE 6

Coseismic Landslide Susceptibility (Wet)

0 (None) 9 (High)

Coseismic landslide is a type of ground deformation that occurs during an earthquake where slope failure creates a mass movement of rock and debris. Saturated ground increases the susceptibility of a landslide occuring from seismic shaking. Coseismic landslides are a significant factor in the risk from earthquake hazard.

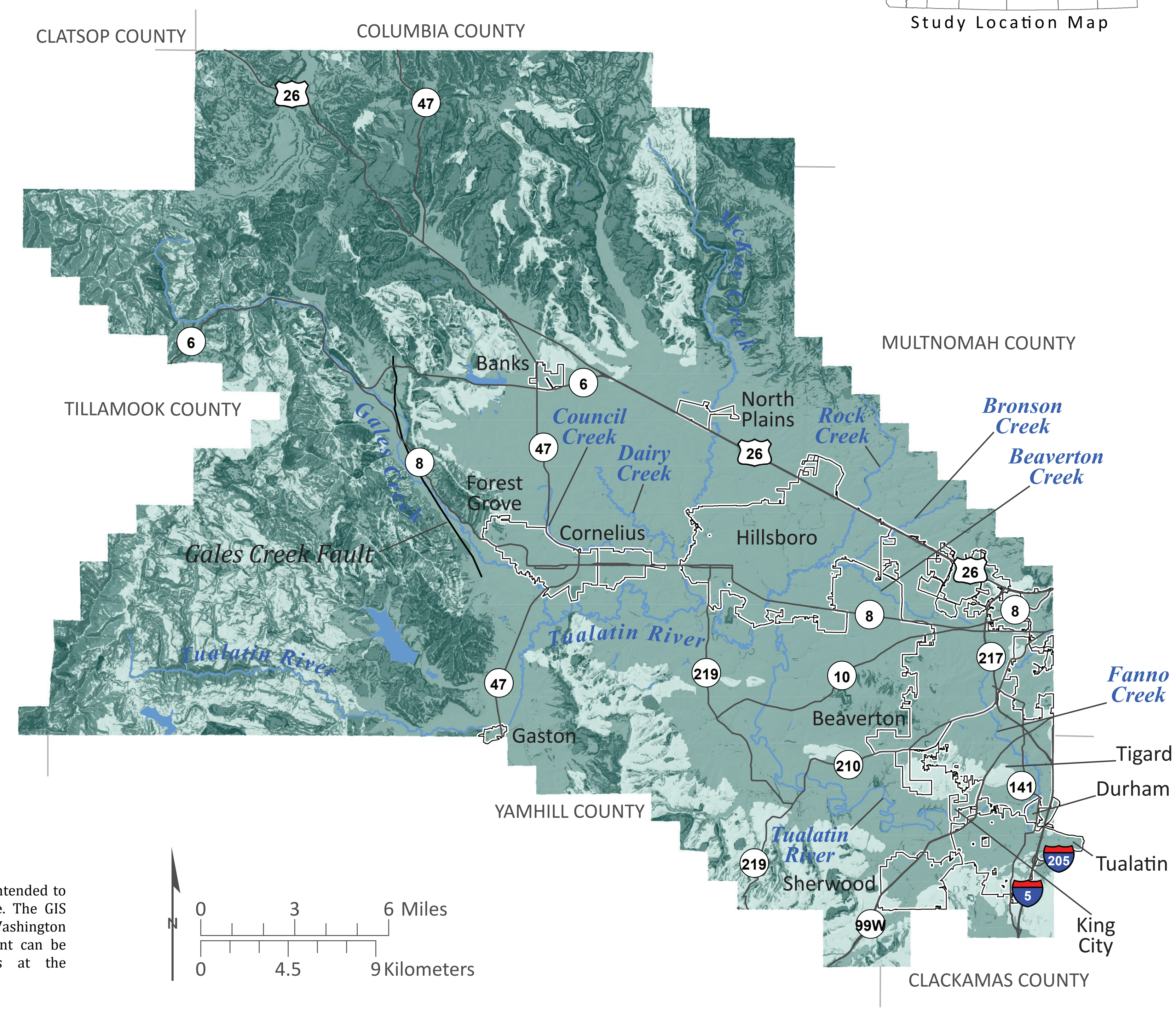


*Unincorporated

Data Sources:
Coseismic Landslide (wet): Oregon Department of Geology and Mineral Industries (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: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by: Matt C. Williams, 2022



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Flood Hazard Map of Washington County, Oregon

PLATE 7

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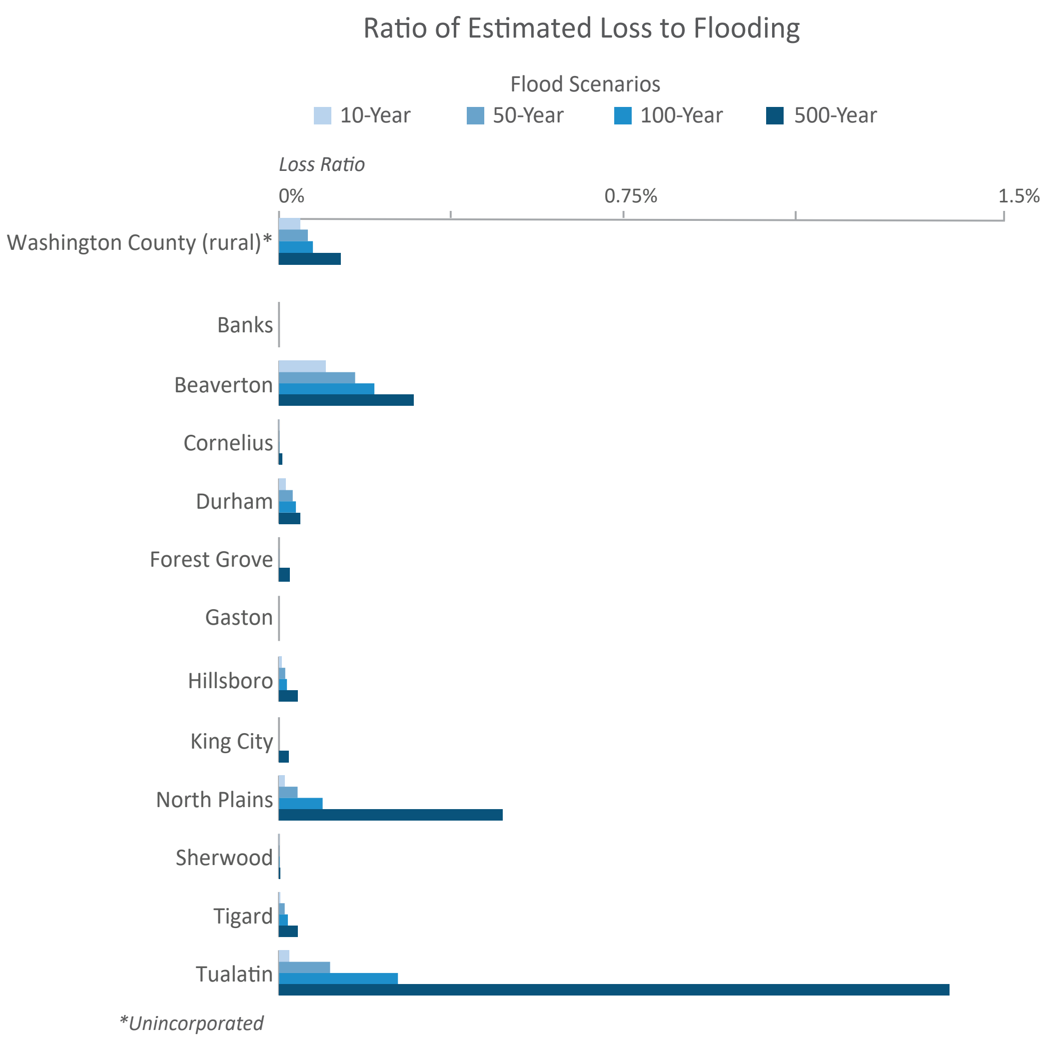
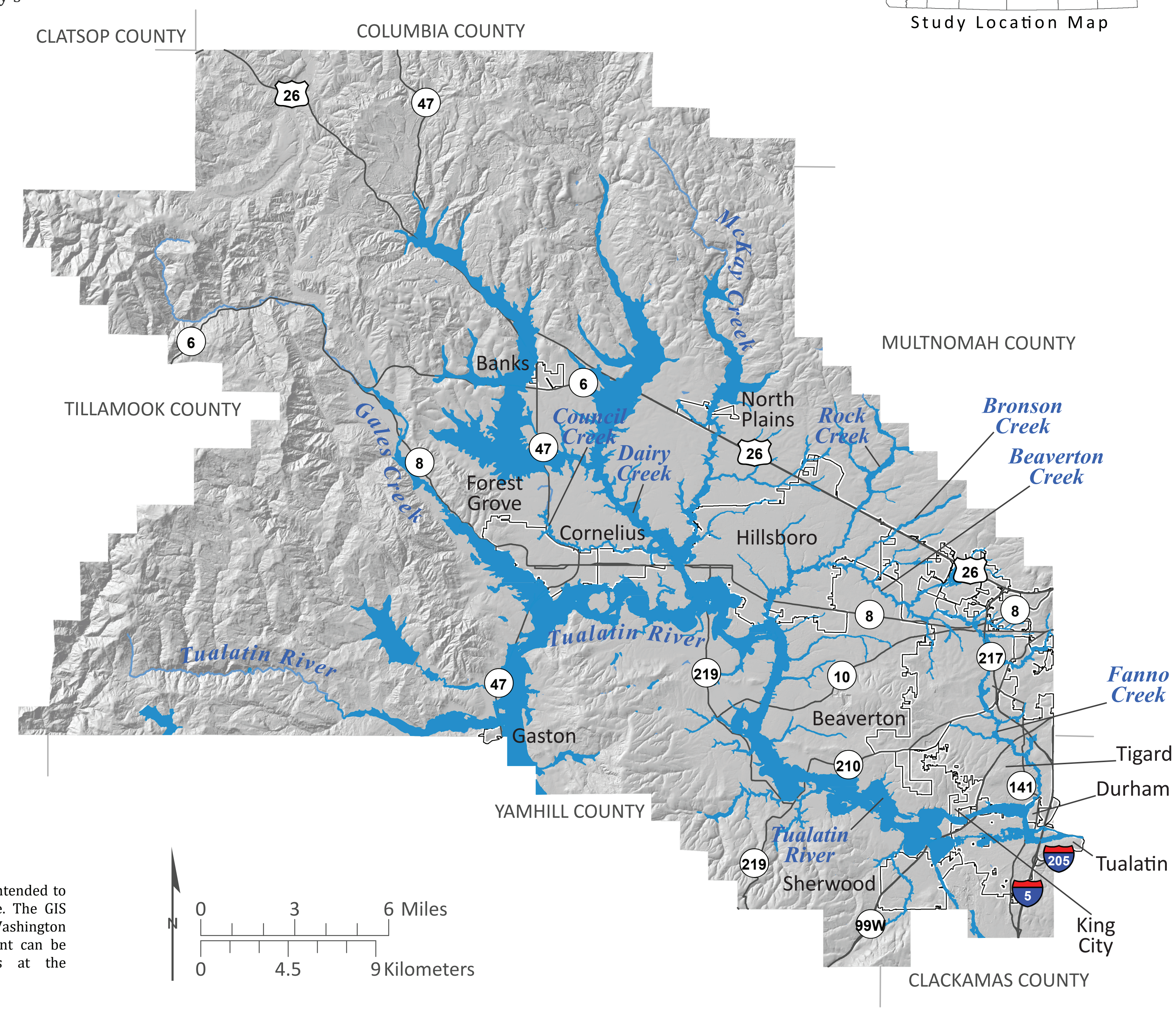
Flood Hazard Zone

100-Year Flood (1% annual chance)

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 Washington County's Digital Flood Insurance Rate Maps.





Data Sources:
Flood hazard zone (100-year): Washington County Flood Insurance Rate Map (2018)
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: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by: Matt C. Williams, 2022

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Landslide Susceptibility Map of Washington County, Oregon

PLATE 8

Landslide Susceptibility

- Low
- Moderate
- High
- Very High

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.

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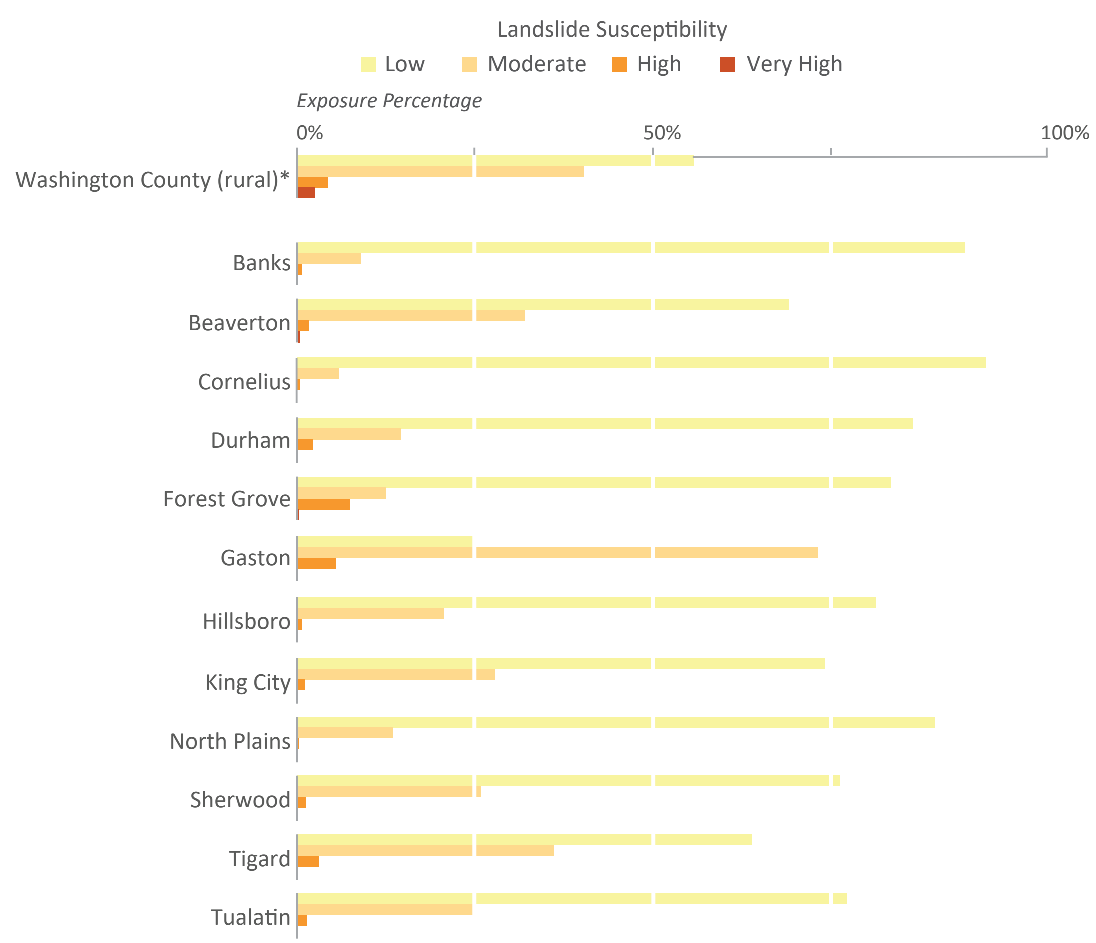
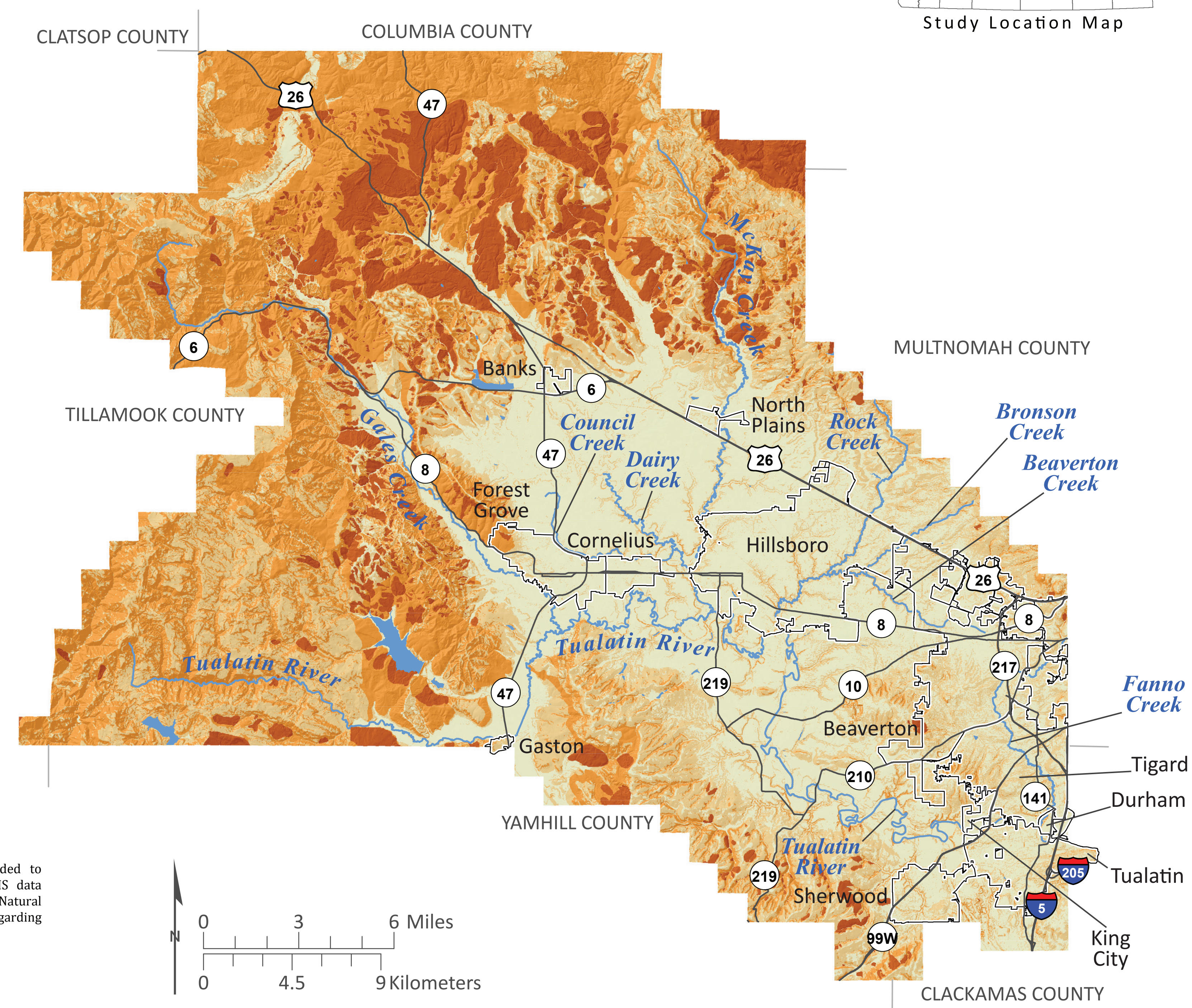
Study Location Map

Percentage of Building Value Exposed to Landslide



*Unincorporated



Data Sources:
Landslide susceptibility: Oregon Department of Geology and Mineral Industries, Burns and others (2016) & Hairston-Porter 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: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by: Matt C. Williams, 2022

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Wildfire Risk Map of Washington County, Oregon

PLATE 9

Wildfire Risk

- Low
- Moderate
- High

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 is derived from a combination of the burn probability (fire history and behavior) and conditional flame length data.

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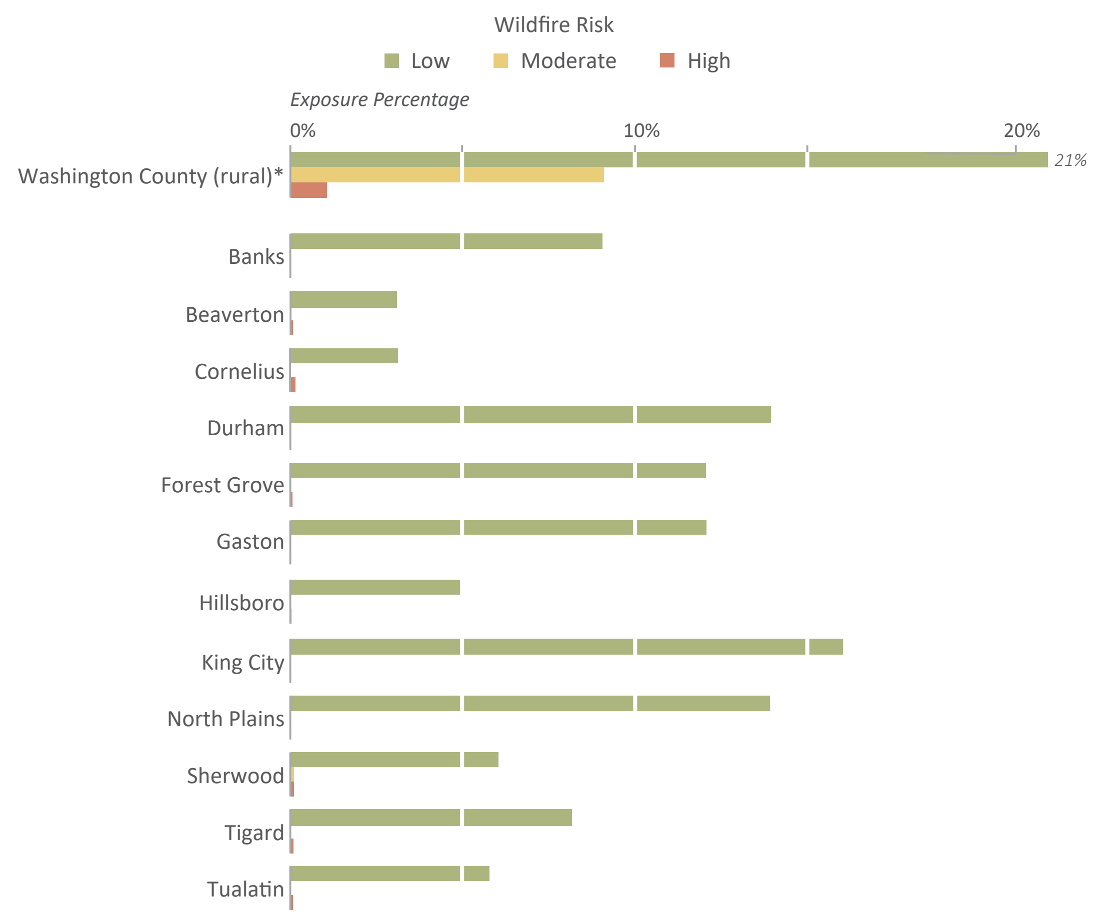
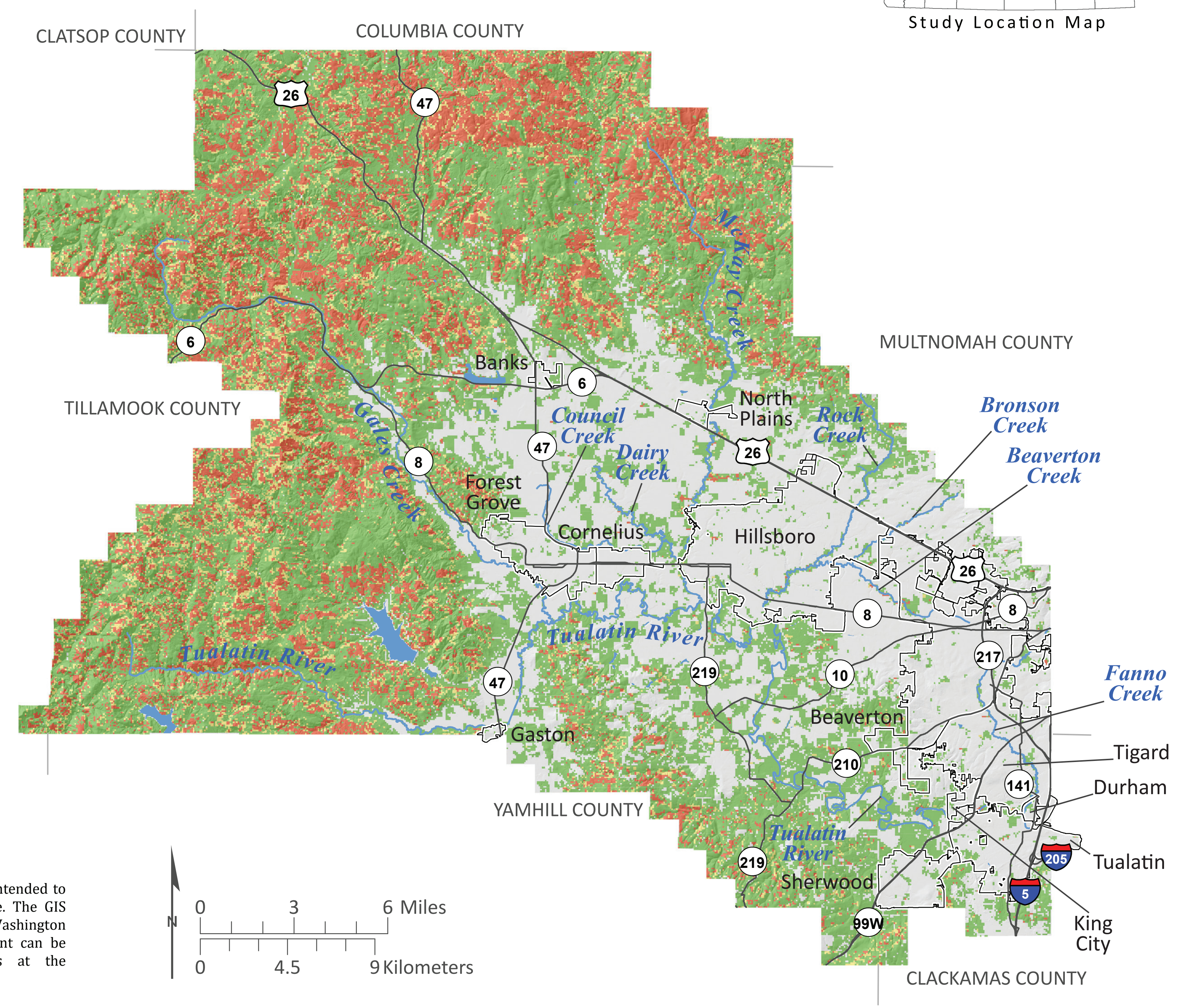
Study Location Map

Percentage of Building Value Exposed to Wildfire



*Unincorporated



Data Sources:
Wildfire risk data: Oregon Department of Forestry, Pyrologix, LCC. (2018)
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: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by: Matt C. Williams, 2022

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PLATE 10

Channel Migration Hazard Map of Washington County, Oregon

Channel Migration Hazard Zone

100-Year Erosion

Channel migration is a process by which a stream's course changes over time due to bank erosion and stream deposition. The channel migration zone is defined by the 30-year Erosion Hazard Area (EHA). To better visualize hazard areas in Washington County, the 100-year EHA has been mapped here. Buildings within these areas are at greater risk to channel migration hazard than other areas.

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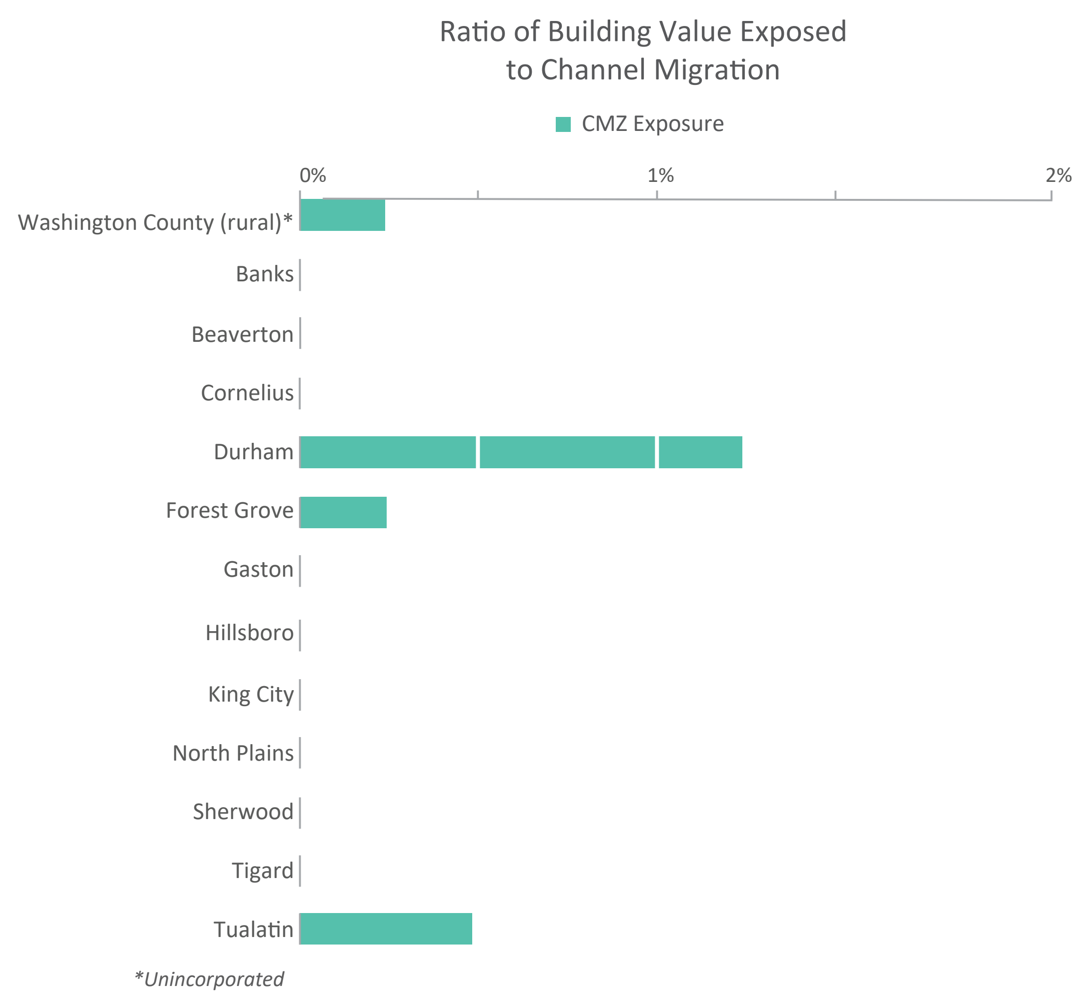

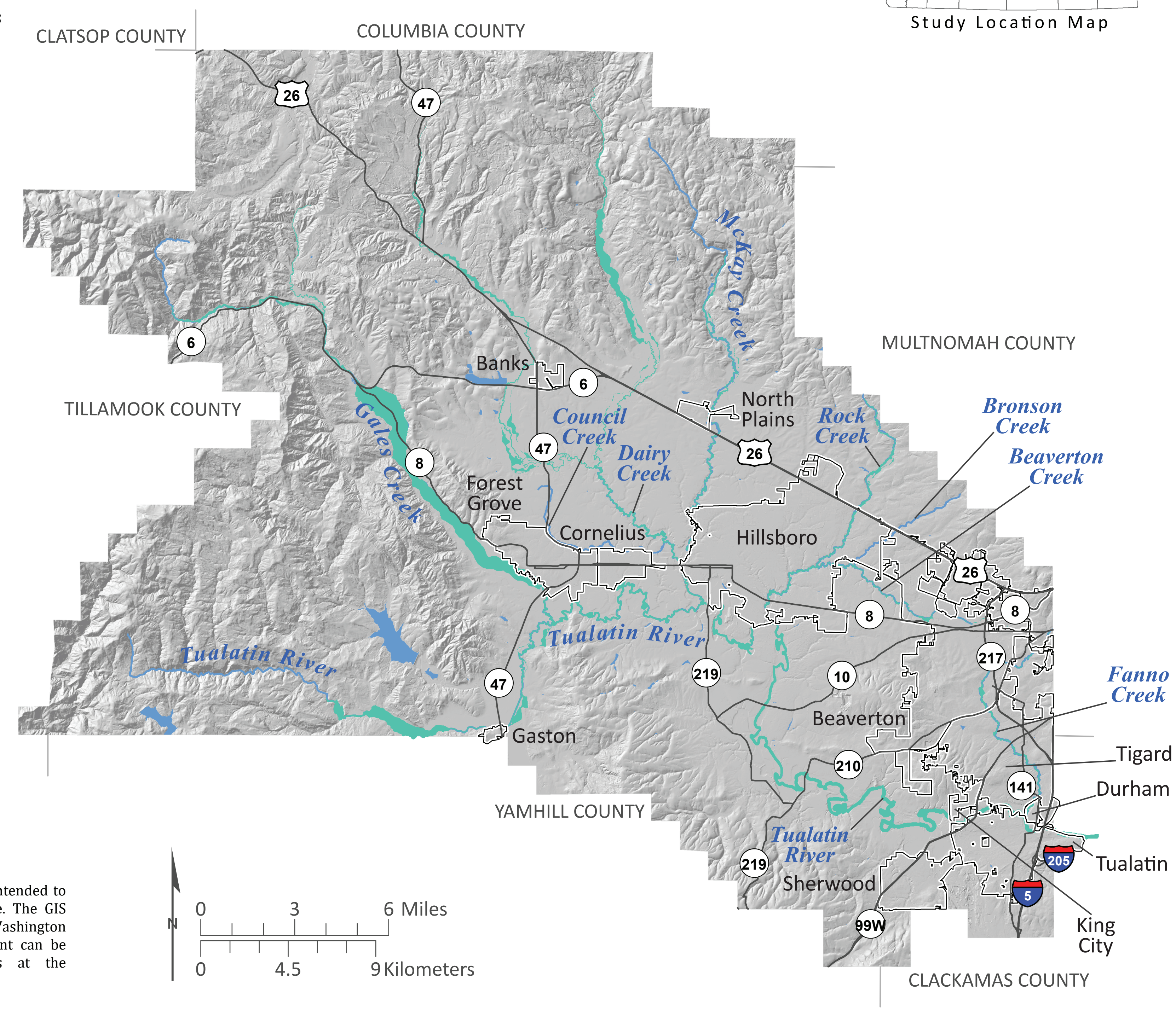

Data Sources:
Channel migration zone (30-year): DOGAMI (Appleby and others, 2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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

Cartography by: Lowell H. Anthony, 2019

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