State of Oregon
Oregon Department of Geology and Mineral Industries
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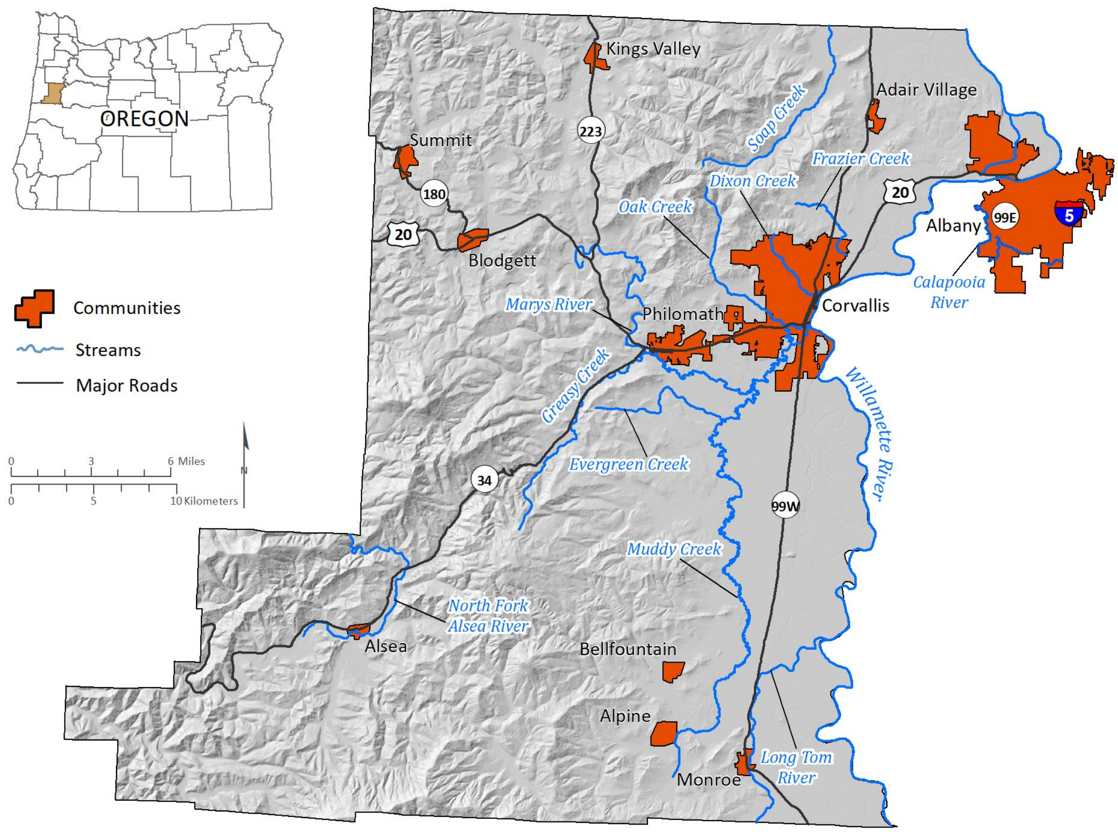
OPEN-FILE REPORT O-23-06

MULTI-HAZARD RISK REPORT FOR BENTON COUNTY, OREGON

INCLUDING THE CITIES OF ADAIR VILLAGE, ALBANY, CORVALLIS, MONROE, AND PHILOMATH, AND THE UNINCORPORATED COMMUNITIES OF ALPINE, ALSEA, BELLFOUNTAIN, BLODGETT, KINGS VALLEY, AND SUMMIT



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2023

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

WHAT'S IN THIS REPORT?

This report describes the methods and results of a natural hazard risk assessment for Benton County communities. The results quantify the impacts of natural hazards to each community and enhance the decision-making process in planning 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.

Benton_County_Risk_Report_Data.gdb

Feature dataset: Asset_Data

feature classes:

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

Metadata in .xml file format:

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

EXECUTIVE SUMMARY

This report was prepared for the communities of Benton County, Oregon, with funding provided by the Federal Emergency Management Agency (FEMA). It describes the methods and results of a natural hazard risk assessment performed in 2022 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 assessment results quantify the impact of natural hazards to each community and enhance the decision-making process in planning for disaster.

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

- In the first task, we created a comprehensive asset database for Benton County 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 (i.e., construction materials, number of floors, usage, etc). Using 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 produced using peer-reviewed methods and with 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. Data sources and coverage are discussed in detail for each hazard in **Assessment Overview and Results.**
- In the third task, we analyzed risk using Esri® ArcGIS Desktop® software. We took two risk assessment approaches: (1) estimated loss (in dollars) to buildings from floods and earthquakes 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, channel migration, and wildfire. Details on recurrence intervals, susceptibility, hazard levels and other particulars are discussed in detail for each hazard in **Assessment Overview and Results.**

The findings and conclusions of this report show the wide range of potential impacts hazards could have on the communities of Benton County. A Cascadia Subduction Zone (CSZ) earthquake (Mw-9.0) will cause extensive damage and losses throughout the county, with most of the critical facilities at high risk. The Turner and Mill Creek Fault Mw-6.6 earthquake showed localized high damages for areas in the northeastern portion of Benton County. We demonstrate the potential for reduction in earthquake damages and losses through seismic retrofits using the building code simulations in the Hazus-MH earthquake model. We also find that the highest potential for population displacement is associated with earthquake, flood, and landslide hazards. Flooding is identified as a threat for some communities in the county (Alsea, Corvallis, Philomath, and Albany) and we quantify the number of elevated structures that are less vulnerable to flood hazard. Our analysis shows that areas with moderate to steep slopes or at the base of steep hillsides are at the greatest risk from landslide hazards, which are present throughout the communities and rural county. Over 400 buildings along Marys River and North Fork Alsea River were exposed to channel migration hazard. Wildfire exposure analysis shows a higher risk for buildings within the wildland-urban interface (WUI) in the western and northern parts of the county.

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 Benton County (rural)
- City of Albany*
- City of Millersburg
- City of Philomath
- Community of Alsea
- Community of Blodgett
- Community of Summit
- City of Adair Village
- City of Corvallis
- City of Monroe
- Community of Alpine
- Community of Bellfountain
- Community of Kings Valley

*The portion of the city of Albany within Linn County is included in this report.

Selected countywide results

Total buildings: 61,091

Total estimated building value: $19 billion

Cascadia Subduction Zone Magnitude 9.0 Earthquake Scenario
Red-tagged buildings[a]: 2,552
Yellow-tagged buildings[b]: 8,936
Loss estimate: $2.9 billion

Turner and Mill Creek Fault Magnitude-6.6 Earthquake Scenario
Red-tagged buildings[a]: 1,898
Yellow-tagged buildings[b]: 5,956
Loss estimate: $2 billion

100-year Flood Scenario
Number of buildings damaged: 2,067
Loss estimate: $88 million

Landslide Exposure (High and Very High-Susceptibility)
Number of buildings exposed: 2,078
Exposed building value: $497 million

Channel Migration Zone* (Erosion Hazard Area – 30-year):
Number of buildings exposed: 402
Exposed building value: $96 million

Wildfire Exposure (High and Moderate Risk):
Number of buildings exposed: 1,777
Exposed building value: $481 million

[a]Red-tagged buildings are considered uninhabitable due to complete damage
[b]Yellow-tagged buildings are considered limited habitability due to extensive damage
*Results are limited the study area of Appleby and others (2021), which covers the North Fork Alsea River and Marys River.

1.0 INTRODUCTION

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

A *natural hazard* is 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 identifies the applicable hazards and analyzes their impacts on the built environment and population, including the cost of recovery. Risk assessments provide key foundational information that can be used to develop mitigation plans, strategies, and actions, so that steps can be taken to prepare for a potential hazard event.

This is a multi-hazard risk assessment analyzing the impacts to buildings and resident population in Benton County. It provides a detailed and comprehensive analysis of natural hazard risk 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 Benton County communities.

Benton County is situated in the northwestern part of Oregon in the Willamette Valley and is subject to natural hazards including: earthquake, riverine flooding, landslides, channel migration, and wildfire. This region of the state is moderately to heavily developed, composed of dense urban areas transitioning to suburban development in unincorporated parts of the study. There are also large uninhabited areas where the county jurisdiction extends into the Oregon Coast Range. Where natural hazards have the potential to damage assets or harm people, the result is natural hazard risk. The primary goal of the risk assessment is to inform communities of the risk posed by various natural hazards and to be a resource for risk reduction actions.

1.1 Purpose

The purpose of this project is to help communities in the study area better understand their risk and increase resilience to earthquakes (including ground shaking, liquefaction and coseismic landslides), riverine flooding, landslides, channel migration, and wildfire. This is accomplished by using 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 a database of critical facilities, tax assessor data, buildings, and population distribution data,
- incorporate and use existing data from the most current geologic, hydrologic, and wildfire hazard studies,
- perform exposure and Hazus–based risk analyses, 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 loss estimation and exposure) were used to assess risk, depending on the type of hazard. These methods are described in the **Methods** section. Countywide results are reported for each hazard in **Community Risk Profiles**. Results for individual communities are detailed in **Appendix A: Community Risk Profiles**. **Appendix B** contains the detailed risk assessment tables used to generate the countywide results and community risk profiles. **Appendix C** provides additional explanation of the Hazus-MH methodology.

Appendix D defines acronyms and other terms used in this report. **Appendix E** contains tabloid-size maps showing the spatial extent of the hazards, assets, and population across Benton County. These appendices can be helpful in clarifying the summarized results in each hazard section.

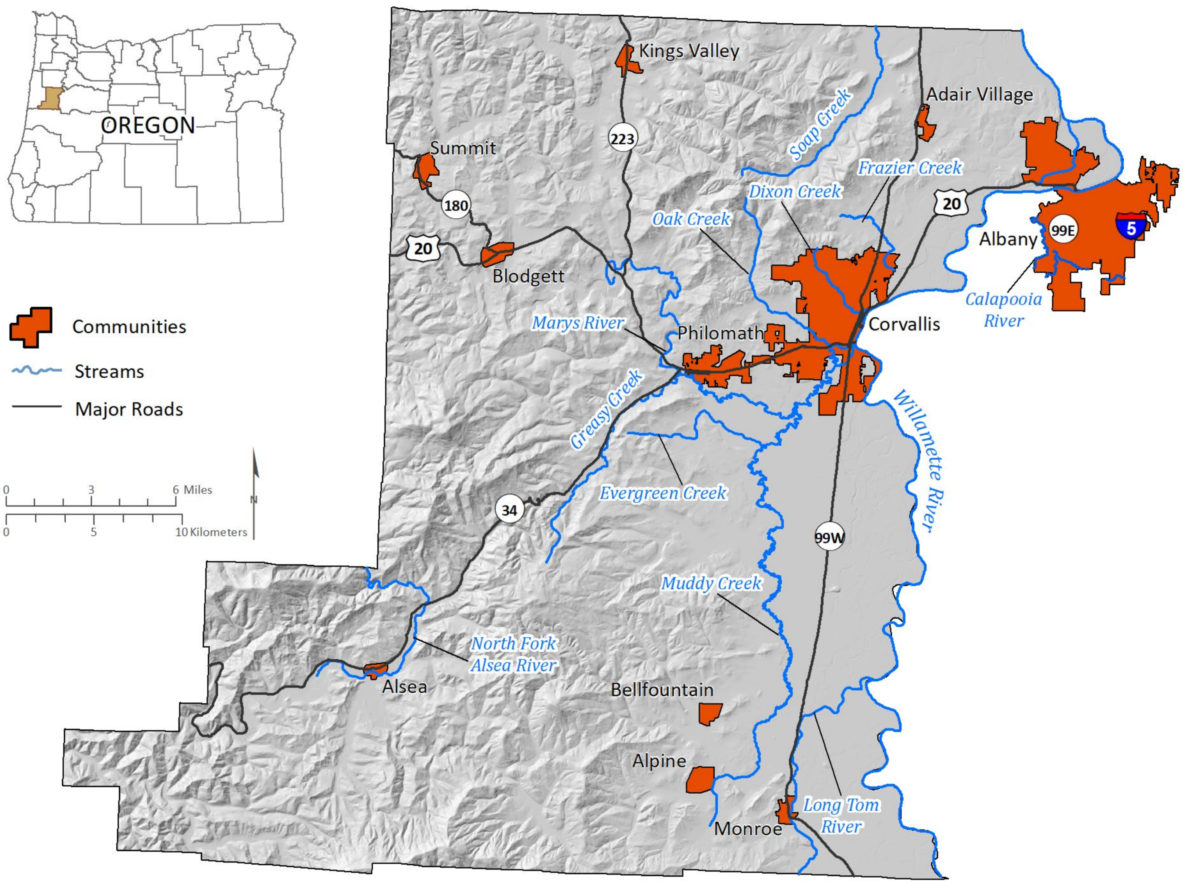
1.2 Study Area

The study area for this project includes the entirety of Benton County, Oregon as well as the portion of the City of Albany that is within Linn County (**Figure 1-1**). Benton County is located in the northwestern portion of the state; the county is bordered by Polk County to the north, Linn County to the east, Lane County to the south, and Lincoln County to the west. The entire eastern boundary of Benton County with Linn County is defined by the Willamette River. The total area of Benton County is 1,756 square kilometers (678 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 geography of western Benton County consists of the heavily forested Oregon Coast Range. Marys Peak, located west of Philomath, is the highest peak in the Oregon Coast Range at 1,249 meters (4,097 feet). The Siuslaw National Forest makes up a significant portion of the county's western half. The eastern half of the county transitions from the heavily forested mountains to gently rolling farmland and then onto the broad flat floor of the Willamette Valley.

The population of Benton County is approximately 144,000 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. Most of the residents reside in the eastern half of the county. The City of Corvallis, which is the county seat and location of Oregon State University, has a population of approximately 60,000. The incorporated communities of the study area are Adair Village, Albany, Corvallis, Monroe, and Philomath (**Figure 1-1**). The portion of Albany that is within Linn County is also included in this study. The unincorporated communities that were examined in this study were Alpine, Alsea, Bellfountain, Blodgett, Kings Valley, and Summit.

Figure 1-1. Study area: Benton County with communities in this study identified. Countywide results for each hazard are presented in Chapter 3. Individual community risk profiles are presented in Appendix A.



1.3 Project Scope

For this risk assessment, we limited the project scope to natural hazard impacts on buildings and population because of data availability, the strengths and limitations of the risk assessment methodology, and funding availability. We did not directly analyze impacts to the local economy, community lifelines, stored hazardous materials, land values, socially vulnerable populations, 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 Hazus®-MH (FEMA, 2012a, 2012b, 2012c), a tool developed by FEMA for calculating damage to buildings from flood and earthquake. Exposure is a simpler method, in which buildings are categorized based on their location relative to various hazard zones. City and county population numbers from the PSU Population Research Center data was used to distribute people into residential structures based on square footage (https://www.pdx.edu/population-research/population-estimate-reports).

A critical component of this risk assessment is a countywide building inventory developed from building footprint data and the Benton County tax assessor database (acquired 2022). The other key component is a suite of datasets that represent the currently best available science for a variety of natural hazards. The geologic hazard scenarios were selected by DOGAMI staff based on their expert knowledge of the datasets; most datasets are DOGAMI publications. In addition to geologic hazards, we included wildfire hazard in this risk assessment. The following is a list of hazards considered in this study and what risk assessment methodologies were applied. See **Table 1-1** for data sources.

Earthquake Risk Assessment

- Hazus-MH loss estimation from a CSZ earthquake magnitude (Mw)-9.0 scenario. Includes earthquake induced or "coseismic" liquefaction, soil amplification class, and landslides.
- Hazus-MH loss estimation from a Turner and Mill Creek Fault Mw-6.6 scenario. Includes 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 and landslide deposit mapping

Channel Migration Risk Assessment

- Exposure based on the 30-year erosion hazard area

Wildfire Risk Assessment

- Exposure based on Overall Wildfire Risk

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

Hazard	Scenario or Classes	Spatial Extent	Data Source
Earthquake	CSZ Mw-9.0	Regional	DOGAMI (Madin and others, 2021)
	Turner and Mill Creek Fault Mw-6.6	Countywide	USGS (Personius, 2002) accessed via Hazus fault database
-Coseismic landslide	Susceptibility – wet (3-10 hazard classes)	Statewide	DOGAMI (Madin and others, 2021)
-Coseismic liquefaction	Susceptibility (1-5 classes)	Countywide	DOGAMI (Hairston-Porter and others, 2021)
-Coseismic soil amplification class	National Earthquake Hazards Reduction Program (A-F classes)	Countywide	DOGAMI (Hairston-Porter and others, 2021)
Flood	Depth Grids: 10% (10-yr) 2% (50-yr) 1% (100-yr) 0.2% (500-yr)	Countywide	DOGAMI (Appleby and others, 2021) – derived from FEMA (2016) data
Landslide	Susceptibility (Low, Moderate, High, Very High)	Statewide	DOGAMI (Burns and others, 2016)
	Deposits	Countywide	DOGAMI (Hairston-Porter and others, 2021)
Channel Migration	Susceptibility (Not Exposed, Exposed)	Marys and North Fork Alsea Rivers	DOGAMI (Appleby and others, 2021)
Wildfire	Overall Wildfire Risk (Low, Moderate, High)	Regional (Pacific Northwest, US)	ODF (Gilbertson-Day and others, 2018)

1.4 Previous Studies

One previous risk assessment has been conducted that included the study area by DOGAMI. Wang (1998) used Hazus-MH to estimate the impact from a Mw-8.5 CSZ earthquake scenario on the state of Oregon. The results of this study were arranged into individual counties. Benton County was estimated to experience a 9.5% loss ratio in the Mw-8.5 CSZ scenario due to its proximity to the earthquake source.

Burns and others (2008) developed earthquake and landslide hazard maps and used Hazus-MH to estimate future earthquake damage for the Mid/Southern Willamette Valley which included Benton County. The Hazus-MH analysis used the Corvallis Fault, magnitude (Mw) 6.5 and CSZ, Mw-9.0. Both scenarios aggregated results at the census tract level using the default Hazus-MH general building stock database. Estimated loss ratios for Benton County were 31% for the Corvallis Fault and 32% for the CSZ scenarios.

We did not compare the results of these projects with previous studies because of the difference in level of detail and accuracy of building information and earthquake inputs.

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 used Hazus-MH version 5.0 (FEMA, 2021), which was the latest version available when we began this risk assessment. 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. Costs 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 a Hazus-MH flood analysis. In this example, most buildings within the 100-year flood zone are estimated to experience losses ranging from >0 to >15%. Buildings with a first-floor height above the level of flooding and those outside the flood zone are expected to experience no losses.

Figure 2-1. 100-year flood zone and building loss estimates example in city of Philomath, Oregon.

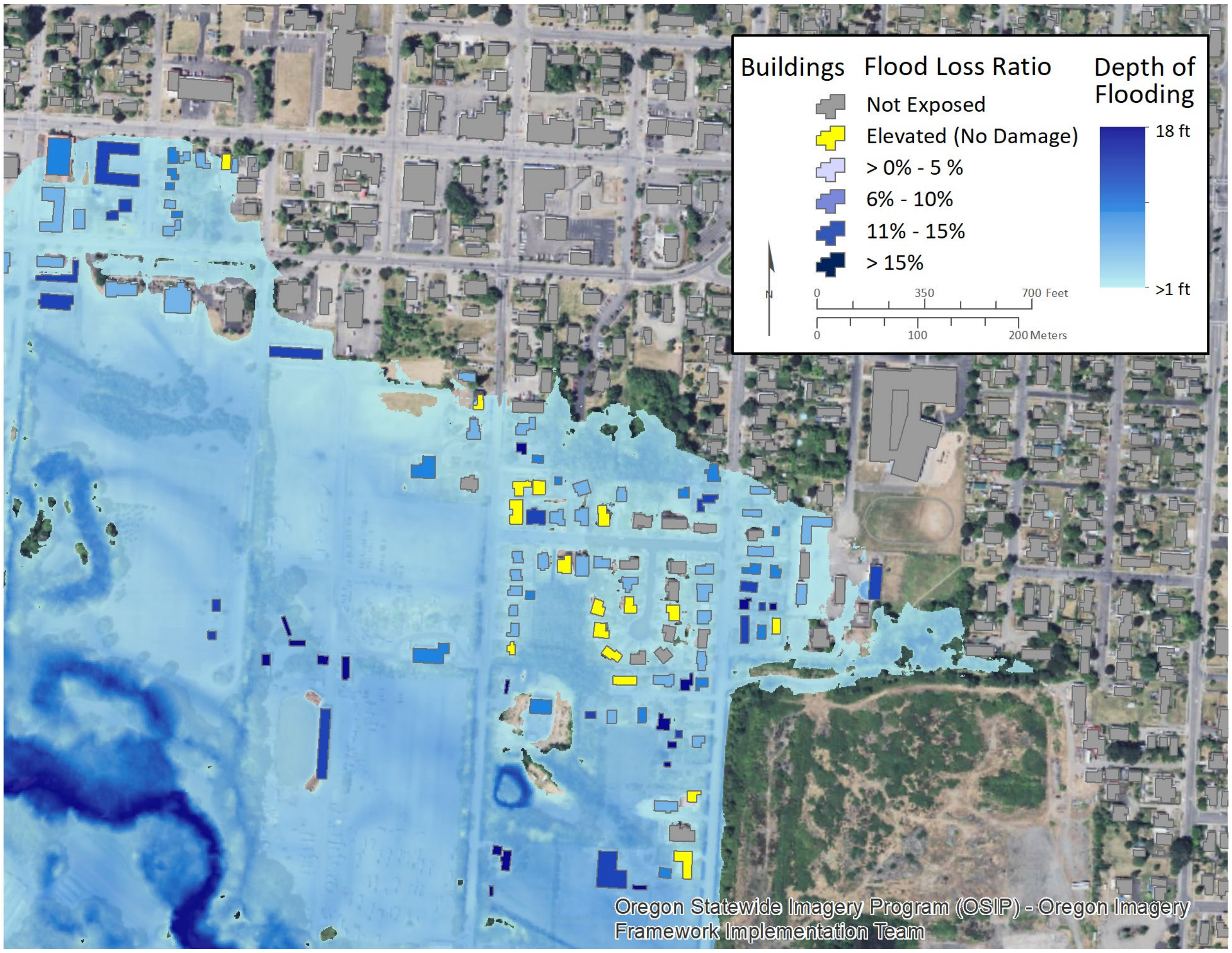


Image source: Oregon Statewide Imagery Program, 2018

Depth grid: Derived from the effective FEMA Flood Insurance Rate Map data for Benton County, 2016

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 landslide, channel migration, and wildfire risk. Exposure methodology identifies the buildings and population that are within a particular natural hazard zone. This is an alternative to the more detailed loss estimation method for those natural hazards that do not have available damage models like in Hazus. It provides a way to easily quantify what is and 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 levels of landslide susceptibility with building footprints colored based on what susceptibility zone the center of the building is within.

Exposure is used for landslide, wildfire, and channel migration hazards. For comparison with loss estimates, exposure is also used for the 1% annual chance flood (100-year flood).

Figure 2-2. Landslide susceptibility areas and building exposure example in Benton County, Oregon.

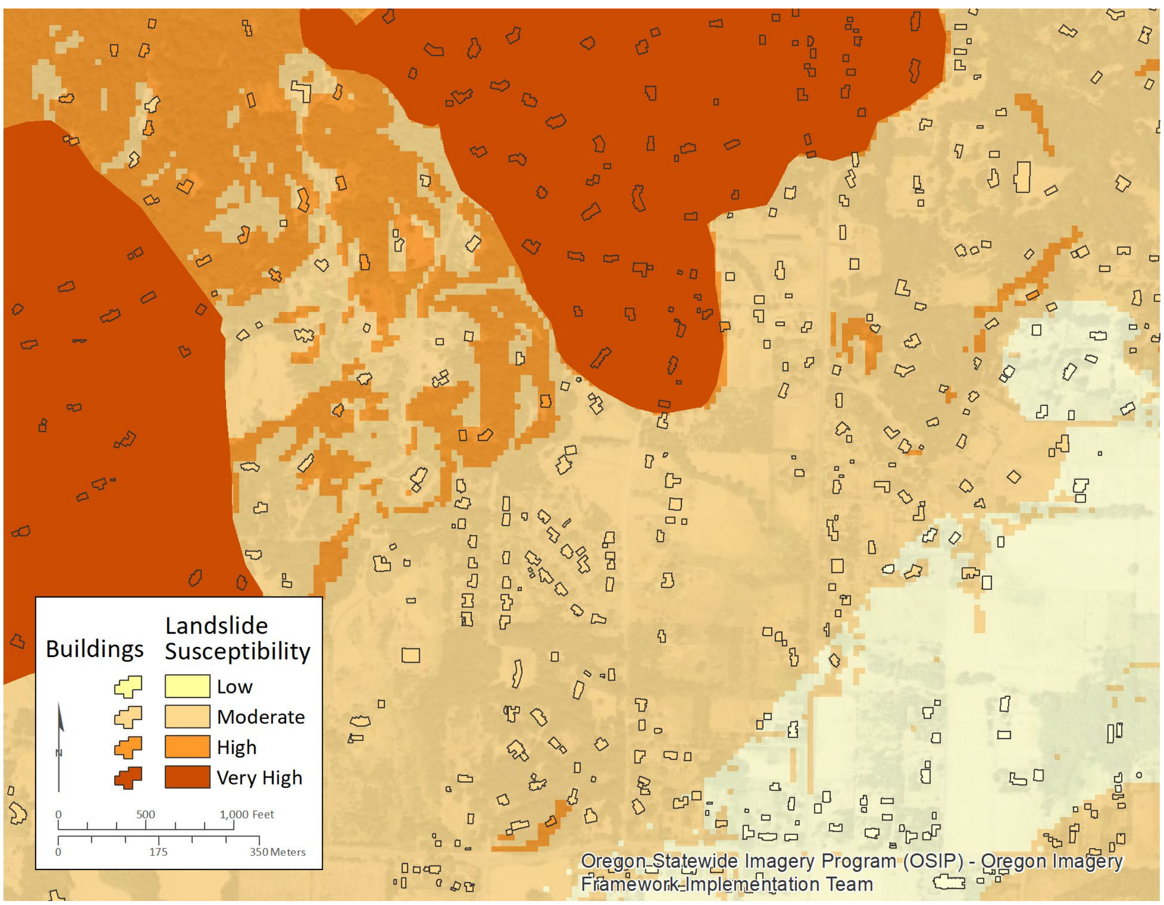


Image source: Oregon Statewide Imagery Program, 2018

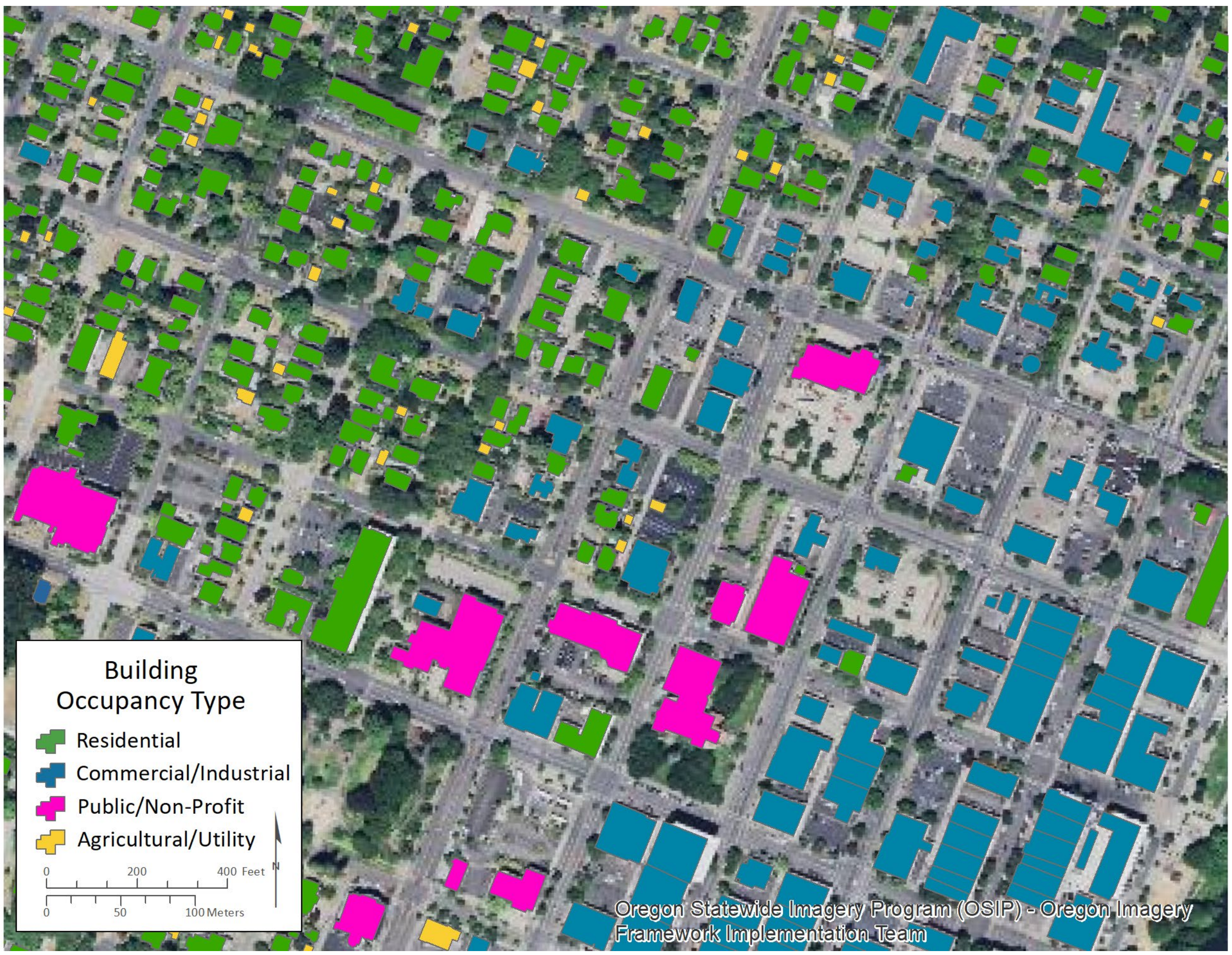
Landslide data source: Landslide susceptibility overview map of Oregon, (Burns and others, 2016) and Benton County landslide deposits, (Hairston-Porter and others, 2021)

2.3 Building Inventory

A key piece of the risk assessment is the countywide building inventory. This inventory consists of all buildings larger than 9.3 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 Benton County. See also Appendix B: **Table B-1.**

To use the building inventory within Hazus-MH, we converted the building footprint polygons 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 Corvallis, Oregon.**



The number of buildings and total building value per community varies significantly in Benton County, with 53 buildings and $11 million for Blodgett to 17,509 buildings and $7.1 billion for Corvallis (**Table 2-1).** A table detailing the occupancy class distribution by community is included in **Appendix B: Detailed Risk Assessment Tables**.

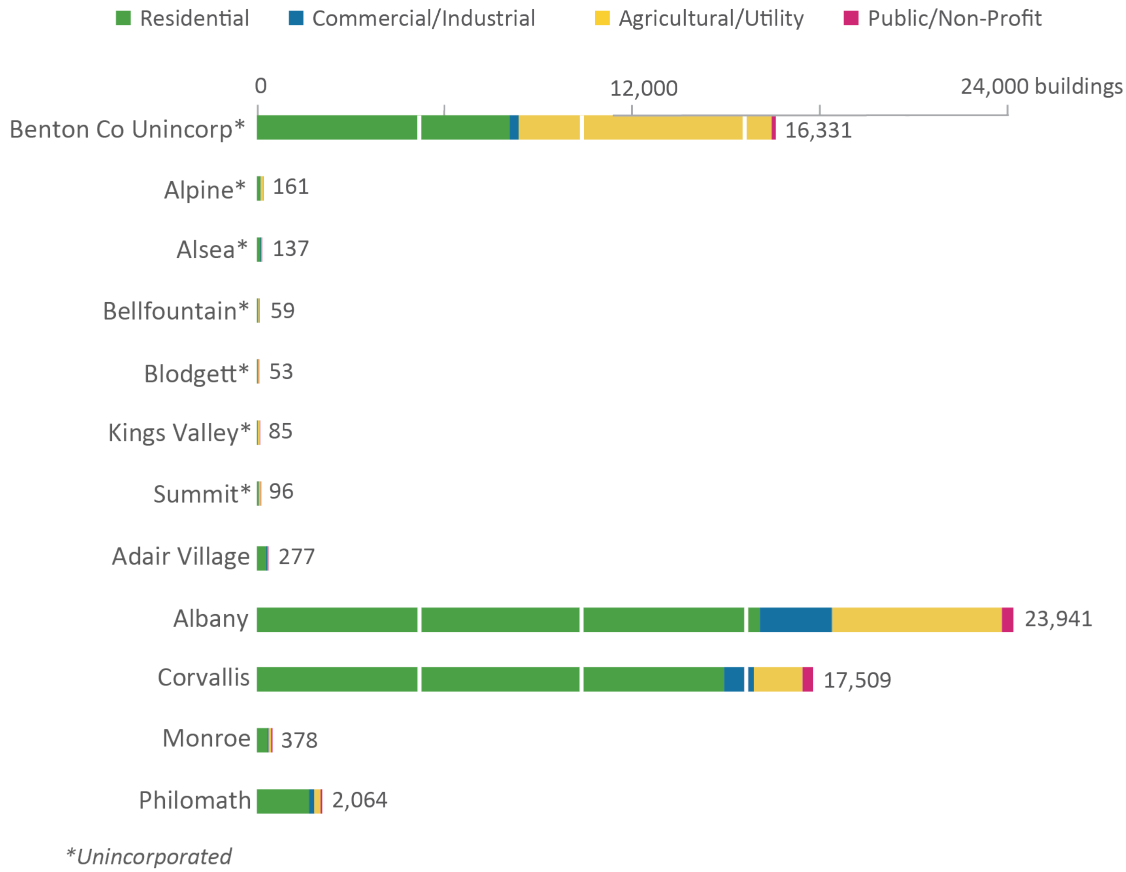
Table 2-1. Benton County building inventory.

Community	Total Number of Buildings	Percentage of Total Buildings	Estimated Total Building Value ($)	Percentage of Total Building Value
Unincorp. Benton Co (rural)	16,331	27%	3,934,253,000	21%
Alpine	161	0.3%	26,781,000	0.1%
Alsea	137	0.2%	30,315,000	0.2%
Bellfountain	59	0.1%	14,814,000	0.1%
Blodgett	53	0.1%	11,186,000	0.1%
Kings Valley	85	0.1%	17,918,000	0.1%
Summit	96	0.2%	20,026,000	0.1%
Total Unincorporated County	16,922	28%	4,055,292,000	22%
Adair Village	277	0.5%	107,166,000	0.6%
Albany	23,941	39%	7,033,549,000	37%
Corvallis	17,509	29%	7,132,168,000	38%
Monroe	378	0.6%	109,046,000	0.6%
Philomath	2,064	3.4%	581,805,000	3.1%
Total Study Area	61,091	100%	19,019,027,000	100%

The building inventory was developed from a building footprints dataset developed in 2021 called the Statewide Building Footprints for Oregon, release 1 (SBFO-1) (Williams, 2021). The SBFO-1 data of Benton County was modified from a building footprints dataset maintained by Benton County, obtained June 2020. The building footprints provide a location and 2D outline of each structure. There are a total of 61,091 buildings within the study area. We define buildings to be permanent structures with walls and a roof that can be occupied by people (Williams, 2021). Other structures, such as dams, water tanks/towers, sewage and water treatment tanks, tents, small garden sheds, hoop-houses or other plastic-covered greenhouses, and grain silos, were not considered buildings and were not included in this analysis.

The Benton County Assessment Office 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 assessment for both loss estimation and analyses. Corvallis and Albany are the communities with the highest total number of buildings and residential use is the most common countywide (**Figure 2-4**).

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



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 Albany and Corvallis (**Table 2-2**). Critical facilities are listed for each community in **Appendix A**.

Table 2-2. Benton 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. Benton Co (rural)	0	0	5	75,619	5	6,108	0	0	1	4,844	5	20,472	16	107,042
Alpine	0	0	1	1,729	1	676	0	0	0	0	1	15	3	2,420
Alsea	1	468	1	9,253	1	1,220	0	0	0	0	0	0	3	10,941
Bellfountain	0	0	1	2,253	1	610	0	0	0	0	0	0	2	2,864
Blodgett	0	0	1	1,874	1	101	0	0	0	0	0	0	2	1,975
Kings Valley	0	0	1	4,591	0	0	0	0	0	0	0	0	1	4,591
Summit	0	0	0	0	1	337	0	0	0	0	0	0	1	337
Total Unincorp. County	1	468	10	95,319	10	9,053	0	0	1	4,844	6	20,487	28	130,170
Adair Village	0	0	1	15,505	1	2,655	0	0	0	0	1	498	2	18,160
Albany	9	14,969	23	73,955	5	9,193	0	0	1	2,828	4	11,407	34	27,538
Corvallis	5	171,755	15	221,554	7	40,745	1	2,920	1	3,107	4	21,868	29	453,015
Monroe	1	559	2	20,510	1	2,237	0	0	0	0	3	1,653	4	24,060
Philomath	0	0	4	53,321	2	5,892	0	0	0	0	3	2,721	7	61,020
Total Study Area	16	187,751	55	480,164	26	69,775	1	2,920	3	10,779	21	58,634	104	713,963

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

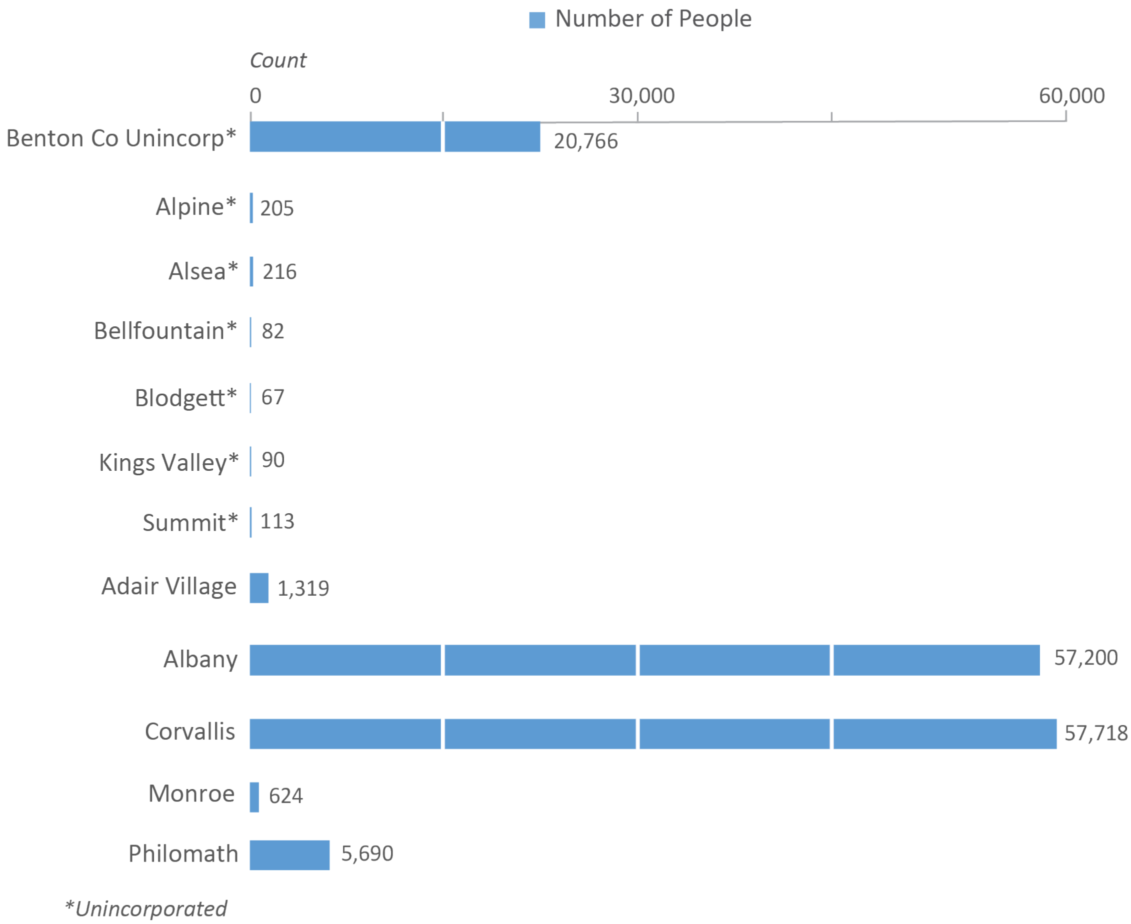
* Category includes buildings that are not traditional (emergency response) critical facilities but considered critical during an emergency based on input from local stakeholders (e.g., water treatment facilities or airports).

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 2020 U.S. Census population of permanent residents per census block was distributed proportionally among residential buildings based on building area. 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 non-permanent populations (e.g., tourists), whose total numbers fluctuate seasonally. Due to lack of information within the assessor and census databases, we cannot distinguish between vacation homes and primary residences. Therefore, our method distributes some of the permanent residents into vacation homes, however they make up a small portion of the residential building stock in most communities (U.S. Census Bureau, 2020b).

From the Census and PSU Population Research Center data, we assessed the risk of the 144,091 residents within the study area that could be affected by a natural hazard scenario. For each natural hazard, with the exception of the earthquake scenario, a simple exposure analysis was used to find the number of potentially displaced residents within a hazard zone. For the earthquake scenario the number of potentially displaced residents was based on residents in buildings estimated to be significantly damaged by the earthquake.

Figure 2-5. Population by Benton County community.



3.0 ASSESSMENT OVERVIEW AND RESULTS

In this risk assessment, we considered five natural hazards (earthquake, flood, landslide, channel migration, and wildfire) that pose a risk to Benton 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 natural 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 Benton County. Individual community results are in **Appendix A: Community Risk Profiles.**

3.1 Earthquake

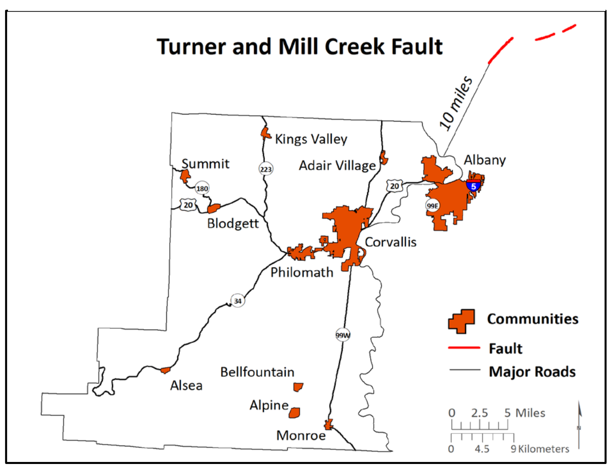
An earthquake is a sudden movement of rock along a fault in the earth's crust, which abruptly releases strain that has accumulated over time. This movement produces waves of shaking that spread in all directions. If an earthquake occurs near populated areas, it may cause casualties, economic disruption,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

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

3.1.1 Scenarios: CSZ and Turner and Mill Creek Fault

Just off Oregon's coast, the Juan de Fuca tectonic plate slides under the North American plate. Oregon (along with the rest of the Pacific Northwest and the nation) sits on the North American plate. This area of interaction between the two plates is known as the Cascadia subduction zone (CSZ). The pressure and friction created by this convergent motion builds potential energy at the plate boundary until the overriding plate (North American) suddenly slips, releasing energy that manifests as strong shaking spread over a wide area. Earthquakes as large as Mw-8 to 9 occur along the CSZ on average every 230-540 years and scientists estimate a 16-22% chance of one happening in the next 50 years (Goldfinger and others, 2012, 2017).

Figure 3-1. Turner and Mill Creek fault location



The other earthquake scenario examined for this report is the Turner and Mill Creek Fault, located approximately 10 miles northeast of Albany and oriented east to west (**Figure 3-1**). This is an ~11 mile (18 km) Quaternary fault estimated to slip less than 0.2mm/yr. Unlike CSZ, which is a very large and deep fault between two tectonics plates, the Turner and Mill Creek Fault is crustal, meaning it is a crack within the North American plate. Despite their comparatively small size, crustal earthquakes can cause significant damage due to their proximity to the surface and the built environment. The estimated maximum fault displacement for the Turner and Mill Creek Fault could produce relatively large (Mw-6.6) earthquakes, enough to pose a significant hazard (Personius, 2002). Although the damage produced from this fault would be far more localized than a CSZ event, it poses a serious seismic threat to the communities in the vicinity of the northeastern portion of Benton County. The current understanding of this fault and various aspects of its frequency and magnitude are limited.

We examined earthquake shaking and ground failure (coseismic liquefaction and landslides) hazards produced from both earthquake scenarios. These two earthquake scenarios were analyzed in Hazus-MH because we observed, from the initial Hazus-MH analyses for this study, that areas around the northeast corner of Benton County were similarly at risk from the Turner and Mill Creek Fault Mw-6.6 as from the far more widespread damaging CSZ Mw-9.0. The effects from either earthquake scenario present a challenge for planners preparing for hazard impacts.

3.1.2 Data sources: CSZ

Most of the earthquake hazard data come from the Oregon Seismic Hazard Database, release 1.0 (OSHD-1), which includes ground shaking and site-specific earthquake data for a CSZ Mw-9.0 event (Madin and others, 2021). In recently published work, the USGS (Wirth and others, 2021) ran 30 CSZ Mw-9.0 simulations that represented the variability of shaking that Madin and others (2021) used to develop the ground shaking datasets in the OSHD-1.

Hazus-MH offers two scenario methods for estimating loss from earthquake: probabilistic and deterministic (FEMA, 2012b). A probabilistic scenario uses U.S. Geological Survey (USGS) National Seismic Hazard Maps, which are derived from seismic hazard curves calculated on a grid of sites across the United States that describe the annual frequency of exceeding a set of ground motions as a result of all possible earthquake sources (USGS, 2019). A deterministic scenario is based on a specific seismic event, which in this case is a CSZ Mw-9.0 event. We selected the deterministic scenario method because the CSZ event is the most likely large earthquake to impact this area (Goldfinger and others, 2012, 2017). We used the deterministic method along with the UDF database so that loss estimates could be calculated on a building-by-building basis.

The following hazard layers used for the loss estimation analysis come from OSHD-1: National Earthquake Hazard Reduction Program (NEHRP) soil classification, peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03), and liquefaction and landslide susceptibility. The liquefaction and landslide susceptibility layers together with PGA were used by the Hazus-MH tool to calculate probability and magnitude of permanent ground deformation.

3.1.3 Countywide results: CSZ

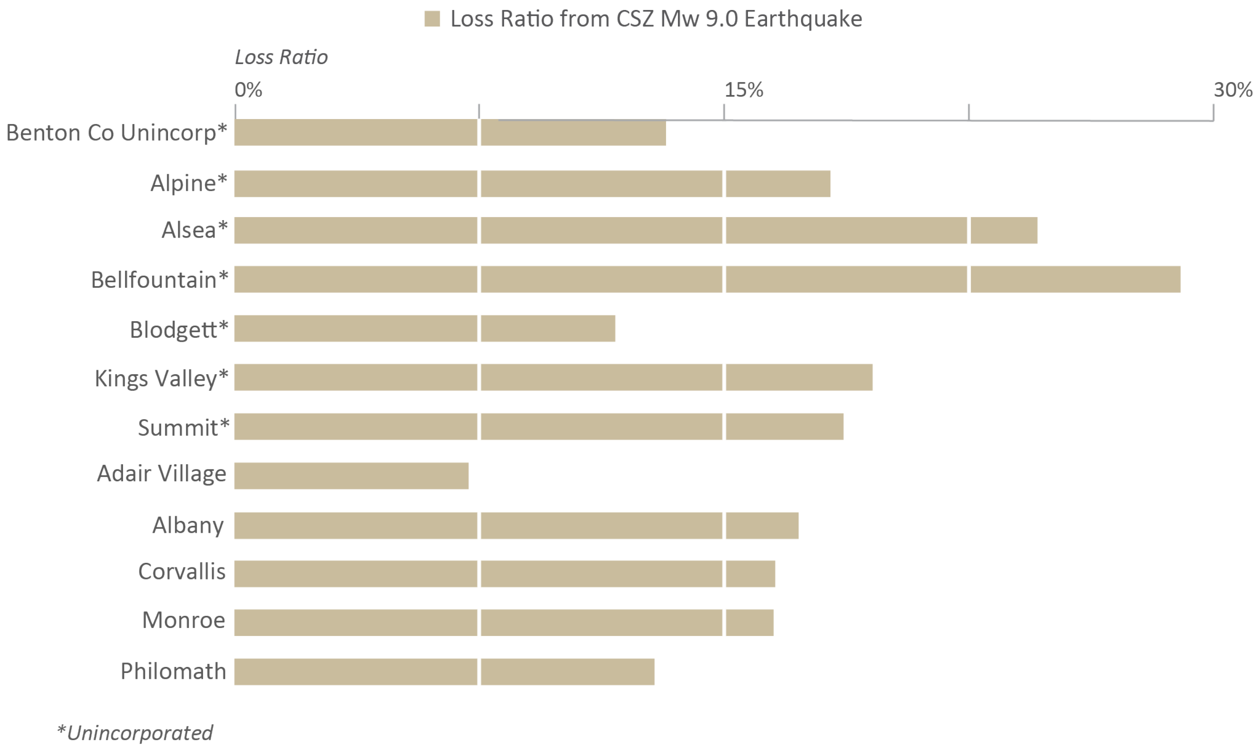
Because an earthquake can affect a wide area, every building in Benton County will be shaken by a CSZ Mw-9.0 earthquake. Hazus-MH loss estimates (see **Table B-2)** for each building are based on a formula where coefficients are multiplied by each of the five damage state percentages (none, low, moderate, extensive, and complete). These damage states are correlated to loss ratios that are then multiplied by the total building replacement value to obtain a loss estimate (FEMA, 2012b). Loss estimates from a CSZ earthquake scenario are presented in **Figure 3-2**.

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

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

The number of potentially displaced residents from our CSZ earthquake scenario was based on the formula: ([Number of Occupants] * [Probability of Complete Damage]) + (0.9 * [Number of Occupants] * [Probability of Extensive Damage]) (FEMA, 2012b).

Figure 3-2. CSZ Mw 9.0 earthquake loss ratio by Benton County community.



The results indicate that Benton County could incur moderate to significant losses (15%) due to a CSZ Mw-9.0 earthquake. Much of the damage is due to soils that amplify seismic shaking. The Willamette River and Marys River floodplains are composed of seismically reactive soils where the majority of the buildings in Benton County are located. Since these soils amplify ground shaking, the probability of earthquake damage is greater for structures built in these areas.

Benton County CSZ Mw-9.0 earthquake results:

- Number of red-tagged buildings: 2,553
- Number of yellow-tagged buildings: 8,936
- Loss estimate: $2,919,744,000
- Loss ratio: 15%
- Non-functioning critical facilities: 79
- Potentially displaced population: 9,505

Although damage caused by coseismic landslides was not specifically looked at in this report, it likely contributes a small amount of the estimated damage from the earthquake hazard in Benton County. Landslide exposure (not to be confused with coseismic landslide analysis) results show that 2.6% of buildings in Benton County are within a very high or high susceptibility zone. We infer that a similar percentage of the total earthquake losses estimated in this study may be due to coseismic landslide.

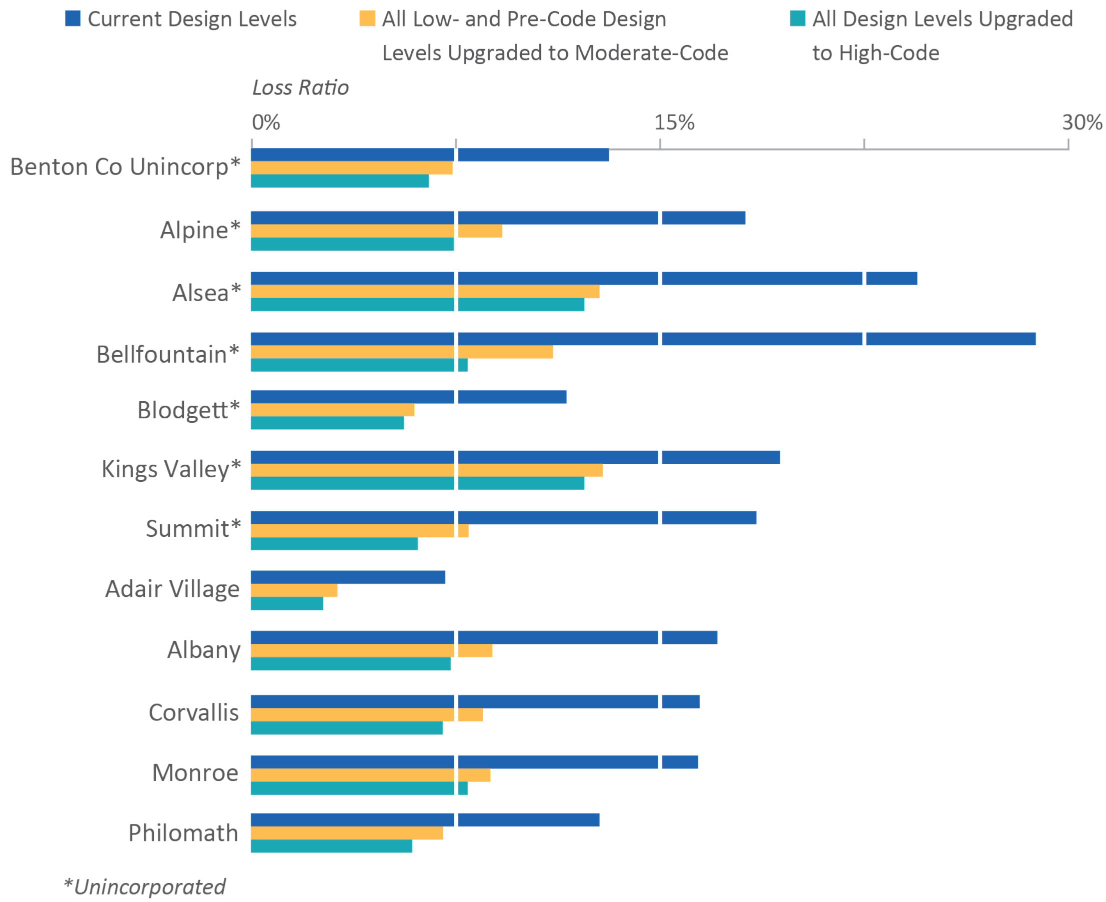
Building vulnerabilities such as the age of the building stock and occupancy type are also contributing factors in loss estimates. The first seismic buildings codes were implemented in Oregon in the 1970's (Judson, 2012) and by the 1990's modern seismic building codes were being enforced. Nearly 75% of Benton County's buildings were built before the 1990's. 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 higher code standards, earthquake risk would be greatly reduced. In this study, a simulation in Hazus-MH earthquake analysis shows that loss ratios drop from 15% to 8%, when all buildings are upgraded to at least moderate code level. While retrofits can decrease earthquake vulnerability, for areas of high landslide or liquefaction susceptibility, additional geotechnical mitigation may be necessary to have an effect on losses. Two simulations of a CSZ Mw-9.0 earthquake where all buildings are upgraded to moderate code standards or to high code standards show significant reductions in loss estimates (**Figure 3-3**).

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 3-3. CSZ Mw-9.0 earthquake loss ratio in Benton County, with simulated seismic building code upgrades.



3.1.4 Data sources: Turner and Mill Creek Fault scenario

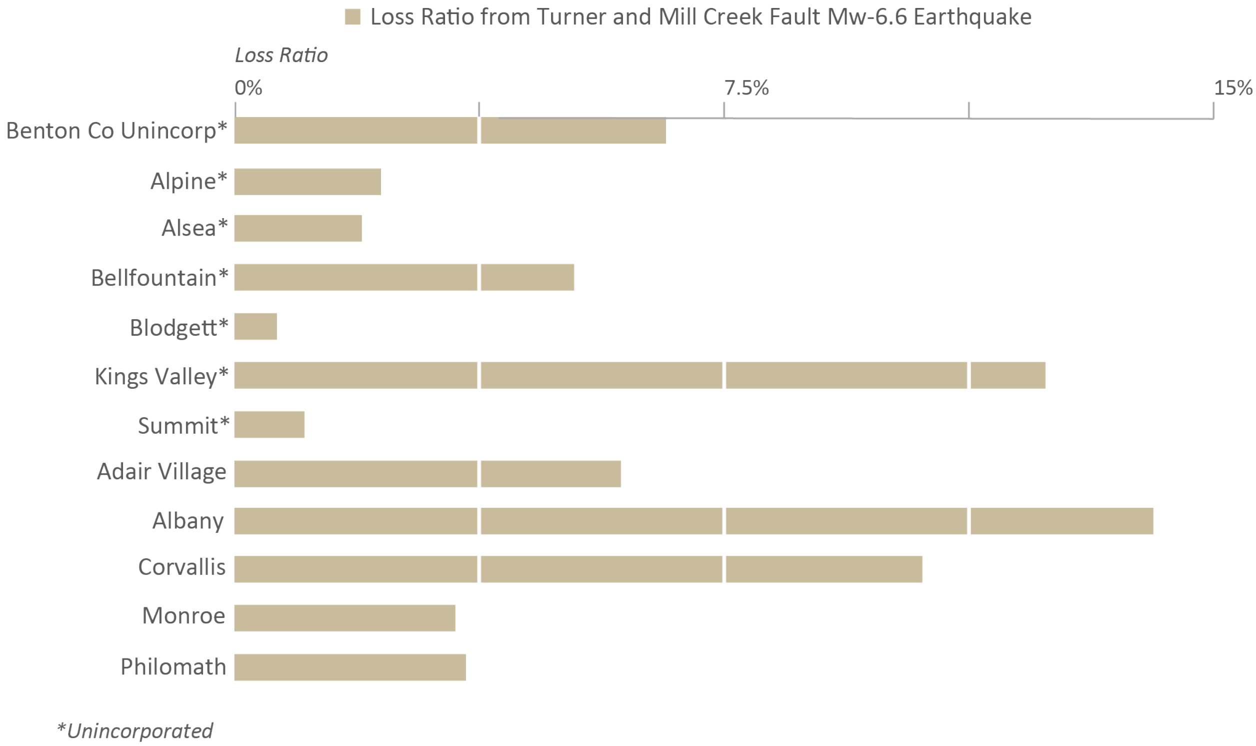
The Mw-6.6 Turner and Mill Creek Fault deterministic scenario was selected as the most appropriate for communicating an alternative earthquake risk for Benton County. The default Hazus-MH earthquake scenario database contained the location and orientation of the fault and provided a recommended maximum magnitude for use in a simulated earthquake event. The epicenter was manually selected and was located at the closest proximity to buildings within the study area.

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, 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-6.6 as the characteristic event.

3.1.5 Countywide results: Turner and Mill Creek Fault scenario

While a CSZ event will cause substantial widespread damage throughout the entire study area, our results indicate a Turner and Mill Creek Fault Mw-6.6 earthquake will cause significant damage (10% - 15% in losses) in the communities in the northeastern portion of the county. Because an earthquake can affect a wide area, it will also cause damage in the other communities in Benton County, but to a lesser degree. **Figure 3-4** shows loss ratios from this earthquake scenario for the communities of Benton County.

Figure 3-4. Earthquake loss ratio from Turner and Mill Creek Fault Mw-6.6 by Benton County community.



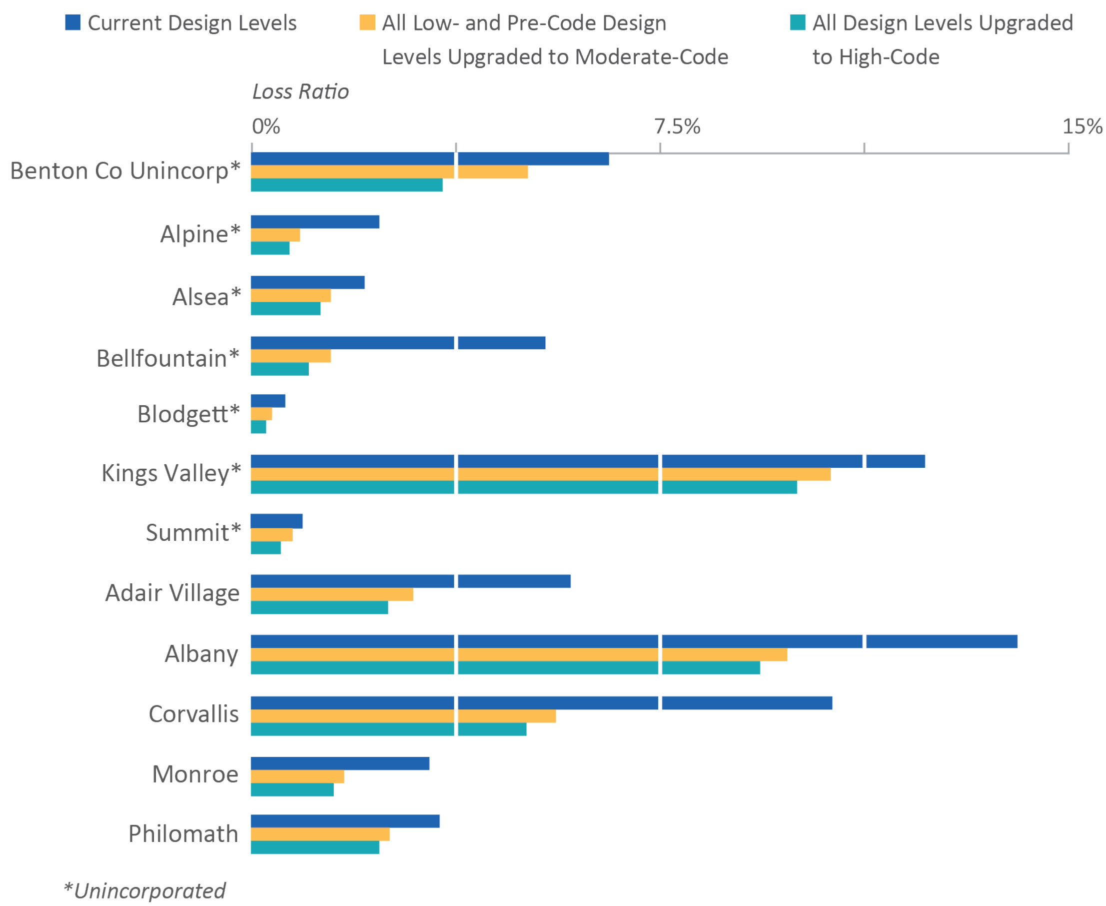
The results indicate that Benton County could incur losses near $2 billion or 10% of their total building assets from a Turner and Mill Creek Fault Mw-6.6 earthquake. These results are strongly influenced by the proximity of buildings to the epicenter of the simulated earthquake. Communities in the northeastern portion of the county are not only close to the epicenter, but also are in areas of highly liquefiable soils. In addition to proximity, liquefaction would exacerbate the level of risk from this earthquake scenario for the communities in this part of the county. We reviewed the results in ArcMap and observed several residential buildings north of Corvallis and west of Highway 99W that have a high risk of damage from this earthquake due to coseismic landslide hazard.

Benton County Turner and Mill Creek Fault Mw-6.6 earthquake results:

- Number of red-tagged buildings: 1,898
- Number of yellow-tagged buildings: 5,956
- Loss estimate: $1,960,037,000
- Loss ratio: 10%
- Non-functioning critical facilities: 37
- Potentially displaced population: 6,774

As with the CSZ earthquake hazard, if buildings could be seismically retrofitted to moderate- or high-code standards, the impact of this event would be greatly reduced. In a simulation by DOGAMI, Hazus-MH earthquake analysis shows that loss estimates drop from 10% to 6.3% when all buildings are brought up to at least moderate-code level. Although these upgrades can decrease earthquake vulnerability, the benefits are minimized in landslide and liquefaction areas, where buildings would need additional geotechnical mitigation to have an effect on losses. **Figure 3-5** illustrates the reduction in loss estimates from a Turner and Mill Creek Fault Mw-6.6 earthquake through two simulations where all buildings are upgraded to at least moderate-code standards and then all buildings to high-code standards.

Figure 3-5. Turner and Mill Creek Mw-6.6 earthquake loss ratio in Benton County, with simulated seismic building code upgrades



3.1.6 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 a Turner and Mill Creek Fault earthquake scenario are likely to incur a significant amount of damage. The communities of Albany, Corvallis, and Kings Valley have the potential for significant losses if this scenario were to occur.
- Buildings along the Willamette River and Marys River are at higher risk from earthquake damage due to significantly higher liquefaction susceptibility.
- An area of residential buildings north of Corvallis and west of the Highway 99W are at risk from earthquake due to coseismic landslide hazard.

- Unreinforced masonry buildings in the older downtown portions of Corvallis and the Oregon State University campus are more vulnerable to substantial damage during an earthquake compared to other nearby structures built to modern standards.
- 70 of the 96 critical facilities in the study area are estimated to be non-functioning due to a CSZ earthquake like the one simulated in this study and 44 are estimated to be non-functioning due to a Turner and Mill Creek Fault earthquake.

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, typically due to excessive rain or snowmelt. 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 Benton 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. More rare 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 advancements, better understanding of hydrologic factors, and longer periods of record for the stream or water body in question.

The major rivers and creeks within the county are the Long Tom, Marys, North Fork Alsea, and Willamette rivers and Dixon, Frazier, Evergreen, Greasy, Oak, Muddy, and Soap creeks. In addition, there are several tributaries to these major streams that have mapped flood zones. All the mapped streams are subject to flooding and could cause damage to buildings in the floodplain.

The impacts of flooding are determined by adverse effects to human activities within the natural and built environment. These adverse impacts can be reduced through mitigation efforts, such as elevating structures above the expected level of flooding or removing structures through FEMA's property acquisition ("buyout") program.

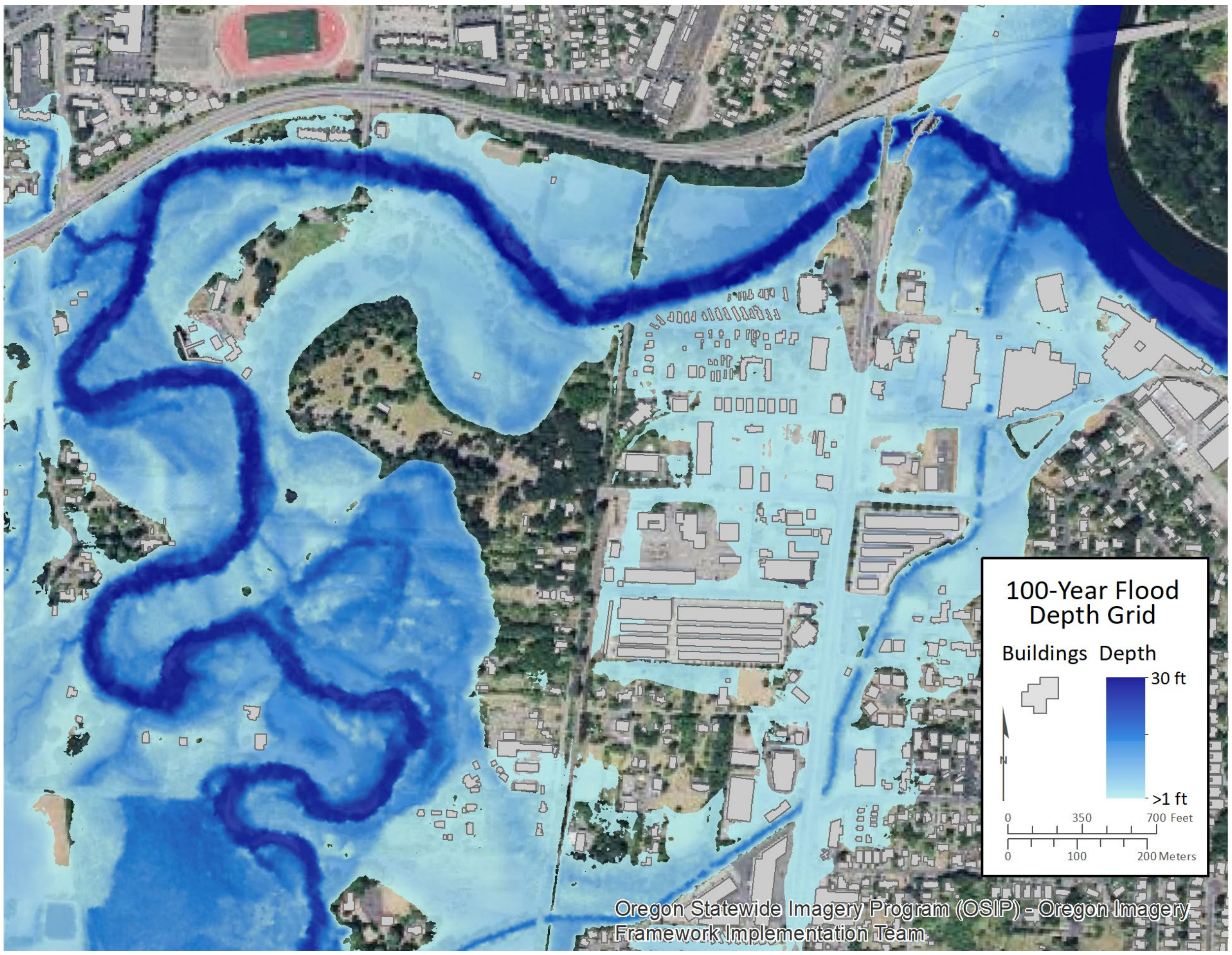
3.2.1 Data sources

The most recent Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) (FEMA, 2016) were used to assess flood risk in this study. Flooding inevitably occurs in areas outside of the detailed mapped areas, however due to limited data availability and variable data resolutions, no other data sources were used in this study. Further information regarding the National Flood Insurance Program (NFIP) related statistics can be found at FEMA's website: https://www.fema.gov/policy-claim-statistics-flood-insurance.

DOGAMI developed the 10-, 50-, 100-, and 500-year depth grids from detailed stream information and high-resolution lidar collected in 2009 and 2012 (Appleby and others, 2021; Willamette Valley 2009 project and Central Coast 2012 project - Oregon Lidar Consortium; see http://www.oregongeology.org/lidar/collectinglidar.htm). The set 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 3-6**). 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 3-6. Flood depth grid example in the city of Corvallis, 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 Benton 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 in this manner for more accurate information on 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 multi-scenario cumulative results.

Benton Countywide 100-year flood loss:

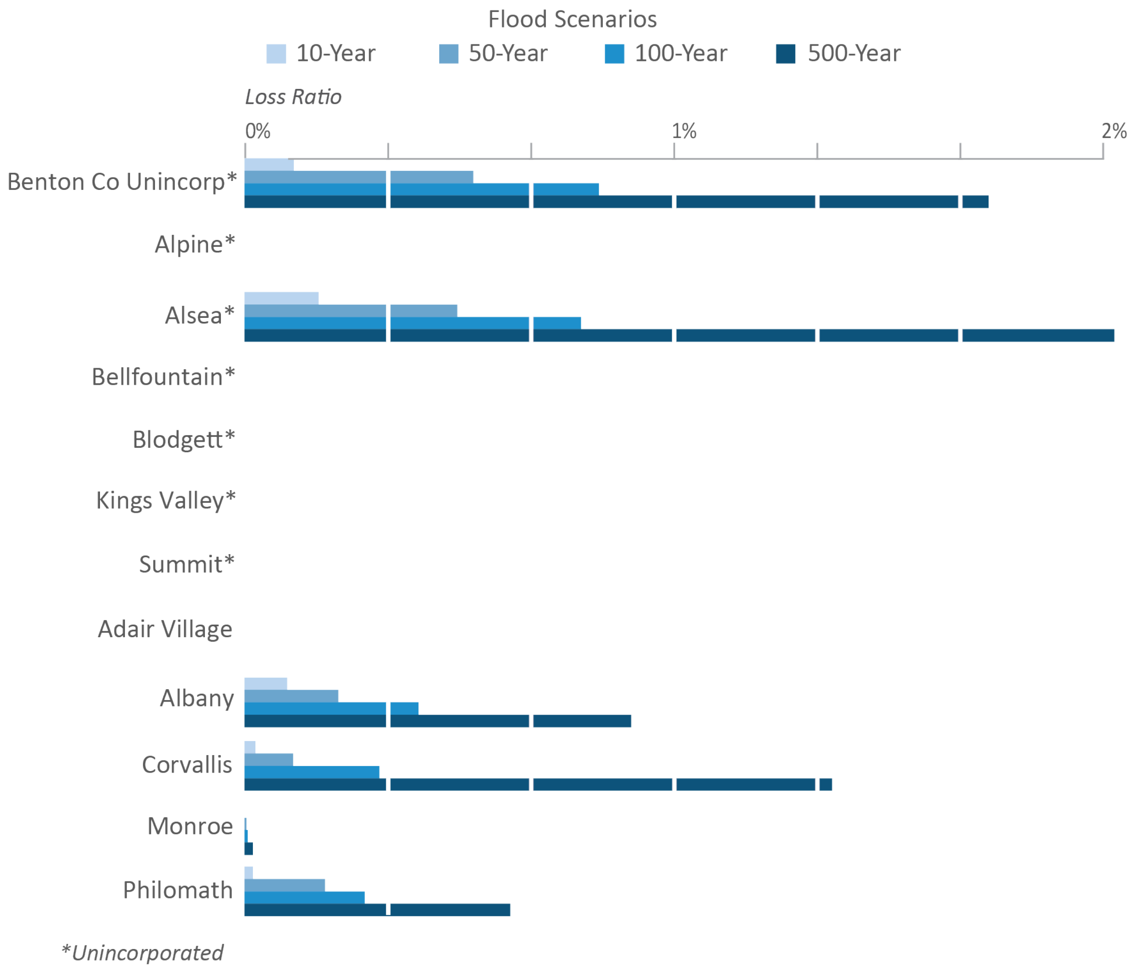
- Number of buildings damaged: 2,067
- Loss estimate: $88,484,000
- Loss ratio: 0.5%
- Damaged critical facilities: 12
- Potentially displaced population: 4,089

3.2.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario for the entire county is over $88 million. While the loss ratio of flood damage for the entirety of Benton County is 0.5%, the impact to areas of development near flood-prone streams is significant (**Figure 3-7**). In 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 information for 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 Benton County are primarily in the areas of Albany, Alsea, and portions of Corvallis. The unincorporated county also has a high level of estimated damage from the major streams and their tributaries that flow through the county (**Figure 3-7**). 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 3-7. Ratio of flood loss estimates by Benton 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 non-damaged buildings from Hazus-MH with the number of exposed buildings in the flood zone. A small proportion (3.7%) of Benton County's buildings were found to be within designated flood zones. Of the 2,298 buildings that are exposed to flooding, we estimate that 301 are above the height of the 100-year flood. This evaluation also estimates that 4,089 residents might have mobility or access issues due to surrounding water. See Appendix B: **Table B-5**for community-based results of flood exposure.

While DFIRM 100-year flood hazard areas include all the studied streams in Benton County and Albany from which the depth grids were derived, the flood hazard zones also include approximate areas of 100-year flooding. These approximate 100-year flood hazard areas are designated as Zone A's on the FEMA DFIRM maps. Since depth grids cannot be created from Zone A information, these areas were excluded from the Hazus flood risk assessment. We included **Table 3-1** to show the exposure of buildings and people to the study area's approximate 100-year flood hazard areas.

Table 3-1. Benton County Zone A exposure.

Community	Total Number of Exposed Buildings	Estimated Exposed Building Value ($)	Total Number of People
Unincorp. Benton Co (rural)	651	142,845,000	615
Alpine	2	105,000	4
Alsea	2	431,000	2
Bellfountain	0	0	0
Blodgett	0	0	0
Kings Valley	31	7,956,000	41
Summit	0	0	0
Total Unincorporated County	686	151,336,000	661
Adair Village	0	0	0
Albany	86	39,393,000	239
Corvallis	95	41,371,000	373
Monroe	16	1,960,000	20
Philomath	23	4,545,000	64
Total Study Area	906	238,605,000	1,357

3.2.5 Areas of significant risk

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

- Many buildings are built within the large floodplain of the Willamette River and are at risk from flood hazard.
- Significant exposure to flooding along the Marys River in the southern portion of Philomath.
- Many buildings in the Thornton Lakes Overflow area of Albany are at risk from flood hazard.
- Many buildings in two areas within Corvallis where Frazier Creek and Marys River confluence with the Willamette River are at high risk from flood hazard.

3.3 Landslide Susceptibility

Landslides are mass movements of rock, debris, or soil most commonly downhill. 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). The most common landslide types in Benton County are debris flows and shallow- and deep-seated landslides.

Because landslides are a site-specific hazard that occur over much smaller spatial extents than most other natural hazards, measuring the risk associated with future landslides for a large area can be difficult. Landslide susceptibility measures the likelihood that a given location will experience a landslide in the future based on a variety of factors including slope, surficial geology, soil type, and the presence of pre-existing landslides.

This study represents our current understanding of landslide susceptibility to measure the risk of landsliding in Benton County. However, changing climate, precipitation patterns, land use, wildfire events, and land and forest management strategies may increase or decrease the susceptibility to landslides.

3.3.1 Data sources

We used the data from the statewide landslide susceptibility map (Burns and others, 2016) and recent landslide inventory mapping in Benton County (Hairston-Porter and others, 2021) (**Figure 3-8**) based on lidar using methods outlined in DOGAMI Special Paper Special Paper 42 (SP-42: Burns and Madin, 2009) for the landslide analysis. The statewide susceptibility layer is an analysis of multiple landslide datasets.

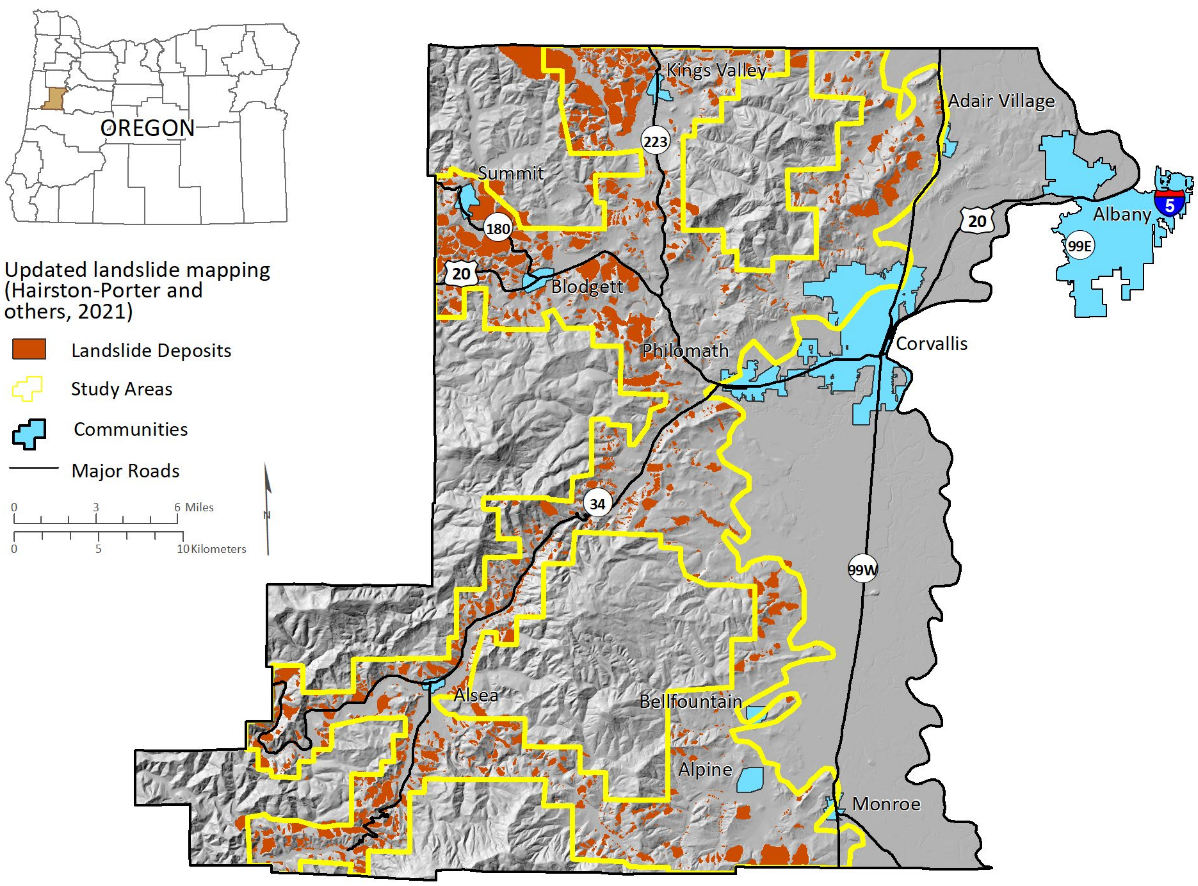
Burns and others (2016) used SLIDO inventory data along with maps of generalized geology and slope to create a landslide susceptibility overview map of Oregon that shows zones of relative susceptibility: Very High, High, Moderate, and Low. Mapped landslides from SLIDO data directly define the Very High landslide susceptibility zone, while SLIDO data coupled with statistical results from generalized geology and slope maps define the other relative susceptibility zones (Burns and others, 2016).

SLIDO, release 3.2 (Burns and Watzig, 2014) was used in the Burns and others (2016) statewide susceptibility analysis, which preceded the new lidar-based inventory mapping of Hairston-Porter and others (2021) and thus this newer mapping was not incorporated into the Statewide Landslide Susceptibility Map.

SLIDO is a compilation of past studies; some studies were completed very recently using new technologies, like lidar-derived topography, and some studies were performed more than 50 years ago. Consequently, SLIDO data vary greatly in scale, scope, and focus and thus in accuracy and resolution across the state. Statewide landslide susceptibility map data have the inherent limitations of SLIDO and of the generalized geology and slope maps used to create the map. Therefore, the statewide landslide susceptibility map varies significantly in quality across the state, depending on the quality of the input datasets. Another limitation is that susceptibility mapping does not include some aspects of landslide hazard, such as runout, where the momentum of the landslide can carry debris beyond the zone deemed to be a high hazard area.

We used the data from the combined Statewide Landslide Susceptibility Map (Burns and others, 2016) and new landslide mapping (Hairston-Porter and others, 2021) in this report to identify the general level of susceptibility of given area to landslide hazards, primarily shallow and deep landslides. We overlaid building and critical facilities data on landslide susceptibility zones to assess the exposure for each community (see **Table B-6**)The total dollar value of exposed buildings was summed for the study area and is reported below. We also estimated the number of people threatened by landslides. Land value losses due to landslides and potentially hazardous unmapped areas that may pose real risk to communities were not examined for this report.

Figure 3-8. Recent landslide mapping in Benton County.



3.3.2 Countywide results

We found that areas along Highway 20 and Route 34 west of Philomath have a high level of exposure to landslide hazard. Communities in terrain with moderate to steep slopes or at the base of steep hillsides may be exposed to landslides. The percentage of building value exposed to very high and high landslide susceptibility is approximately 2.7% for the entire study area.

We combined high and very high susceptibility zones as the primary scenario to provide a general sense of community risk for planning purposes (see Appendix E, **Plate 8**). These susceptibility zones represent areas most susceptible to landslides with the highest impact to the community.

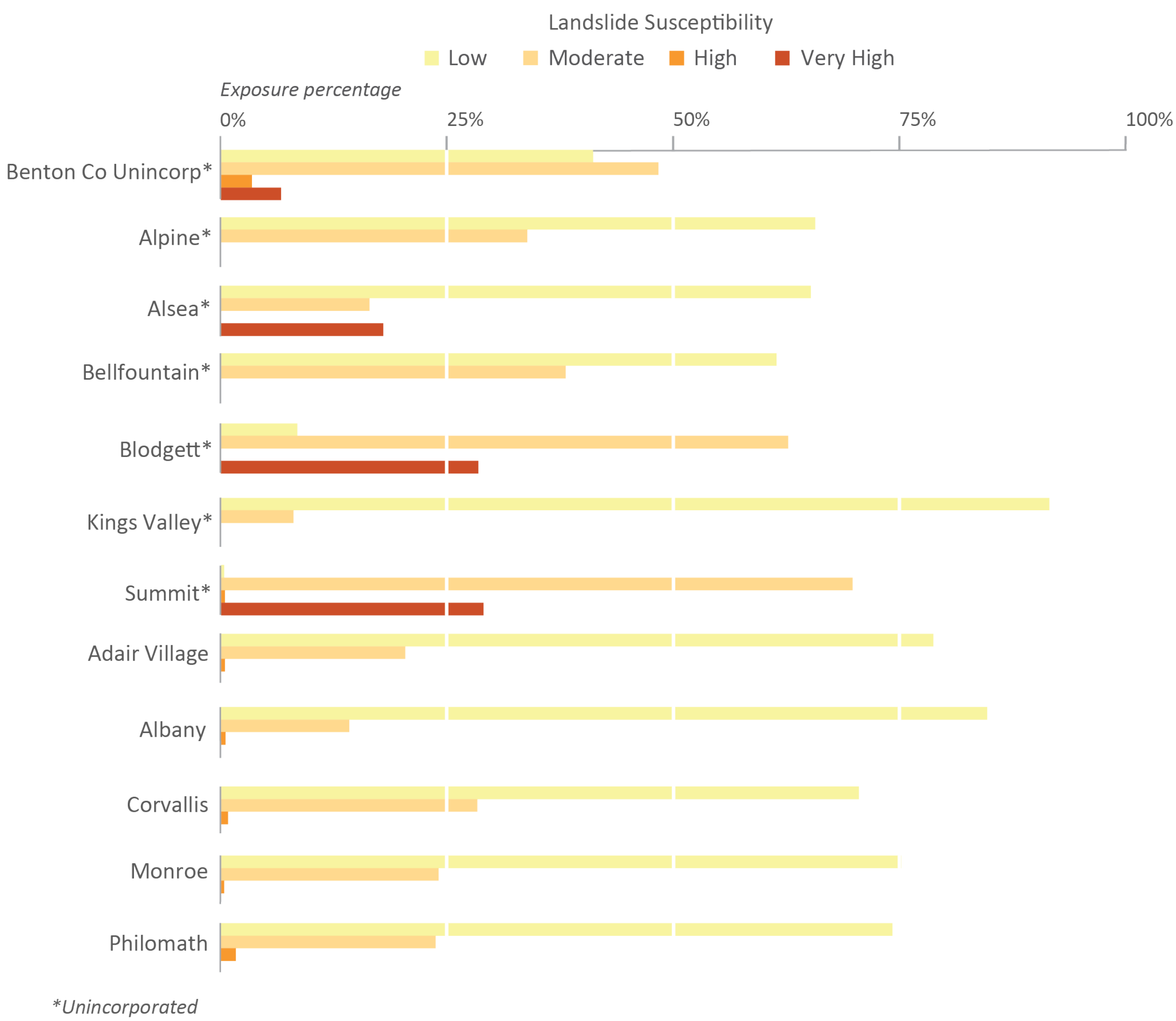
For this risk assessment we compared building locations to geographic extents of the landslide susceptibility zones (**Figure 3-9**). The exposure results shown below are for the high and very high susceptibility zones. See **Appendix B: Detailed Risk Assessment Tables** for exposure analysis results of all susceptibility categories.

Benton Countywide landslide exposure (High and Very High susceptibility):

- Number of buildings: 2,078
- Value of exposed buildings: $496,739,000
- Percentage of total county value exposed: 2.7%
- Critical facilities exposed: 2
- Potentially displaced population: 3,473

Most of the developed land in Benton County is located on the gentle terrain found in the Willamette River Valley, which is predominantly classified as having a low landslide susceptibility. However, there are developed areas just north and west of Corvallis that are highly susceptible to landslide hazard. Landslide hazard is also ubiquitous in the western portion of Benton County which may present challenges for planning and mitigation efforts. Awareness of nearby areas of landslide hazard is beneficial to reducing risk for every community and rural area of Benton County.

Figure 3-9. Landslide susceptibility exposure by Benton 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:

- Buildings in the unincorporated county along Highway 20 and Route 34 are within very high and high risk landslide zones.
- The communities of Alsea, Blodgett, and Summit, in the mountainous western part of the county, have a significant amount of exposure to High and Very High landslide hazard.
- Several residential buildings north of Corvallis and west of Highway 99W are within very high and high risk landslide zones.

3.4 Channel Migration

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 have 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 a river to dissipate its energy and deposit sediment over a wider area (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 through erosion and flooding. 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).

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.

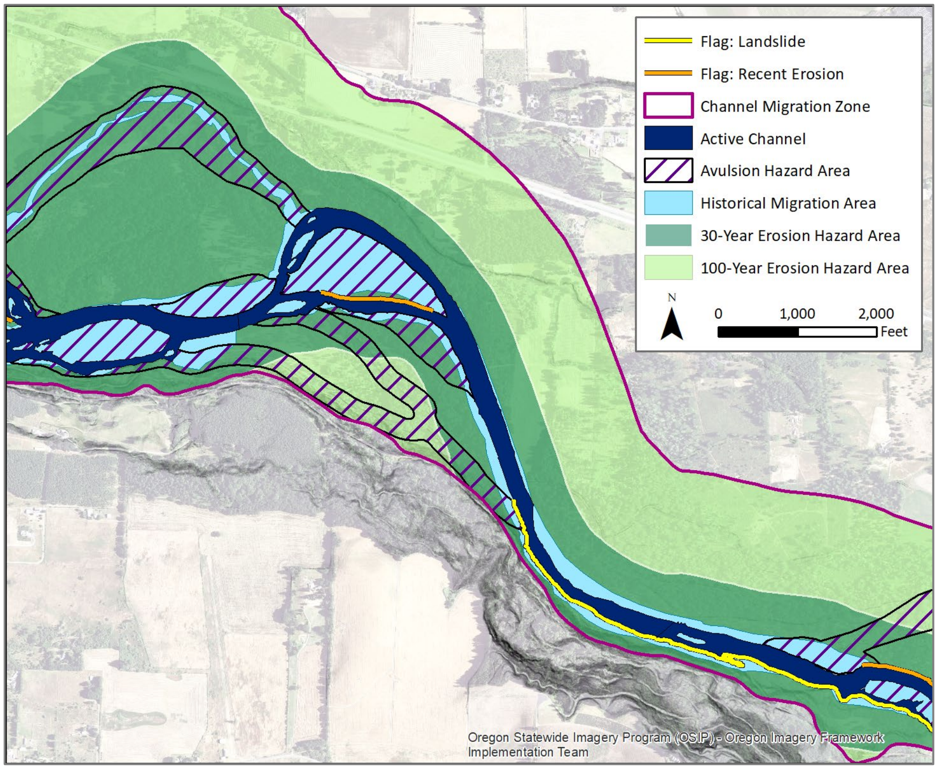
3.4.1 Data sources

The channel migration zones used for this report were developed by Appleby and others (2021) for the North Fork Alsea River and Marys River. DOGAMI's CMZ mapping considers areas of historical channel migration as well as, potential future 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 CMZ is subdivided into seven components: the active channel, historical migration area, 30-year and 100-year erosion hazard areas, the avulsion hazard area, and flagged section of streambank that are actively eroding or adjacent to landslides (**Figure 3-10**). The methodology for calculating each component and how they are combined are described in Appleby and others (2021).

It is important to note that the total study area in Benton County for channel migration hazard is limited to the North Fork Alsea River and Marys River. These study areas do not encompass the totality of the channel migration hazard that could be present within the county. Structures built in proximity to waterways are potentially at risk to channel migration hazard even if not within a studied hazard area.

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. The following section presents the estimated total dollar value of exposed buildings and the number of people potentially displaced from the 30-year CMZ. Land value losses due to CMZ were not examined for this report.

Figure 3-10.Example diagram of the components of a CMZ map in Oregon, 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

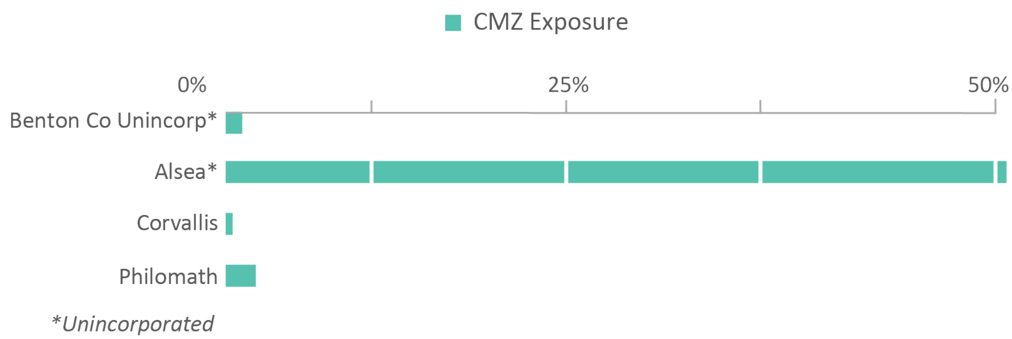
Mapped channel migration areas along the North Fork Alsea River and Marys River show a very high level of risk from this hazard for many communities along either watercourse. To quantify risk, the exposure analysis was conducted by determining which buildings were within or outside of the CMZ (see Appendix E: **Plate 9**). Due to the frequency of shifting channel patterns in streams, channel migration can be a serious hazard in areas close to stream regardless of if they have been mapped as a hazard or not.

Benton County channel migration exposure (100-year Erosion Hazard Area):

- Number of buildings: 402
- Value of exposed buildings: $96,427,000
- Percentage of total county value exposed: 0.8%
- Critical facilities exposed: 3
- Potentially displaced population: 454

A significant number of buildings in Alsea and the southern portion of Philomath are within areas where channel migration is likely to occur. Nearly half of the buildings in Alsea are within the 30-year erosion hazard zone. **Figure 3-11** presents the estimated total building value at risk from channel migration for the communities of Alsea, Corvallis and Philomath. See **Appendix B: Detailed Risk Assessment Tables** for complete analysis results.

Figure 3-11. 30-year erosion hazard exposure by Benton County community within the study area of Appleby and others (2021).



Note: Communities in figure limited to communities within the study area of Appleby and others (2021).

3.4.3 Areas of significant risk

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

- A significant portion (>50%) of the buildings in Alsea are at risk from channel migration hazard from the North Fork Alsea River.
- The southern part of Philomath is within the 100-year channel migration zone from the Marys River.

3.5 Wildfire

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

The 2016 Benton County Community Wildfire Protection Plan (BCCWPP) recommended that the county develop policies addressing fire restriction enforcement, wildland urban interface standards, and building code enforcement related to emergency access. Forests cover large portions of the study area and play an important role in the local economy, but also surround homes and businesses (BCCWPP, 2016). Contact the Benton County Planning Department for specific requirements related to the county's comprehensive plan.

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.

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, the burn probability dataset, a dataset included in the PNRA database, was used to measure the risk to communities in Benton County.

Using guidance from ODF, we categorized the Overall Wildfire Risk dataset into low, moderate, and high-hazard zones for the wildfire exposure analysis. Overall Wildfire Risk was developed as a combination of burn probability and the presence of infrastructure and assets. The range of values in the risk dataset describe the level of potential impact and are characterized by negative values that indicate very high risk to zero which indicates low risk. The risk dataset also includes positive values that represent uninhabited areas that benefit from wildfire, but these were combined into the low-risk category (Gilbertson-Day and others, 2018). In many areas with moderate to dense development there are no pixel values, which indicates an Overall Wildfire Risk of none.

Overall Wildfire Risk values were grouped into three hazard categories:

- Low wildfire hazard (-0.000011 to 0.005)
- Moderate wildfire hazard (-0.000119 to -0.000011)
- High wildfire hazard (-0.203 to -0.000119)

We overlaid the buildings layer and critical facilities 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 losses, infrastructure, and environmental impacts due to wildfire were not examined for this project.

3.5.2 Countywide results

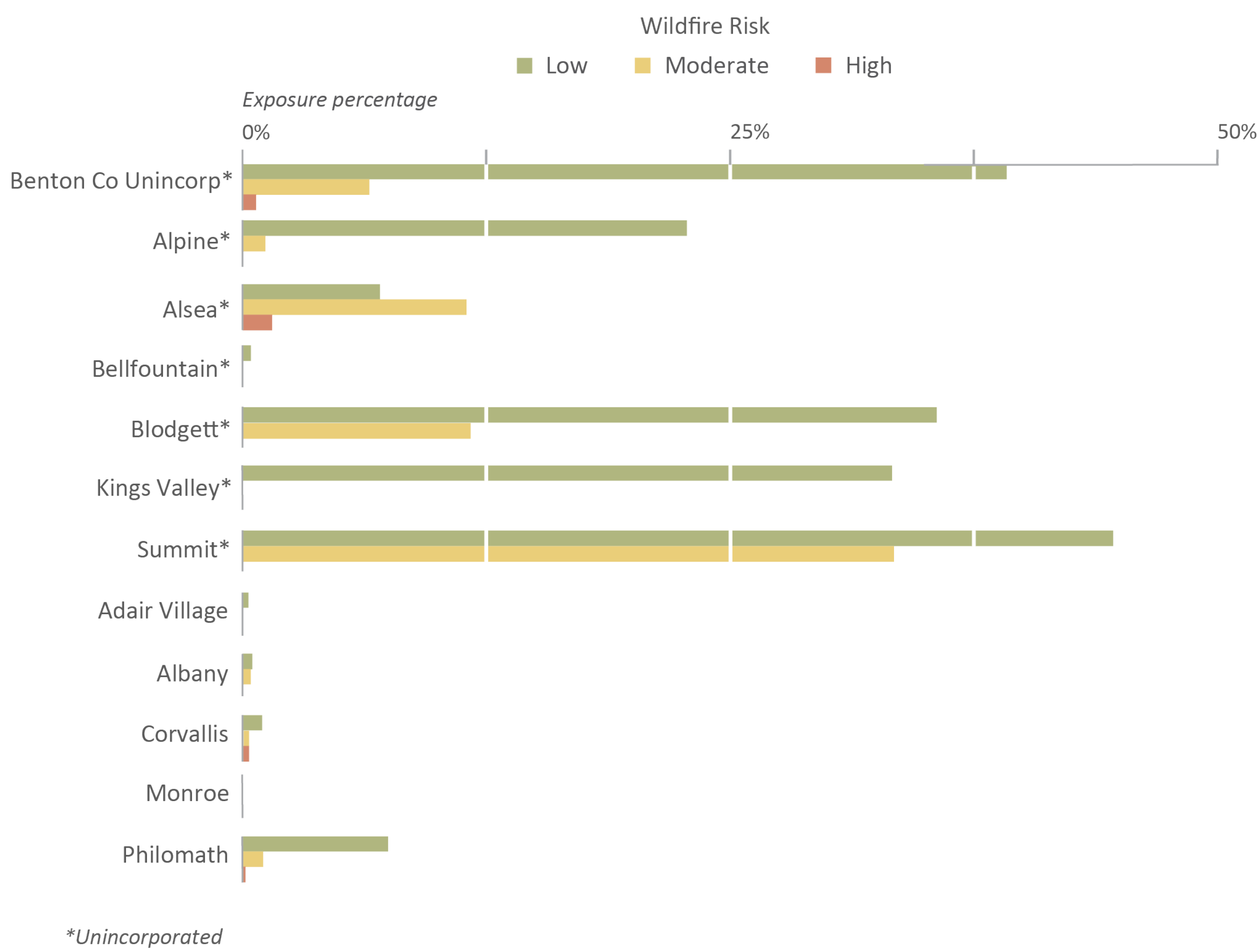
The High risk category was chosen as the primary scenario for this report because it represents areas that have the highest potential for losses. However, Low risk is not the same as no hazard. Moderate wildfire risk is included with High risk in the assessment of exposure, because under certain conditions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

Benton Countywide wildfire exposure (High or Moderate Risk):

- Number of buildings: 1,777
- Value of exposed buildings: $481,260,000
- Percentage of total county value exposed: 2.5%
- Critical facilities exposed: 2
- Potentially displaced population: 3,369

For this risk assessment, the building locations were compared to the geographic extent of the wildfire risk categories. One hundred buildings in the heavily forested unincorporated parts of western Benton County are exposed to High or Moderate wildfire hazard (see Appendix E: **Plate 10**). Portions of heavily forested areas in western Benton County, where the communities of Alsea, Blodgett, and Summit are located, have the highest percentage of exposure to High and Moderate wildfire hazard within the study area. **Figure 3-12** illustrates the level of risk from wildfire for the different communities of Benton County. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Figure 3-12. Wildfire Risk exposure by Benton 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:

- While the overall probability of wildfire hazard in Benton County is low, it is still a possibility, especially in the heavily forested unincorporated parts of the county. Nearby wildfire prone areas also pose a risk related to evacuation routes and hazardous smoke.
- The communities of Alsea, Blodgett, and Summit have a higher risk to wildfire than other communities in the county.
- In Albany, Corvallis, and Philomath, structures built in the WUI are at elevated risk from wildfire relative to structures in areas more densely developed.
- Moderate to high risk of wildfire exists for the forested northern parts of the unincorporated 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 Benton County can occur from a CSZ Mw-9.0 earthquake—**Based on the results of the CSZ Mw-9.0 earthquake, every community in Benton County will experience significant impact and disruption from such an event. Results show that this earthquake could cause building value losses ranging from 10% to 30% across all communities. Many buildings along the Willamette River and Marys River floodplains could see earthquake damage due to ground deformation related to liquefaction. High vulnerability within the building inventory (primarily unreinforced masonry) also contributed to losses expected in the county.
- **Significant damage and losses for some areas in Benton County can occur from a Turner and Mill Creek Fault earthquake** — Based on the results of a Turner and Mill Creek Fault Mw-6.6 earthquake, some communities in Benton County will experience significant impact and disruption. Results show that an earthquake can cause building losses ranging from 10% to 15% for buildings in the northeastern part of Benton County. Some communities like Corvallis, Kings Valley, and Albany can expect earthquake damage due to proximity to the epicenter (i.e., severe shaking) and ground deformation related to liquefaction. High vulnerability within the building inventory (primarily 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 15% to 8% for a CSZ event and 10% to 6.3% for a Turner and Mill Creek Fault event. 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 Corvallis could reduce losses from 16% to 8% for a CSZ event and 9.2% to 5.4% for a Turner and Mill Creek Fault event by retrofitting all

buildings to at least moderate code. While seismic retrofits are an effective strategy for reducing earthquake shaking damage, it should be noted that earthquake-induced liquefaction hazards will also be present in areas along the Willamette River and Marys 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 other hazards we examined. This is likely due to the difference between the type of results from loss estimation and exposure analysis, as well as the limited area impacted by flooding. Flooding is one of the most frequently occurring natural hazards and thus commonly has repetitive losses which occur with recurrence intervals of 10s to 100s of years versus earthquake hazards with recurrence intervals of 100s to thousands of years. We estimate that an average of 12% building value loss occurs for buildings within the 100-year flood zone. The areas most vulnerable to flood hazard within the study are buildings along the Willamette River, the Thornton Lakes Overflow near Albany, and where the Frazier Creek and Marys River confluences with the Willamette River in Corvallis.
- **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, in the city of Corvallis an estimated 171 buildings exposed to flooding are elevated above the base flood elevation (BFE). Based on the number of buildings exposed to flooding throughout the county, many would benefit from elevating above the level of flooding.
- **Landslide risk 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 very accurate landslide hazard maps. We used exposure analysis to assess the threat from landslide hazards. The developed areas along highway 20 and route 34, a residential area north of Corvallis, and communities in the mountainous western part of the county (Alsea, Blodgett, and Summit) are highly susceptible to landslide hazards. Nearly 30% of the buildings in Blodgett and Summit 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 to channel migration hazard**—Exposure analysis shows that channel migration hazard is a threat to communities and buildings along the Marys River and North Fork Alsea River. The community of Alsea has very high risk from channel migration hazard, with approximately half of the buildings exposed to the hazard.
- **Wildfire risk is higher in the wildland-urban interface portions of the county**—Exposure analysis shows that buildings in rural northern portions of the county are at higher risk from wildfire than other areas in the county. The forested and less populated northern and western portions of the county correspond to high and moderate wildfire hazard. The communities of Alsea, Blodgett, and Summit have the highest risk from wildfire compared to other communities in the county. Over 6% 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 a CSZ event 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 have estimated that 73% (70 of 96) of Benton County's critical facilities will be non-functioning after a CSZ Mw-9.0 earthquake and 38% (36 of 96) will be non-functioning after a Turner and Mill Creek Fault Mw-6.6 earthquake. We found that 10 critical facilities are exposed to flood hazard.

- **The biggest causes of displacement to population are earthquake, flood, and landslide hazards**—Potential displacement of permanent residents from natural hazards was estimated within this report. We estimated that there is risk to 16% of the population in the county from a CSZ Mw-9.0 earthquake and 11% from a Turner and Mill Creek earthquake. Flood hazard is a potential threat to 6.7% of permanent residents and are vulnerable to displacement. Landslide hazard is a potential threat to 5.7% of permanent residents and are vulnerable to displacement. A small percentage of residents are vulnerable to displacement from 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 of 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** – With the exception of earthquakes, other hazards like flood, landslide, channel migration, and wildfire are extremely unlikely to occur across the fully mapped extent of the hazard zones. 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 an entire community. While we report the overall impacts of a given hazard scenario, the losses from a single hazard event probably will not be as severe and widespread.
- **Loss estimation for individual buildings** – Hazus-MH is a model, not reality, which is an important factor when considering the loss ratio of an individual building. On-the-ground mitigation, such as elevation of buildings to avoid flood loss, has been only minimally captured. Also, due to a lack of building material information, assumptions were made about the distribution of wood, steel, and un-reinforced masonry buildings. Loss estimation is most insightful when individual building results are aggregated to the community level because it reduces the impact of data outliers.
- **Loss estimation versus exposure** – We recommend careful interpretation of exposure results. This is due to the spatial and temporal variability of natural hazards (described above) and the inability to perform loss estimations due to the lack of Hazus-MH damage functions. Exposure is reported in terms of total building value, which could imply a total loss of the buildings in a particular hazard zone, but this is not the case. Exposure is simply a calculation of the number of buildings and their value and does not make estimates about the level to which an individual building could be damaged.

- **Population variability** – Some of the communities in Benton County have vacation homes and rentals, which are typically occupied during the summer. Our estimates of potentially displaced people rely on permanent populations published in the 2020 U.S. Census (United States Census Bureau, 2020b) and 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 assessment 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 was 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.
- **Changing Conditions** – This assessment did not account for potential changes in climate, land use, or population; it is a snapshot of Benton County's current risk from natural hazards. Human-induced climate change poses a significant and widespread risk to people around the world. In Oregon, climate change is expected to impact the frequency and intensity of floods, wildfires, and landslides, but quantifying this impact was beyond the scope of this study.

6.0 RECOMMENDATIONS

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

6.1 Awareness and Preparation

Natural hazard awareness is crucial to lowering risk and lessening the impacts of natural hazards. When community members understand their risk and know the role that they play in preparedness, the community will become a much safer place to live. Awareness and preparation not only reduce the initial impact from natural hazards, but they also reduce the time a community needs to recover from a disaster, 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 partnering with local officials in the development of additional effective resources could help reach a broader community and user groups.

6.2 Planning

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

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

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

6.3 Emergency Response

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

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

6.4 Mitigation Funding Opportunities

Several state and federal funding options are available to communities that are susceptible to natural hazards and have specific cost-effective mitigation projects they wish to accomplish. 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. OEM has produced a document that can assist local officials in applying for mitigation funds (https://www.oregon.gov/OEM/Documents/Oregon_Hazard_Mitigation_Grant_Program_Handbook.pdf).

At the time of writing this report, FEMA has five programs that assist with mitigation funding for natural hazards: Hazard Mitigation Grant Program (HMGP), HMGP Post-Fire Assistance, Pre-Disaster

Mitigation (PDM) Grant Program, Building Resilient Infrastructure and Communities (BRIC) grant program, and Flood Mitigation Assistance (FMA) (https://www.fema.gov/grants/mitigation). 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 73% of critical facilities (**Appendix A: Community Risk Profiles**) will be damaged by a CSZ earthquake scenario described in this report, which will have many direct and indirect negative effects on first-response and recovery efforts.
- Identify communities and buildings that would benefit from seismic upgrades.

6.5.2 Flood

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

6.5.5 Channel migration

- Future development in areas with the largest CMZs, particularly Marys River and North Fork Alsea River, could incorporate 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 multi-purpose including areas that provide or improve flood water storage, riparian and aquatic habitat restoration, climate change resilience, and water quality.

7.0 ACKNOWLEDGMENTS

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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, we provide a list of critical facilities (**in bold**) and other community lifelines with each of their risk to hazard examined in this study indicated by an "X".

A.1 Unincorporated Benton County (Rural)

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

Community Overview

Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Unincorporated Benton County (rural)	20,766	16,331	15	3,934,253,000

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	828	4.0%	842	2	34,480,000	0.9%
Earthquake	CSZ Mw-9.0 Deterministic	806	3.9%	2,982	10	506,585,000	13%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	338	1.6%	1343	0	264,564,000	6.7%

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	2,516	12.1%	1,729	0	398,676,000	10%
Channel Migration	Channel Migration Zone	258	1.2%	254	0	53,663,000	1.4%
Wildfire	High and Moderate Risk	1,740	8.4%	1,172	0	250,624,000	6.4%

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

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

Table A-2. Unincorporated Benton County (rural) critical facilities and other lifelines.

Critical Facilities and Lifelines by Community	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
	Exposed	>50% Prob.	>50% Prob.	Exposed	Exposed	Exposed
Adair Village STP	-	X	-	-	-	-
Alsea Food Bank	-	X	-	X	-	-
Alsea Gleaners	-	X	-	-	-	-
Camp Adair	-	X	-	-	-	-
Corvallis Locke Fire Station	-	-	-	-	-	-
Corvallis Municipal Airport	-	X	-	-	-	-
Corvallis Waldorf School	-	X	-	-	-	-
Crescent Valley High School	X	X	-	-	-	-
Fir Grove Primary School	-	X	-	-	-	-
Flying Tom Landing Strip	-	-	-	-	-	-
Hoskins - Kings Valley RFPD	-	-	-	-	-	-
Lobster Valley Church of Christ	-	-	-	X	-	-
Mountain View Elementary School	-	X	-	-	-	-
Muddy Creek Charter School	-	X	-	-	-	-
ODF Fire Station	-	X	-	-	-	-
Philomath Fire and Rescue Station 202	-	-	-	-	-	-
Philomath Fire and Rescue Station 203	-	-	-	-	-	-
Philomath Wastewater Treatment Plant	X	X	-	-	-	-
Rock Creek Water Treatment	-	-	-	-	-	-
The Alsea Fellowship Church	-	-	-	-	-	-
The Alsea Hope Grange	-	X	-	-	-	-
Wren substation	-	-	-	-	-	-

A.2 Unincorporated Community of Alpine

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

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Alpine		205	161		3		26,781,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake	CSZ Mw-9.0 Deterministic	22	10.7%	49	2	4,763,000	18%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	1	0.6%	3	0	522,000	1.9%
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	0	0%	0	0	0	0%
Wildfire	High and Moderate Risk	4	2.0%	2	0	291,000	1.1%

[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-4. Unincorporated community of Alpine critical facilities and other lifelines.

	Flood 1% Annual Chance	**CSZ 9.0 Earthquake Moderate to Complete Damage**	**Turner and Mill Creek 6.6 Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High or Moderate Risk**
Critical Facilities and Lifelines by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**
Alpine School	-	X	-	-	-
Alpine Wastewater	-	-	-	-	-
Monroe Fire Department Station 1	-	X	-	-	-

A.3 Unincorporated Community of Alsea

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

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Alsea	216	137	3	30,315,000

Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	17	7.7%	17	1	252,000	0.8%
Earthquake	CSZ Mw-9.0 Deterministic	45	21.0%	62	1	7,268,000	24%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	1	0.4%	4	0	531,000	1.8%

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	66	30.5%	32	1	5,466,000	18%
Channel Migration	Channel Migration Zone	79	37%	50	3	16,937	56%
Wildfire	High and Moderate Risk	28	13%	18	1	3,683,000	12%

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

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

Table A-6. Unincorporated community of Alsea critical facilities and other lifelines.

	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
Critical Facilities and Lifelines by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Alsea Community School	X	X	-	-	X	X
Alsea Health Center	-	-	-	-	-	-
Alsea Public Library	-	-	-	X	-	-
Alsea substation	-	-	-	-	X	-
Alsea RFPD	-	-	-	-	X	-

A.4 Unincorporated Community of Bellfountain

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

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Bellfountain	82	59	2	14,814,000

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 Mw-9.0 Deterministic	3	3.9%	17	2	4,184,000	28%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	0	0%	2	0	674,000	4.6%

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	0	0%	0	0	0	0%
Wildfire	High and 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-8. Unincorporated community of Bellfountain critical facilities and other lifelines.

	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High or Moderate Risk
Critical Facilities and Lifelines by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**
Bellfountain Cornerstone Christian School	-	X	-	-	-
Monroe Fire Station 3	-	X	-	-	-

A.5 Unincorporated Community of Blodgett

Table A-9. Unincorporated community of Blodgett hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Blodgett	67	53	2	11,186,000

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 Mw-9.0 Deterministic	8	12.0%	16	0	1,271,000	11%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	0	0%	0	0	58,000	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	36	53.7%	22	1	3,195,000	29%
Wildfire	High and Moderate Risk	4	6.0%	3	0	1,282,000	11%

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

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

Table A-10. Unincorporated community of Blodgett critical facilities and other lifelines.

	Flood 1% Annual Chance	**CSZ 9.0 Earthquake Moderate to Complete Damage**	**Turner and Mill Creek 6.6 Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High or Moderate Risk**
Critical Facilities and Lifelines by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**
Blodgett Elementary	-	-	-	X	-
Blodgett Summit FD Station 600	-	-	-	-	-

A.6 Unincorporated Community of Kings Valley

Table A-11. Unincorporated community of Kings Valley hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Kings Valley	90	85	1	17,918,000

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 Mw-9.0 Deterministic	12	13.3%	28	1	3,412,000	19%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	4	4.6%	18	0	2,214,000	12%

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	0	0%	0	0	0	0%
Wildfire	High and 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-12. Unincorporated community of Kings Valley critical facilities and other lifelines.

	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High or Moderate Risk
Critical Facilities and Lifelines by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**
Kings Valley Charter School	-	X	-	-	-

A.7 Unincorporated Community of Summit

Table A-13. Unincorporated community of Summit hazard profile and other lifelines.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Summit		113	96		1	20,026,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake	CSZ Mw-9.0 Deterministic	12	10.7%	18	1	3,641,000	18%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	0	0%	1	0	177,000	0.9%
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	40	35.7%	38	0	5,921,000	30%
Wildfire	High and Moderate Risk	26	23%	20	1	6,884,000	34%

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

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

Table A-14. Unincorporated community of Summit critical facilities.

Critical Facilities and Lifelines by Community	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High or Moderate Risk
	Exposed	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**
Blodgett-Summit RFPD Station 2	-	X	-	-	X

A.8 City of Adair Village

Table A-15. City of Adair Village hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Adair Village		1,319	277		3		107,166,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake	CSZ Mw-9.0 Deterministic	12	0.9%	18	3	7,486,000	7.0%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	14	1%	18	0	5,822,000	5.4%
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	12	0.9%	2	0	497,000	0.5%
Wildfire	High and 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-16. City of Adair Village critical facilities and other lifelines.

Critical Facilities and Lifelines by Community	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High or Moderate Risk
	Exposed	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**
Adair City Hall	-	X	-	-	-
Adair Rural Fire and Rescue	-	X	-	-	-
Santiam Christian School	-	X	-	-	-
Village Christian Church	-	X	-	-	-

A.9 City of Albany

Table A-17. City of Albany hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Albany	57,200	23,941	34	7,033,549,000	

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	964	1.7%	509	1	28,271,000	0.4%
Earthquake	CSZ Mw-9.0 Deterministic	2,457	4.3%	4,512	21	1,159,096,000	17%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	2,900	5.1%	4,309	19	1,011,785,000	14%

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	151	0.3%	75	0	17,700,000	0.3%
Wildfire	High and 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-18. City of Albany critical facilities.

Critical Facilities and Lifelines by Community	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High or Moderate Risk
	Exposed	>50% Prob.	>50% Prob.	Exposed	Exposed
Albany-Millersburg WRF	X	X	X	-	-
Albany Armory	-	X	X	-	-
Albany Christian School	-	-	-	-	-
Albany Fire Dept. Station 11	-	-	-	-	-
Albany Fire Dept. Station 12	-	X	-	-	-
Albany Fire Dept. Station 13	-	-	-	-	-
Albany Fire Dept. Station 14	-	-	-	-	-
Albany Maintenance Station	-	X	X	-	-
Albany Options School	-	-	-	-	-
Albany Police Department	-	X	-	-	-
Albany Public Works	-	X	X	-	-
Central Elementary	-	X	X	-	-
Circle of Friends Learning Center	-	X	X	-	-
First United Methodist Early Learning Center	-	-	-	-	-
Good Shepherd Lutheran School	-	-	-	-	-
Lafayette Elementary	-	X	X	-	-
Liberty Elementary	-	X	X	-	-
Linn County Road Department	-	X	-	-	-
Memorial Middle School	-	X	X	-	-
North Albany Elementary School	-	X	X	-	-
North Albany Middle School	-	X	X	-	-
Oak Elementary	-	X	X	-	-
Periwinkle Elementary	-	X	X	-	-
Samaritan Albany General Hospital	-	X	X	-	-
South Albany High School	-	-	-	-	-
South Shore Elementary	-	X	X	-	-
St Marys Catholic School	-	-	-	-	-
Standard Christian School	-	-	-	-	-
Sundborn Montessori School	-	-	-	-	-
Sunrise Elementary	-	-	-	-	-
Takena Elementary	-	X	X	-	-
Timber Ridge School	-	-	X	-	-
Waverly Elementary	-	X	X	-	-
West Albany High School	-	X	X	-	-

A.10 City of Corvallis

Table A-19. City of Corvallis hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Corvallis	57,718	17,509	33	7,132,168,000	

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	2,036	3.5%	603	3	23,743,000	0.3%
Earthquake	CSZ Mw-9.0 Deterministic	5,881	10.2%	3,295	26	1,131,548,000	16%
Earthquake	Turner and Mill Creek Fault Mw-6.6 Deterministic	3464	6%	2040	15	649,732,000	9.1%

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	538	0.9%	146	0	55,189,000	0.8%
Channel Migration	Channel Migration Zone	100	0.2%	61	0	11,280,000	0.2%
Wildfire	High and Moderate Risk	1,270	2.2%	376	0	174,380,000	2.4%

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

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

Table A-20. City of Corvallis critical facilities and other lifelines.

Critical Facilities and Lifelines by Community	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
	Exposed	>50% Prob.	>50% Prob.	Exposed	Exposed	Exposed
Adams Elementary School	-	X	X	-	-	-
Ashbrook Independent School	-	-	-	-	-	-
Benton Center	-	X	-	-	-	-
Benton County Circuit Court	-	X	X	-	-	-
Benton County Health Services	-	X	-	-	-	-
Benton County Public Works	X	X	X	-	-	-
Boyter's Golden Horizon, Inc.	-	X	-	-	-	-
Cheldelin Middle School	-	X	X	-	-	-
City Hall Annex and Law Library	-	X	X	-	-	-
College Hill Alternative High School	-	X	-	-	-	-
Conifer House Nursing Home	X	X	X	-	-	-
Corvallis-Benton County Public Library	-	-	-	-	-	-
Corvallis Armory-Smith Hall	-	X	-	-	-	-
Corvallis Care Center	-	X	-	-	-	-

Critical Facilities and Lifelines by Community	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
	Exposed	>50% Prob.	>50% Prob.	Exposed	Exposed	Exposed
Corvallis City Hall	-	X	X	-	-	-
Corvallis Community Center		X	X	-	-	-
Corvallis Fire Station No 1	-	-	-	-	-	-
Corvallis Fire Station No 2	-	X	-	-	-	-
Corvallis Fire Station No 3	-	X	-	-	-	-
Corvallis Fire Station No 4	-	-	-	-	-	-
Corvallis Fire Station No 5	-	-	-	-	-	-
Corvallis High School	X	X	X	-	-	-
Corvallis Manor	X	X	X	-	-	-
Corvallis Montessori School	-	X	X	-	-	-
Corvallis Municipal Court		X	X	-	-	-
Corvallis Police Department	-	X	X	-	-	-
Corvallis Public Works	-	X	X	-	-	-
Corvallis Wastewater Reclamation	X	X	X	-	-	-
Franklin School	-	X	-	-	-	-
Garfield Elementary School	-	X	X	-	-	-
Good Samaritan - The Corvallis Clinic	-	-	-	-	-	-
Good Samaritan Corvallis Medical Center	-	-	-	-	-	-
Good Samaritan School	-	X	-	-	-	-
Good Samaritan Wellness Center	-	X	-	-	-	-
Hoover Elementary School	-	X	X	-	-	-
Jefferson Elementary School	-	X	X	-	-	-
Lincoln Elementary School	-	X	X	-	-	-
Linus Pauling Middle School	-	X	-	-	-	-
Madison Building	-	X	X	-	-	-
OSP - OSU Campus	-	X	-	-	-	-
OSU Health Center	-	X	X	-	-	-
Parks and Recreation Admin	-	-	X	-	X	-
Parks and Recreation Maintenance	X	-	X	-	X	-
Prestige Senior Living West Hills	-	-	-	-	-	-
Regent Retirement Center	-	-	-	-	-	-
Samaritan Heart of the Valley	-	X	-	-	-	-
Stoneybrook Senior Living	-	-	-	-	-	-
Wilson Elementary School	-	X	X	-	-	-

A.11 City of Monroe

Table A-21. City of Monroe hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Monroe		624	378		7		109,046,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	1	1	10,000	0.0%
Earthquake*	CSZ Mw-9.0 Deterministic	51	8.2%	126	5	17,540,000	16%
Earthquake*	Turner and Mill Creek Fault Mw-6.6 Deterministic	3	0.5%	17	1	3,555,000	3.3%
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	1	0.2%	3	0	377,000	0.3%
Wildfire	High and 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-22. City of Monroe critical facilities and other lifelines.

Critical Facilities and Lifelines by Community	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High or Moderate Risk
	Exposed	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**
Monroe Area Community Center	-	X	-	-	-
Monroe City Hall	-	X	-	-	-
Monroe Community Library	-	-	-	-	-
Monroe Grade School	-	X	-	-	-
Monroe Health Center	-	-	-	-	-
Monroe High School	-	-	-	-	-
Monroe RFPD - Station 2	-	X	-	-	-
Monroe STP	X	X	X	-	-
Monroe Water Treatment Facility	-	X	-	-	-
Old Mill Center Relief Nursery	-	-	-	-	-
South Benton Community Museum	-	X	-	-	-
South Benton Food Pantry	-	X	-	-	-

A.12 City of Philomath

Table A-23. City of Philomath hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Philomath	5,690	2,064	9	581,805,000

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	244	4.3%	95	4	1,728,000	0.3%
Earthquake*	CSZ Mw-9.0 Deterministic	195	3.4%	366	3	72,950,000	13%
Earthquake*	Turner and Mill Creek Fault Mw-6.6 Deterministic	48	0.8%	99	2	20,401,000	3.5%

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	112	2.0%	31	0	9,718,000	1.7%
Channel Migration	Channel Migration Zone	17	0.3%	37	0	14,547,000	2.5%
Wildfire	High and Moderate Risk	132	2.3%	56	0	11,146,000	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-24. City of Philomath critical facilities and other lifelines.

Critical Facilities and Lifelines by Community	Flood 1% Annual Chance	CSZ 9.0 Earthquake Moderate to Complete Damage	Turner and Mill Creek 6.6 Moderate to Complete Damage	Landslide High and Very High Susceptibility	Channel Migration Zone	Wildfire High or Moderate Risk
	Exposed	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Benton County Historical Museum	-	X	-	-	-	-
Clemens Primary School	-	X	X	-	-	-
Philomath City Hall	X	-	-	-	-	-
Philomath Community Library	-	-	-	-	-	-
Philomath Elementary School*	-	-	-	-	-	-
Philomath High School*	-	-	-	-	-	-
Philomath Middle School*	-	-	-	-	-	-
Philomath Police Department	X	-	-	-	-	-
Philomath Public Works	X	X	X	-	-	-
Philomath RFPD*	-	-	-	-	-	-
Philomath Water Treatment Plant	X	X	-	-	-	-

*Critical facility has been mitigated for seismic risk.

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

Table B-1. Benton County building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Non-Profit			All Buildings			
Community	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Number of Buildings per Study Area Total	Building Value ($)	Value of Buildings per Study Area Total
Unincorp. Benton Co (rural)	7,960	1,934,898	49%	284	270,784	6.9%	7,962	1,560,801	40%	125	167,770	4.3%	16,331	27%	3,934,253	21%
Alpine	82	9,279	35%	4	2,842	10.6%	72	13,410	50%	3	1,249	4.7%	161	0.3%	26,781	0.1%
Alsea	89	12,249	40%	17	3,567	11.8%	22	2,983	9.8%	9	11,516	38.0%	137	0.2%	30,315	0.2%
Bellfountain	30	4,877	33%	3	782	5.3%	23	6,183	41.7%	3	2,972	20.1%	59	0.1%	14,814	0.1%
Blodgett	28	4,381	39%	1	441	4%	21	3,675	32.9%	3	2,689	24.0%	53	0.1%	11,186	0.1%
Kings Valley	28	4,314	24%	2	323	1.8%	48	8,301	46.3%	7	4,981	27.8%	85	0.1%	17,918	0.1%
Summit	47	8,698	43%	1	4,242	21.2%	47	6,748	33.7%	1	337	2%	96	0.2%	20,026	0.1%
Total Unincorp. County	8,264	1,978,696	49%	312	282,981	7%	8,195	1,602,101	40%	151	191,514	5%	16,922	28%	4,055,292	21%
Adair Village	236	58,252	54%	20	26,154	24%	9	1,276	1.2%	12	21,484	20%	277	0.5%	107,166	0.6%
Albany	18,316	4,669,707	66%	1,282	1,604,927	23%	3,890	248,367	3.5%	453	510,549	7.3%	23,941	39%	7,033,549	37%
Corvallis	14,709	4,511,844	63%	932	1,514,056	21%	1,531	151,737	2%	337	954,530	13%	17,509	29%	7,132,168	38%
Monroe	266	54,610	50%	20	7,684	7%	63	7,484	7%	29	39,268	36.0%	378	0.6%	109,046	0.6%
Philomath	1,644	373,240	64%	169	106,094	18%	197	18,852	3.2%	54	83,619	14%	2,064	3.4%	581,805	3.1%
Total Study Area	43,435	11,646,349	61%	2,735	3,541,896	19%	13,885	2,029,817	11%	1,036	1,800,964	9%	61,091	100%	19,019,026	100%

Table B-2. CSZ Mw-9.0 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. Benton Co (rural)	16,331	3,934,253	2,275	707	506,585	13%	1,421	301	285,111	7%
Alpine	161	26,781	38	11	4,763	18%	19	3	2,420	9%
Alsea	137	30,315	37	25	7,268	24%	26	6	3,800	13%
Bellfountain	59	14,814	13	4	4,184	28%	6	1	1,609	11%
Blodgett	53	11,186	11	5	1,271	11%	5	1	658	6%
Kings Valley	85	17,918	19	8	3,412	19%	15	4	2,269	13%
Summit	96	20,026	14	4	3,641	18%	9	2	1,567	8%
Total Unincorp. County	16,922	4,055,292	2,406	765	531,124	13%	1,500	318	297,434	7%
Adair Village	277	107,166	15	3	7,486	7%	10	2	3,334	3%
Albany	23941	7,033,549	3,600	912	1,159,096	17%	2,112	448	586,768	8%
Corvallis	17,509	7,132,168	2,526	769	1,131,548	16%	1,576	334	594,868	8%
Monroe	378	109,046	100	26	17,540	16%	48	8	9,389	9%
Philomath	2,064	581,805	289	77	72,950	13%	155	31	40,197	7%
Total Study Area	61,091	19,019,026	8,936	2,552	2,919,744	15%	5,401	1,141	1,531,990	8%

Table B-3. Turner and Mill Creek Fault Mw-6.6 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. Benton Co (rural)	16,331	3,934,253	1032	311	264,564	6.7%	752	172	166,172	4.2%
Alpine	161	26,781	3	0	522	1.9%	1	0	210	0.8%
Alsea	137	30,315	3	1	531	1.8%	2	0	382	1.3%
Bellfountain	59	14,814	2	0	674	4.6%	0	0	183	1.2%
Blodgett	53	11,186	0	0	58	0.5%	0	0	24	0.2%
Kings Valley	85	17,918	15	3	2,214	12%	13	3	1,912	11%
Summit	96	20,026	1	0	177	0.9%	0	0	88	0.4%
Total Unincorp. County	16,922	4,055,292	1,056	315	268,740	6.6%	768	175	168,971	7%
Adair Village	277	107,166	15	3	5,822	5.4%	11	3	3,155	2.9%
Albany	23,941	7,033,549	3,178	1,131	1,011,785	14%	2,389	599	627,239	8.9%
Corvallis	17,509	7,132,168	1610	430	649,732	9.1%	1,053	238	385,541	5.4%
Monroe	378	109,046	15	2	3,555	3.3%	5	1	1,814	1.7%
Philomath	2,064	581,805	82	17	20,401	3.5%	51	12	12,880	2.2%
Total Study Area	61,091	19,019,026	5,956	1,898	1,685,473	10%	4,277	1,028	1,199,600	6.3%

Table B-4. 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. Benton Co (rural)	16,331	3,934,253	216	4,805	0.1%	627	22,246	0.6%	842	34,480	0.9%	1,176	72,299	1.8%
Alpine	161	26,781	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Alsea	137	30,315	3	56	0.2%	13	159	0.5%	17	252	0.8%	25	652	2.1%
Bellfountain	59	14,814	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Blodgett	53	11,186	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Kings Valley	85	17,918	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Summit	96	20,026	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Total Unincorp. County	16,922	4,055,292	219	4,861	0.1%	640	22,405	0.6%	859	34,733	0.9%	1,201	72,950	1.8%
Adair Village	277	107,166	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Albany	23,941	7,033,549	94	4,451	0.1%	250	14,794	0.2%	509	28,271	0.4%	1,038	74,980	1.0%
Corvallis	17,509	7,132,168	51	1,965	0.0%	226	8,648	0.1%	603	23,743	0.3%	1,590	103,599	1.5%
Monroe	378	109,046	0	0	0.0%	1	6	0.0%	1	10	0.0%	2	23	0.0%
Philomath	2,064	581,805	21	126	0.0%	76	1,162	0.2%	95	1,728	0.3%	144	3,818	0.7%
Total Study Area	61,091	19,019,026	385	11,403	0.1%	1,193	47,015	0.3%	2,067	88,485	0.5%	3,975	255,370	1.3%

Table B-5. 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. Benton Co (rural)	16,331	20,766	828	4.0%	884	5.4%	42
Alpine	161	205	0	0.0%	0	0.0%	0
Alsea	137	216	17	7.7%	19	13.9%	2
Bellfountain	59	82	0	0.0%	0	0.0%	0
Blodgett	53	67	0	0.0%	0	0.0%	0
Kings Valley	85	90	0	0.0%	0	0.0%	0
Summit	96	113	0	0.0%	0	0.0%	0
Total Unincorp. County	16,922	21,540	845	3.9%	903	5.3%	44
Adair Village	277	1,319	0	0%	0	0%	0
Albany	23,941	57,200	964	1.7%	509	2.1%	70
Corvallis	17,509	57,718	2,036	4%	774	4%	171
Monroe	378	624	0	0%	1	0%	0
Philomath	2,064	5,690	244	4%	111	5%	16
Total Study Area	61,091	144,091	4,089	2.8%	2,298	3.7%	301

Table B-6. Landslide exposure.

(all dollar amounts in thousands)

Community	Total Number of Buildings	Total Estimated Building Value ($)	Very High Susceptibility			High Susceptibility			Moderate Susceptibility		
			Number of Buildings	Building Value ($)	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. Benton Co (rural)	16,331	3,934,253	1,153	263,280	6.7%	576	135,396	3.4%	8,511	1,910,337	49%
Alpine	161	26,781	0	0	0.0%	0	0	0.0%	64	9,112	34%
Alsea	137	30,315	32	5,466	18%	0	0	0.0%	27	5,001	16%
Bellfountain	59	14,814	0	0	0.0%	0	0	0.0%	21	5,673	38%
Blodgett	53	11,186	22	3,195	28.6%	0	0	0.0%	27	7,043	63%
Kings Valley	85	17,918	0	0	0%	0	0	0.0%	12	1,442	8%
Summit	96	20,026	37	5,833	29.1%	1	88	0.4%	57	14,035	70%
Total Unincorp. County	16,922	4,055,292	1,244	277,774	6.8%	577	135,483	3.3%	8,719	1,952,643	48%
Adair Village	277	107,166	0	0	0%	2	497	0.5%	78	21,933	20%
Albany	23,941	7,033,549	0	0	0%	75	17,700	0.3%	3,831	972,522	14%
Corvallis	17,509	7,132,168	0	0	0%	146	55,189	0.8%	5,062	2,029,140	28%
Monroe	378	109,046	0	0	0%	3	377	0.3%	90	26,327	24%
Philomath	2,064	581,805	0	0	0%	31	9,718	1.7%	475	138,661	24%
Total Study Area	61,091	19,019,026	1,244	277,774	1.5%	834	218,964	1.2%	18,255	5,141,226	27%

Table B-7. Channel migration exposure

(all dollar amounts in thousands)

				Channel Migration Hazard				
Community*	**Total Number of Buildings**	**Total Population**	**Total Estimated Building Value ($)**	**Potentially Displaced Residents from channel migration Exposure**	**% Potentially Displaced Residents from channel migration Exposure**	**Number of Buildings Exposed**	**Building Value ($)**	**Ratio of Exposure Value**
Unincorp. Benton Co (rural)	16,331	20,766	3,934,253	258	1.2%	254	53,663	1.4%
Alsea	137	216	30,315	79	37%	50	16,937	56%
Total Unincorp. County	16,468	20,982	3,964,568	337	1.6%	304	70,600	1.8%
Corvallis	17,509	57,718	7,132,168	100	0.2%	61	11,280	0.2%
Philomath	2,064	5,690	581,805	17	0.3%	37	14,547	2.5%
Total Study Area	36,041	84,390	11,678,541	454	0.5%	402	96,427	0.8%

*Communities in table limited to communities within the study area of Appleby and others (2021).

Table B-8. Wildfire exposure.

			(all dollar amounts in thousands)								
			High Hazard			Moderate Hazard			Low Hazard		
Community	Total Number of Buildings	Total Estimated Building Value ($)	Number of Buildings	Building Value ($)	Percent of Building Value Exposed	Number of Buildings	Building Value ($)	Percent of Building Value Exposed	Number of Buildings	Building Value ($)	Percent of Building Value Exposed
Unincorp. Benton Co (rural)	16,331	3,934,253	66	13,611	0.3%	1,106	237,013	6.0%	7,198	1,558,060	40%
Alpine	161	26,781	0	0	0%	2	291	1.1%	41	6,094	23%
Alsea	137	30,315	2	488	1.6%	16	3,195	11%	16	2,056	6.8%
Bellfountain	59	14,814	0	0	0%	0	0	0%	1	48	0.3%
Blodgett	53	11,186	0	0	0%	3	1,282	11%	28	3,983	36%
Kings Valley	85	17,918	0	0	0%	0	0	0%	38	6,007	34%
Summit	96	20,026	0	0	0%	20	6,884	34%	54	8,952	45%
Total Unincorp. County	16,922	4,055,292	68	14,099	0.3%	1,147	248,666	6.1%	7,376	1,585,200	39%
Adair Village	277	107,166	0	0	0%	0	0	0%	2	622	0.6%
Albany	23,941	7,033,549	0	0	0%	130	32,969	0.5%	315	87,252	1.2%
Corvallis	17,509	7,132,168	38	44,136	0.6%	338	130,244	1.8%	668	219,792	3.1%
Monroe	378	109,046	0	0	0%	0	0	0%	0	0	0%
Philomath	2,064	581,805	2	640	0.1%	54	10,506	1.8%	81	38,064	6.6%
Total Study Area	61,091	19,019,026	108	58,876	0.3%	1,669	422,385	2.2%	8,442	1,930,931	10%

APPENDIX C. HAZUS-MH METHODOLOGY

C.1 Software

We performed all loss estimations using Hazus®-MH 4.2 and ArcGIS® Desktop® 10.2.2.

C.2 User-Defined Facilities (UDF) Database

A UDF database was compiled for all buildings in Benton County for use in both the flood and earthquake modules of Hazus-MH. The Benton 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 Benton County assessor database was used whenever possible, but in many cases that database did not provide the necessary information. The following is list of attributes and their sources:

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

- **Year built** – The year of construction that is used to attribute the Building Design Level field for the earthquake analysis (see "Building Design" below). The year a UDF was built is obtained from Benton 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 square footage 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 Benton 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 Benton 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, 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 Benton 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 Benton 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 (Benton 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, 2020a) 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 Benton County. **Table C-1** outlines the benchmark years that apply to buildings within Benton County.

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

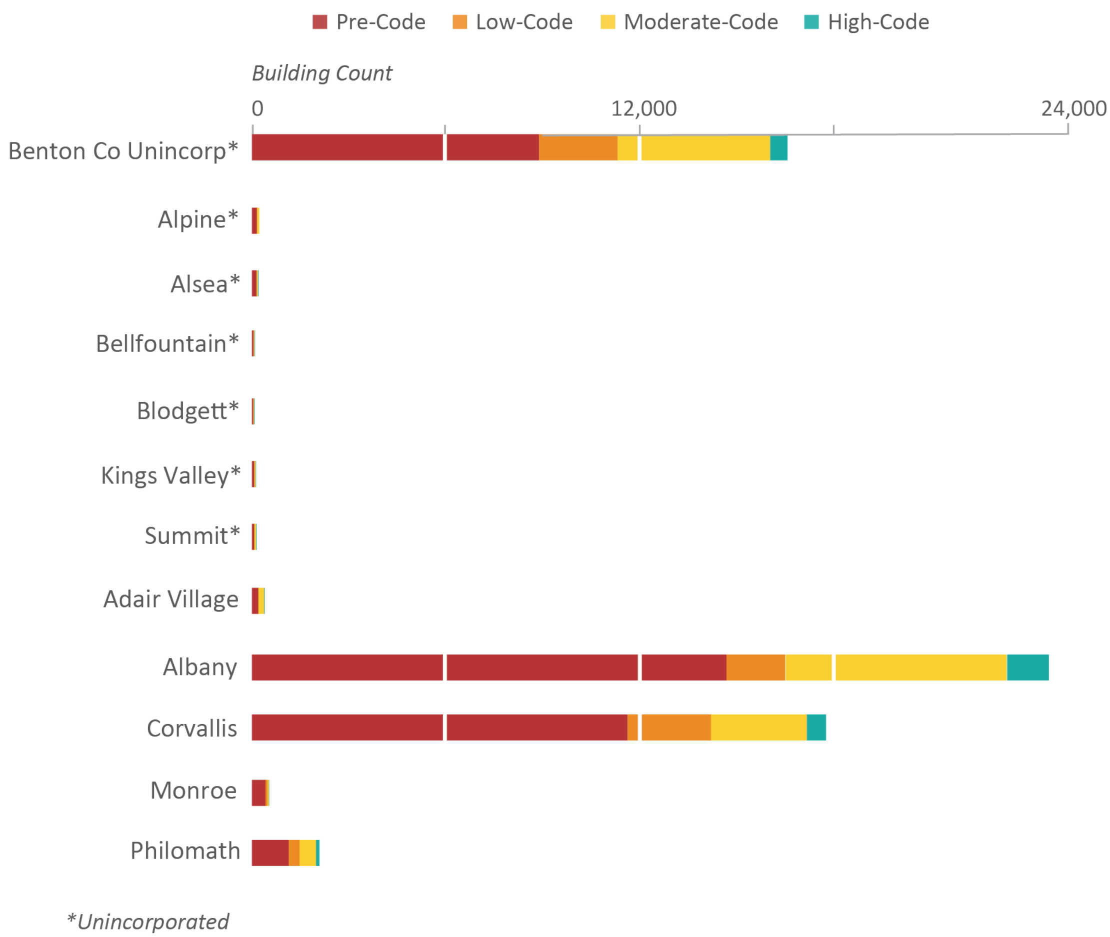
Building Type	Year Built	Design Level	Basis
Single-Family Dwelling (includes Duplexes)	prior to 1976	Pre Code	Interpretation of Judson (Judson, 2012)
	1976–1991	Low Code	
	1992–2003	Moderate Code	
	2004–2016	High Code	
Manufactured Housing	prior to 2003	Pre Code	Interpretation of OR BCD 2002 Manufactured 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 2022 Oregon Benefit-Cost Analysis Tool, p. 24 (Business Oregon, 2022)
	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 Benton 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. Benton Co (rural)	16,331	8,762	54%	2,392	15%	4,656	29%	521	3.2%
Alpine	161	110	68%	13	8.1%	38	23.6%	0	0.0%
Alsea	137	106	77%	7	5%	22	16%	2	1.5%
Bellfountain	59	42	71%	2	3%	14	24%	1	1.7%
Blodgett	53	35	66%	4	7.5%	12	22.6%	2	3.8%
Kings Valley	85	48	56%	10	12%	26	31%	1	1.2%
Summit	96	52	54%	10	10.4%	31	32.3%	3	3.1%
Total Unincorp. County	16,922	9,155	54%	2,438	14%	4,799	28%	530	3.1%
Adair Village	277	141	51%	4	1%	129	47%	3	1.1%
Albany	23,941	14,604	61%	2,872	12%	4,492	19%	1,973	8%
Corvallis	17,509	11,457	65%	2,543	15%	2,920	17%	589	3%
Monroe	378	300	79%	46	12%	26	6.9%	6	1.6%
Philomath	2,064	1,122	54%	333	16%	505	25%	104	5.0%
Total Study Area	61,091	36,779	60%	8,236	14%	12,871	21%	3,205	5%

Figure C-1. Seismic design level by Benton 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 Benton County FIRMs (FEMA, 2016). 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. The default value of 5 feet was used for the water table depth value.

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-percent chance of being equaled or exceeded each year. Sometimes referred to as the 100-year flood.

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

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

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

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

Flood Insurance Rate Map (FIRM) – An official map of a community, on which FEMA has delineated both the 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.

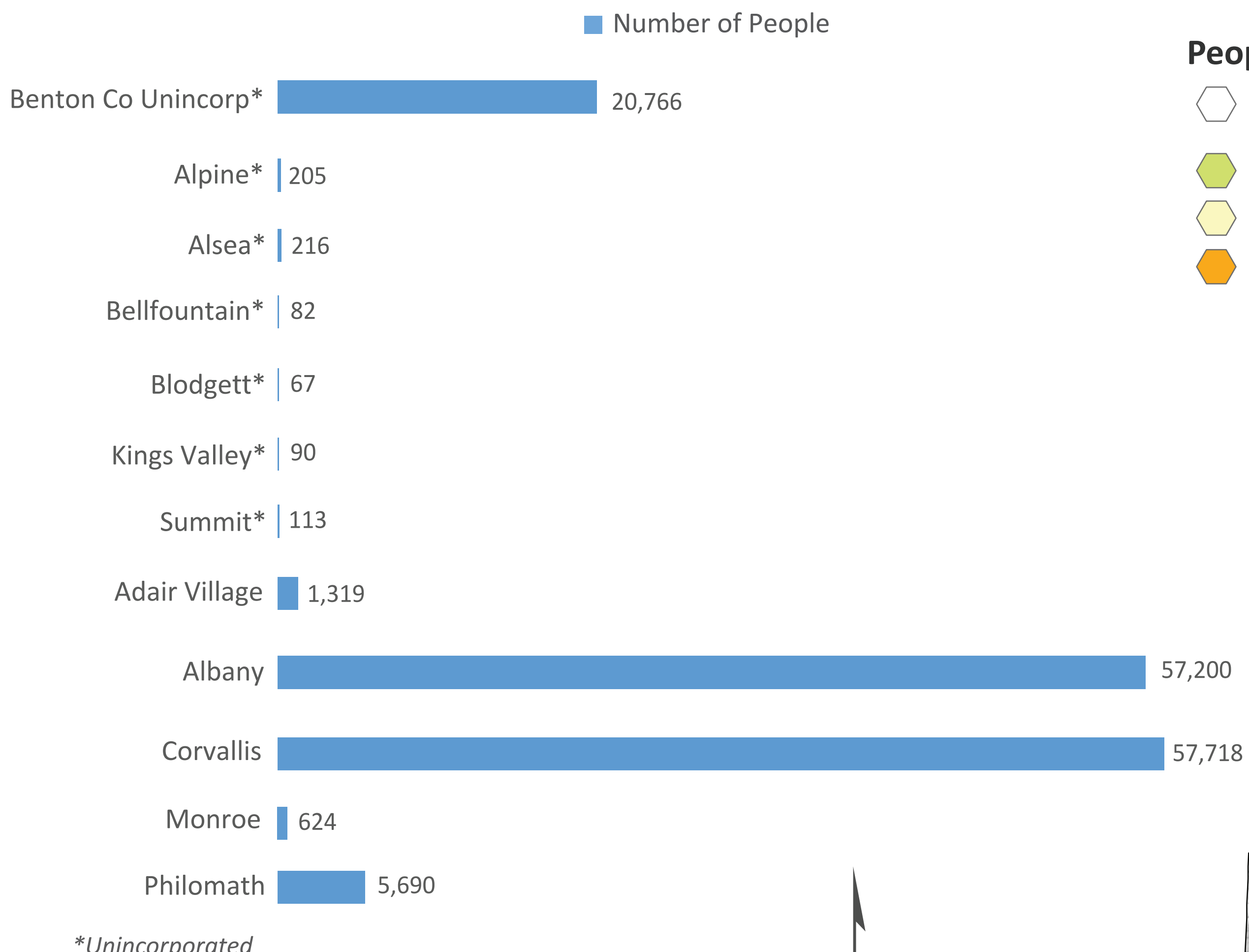
Vulnerability – Characteristics that make people or assets more susceptible to a natural hazard.

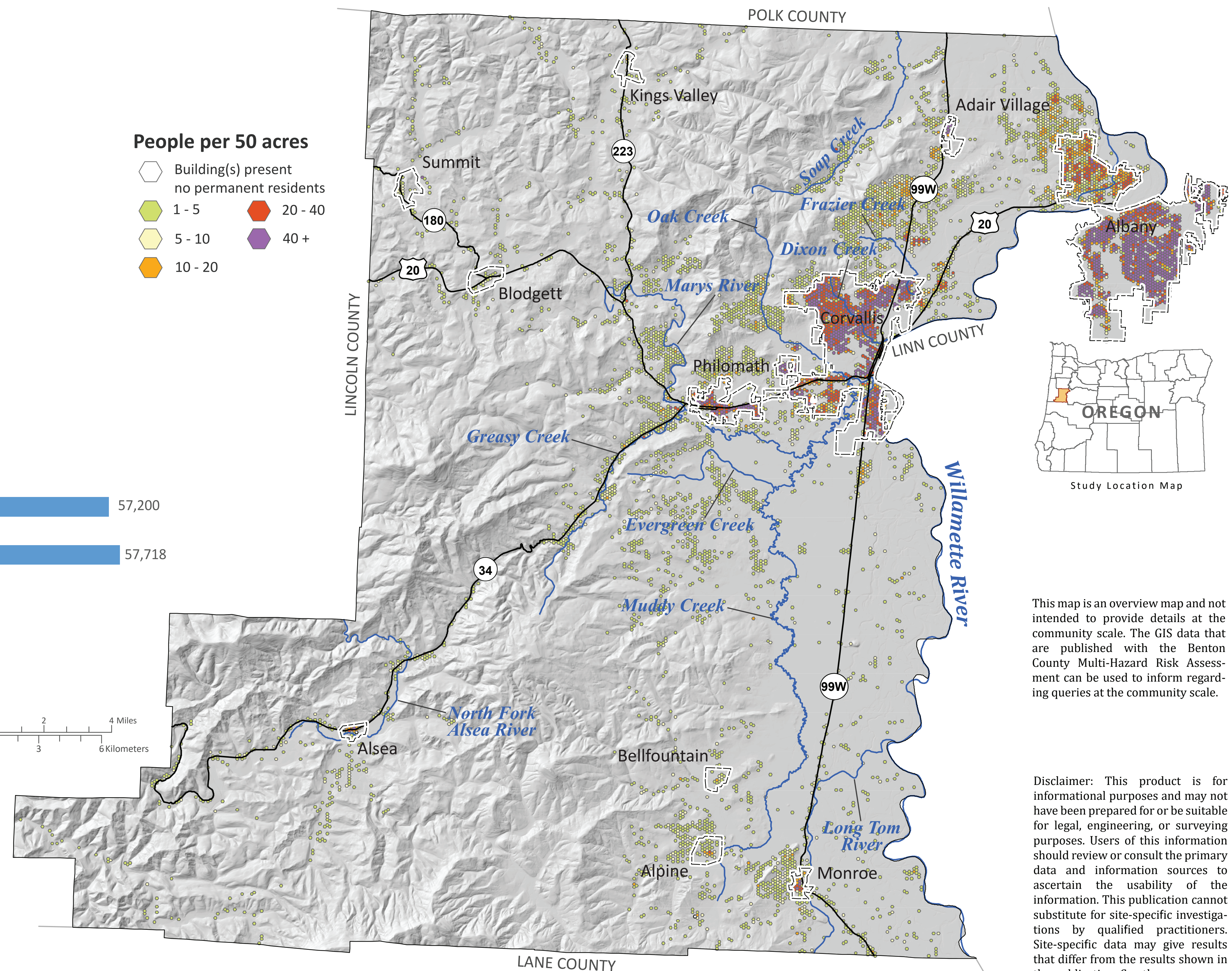
APPENDIX E. MAP PLATES

See appendix folder for individual map PDFs.

PLATE 1

Population Density Map of Benton County, Oregon





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

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

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

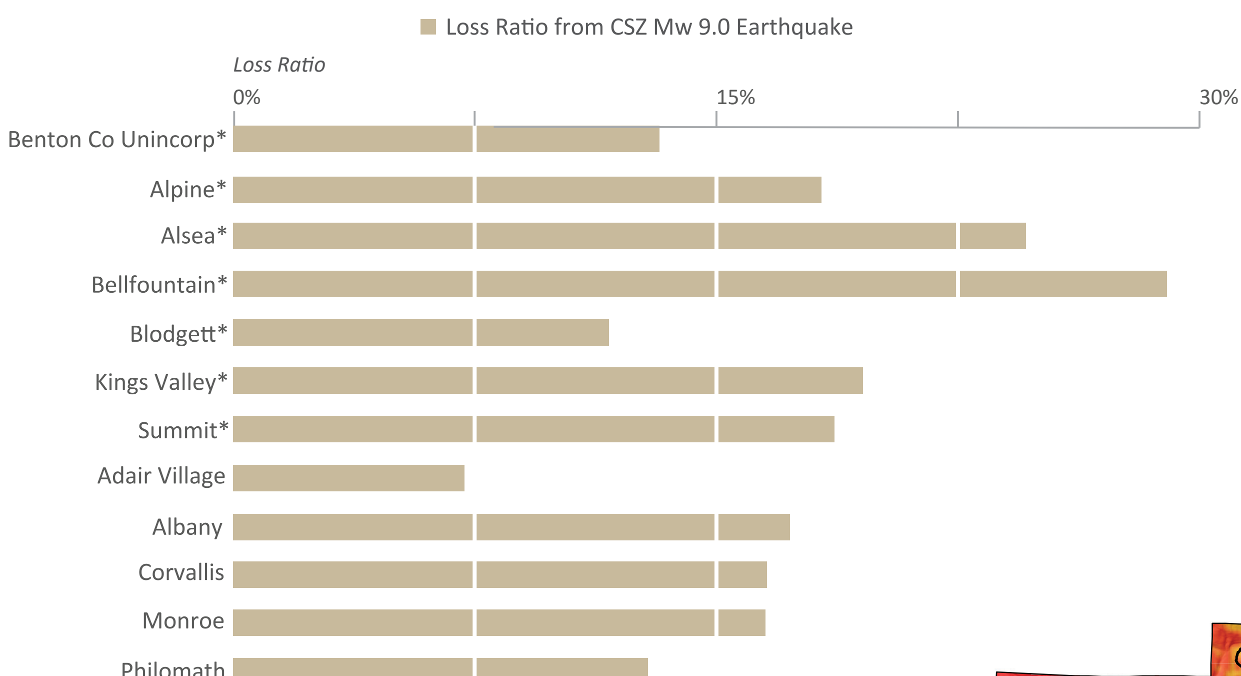
Cartography by:Matt C. Williams, 2022

PLATE 2

CSZ Magnitude-9.0 Earthquake Shaking Map of Benton County, Oregon

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

Modified Mercalli	Perceived Shaking	Potential Damage	Peak Ground Acceleration (g)
I	Not felt	None	< 0.000464
II	Weak	None	0.000464 - 0.00297
III	Weak	None	0.000464 - 0.00297
IV	Light	None	0.00297 - 0.0276
V	Moderate	Very Light	0.0276 - 0.115
VI	Strong	Light	0.115 - 0.215
VII	Very Strong	Moderate	0.215 - 0.401
VIII	Severe	Mod./Heavy	0.401 - 0.747
IX	Violent	Heavy	0.747 - 1.39
X	Extreme	Very Heavy	> 1.39



*Unincorporated

Data Sources:
Earthquake peak ground acceleration: 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

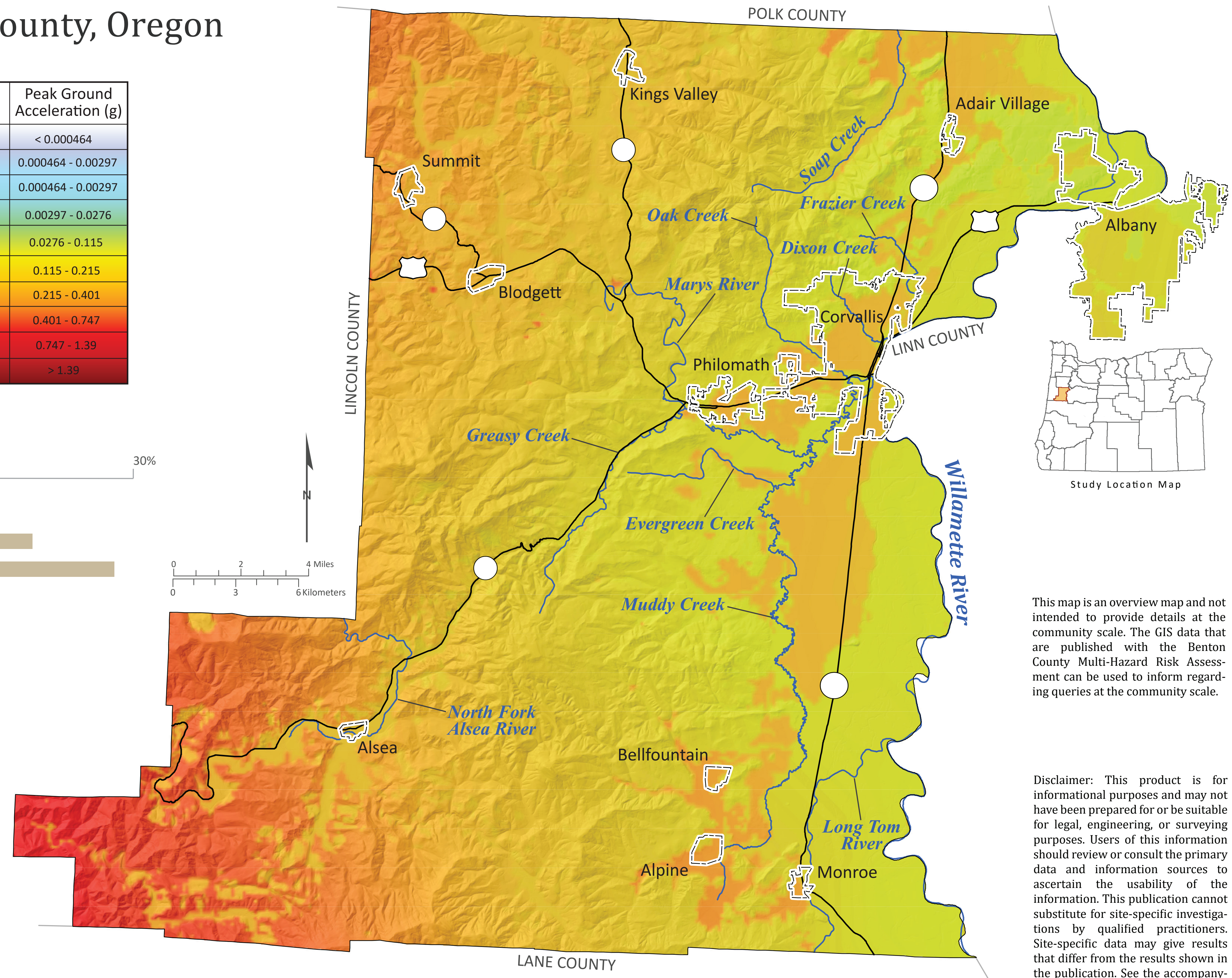


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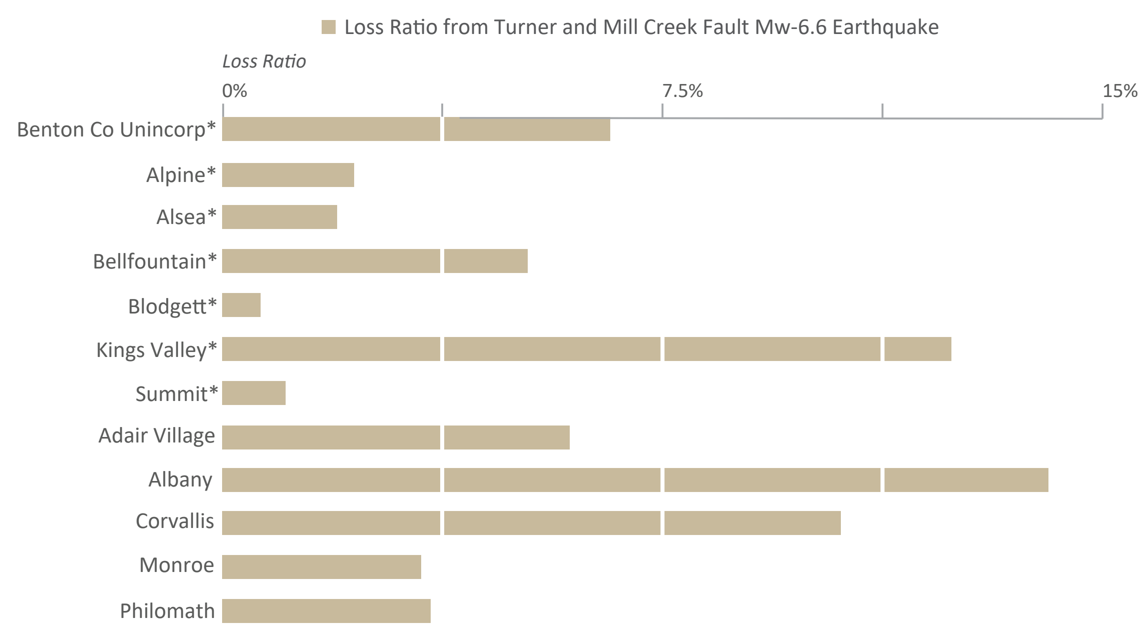
PLATE 3

Turner and Mill Creek Fault Magnitude-6.6 Earthquake Shaking Map of Benton County, Oregon

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

Modified Mercalli	Perceived Shaking	Potential Damage	Peak Ground Acceleration (g)
I	Not felt	None	< 0.000464
II	Weak	None	0.000464 - 0.00297
III	Weak	None	0.000464 - 0.00297
IV	Light	None	0.00297 - 0.0276
V	Moderate	Very Light	0.0276 - 0.115
VI	Strong	Light	0.115 - 0.215
VII	Very Strong	Moderate	0.215 - 0.401
VIII	Severe	Mod./Heavy	0.401 - 0.747
IX	Violent	Heavy	0.747 - 1.39
X	Extreme	Very Heavy	> 1.39



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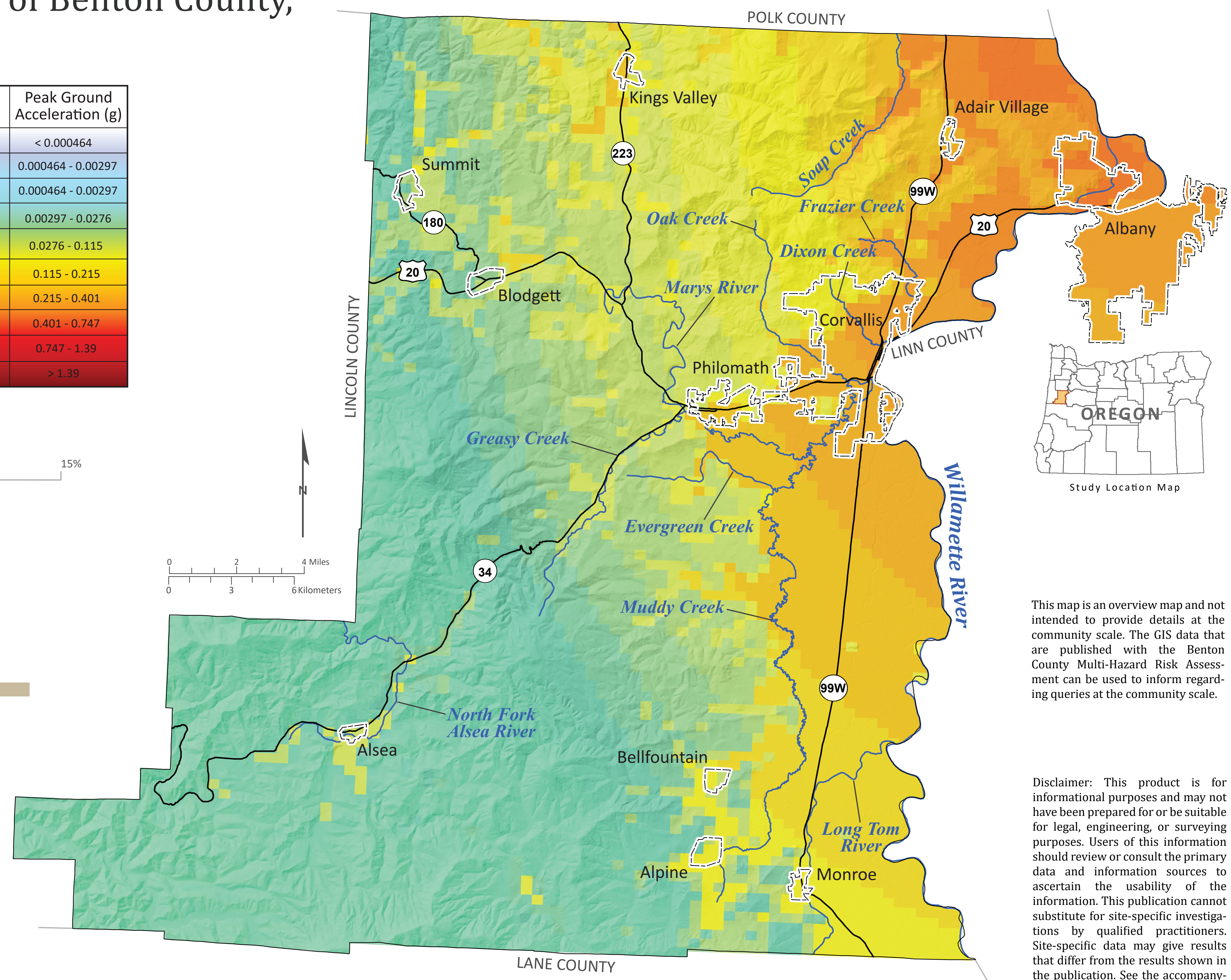

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Data Sources:
Earthquake peak ground acceleration: Generated from Hazus 5.0 earthquake analysis (2022)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City 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

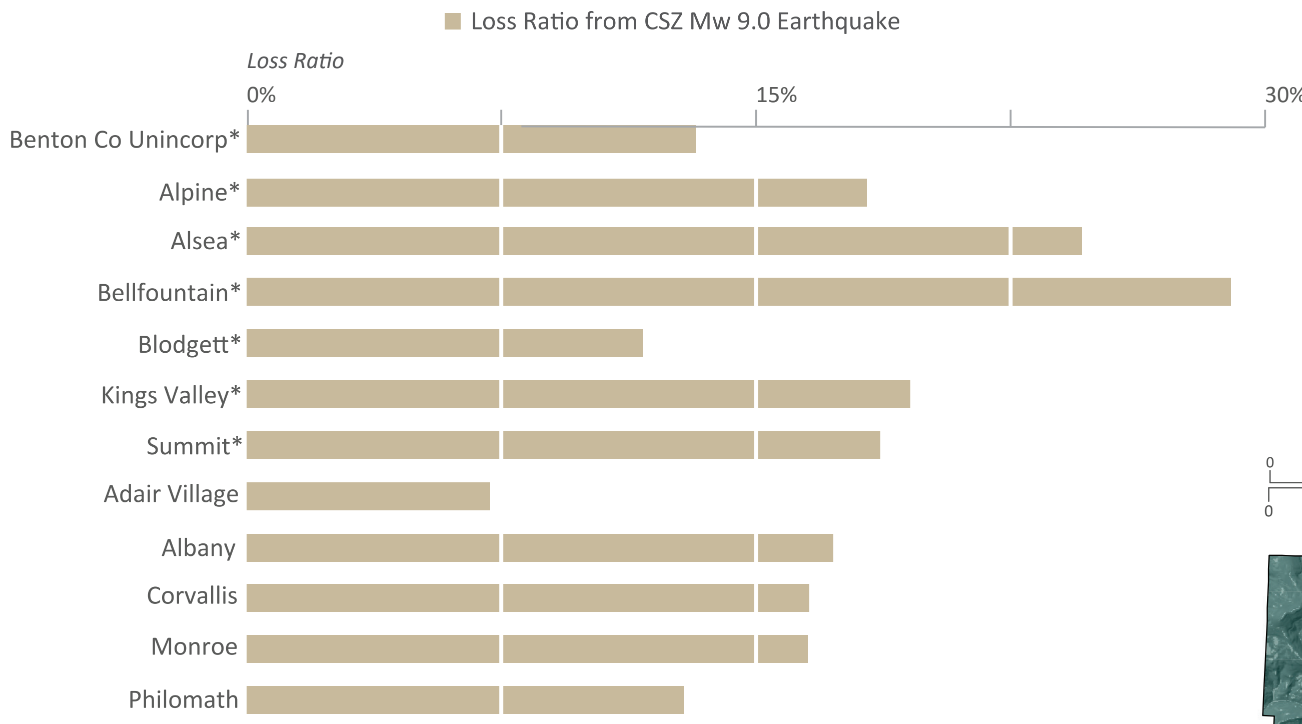
Cartography by:Matt C. Williams, 2022

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

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.

Coseismic Landslide Susceptibility (Wet)

0 (None) 9 (High)



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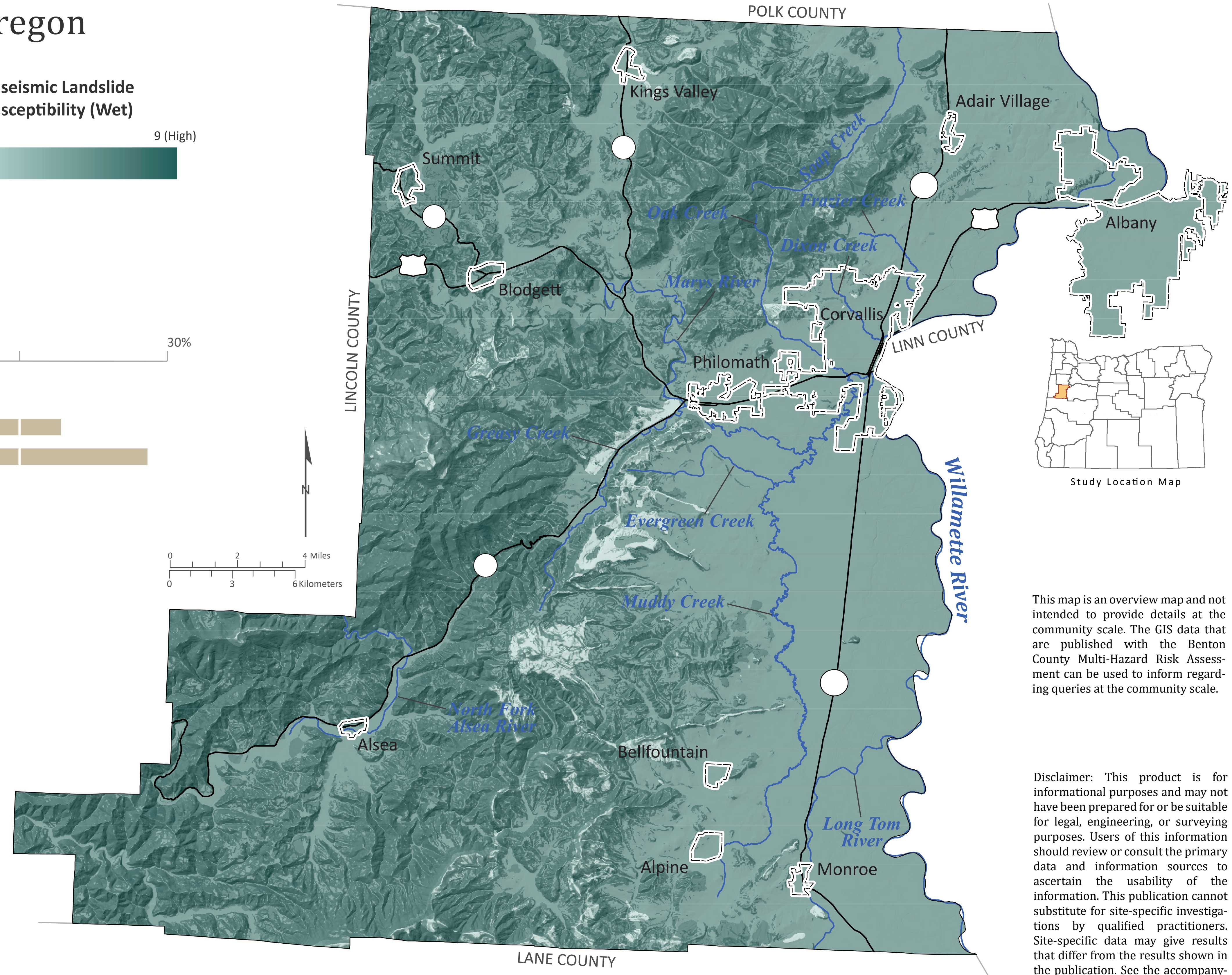

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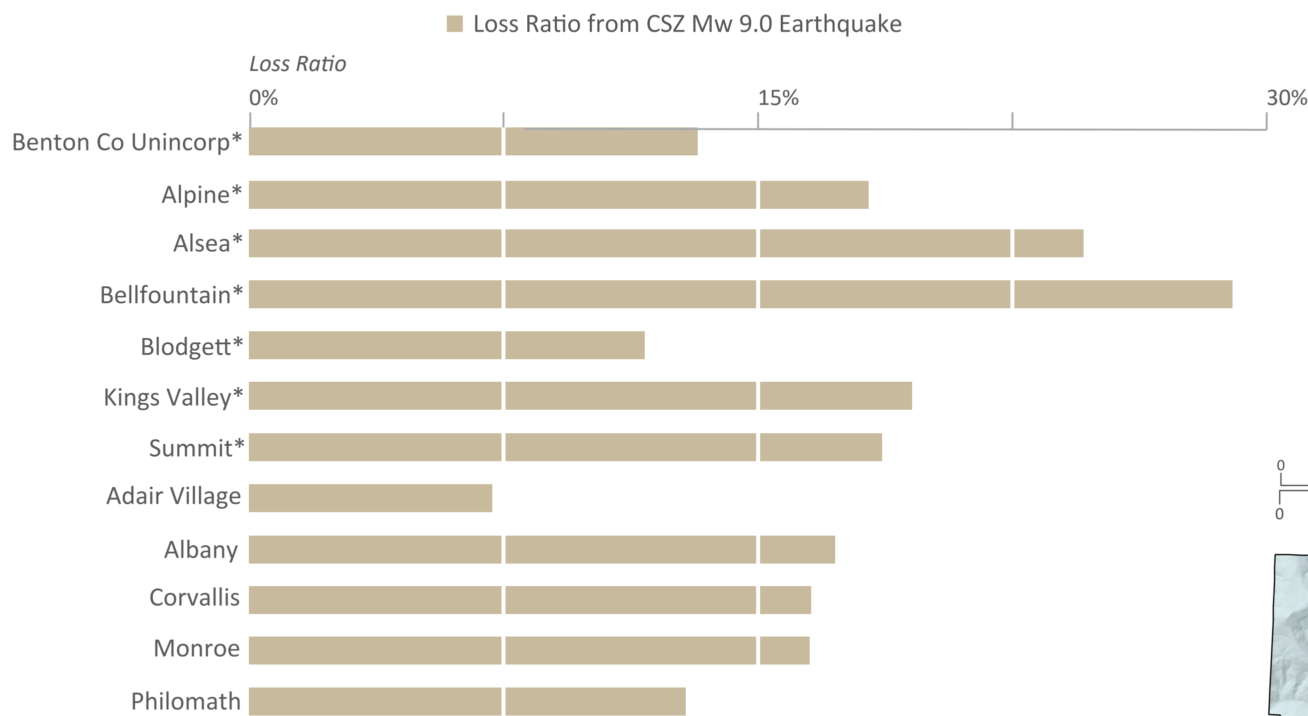
Data Sources:
Coseismic Landslide (wet): Oregon Department of Geology and Mineral Industries (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: 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

Liquefaction Susceptibility Map of Benton County, Oregon

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 the risk from earthquake hazard.



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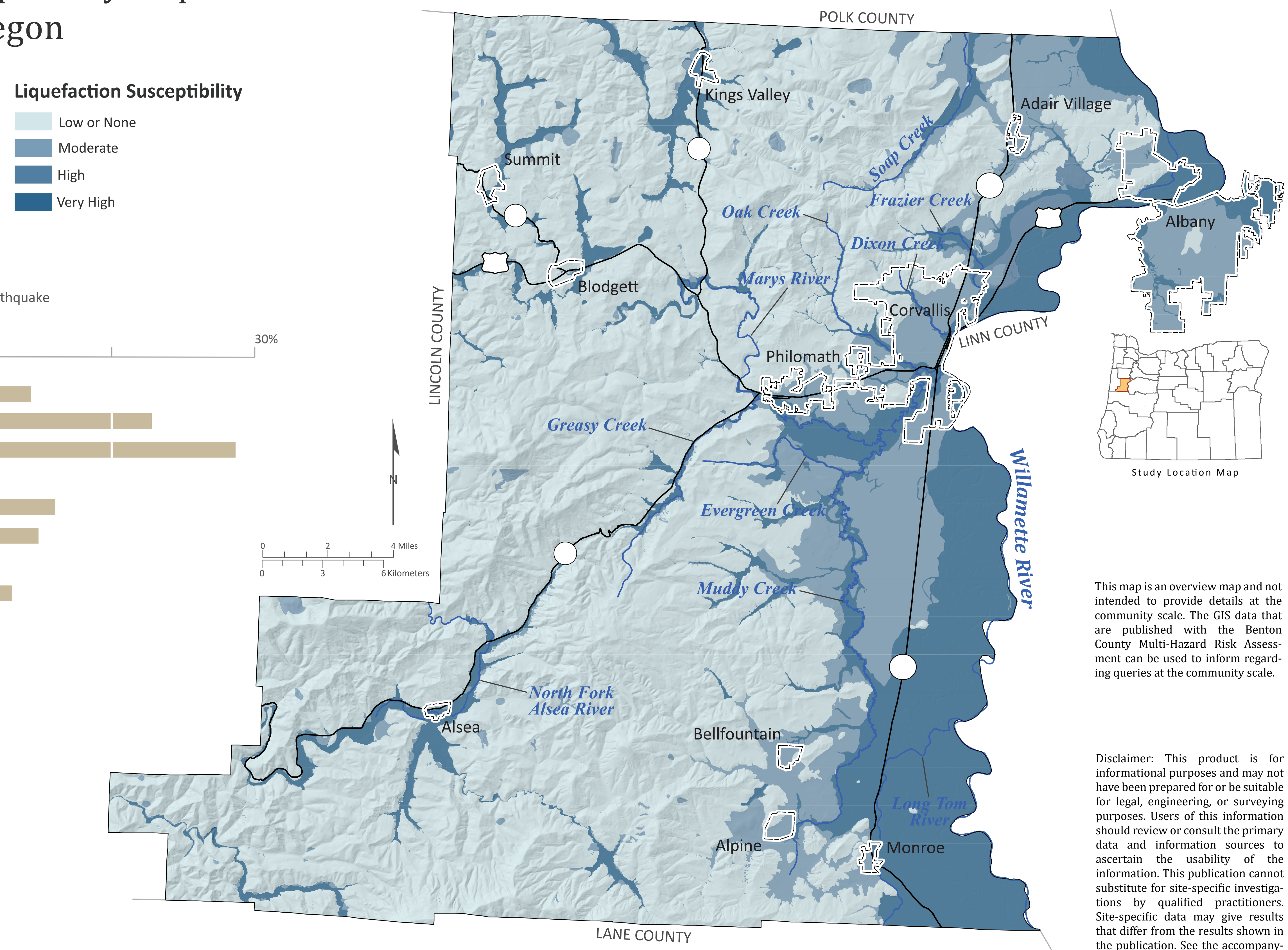

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Data Sources:
Liquefaction susceptibility: Oregon Department of Geology and Mineral Industries (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City 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

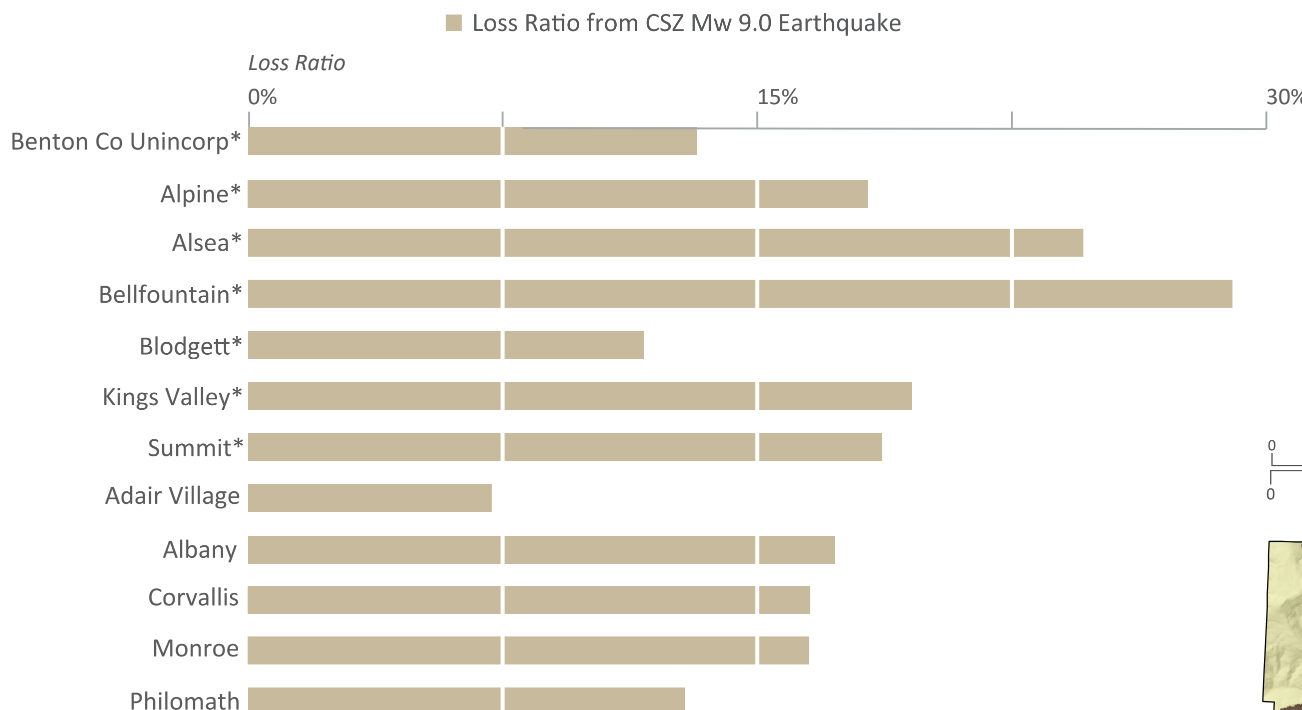
Cartography by:Matt C. Williams, 2022

Site Amplification Class Map of Benton County, Oregon

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

NEHRP Class

- B
- C
- D
- E, F



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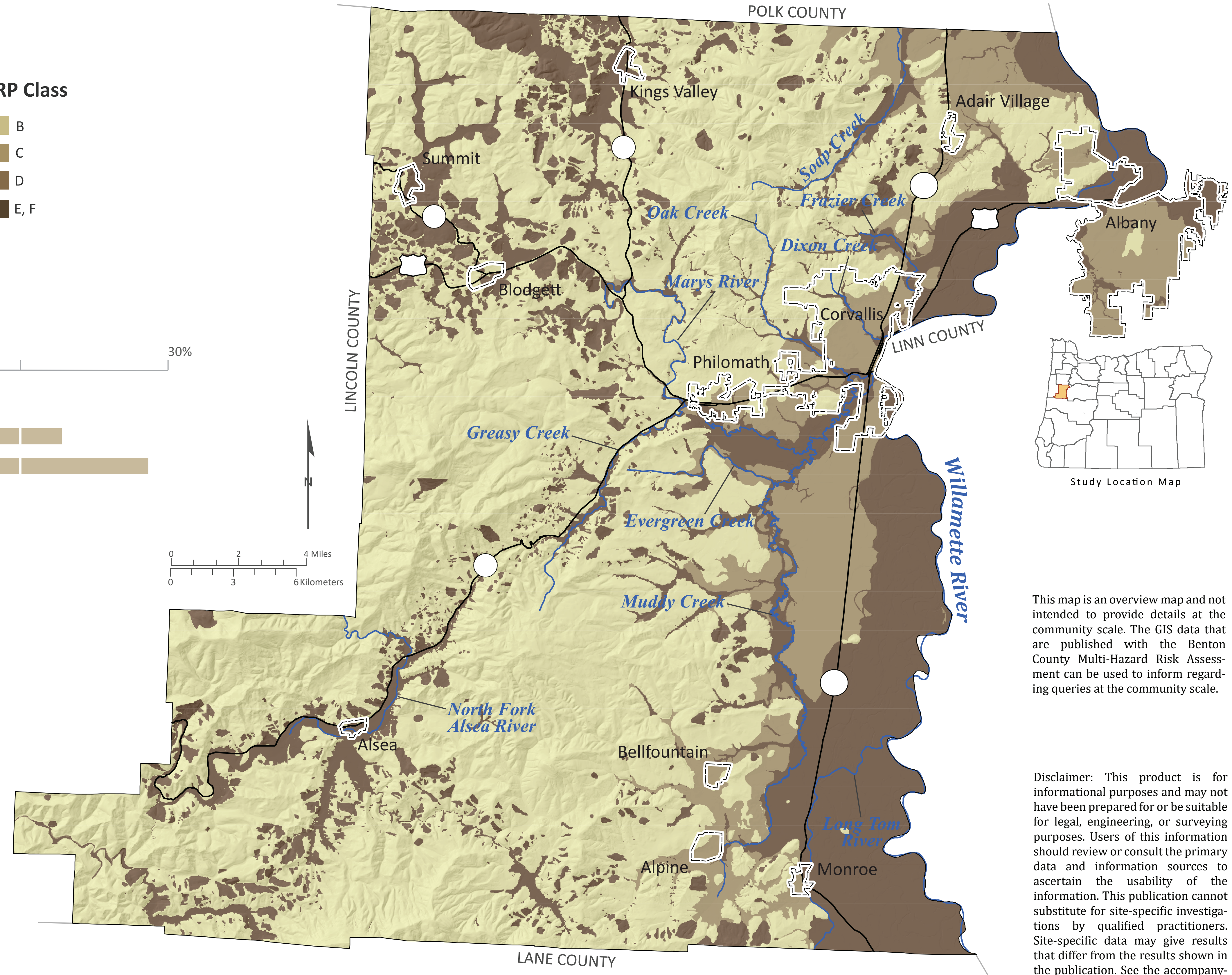

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Data Sources:
Soil amplification: Oregon Department of Geology and Mineral Industries (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: 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

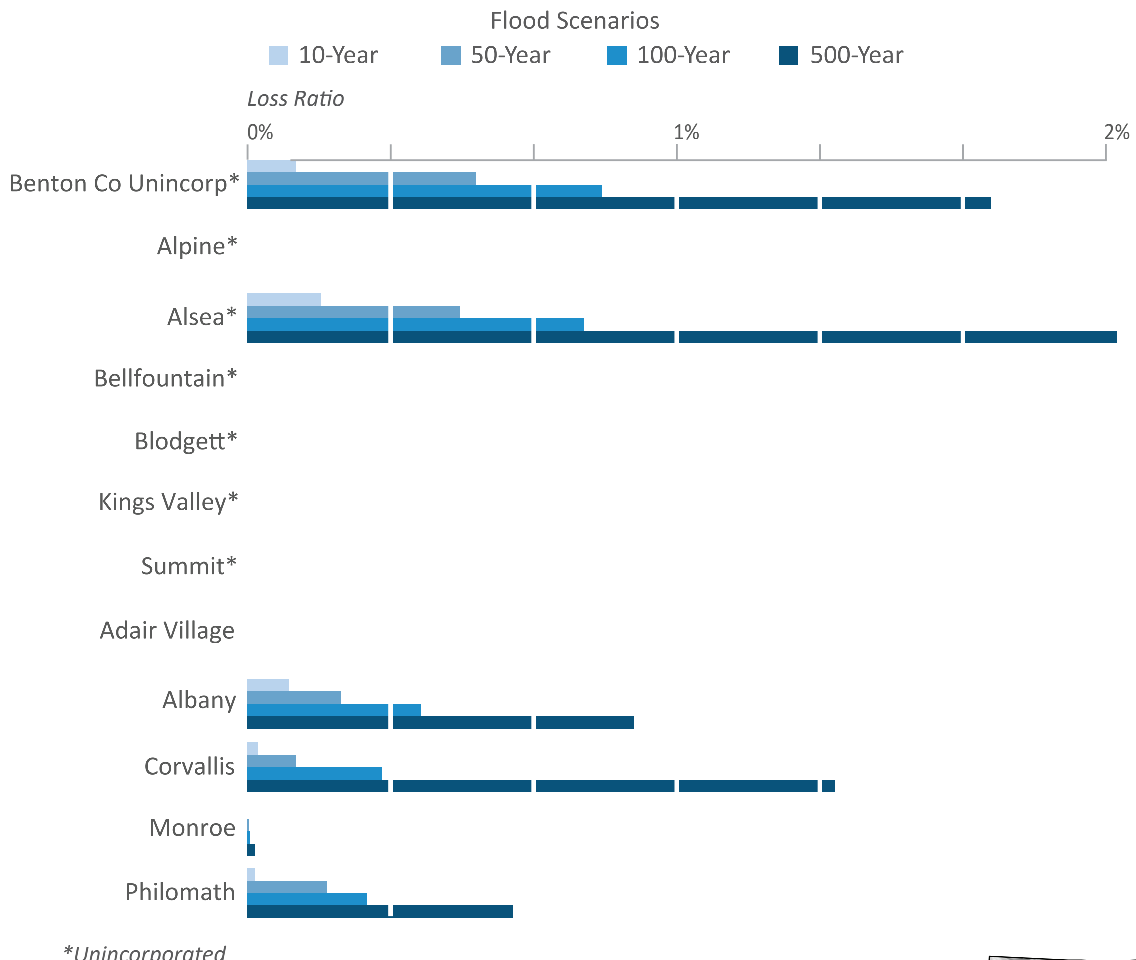
PLATE 7

Flood Hazard Map of Benton County, Oregon

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

Flood Hazard Zone

100-Year Flood (1% annual chance)



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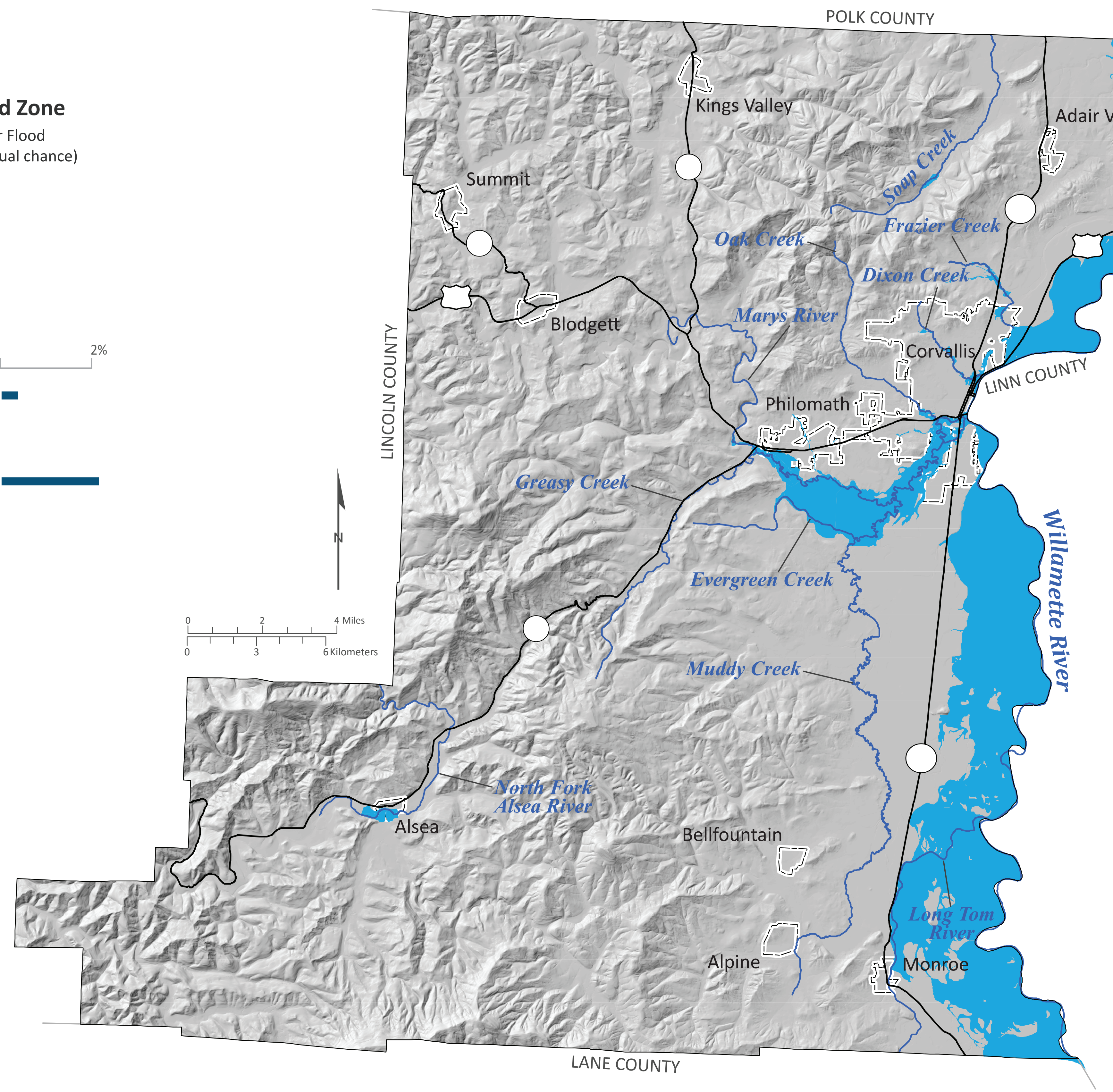

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Data Sources:
Flood hazard zone (100-year): Benton County Flood Insurance Rate Map (2016)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: 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

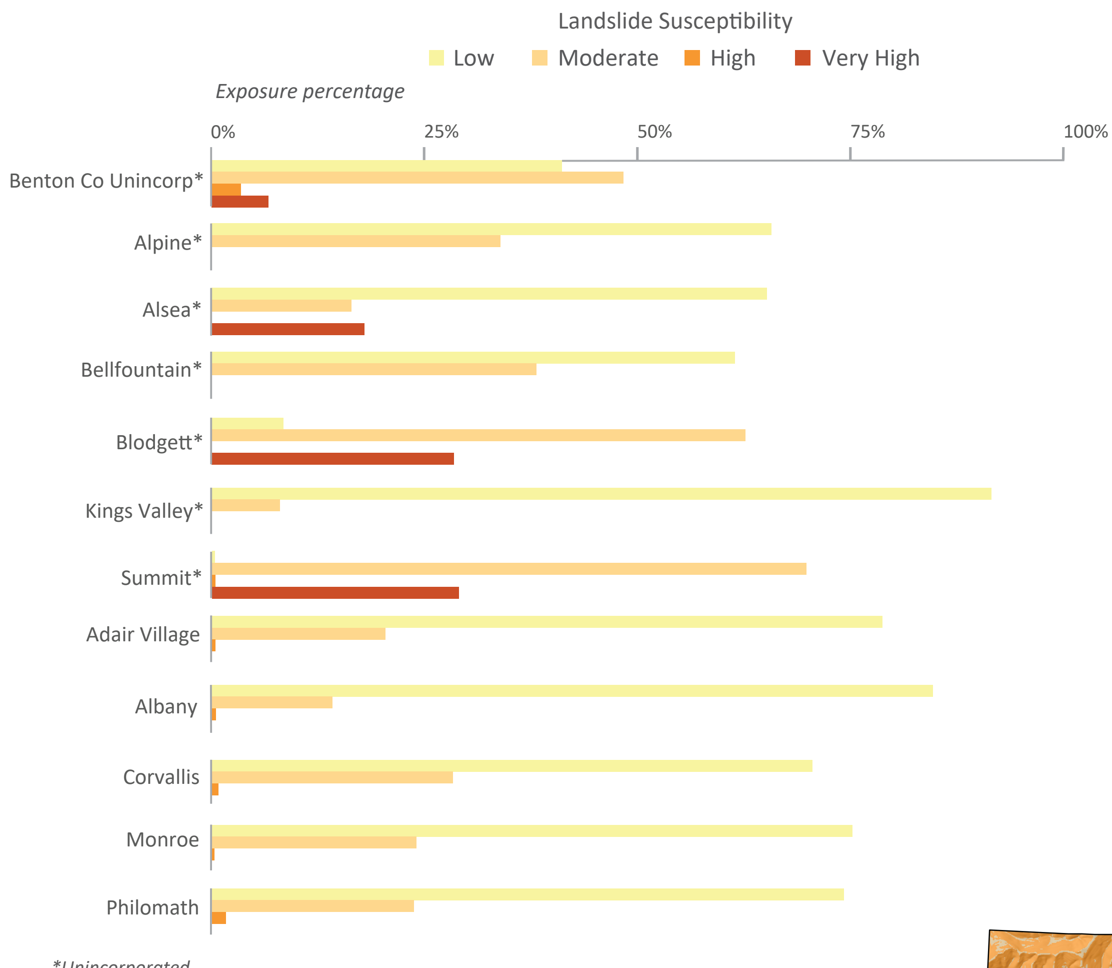
Cartography by:Matt C. Williams, 2022

Landslide Susceptibility Map of Benton County, Oregon

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

Landslide Susceptibility

- Low
- Moderate
- High
- Very High



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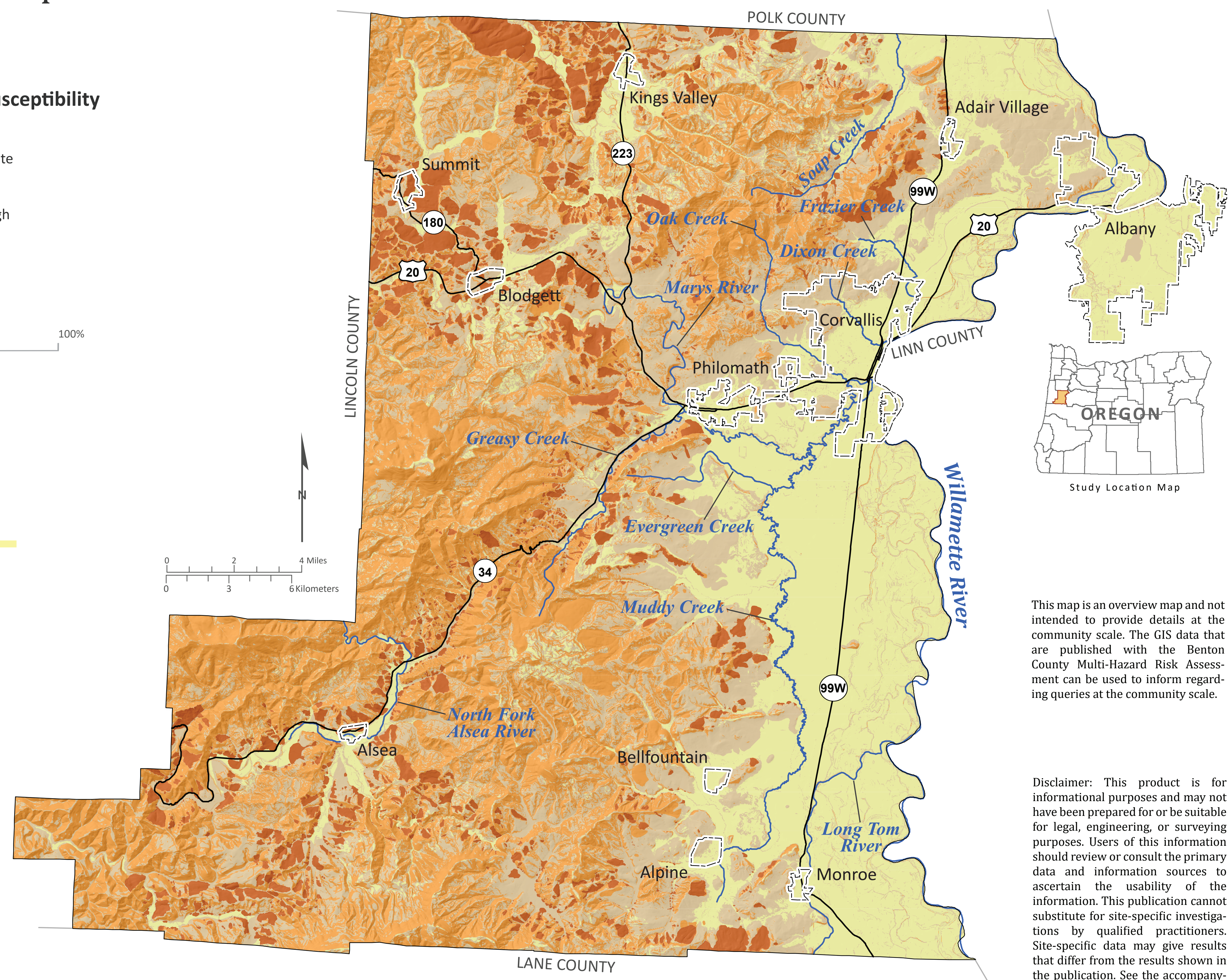

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Data Sources:
Landslide susceptibility: Oregon Department of Geology and Mineral Industries, Burns and others (2016) & Hairston-Porter and others (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey 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

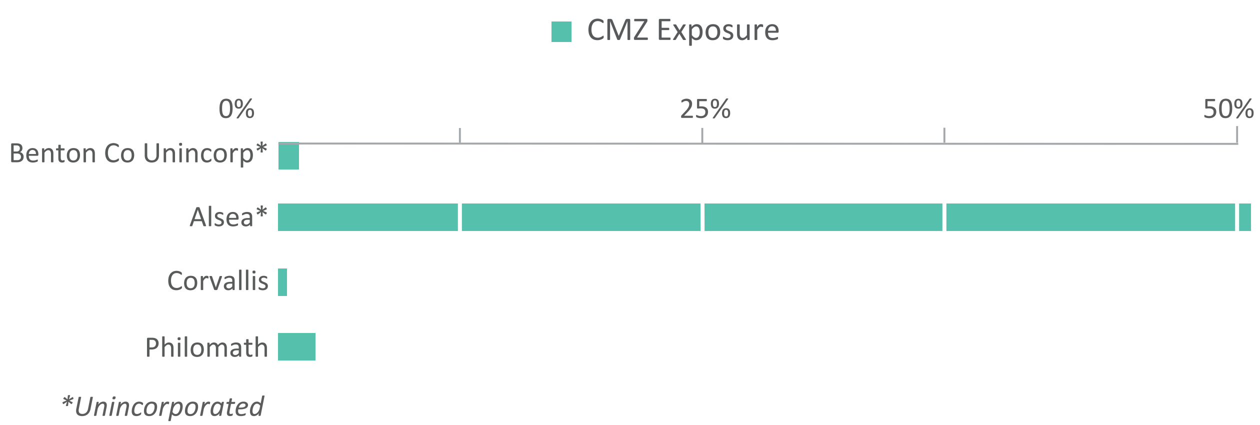
PLATE 9

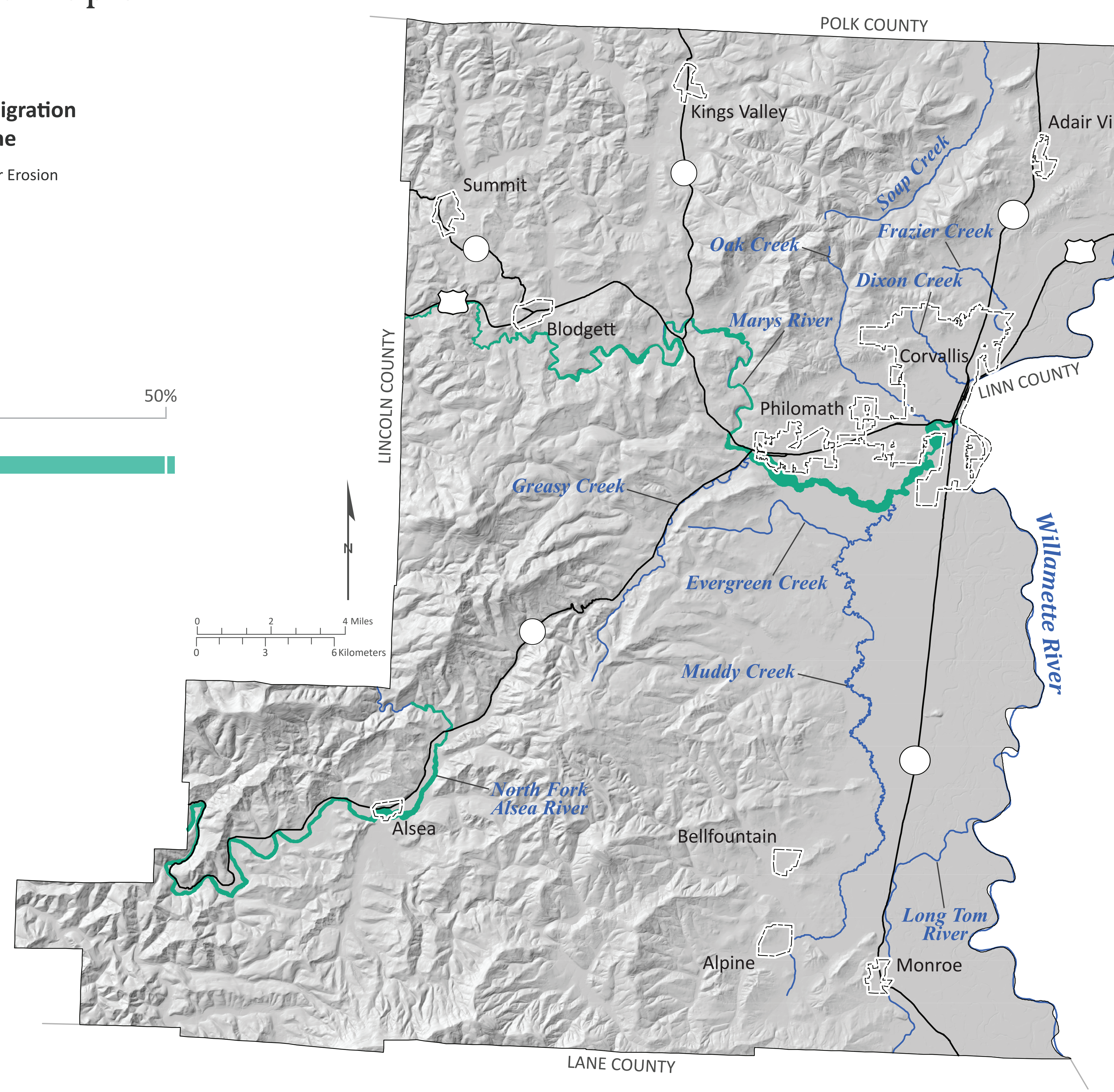
Channel Migration Hazard Map of Benton County, Oregon

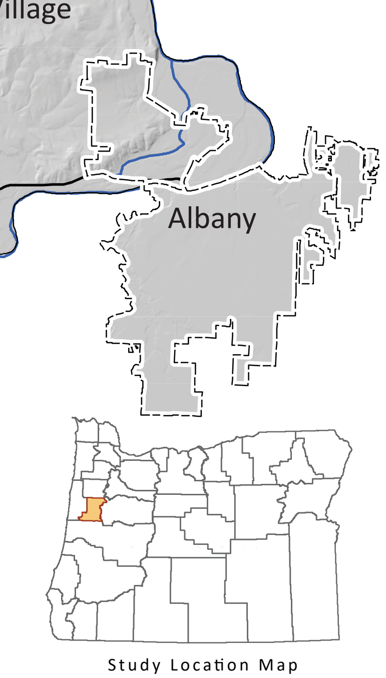
Channel migration is a process by which a stream's course changes over time due to bank erosion and stream deposition. The channel migration zone is defined by the 100-year Erosion Hazard Area (EHA). Shown are the 100-year EHA in Benton County. Buildings within these areas are at greater risk to channel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

Channel Migration Hazard Zone

100-Year Erosion







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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:Matt C. Williams, 2022

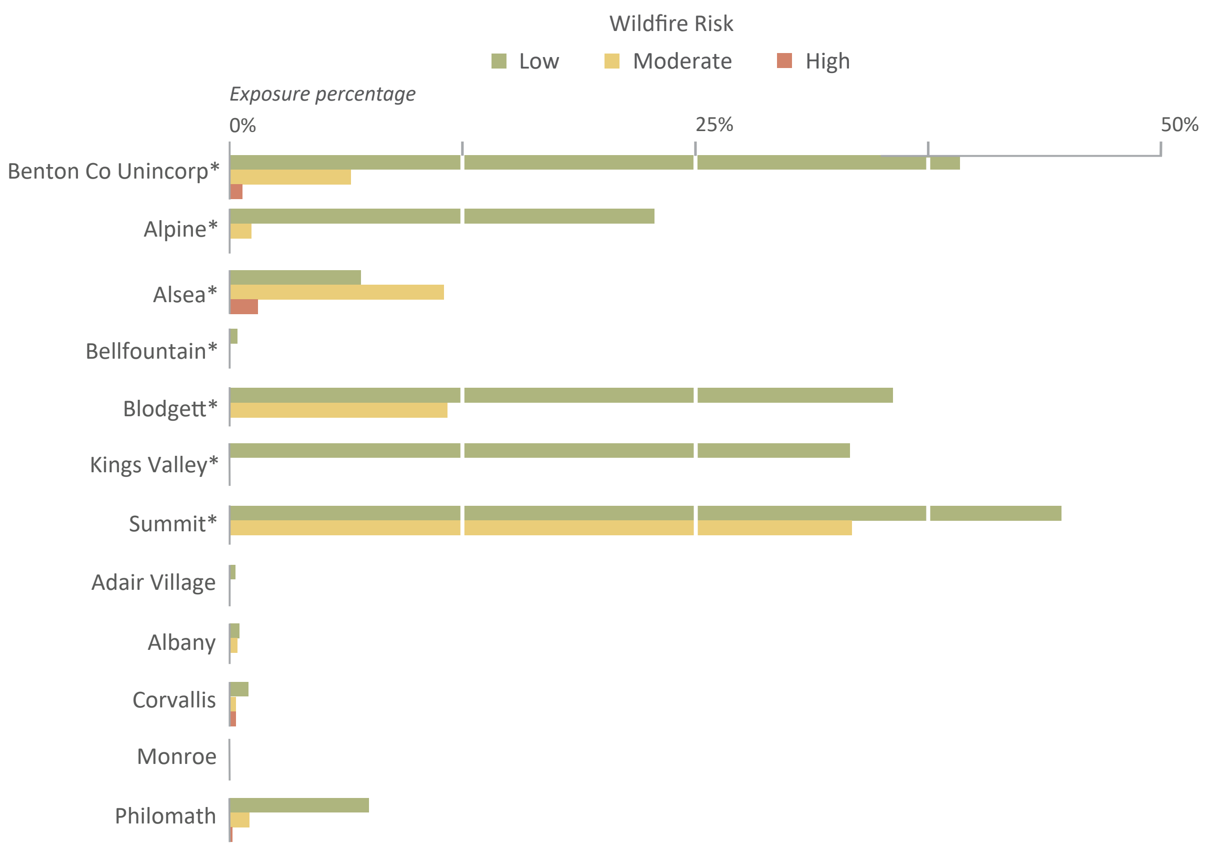
PLATE 10

Wildfire Risk Map of Benton County, Oregon

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.

Wildfire Risk

- Low
- Moderate
- High



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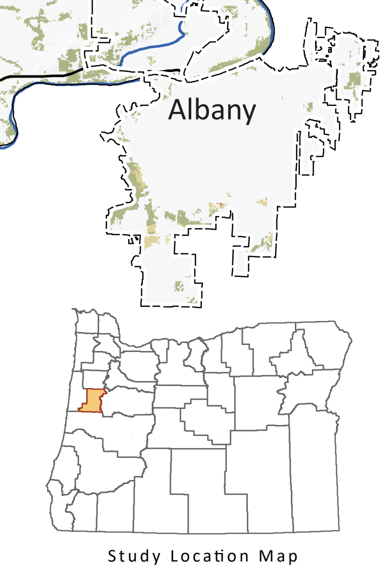

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Data Sources:
Wildfire risk data: Oregon Department of Forestry, Pyrologix, LCC. (2018)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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Cartography by:Matt C. Williams, 2022