Clark Regional Emergency Services Agency

Clark Regional Natural Hazard Mitigation Plan Volume 1—Planning Area-Wide Elements

Approved: March 31, 2023

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PREPARED BY

Clark Regional Emergency Services Agency

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EXECUTIVE SUMMARY

Hazard mitigation is the use of long-term and short-term policies, programs, projects, and other activities to alleviate the death, injury, and property damage that can result from a disaster. Clark County and a partnership of local governments within the County, led by Clark Regional Emergency Management Services (CRESA), have developed a countywide hazard mitigation plan to reduce risks from natural disasters. The plan complies with hazard mitigation planning requirements to establish eligibility for funding under Federal Emergency Management Agency grant programs.

PREVIOUS HAZARD MITIGATION PLANNING IN CLARK COUNTY

Federal regulations require periodic updates of hazard mitigation plans to reevaluate recommendations, monitor the impacts of actions that have been accomplished, and determine if there is a need to change the focus of mitigation strategies. A jurisdiction covered by a plan that has expired is no longer in compliance with the federal requirements for hazard mitigation planning.

Clark County and its seven cities prepared an initial hazard mitigation plan that was approved by the Federal Emergency Management Agency in 2004. In 2016, a comprehensive update to the initial plan was enacted to reestablish grant eligibility for the original planning partnership and to expand eligibility to participating special purpose districts and the City of Woodland. Planning partners who participated in the initial planning effort made efforts to reconcile the status of actions identified in the 2004 plan to the best of their abilities. Due to the significant amount of time that has passed since initial development and other factors such as staff turnover, not all action items were able to be reconciled. Through this planning effort, the planning partnership, led by CRESA, had recommitted to establishing implementation and maintenance processes that will be followed over the performance period of the 2016 plan. A hazard mitigation working group has been established that would meet to coordinate efforts and conduct updates.

In 2022, the current update was enacted to build upon the previous comprehensive update and update the plan with new data, new partners, and updated annexes. The COVID-19 pandemic required the process to go virtual, and coordination was conducted utilizing online platforms. Participating planning partners are listed in Tables ES-1 and ES-2. Eighteen local governments are seeking Disaster Mitigation Act compliance through this planning effort.

Table ES-1-1. Municipal Planning Partners

Jurisdiction	Point of Contact	Title	Jurisdiction	Point of Contact	Title
Clark County	Mike Lewis	Emergency Manager	City of Vancouver	Gene Juve	Emergency Manager
City of Battle Ground	Mark Herceg	Public Works Director	City of Washougal	Mitch Kneipp	Community Development Director
City of Camas	Lauren Hollenbeck	Senior Planner	City of Ridgefield	Lee Knottnerus	Deputy City Manager

Jurisdiction	Point of Contact	Title	Jurisdiction	Point of Contact	Title
City of La Center	Maria Swinger-Inskeep	Director of Administrative Services	Town of Yacolt	Stephanie Fields	Town Clerk

Table ES-1-2. Special Purpose District Planning Partners

Jurisdiction	Point of Contact	Title	Jurisdiction	Point of Contact	Title
Fire District 3	Jason Mansfield	Division Chief	Ridgefield School District	Chris Griffith	Assistant Superintendent
Port of Vancouver	Scott Ouchi	Emergency Manager	Clark Public Utilities	Chrystal Jones	Emergency & Environmental Coordinator
Battle Ground Public Schools	Cheri Dailey	Director of Business & Risk Management	Clark Regional Wastewater District	Shawn Moore	District Engineer
Evergreen Public Schools	Shane Gardner	Director of Safety & Security	C-TRAN	Scott Deutsch	Director of Safety & Risk
Vancouver Public Schools	Nicole Daltoso	Senior Director of Capital Facilities			

PLAN UPDATE PROCESS

Updating the plan consisted of the following phases:

- **Phase 1, Organize Resources**—A planning team was assembled for the plan update, consisting of staff from CRESA and representatives from each of the 18 planning partners. The team conducted outreach to establish the planning partnership. A 18-member planning team was assembled to oversee the plan update. Coordination with other local, state and federal agencies involved in hazard mitigation occurred throughout the plan update process. This phase included a review of the existing plan, the Washington State Hazard Mitigation Plan, and existing programs that may support hazard mitigation actions.
- **Phase 2, Update Goals, Objectives and Actions**—The Planning Team reviewed and updated the goals and objectives from the 2016 plan. The planning partnership selected a range of appropriate mitigation actions to work toward achieving the goals set forth in this plan update. Additionally, the Steering Committee selected a set of county-wide mitigation actions.
- **Phase 3, Develop Plan Implementation and Maintenance Strategy**—The Planning Team developed a plan implementation and maintenance strategy that includes the establishment of a hazard mitigation working group, annual progress reporting, a strategy for continued public involvement, a commitment to plan integration with other relevant plans and programs, and a recommitment from the planning partnership to actively maintain the plan over the five-year performance period.
- **Phase 4, Assemble the Updated Plan**—The Planning Team assembled a document to meet federal hazard mitigation planning requirements for all partners. The updated plan contains two volumes. Volume 1 contains components that apply to all partners and the broader planning area. Volume 2 contains all components that are jurisdiction-specific. Each planning partner has a dedicated annex in Volume 2.

- **Phase 5, Plan Adoption/Implementation**—Once pre-adoption approval has been granted by Washington State's Emergency Management Division and FEMA Region X, the final adoption phase will begin. Each planning partner will individually adopt the updated plan.

Phase 6, Plan Implementation, will occur over the next five years as the planning partnership begins to implement the county-wide and jurisdiction specific actions identified in this plan.

RISK ASSESSMENT RESULTS

Based on the risk assessment, hazards were ranked as follows for the risk they pose to the overall planning area as shown in Table ES-3.

Table ES-1-3. Hazard Risk Ranking

Hazard Ranking	Hazard Event	Category
1	Earthquake	High
1	Severe weather	High
2	Flood	Medium
2	Landslide	Medium
2	Wildfire	Medium
3	Volcano	Low
4	Drought	Low
5	Dam failure	Low

Each planning partner also ranked hazards for its own area. Table ES-4 summarizes the categories of high, medium and low (relative to other rankings) based on the numerical ratings that each jurisdiction assigned each hazard. The results indicate the following general patterns:

- The earthquake and severe weather hazards were most commonly ranked as high.
- The flood and landslide hazards were most commonly ranked as medium.
- The dam failure, drought, volcano and wildfire hazard were most commonly ranked as low.

Table ES-1-4. Summary of Hazard Ranking Results

	Number of Jurisdictions Assigning Ranking to Hazard			
	High	Medium	Low	Not Ranked
Dam Failure	0	1	11	5
Drought	0	0	15	2
Earthquake	15	2	0	0
Flood	2	11	4	0
Landslide	0	10	7	0
Severe weather	15	1	1	0
Volcano	0	3	14	0
Wildfire	2	4	8	3

MITIGATION PURPOSE STATEMENT, GOALS AND OBJECTIVES

The following purpose statement guided the Steering Committee and the planning partnership in selecting the actions contained in this plan update:

> Define natural hazard risk and, through collaboration and partnerships, establish strategies and actions for reducing the impacts of disasters in Clark County.

The Steering Committee and the planning partnership established the following goals for the plan update:

- Reduce and prevent the loss of life and property.
- Protect public services and critical facilities from the impacts of natural disasters.
- Increase public awareness of vulnerability to natural hazards and educate on risk reduction strategies.
- Promote community resilience.
- Protect environmental resources and utilize natural systems to reduce natural hazard impacts.
- Develop and implement cost-effective mitigation strategies.

The following objectives were identified that meet multiple goals, helping to establish priorities for recommended mitigation actions:

1. Inform the public on the risk exposure to natural hazards and ways to increase the public's capability to prepare, respond, recover and mitigate the impacts of these events.
2. Reduce the impacts of hazards on vulnerable populations.
3. Improve and maintain systems that provide warning and emergency communications.
4. Work cooperatively with stakeholders in planning for and reducing the impacts of natural hazards.
5. Incorporate risk reduction strategies in new and updated infrastructure and development plans to reduce the impacts of natural hazards.
6. Integrate natural hazard mitigation goals and objectives into other existing plans and programs within the planning area.
7. Provide incentives for development and land use techniques that reduce risks.
8. Strengthen and build redundancy into infrastructure, prioritizing areas that may be potentially isolated areas.
9. Retrofit, purchase, or relocate structures in high hazard areas, especially those known to be repetitively damaged.
10. Avoid, minimize or mitigate risks to critical facilities and infrastructure.
11. Support and enhance environmental protection and sustainability activities that may also accomplish mitigation objectives.
12. Use the best available data, science and technologies to implement mitigation strategies.

MITIGATION ACTIONS

Status of Previous Plan Initiatives

Table ES-5 summarizes the initiatives that were recommended in the previous version of the hazard mitigation plan and their implementation status at the time this update was prepared.

Table ES-5. County-Wide Mitigation Actions

Action Item	Completed	Carry Over to Plan Update	Removed; No Longer Feasible
Establish a county-wide repository of perishable data from hazard events and develop a standard form for capturing information		X	
Comments: Specific jurisdictions have begun looking at how to best collect data, but a regional effort is still outstanding.			

Develop a county-wide recovery/resiliency plan		X	
Comments: A regional recovery framework was completed for the 5-County Portland-Vancouver Metro Region, which includes Clark County in 2018. Each of the 5 counties had planned to create a local framework which connects to the regional framework, but the plan was delayed due to the COVID-19 pandemic.			
Participate in the plan implementation hazard mitigation working group by sharing lessons learned and mitigation success stories and actively participating in progress reporting		X	
Comments: Continued Action Item			
Support and guide the technology for regional hazard warning systems	X		
Comments: Continued Action Item			
Ensure that a link to the hazard mitigation plan website hosted by CRESA is posted conspicuously on each planning partner website		X	
Comments: Continued Action Item			
Support regional collaboration and consistency in hazard mitigation implementation and programs		X	
Comments: Continued Action Item			
Where appropriate, support retro-fitting, relocating or acquisition from willing property owners of structures located in hazard-prone areas to protect structures from future damage, with repetitive and severe repetitive loss as a priority. Seek opportunities to leverage partnerships within the planning area in these pursuits		X	
Comments: Continued Action Item			
Utilize information contained within the Clark Regional Natural Hazard Mitigation Plan to support updates to other emergency management plans in effect within the planning area		X	
Comments: Continued Action Item			
Utilize information contained within the Clark Regional Natural Hazard Mitigation Plan to support updates to other plans in effect within the planning area		X	
Comments: Continued Action Item			
Develop the capacity for a regional post-disaster volunteer coordination program		X	
Comments: Work in this area had begun through the Clark County Community Organizations Active in Disasters (CC-COAD) group, though much work remains to be completed.			
Explore opportunities with all community stakeholders to implement, identify and fund mitigation actions		X	
Comments: Continued Action Item			
Continue regional partnerships to improve and enhance mitigation efforts in the larger region		X	
Comments: Continued Action Item			
Establish guidelines to increase communication and coordination of mitigation actions across agencies whenever feasible		X	
Comments: Continued Action Item			

Continue to work with planning partners and other stakeholders to clearly articulate and define emergency management roles and responsibilities within the County, including the implementation of identified mitigation actions.		X	
Comments: Continued Action Item			

a. HMGP = Hazard Mitigation Grant Program; FMA = Flood Mitigation Assistance = PDM = Pre-Disaster Mitigation Assistance; CDBG-DR = Community Development Block Grants Disaster Recovery; UASI = Urban Area Security Initiative

HAZARD MITIGATION ACTION PLAN

Mitigation actions presented in this update are activities designed to reduce or eliminate losses resulting from natural hazards. The update process resulted in the identification of more than 272 mitigation actions for implementation by individual planning partners, as presented in Volume 2 of this plan. In addition, the steering committee and planning partnership identified 13 countywide actions benefiting the whole partnership, as listed in Table ES-5.

Table ES-5

Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Lead Agency	Estimated Cost	Sources of Funding[a]	Timeline
CW-1—Establish a county-wide repository of perishable data from hazard events and develop a standard form for capturing information						
New and existing	All hazards	4, 12	CRESA	Low	Staff time	Short-term
CW-2—Develop a county-wide recovery/resiliency plan						
New and existing	All hazards	2, 4, 6	CRESA	High	Local, possible grant funding (UASI)	Short-term
CW-3—Participate in the plan implementation hazard mitigation working group by sharing lessons learned and mitigation success stories and actively participating in progress reporting						
New and existing	All hazards	1, 4, 6, 12	Planning Partners/ facilitated by CRESA	Low	Staff time	Ongoing
CW-4—Ensure that a link to the hazard mitigation plan website hosted by CRESA is posted conspicuously on each planning partner website						
N/A	All hazards	1, 4	Planning Partners	Low	Staff time	Short-term
CW-5—Support regional collaboration and consistency in hazard mitigation implementation and programs						
New and existing	All hazards	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	Clark County/CRESA	Low	Staff time	Ongoing
CW-6—Where appropriate, support retro-fitting, relocating or acquisition from willing property owners of structures located in hazard-prone areas to protect structures from future damage, with repetitive and severe repetitive loss as a priority. Seek opportunities to leverage partnerships within the planning area in these pursuits						
Existing	All hazards	4, 5, 7, 9, 10	Planning Partners	High	HMGP, PDM, FMA, CDBG-DR	Ongoing
CW-7—Utilize information contained within the Clark Regional Natural Hazard Mitigation Plan to support updates to other emergency management plans in effect within the planning area						
New and existing	All hazards	2, 4	CRESA	Low	Staff time	Ongoing
CW-8—Utilize information contained within the Clark Regional Natural Hazard Mitigation Plan to support updates to other plans in effect within the planning area						
New and existing	All hazards	2, 4, 5	Planning Partners	Low	Staff time	Ongoing
CW-9—Develop the capacity for a regional post-disaster volunteer coordination program						
N/A	All hazards	1, 2, 3, 4	CRESA	Medium	Staff time, Local funds	Long-term
CW-10—Explore opportunities with all community stakeholders to implement, identify and fund mitigation actions						
New and existing	All hazards	1, 2, 4,12	CRESA	Medium	Staff time, Local funds	Ongoing

Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Lead Agency	Estimated Cost	Sources of Funding[a]	Timeline
CW-11—Continue regional partnerships to improve and enhance mitigation efforts in the larger region						
New and existing	All hazards	1, 4	CRESA	Low	Staff-time	Ongoing
CW-12—Establish guidelines to increase communication and coordination of mitigation actions across agencies whenever feasible						
New and existing	All hazards	4	CRESA	Low	Staff time	Short-term
CW-13—Continue to work with planning partners and other stakeholders to clearly articulate and define emergency management roles and responsibilities within the County, including the implementation of identified mitigation actions.						
New and existing	All hazards	1, 4, 6	CRESA	Low	Staff time	Ongoing

IMPLEMENTATION

Full implementation of the recommendations of this plan will require time and resources. The measure of the plan's success will be its ability to adapt to changing conditions. Clark County and its planning partners will assume responsibility for adopting the recommendations of this plan and committing resources toward implementation. The framework established by this plan commits all planning partners to pursue actions when the benefits of a project exceed its costs. The planning partnership developed this plan with extensive public input, and public support of the actions identified in this plan will help ensure the plan's success.

Part 1. BACKGROUND AND METHODS

1. INTRODUCTION TO HAZARD MITIGATION PLANNING

1.1 ABOUT HAZARD MITIGATION

1.1.1 What Is It?

As the cost of disasters continues to rise, communities must find ways to reduce hazard risks. The term "hazard mitigation" refers to actions that reduce or eliminate long-term risks caused by hazards such as earthquakes, floods, storms, and wildfires. It involves strategies such as planning, policy changes, programs, projects, and other activities that can mitigate the impacts of hazards. Without an investment in hazard mitigation, repeated disasters result in repeated damage and rebuilding. This recurrent reconstruction becomes more expensive as the years go by. Hazard mitigation breaks this costly cycle of damage and reconstruction by taking a long-term view of rebuilding and recovering from disasters.

1.1.2 When Does it Apply?

The federal Disaster Mitigation Act (DMA) of 2000 requires state and local governments to develop hazard mitigation plans as a condition for federal disaster grant assistance. The DMA emphasizes planning for disasters before they occur. However, hazard mitigation is also essential to post-disaster recovery. After disasters, repairs and reconstruction often just restore damaged property to pre-disaster conditions. The implementation of additional hazard mitigation actions leads to building smarter, safer, and more resilient communities that are better able to reduce future injuries and damage.

1.1.3 Who Is Responsible?

The responsibility for hazard mitigation lies with private property owners; business and industry; and local, state and federal governments. The Federal Emergency Management Agency (FEMA) encourages multi-jurisdictional planning under its guidance for the DMA, urging state and local authorities to work together on pre-disaster planning. The enhanced planning network called for by the DMA helps local governments articulate accurate needs for mitigation, resulting in faster allocation of funding and more cost-effective risk reduction projects. One of the benefits of multi-jurisdictional planning is the ability to pool resources and eliminate redundant activities within a planning area that has uniform risk exposure and vulnerabilities.

1.1.4 How Is It Developed and Implemented?

The DMA promotes sustainability for disaster resistance. "Sustainable hazard mitigation" includes the sound management of natural resources and the recognition that hazards and mitigation must be understood in the largest possible social and economic context. Efforts to reduce risks should be compatible with other community goals, which may be related to economic development, sustainability, public and environmental health, or other issues. As communities plan for new development and improvements to existing infrastructure, mitigation should be an important consideration.

1.2 HAZARD MITIGATION FOR CLARK COUNTY

In 2016, the *Clark Regional Natural Hazard Mitigation Plan* was Clark County's first comprehensive hazard mitigation plan update since the *Clark County Multi-Jurisdictional All-Hazard Mitigation Plan* was initially adopted in 2004. The 2022 update brings us an opportunity to look at the work that was done to ensure that current iteration continues to identify resources and strategies for reducing risk from natural hazards. Strategies were selected because they meet a program requirement and the needs of the planning partners and their residents. The plan will help guide and coordinate mitigation activities throughout the planning area. The main purpose of the plan is to identify risks posed by hazards and to present strategies to reduce the impact of hazard events. The plan also meets the following objectives:

- Meet or exceed requirements of the DMA.
- Enable all planning partners to use federal grant funding to reduce risk through mitigation.
- Meet the needs of each planning partner.
- Create a risk assessment that focuses on Clark County hazards of concern.
- Create a single planning document that integrates all planning partners into a framework that supports partnerships within the county, and puts all partners on the same planning cycle for future updates.
- Meet the planning requirements of FEMA's Community Rating System (CRS), allowing planning partners that participate in the CRS program to maintain or enhance their CRS classifications.
- Coordinate existing plans and programs so that high-priority actions and projects to mitigate possible disaster impacts are funded and implemented.

The process of developing and implementing this plan encompasses eight phases:

- Phase 1—Organize resources
- Phase 2—Perform a risk assessment
- Phase 3—Develop and implement a public involvement strategy
- Phase 4—Identify goals, objectives and actions
- Phase 5—Develop a plan maintenance strategy
- Phase 6—Assemble the updated plan
- Phase 7—Initiate and complete plan review and adoption
- Phase 8—Implement the approved, adopted plan.

The methodology and results of Phases 1 through 5 are presented within this document. Phases 6 through 8 represent activities to move from planning through adoption to implementation of targeted mitigation actions.

1.3 WHO WILL BENEFIT FROM THIS PLAN?

Effective hazard mitigation can provide the following benefits:

- Reduce the loss of life, property, essential services, critical facilities, and economic hardship
- Reduce short-term and long-term recovery and reconstruction costs
- Increase cooperation and communication within the community through the planning process
- Increase potential for state and federal funding for pre- and post-disaster projects.

All residents and businesses of Clark County are the ultimate beneficiaries of this hazard mitigation plan update. The plan identifies strategies and actions that will reduce risk for those who live in, work in, and visit the county. It provides a viable planning framework for all foreseeable natural hazards that may impact the county. Participation in the development of the plan by key stakeholders in the county helped ensure that outcomes will be mutually beneficial. The resources and background information in the plan are applicable countywide, and the plan's goals and recommendations can lay groundwork for the development and implementation of local mitigation activities and partnerships.

1.4 HOW TO USE THIS PLAN

In order to fulfill the requirements of the DMA and be eligible for federal disaster funding grant programs, a local hazard mitigation plan must contain a set of information as outlined in the Code of Federal Regulations (see box at right). The *Clark Regional Natural Hazard Mitigation Plan* has been organized to provide all the required information. Notations are provided throughout the plan indicating specific requirements being addressed.

> **REQUIRED CONTENT FOR LOCAL HAZARD MITIGATION PLANS (44 CFR 201.6(c))**
>
> **1.** Documentation of the process used to develop the plan, including who was involved and how the public was involved.
>
> **2.** A risk assessment that provides the following information:
> - A description of the type, location, and extent of all natural hazards that can affect the jurisdiction, previous occurrences of hazard events, and the probability of future hazard events.
> - A description of the jurisdiction's vulnerability to the hazards in terms of:
>   - Buildings, infrastructure and critical facilities located in hazard areas
>   - Potential dollar losses
>   - Development trends and the ability to consider mitigation in land use decisions.
> - Assessment of each participating jurisdiction's risks where they vary from those of the entire planning area.
>
> **3.** A mitigation strategy for reducing potential losses identified in the risk assessment:
> - A description of mitigation goals.
> - A range of mitigation actions and projects to consider.
> - An action plan for each participating jurisdiction recommending and prioritizing specific mitigation actions.
>
> **4.** A plan maintenance process that includes:
> - A schedule for monitoring, evaluating, and updating the mitigation plan.
> - A process for incorporating the requirements of the mitigation plan into other local planning mechanisms.
> - A plan for ongoing public participation.
>
> **5.** Documentation that the plan has been formally adopted by the governing body of each jurisdiction requesting approval of the plan.

This plan has been set up in two volumes so that elements that are jurisdiction-specific can easily be distinguished from those that apply to the whole planning area:

- **Volume 1**—Volume 1 includes all federally required elements of a disaster mitigation plan that apply to the entire planning area. This includes the description of the planning process, public involvement strategy, goals and objectives, countywide hazard risk assessment, countywide mitigation actions, and a plan maintenance strategy. The following appendices at the end of Volume 1 include supporting information:
  - Appendix A—A glossary of acronyms and definitions
  - Appendix B—The Steering Committee ground rules
  - Appendix C—Hazard mitigation questionnaire and summary of results.
  - Appendix D—Planning partner updates distributed through the course of the planning process
  - Appendix E—Concepts and methods used for hazard mapping
  - Appendix F—Plan adoption resolutions from Planning Partners
  - Appendix G—A template for progress reports to be completed as this plan is implemented.
  - Appendix H—The FEMA plan review crosswalk for this plan
- **Volume 2**—Volume 2 includes all federally required jurisdiction-specific elements, in annexes for each participating jurisdiction. It includes a description of the participation requirements that each jurisdiction agreed to, as well as instructions and templates that the partners used to

complete their annexes. Volume 2 also includes "linkage" procedures for eligible jurisdictions that did not participate in development of this plan but wish to adopt it in the future.

All planning partners will adopt Volume 1 in its entirety and at least the following parts of Volume 2: Part 1; each partner's jurisdiction-specific annex; and the appendices.

2. PLAN UPDATE—WHAT HAS CHANGED

1.1 THE PREVIOUS PLAN

The inevitability of natural hazards and the growing population and activity in Clark County create a need to develop strategies, coordinate resources, and increase public awareness to mitigate future hazard events. To accomplish these objectives, Clark County and its cities prepared a hazard mitigation plan in 2004, which was formally approved by FEMA Region X on December 16, 2004. This effort was led by the Clark Regional Emergency Services Agency (CRESA), which provides emergency management for Clark County and the Cities of Battle Ground, Camas, La Center, Ridgefield, Vancouver, Washougal, and Yacolt. The plan development was funded in part by a planning grant from the federal Hazard Mitigation Grant Program, which was applied for and received after the 2001 Nisqually Earthquake and resulting presidential disaster declaration. Several factors initiated this planning effort:

- The Clark County area has significant exposure to numerous natural hazards that have caused millions of dollars in past damage.
- The participating partners (Clark County and cities and districts within the county) want to be proactive in preparedness for the probable impacts of natural hazards.
- Local resources to undertake risk reduction actions are limited. Being able to leverage federal financial assistance is paramount to successful hazard mitigation.

The 2004 plan was presented in a single volume that addressed eight hazards: earthquakes, floods, severe weather, volcanic eruption, landslide, wildfire, hazardous materials release, and terrorism. Five goals and 11 objectives were identified to guide the identification and selection of mitigation actions to reduce risk from these hazards. The mitigation action plan included 47 targeted mitigation initiatives that were defined and prioritized through a workshop process with Stakeholder Committee members. Jurisdiction-specific risk assessment information and mitigation actions were presented in two chapters covering all participating jurisdictions.

The performance period of the initial plan ran from 2004 to its expiration in 2009. Due to the length of time that the 2004 remain expired, the 2016 *Clark Regional Natural Hazard Mitigation Plan* was considered as a new plan with a new process and a new direction. The process brought in additional planning partners to cover many of the special districts within the community. The 2016 planning process allowed partners to look at mitigation planning in a new light and determine the best way to move forward for each jurisdiction involved. The plan was approved on August 16, 2017.

2.1 WHY UPDATE?

Natural hazards continue to impact residents, property, the environment and the economy of Clark County. Since the initial planning effort, the communities of Clark County have undergone changes in their composition, development patterns, and priorities. This update provides an opportunity to reevaluate recommendations, monitor the impacts of actions that have been accomplished, and determine if there is a need to change the focus of mitigation strategies.

2.1.1 Changes in Development

Hazard mitigation plans must be revised to reflect changes in development within the planning area during the previous performance period of the plan (44 CFR Section 201.6(d)(3)). The plan must describe development changes in hazard-prone areas that increased or decreased vulnerability for each jurisdiction since the last plan was approved. If no changes in development impacted the jurisdiction's overall vulnerability, then plan updates may validate the information in the previously approved plan. The intent of this requirement is to ensure that the mitigation strategy continues to address the risk and vulnerability of existing and potential development and takes into consideration possible future conditions that could impact vulnerability.

Clark County and its incorporated cities have experienced relatively moderate changes in population, housing and land use in recent years. The total County population increased 11.4 percent from 2015 to 2020, to 503,311. Unincorporated areas saw a population growth of 5.5 percent over that time and incorporated areas grew 6.8 percent. Land uses have remained mostly constant, with minor changes in some places, mostly in Camas, La Center, and Yacolt (Clark County, 2016).

From 2000 to 2019, Clark County's estimated total housing units increased from 134,030 to 189,853—a 42-percent increase. Vacant and renter-occupied units were also on the rise, but so were household income and the ability for individuals to secure adequate housing (Clark County, 2016).

The county lost 6 percent of its employment base in the economic downturn starting in 2008, worse than the nation and state. In 2013 the downward employment trend in Clark County reversed and job growth began accelerating (Clark County, 2016).

There was a major update of Clark County's Shoreline Master Program in 2012 with reviews conducted and amendments approved most recently in 2020 to comply with amendments to the State Shoreline Management Act. The changes were relatively minor—simplifying shoreline designations, making them more consistent with the cities, protecting shoreline environmental functions, and encouraging public access and water-dependent use (Clark County, 2016).

A Rural Lands Task Force has been established to examine and make recommendations on how the County could facilitate more efficient use of its rural and resource lands (Clark County, 2016).

Changes in development are difficult to assess between the 2004 and 2016 hazard mitigation plans due to a variety of factors. One particularly important factor is that the 2004 plan loss estimates focused on residential losses, while the 2016 update assesses all general building stock in the planning area. Exposure and vulnerability are discussed as appropriate in the risk assessment portion of this plan; however, it should be noted that the changes in methodology used to assess risk between the planning processes are significant. Clark County and its cities have adopted comprehensive plans that govern land-use decisions and policy-making, as well as a building code and specialty ordinances based on state and federal mandates. This plan update assumes that some new development triggered by the increase in population occurred in hazard areas. Because all such new development would have been regulated pursuant to local programs and codes, it is generally assumed that vulnerability did not increase even if exposure did. Now that the planning area is equipped with tools such as a level 2 user-defined Hazus–MH model for the planning area, this type of comparative analysis will be possible for future updates to this plan.

The 2022 hazard mitigation plan update was unable to provide additional focus on development assessments and hazard risk assessments due to the COVID-19 Pandemic. The planning team was unable to dedicate time to the plan due to staffing shortages, budgetary restrictions, and planning team members working in the emergency operations center for numerous activations.

2.1.2 Federal Eligibility

Federal planning requirements stipulate that hazard mitigation plans must present a schedule for monitoring, evaluating, and updating the plan. A jurisdiction covered by a plan that has expired is not able to pursue elements of federal funding for which a current hazard mitigation plan is a prerequisite. The schedule for updating the plan in the 2004 effort was not followed, and that plan expired in 2009. 11 years passed since the initial planning effort, and coverage has lapsed from 2009 until the updated plan was approved in 2017. During the 2017 plan update, CRESA committed to maintaining this plan in accordance with federal requirements on behalf of the Clark regional hazard mitigation planning partnership that has committed to this process. The current update is being completed in compliance of federal expectations.

2.2 THE UPDATED PLAN—WHAT IS DIFFERENT?

The 2023 plan update was a challenge due to the kickoff being pushed back due to the COVID-19 Pandemic. The pandemic also limited the planning partner's available time and staffing to work on the mitigation plan update. To respect our partner's ability to complete the plan, we kept the plan update fairly simple and did not make changes to the structure of the plan. The mitigation plan update focused on updating the hazard analysis with updated/new information and data, as well as updating the jurisdictional annexes. We also added 2 new partners into the planning process, but lost one along the way.

Table 2-1 indicates the major changes between the two plans as they relate to 44 CFR planning requirements.

Table 2-1. Plan Changes Crosswalk

44 CFR Requirement	Previous Plan	Updated Plan
§201.6(b): In order to develop a more comprehensive approach to reducing the effects of natural disasters, the planning process shall include: (1) An opportunity for the public to comment on the plan during the drafting stage and prior to plan approval; (2) An opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have the authority to regulate development, as well as businesses, academia and other private and non-profit interests to be involved in the planning process; and (3) Review and incorporation, if appropriate, of existing plans, studies, reports, and technical information.	The plan update was facilitated through a Steering Committee made up of stakeholders within the planning area. The Steering Committee was responsible for review of relevant plans and programs, review and identification of goals and objectives, confirmation of a public involvement strategy, development of a plan implementation and maintenance strategy, and review and approval of the draft plan. All Steering Committee meetings were open to the public. Additional public input was received through several public events early and late in the planning process and through a public survey. A 30-day public comment period was held before the draft plan was submitted for review. Agency coordination occurred through several avenues including the development of the risk assessment, monthly updates on plan progress distributed to a mailing list, attendance at steering committee meetings, the composition of the Steering Committee and the dissemination of the draft plan for public comment.	The plan update was facilitated through a Planning Team made up of representatives within the planning area. The Planning Team was responsible for review of relevant plans and programs, review and identification of goals and objectives, confirmation of a public involvement strategy, development of a plan implementation and maintenance strategy, and review and approval of the draft plan. Public input was received through release of a public feedback draft and social media updates. Due to limited outreach events stemming from the COVID-19 Pandemic, most outreach was conducted virtually. A 30-day public comment period was held before the draft plan was submitted for review. Agency coordination occurred through several avenues including the development of the risk assessment through a collaborative virtual platform, attendance at planning team meetings, and the dissemination of the draft plan for public comment.
§201.6(c)(2): The plan shall include a risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.	A comprehensive risk assessment for the planning area that looks at 8 natural hazards of concern: dam failure, drought, earthquake, flood, landslide, severe weather, volcanic hazards, and wildfire. This assessment used the best available data and science with the Hazus-MH (version 2.2) risk assessment software and GIS analysis.	Time and funding limitations prevented a full Hazus-MH risk assessment from being completed, but information was updated where relevant new data was available. All relevant data tables and figures were updated to include the most up-to-date information. Additionally, information from the Portland-Vancouver Metro Area's Enhanced Earthquake Analysis was included in the analysis.
§201.6(c)(2)(i): [The risk assessment shall include a] description of the … location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.	Comprehensive risk assessments of each hazard of concern are presented in Chapters 7 through 14. Each chapter includes the following: • Hazard profile, including maps of extent and location, historical occurrences, frequency, severity and warning time • Secondary hazards • Exposure of people, property, critical facilities and environment • Vulnerability of people, property, critical facilities and natural environment • Future trends • Scenarios • Issues. Each hazard is compared to each other via a risk ranking methodology described in Chapter 15.	Comprehensive risk assessments of each hazard of concern are presented in Chapters 7 through 14. Each chapter includes the following: • Hazard profile, including maps of extent and location, historical occurrences, frequency, severity and warning time • Secondary hazards • Exposure of people, property, critical facilities and environment • Vulnerability of people, property, critical facilities and natural environment • Future trends • Scenarios • Issues. Each hazard is compared to each other via a risk ranking methodology described in Chapter 15.

44 CFR Requirement	Previous Plan	Updated Plan
§201.6(c)(2)(ii): [The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i). This description shall include an overall summary of each hazard and its impact on the community	Vulnerability was assessed for all hazards of concern. The Hazus-MH computer model was used for the dam failure, earthquake, and flood hazards. These were Level-2 (user-defined) analyses using coordinating agency and County data. Critical facilities and assets were defined and inventoried using the Hazus Comprehensive Data Management System and other available datasets. Outputs were generated for other hazards by applying an estimated damage function to affected assets when available. The asset inventory was extracted from the Hazus-MH model. Best available data were used for all analyses.	The current plan utilizes the information from the 2016 hazard analysis and provide updated data/information as supplement to the previous needs.
§201.6(c)(2)(ii): [The risk assessment] must also address National Flood Insurance Program insured structures that have been repetitively damaged floods	The description of the National Flood Insurance Program and repetitive loss discussion was enhanced to meet new DMA and CRS planning requirements. The update includes an analysis of repetitive loss properties. For these properties the type of structure was determined and likely causes of flooding were cited, and the information was reflected on maps. National Flood Insurance Program capability is also assessed for each jurisdiction in Volume II.	The repetitive loss properties were updated to include losses between the previous plan and the current.
§201.6(c)(2)(ii)(A): The plan should describe vulnerability in terms of the types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard area.	A complete inventory of the numbers and types of buildings exposed was generated for each hazard of concern. The Steering Committee defined "critical facilities" as they pertained to the planning area, and these facilities were inventoried. Each hazard chapter provides a discussion of future development trends as they pertain to the hazard.	Future development numbers were updated to the best of the ability. Limited changes have been made to the comprehensive growth plan since the last update. The current growth plan is current through 2035. Estimates were updated where data allowed.
§201.6(c)(2)(ii)(B): [The plan should describe vulnerability in terms of an] estimate of the potential dollar losses to vulnerable structures identified in paragraph (c)(2)(i)(A) and a description of the methodology used to prepare the estimate.	Dollar loss estimations were generated for all hazards of concern likely to impact property. These were generated by Hazus for the dam failure, earthquake, and flood. For the other hazards, loss estimates were generated by applying a regionally relevant damage function to the exposed inventory. In all cases, a damage function was applied to an asset inventory. The asset inventory was the same for all hazards and was generated in the Hazus-MH model.	Funding and time constraints prevented running a full comprehensive vulnerability assessment. While there has been development and inflation since the 2016 plan was completed, the estimates from the 2016 Hazus-MH analysis were used for this update, with the understanding that a full analysis will need to be run for the next mitigation plan update.

44 CFR Requirement	Previous Plan	Updated Plan
§201.6(c)(2)(ii)(C): [The plan should describe vulnerability in terms of] providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.	There is a discussion on future development trends as they pertain to each hazard of concern. This discussion looks predominantly at the existing land use and the current regulatory environment that dictates this land use and also includes information on vacant buildable lands where feasible.	There is a discussion on future development trends as they pertain to each hazard of concern. This discussion looks predominantly at the existing land use and the current regulatory environment that dictates this land use and also includes information on vacant buildable lands where feasible.
§201.6(c)(2)(iii): For multi-jurisdictional plans, the risk assessment must assess each jurisdiction's risks where they vary from the risks facing the entire planning area.	Risk assessment results were generated for each planning partner to support the concept of risk ranking, which was performed by each planning partner. Risk ranking was used by each planning partner to provide vision and focus to action plan development.	Risk assessment results were generated for each planning partner to support the concept of risk ranking, which was performed by each planning partner. Risk ranking was used by each planning partner to provide vision and focus to action plan development
§201.6(c)(3): The plan shall include a mitigation strategy that provides the jurisdiction's blueprint for reducing the potential losses identified in the risk assessment, based on existing authorities, policies, programs and resources, and its ability to expand on and improve these existing tools.	Action plans were developed for each planning partner via a facilitated process that includes: • Risk ranking • Capability assessment • Action alternative review • Action selection • Action prioritization • Action category analysis	Action plans were developed for each planning partner via a facilitated process that includes: • Risk ranking • Capability assessment • Action alternative review • Action selection • Action prioritization • Action category analysis
§201.6(c)(3)(i): [The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.	The plan update identifies a purpose, 6 goals and 12 objectives. Goals were selected that support the purpose, objectives were selected that meet multiple goals, and actions were selected and prioritized based on meeting multiple objectives.	The plan update identifies a purpose, 6 goals and 12 objectives. Goals were selected that support the purpose, objectives were selected that meet multiple goals, and actions were selected and prioritized based on meeting multiple objectives.
§201.6(c)(3)(ii): [The mitigation strategy shall include a] section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of each hazard, with particular emphasis on new and existing buildings and infrastructure.	A hazard mitigation best practices catalog was developed through a facilitated process that looks at strengths, weaknesses, obstacles and opportunities in the planning area. This catalog identifies actions that manipulate the hazard, reduce exposure to the hazard, reduce vulnerability, and increase mitigation capability. The catalog further segregates actions by scale of implementation. A table in the action plan section analyzes each action by mitigation type to illustrate the range of actions selected.	A hazard mitigation best practices catalog was developed through a facilitated process that looks at strengths, weaknesses, obstacles and opportunities in the planning area. This catalog identifies actions that manipulate the hazard, reduce exposure to the hazard, reduce vulnerability, and increase mitigation capability. The catalog further segregates actions by scale of implementation. A table in the action plan section analyzes each action by mitigation type to illustrate the range of actions selected.
§201.6(c)(3)(ii): [The mitigation strategy] must also address the jurisdiction's participation in the National Flood Insurance Program, and continued compliance with the program's requirements, as appropriate.	All municipal planning partners were asked to assess National Flood Insurance Program capability in their jurisdictional annexes. All participating communities have identified actions supporting continued compliance and good standing under the program.	All municipal planning partners were asked to assess National Flood Insurance Program capability in their jurisdictional annexes. All participating communities have identified actions supporting continued compliance and good standing under the program.

44 CFR Requirement	Previous Plan	Updated Plan
§201.6(c)(3)(iii): [The mitigation strategy shall describe] how the actions identified in Section (c)(3)(ii) will be prioritized, implemented, and administered by the local jurisdiction. Prioritization shall include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.	Each of the recommended actions is prioritized using a qualitative methodology that looked at the objectives the project will meet, the timeline for completion, how the project will be funded, the impact of the project, the benefits of the project and the costs of the project. This prioritization scheme is detailed in Chapter 18.	Each of the recommended actions is prioritized using a qualitative methodology that looked at the objectives the project will meet, the timeline for completion, how the project will be funded, the impact of the project, the benefits of the project and the costs of the project. This prioritization scheme is detailed in Chapter 18.
§201.6(c)(4)(i): [The plan maintenance process shall include a] section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan within a five-year cycle.	A detailed plan maintenance strategy is provided that includes the following: • Annual review and progress reporting • Defined role for Steering Committee • Plan update triggers • Plan incorporation guidelines • Strategy for continuing public involvement • Grant coordination protocol	A detailed plan maintenance strategy is provided that includes the following: • Annual review and progress reporting • Defined role for Steering Committee • Plan update triggers • Plan incorporation guidelines • Strategy for continuing public involvement • Grant coordination protocol
§201.6(c)(4)(ii): [The plan shall include a] process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvement plans, when appropriate.	This is included in the detailed plan maintenance strategy and also discussed in each jurisdictional annex.	This is included in the detailed plan maintenance strategy and also discussed in each jurisdictional annex.
§201.6(c)(4)(iii): [The plan maintenance process shall include a] discussion on how the community will continue public participation in the plan maintenance process.	This is included in the detailed plan maintenance strategy.	This is included in the detailed plan maintenance strategy.
§201.6(c)(5): [The local hazard mitigation plan shall include] documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval of the plan (e.g., City Council, County Commission, Tribal Council).	17 planning partners will seek DMA compliance for this plan. Appendix G contains the resolutions of all planning partners that adopted this plan	

3. PLANNING APPROACH

The planning effort to prepare the 2022 update to the *Clark Regional Natural Hazard Mitigation Plan* required a unique approach due to disruptions in planning team availability and the inability to meet in person due the 2019 COVID Pandemic. The process necessitated online meetings and utilization of an online collaboration platform. The approach to developing this hazard mitigation plan encouraged participation from many stakeholders. The activities carried out under this approach are described in the following sections (44 CFR, Section 201.6(c)(1)).

3.1 FORMATION OF THE PLANNING TEAM

A planning team was convened with representation of members of each of the jurisdictions involved in the planning update effort. The planning team was led by the Mitigation Coordinator at Clark Regional Emergency Services Agency acting as the Project Manager. The Project Manager presented the timeline, priorities, goals, and tools to be utilized by the planning team. They also managed the online collaborative planning workspace and facilitated virtual meetings.

3.2 ESTABLISHMENT OF THE PLANNING PARTNERSHIP

In order to promote the wise use of resources and to encourage coordination within the County, CRESA encouraged all eligible local governments to participate in this hazard mitigation planning process. The planning team invited all local governments to a planning partner kickoff meeting on Sept 28, 2021. This meeting was held to introduce the planning team, provide an overview of the mitigation planning process and solicit planning partners. Key objectives were as follows:

- Provide an overview of the Disaster Mitigation Act.
- Describe the reasons for a plan.
- Introduce the planning team.
- Outline the work plan.
- Outline planning partner expectations.
- Seek commitment to the planning partnership.
- Explain the role of CRESA in maintaining the plan and the partnership.

Each jurisdiction wishing to join the planning partnership was asked to provide a “letter of intent to participate” that designated a primary and secondary point of contact for the jurisdiction and confirmed the jurisdiction’s commitment to the process and understanding of expectations. Linkage procedures have been established (see Volume 2 of this plan) for any jurisdiction wishing to link to the Clark County plan in the future. The municipal planning partners covered under this plan are shown in Table 3-1. The special purpose district planning partners are shown in Table 3-2.

Table 3-1. Municipal Planning Partners

Jurisdiction	Point of Contact	Title	Jurisdiction	Point of Contact	Title
Clark County	Mike Lewis	Emergency Manager	City of Vancouver	Gene Juve	Emergency Manager
City of Battle Ground	Mark Herceg	Public Works Director	City of Washougal	Mitch Kneipp	Community Development Director

Jurisdiction	Point of Contact	Title	Jurisdiction	Point of Contact	Title
City of Camas	Lauren Hollenbeck	Senior Planner	City of Ridgefield	Lee Knottnerus	Deputy City Manager
City of La Center	Maria Swinger-Inskeep	Director of Administrative Services	Town of Yacolt	Stephanie Fields	Town Clerk

Table 3-2. Special Purpose District Planning Partners

Jurisdiction	Point of Contact	Title	Jurisdiction	Point of Contact	Title
Fire District 3	Jason Mansfield	Division Chief	Ridgefield School District	Chris Griffith	Assistant Superintendent
Port of Vancouver	Scott Ouchi	Emergency Manager	Clark Public Utilities	Chrystal Jones	Emergency & Environmental Coordinator
Battle Ground Public Schools	Cheri Dailey	Director of Business & Risk Management	Clark Regional Wastewater District	Shawn Moore	District Engineer
Evergreen Public Schools	Shane Gardner	Director of Safety & Security	C-TRAN	Scott Deutsch	Director of Safety & Risk
Vancouver Public Schools	Nicole Daltoso	Senior Director of Capital Facilities			

3.3 THE STEERING COMMITTEE

A change from the 2016 plan was to eliminate the Steering Committee and focus on interfacing directly with the planning partners. This change was partly in response to many jurisdictions having changes in workflows and representative availability due to the 2019 COVID Pandemic. Asking members of the planning team to take on additional duties at this time was untenable. This approach will be reviewed for the next update to determine the best way forward then.

3.4 COORDINATION WITH OTHER AGENCIES

Opportunities for involvement in the hazard mitigation planning process must be provided to neighboring communities, local and regional agencies involved in hazard mitigation, agencies with authority to regulate development, businesses, academia, and other private and nonprofit interests (44 CFR, Section 201.6(b)(2)). This task was accomplished by the planning team as follows:

- **Planning Partnership Formation**—Eligible local jurisdictions in the planning area were invited to participate in the planning partnership. This included 35 municipalities and special purpose districts, of which 18 submitted letters of intent to participate in the planning partnership.
- **Steering Committee Involvement**—Agency representatives were invited to participate on the Steering Committee. In addition to the agencies that ultimately agreed to serve on the committee, the following agencies and organizations were contacted regarding their participation, but were unable to participate:
  - Cascade Volcano Observatory
  - Clark County Local Emergency Planning Committee
  - Fire Chiefs Association
  - Washington Department of Natural Resources.
- **Data Provision**—The following agencies were contacted during the course of the planning process to provide data or technical input:

  - Cascade Volcano Observatory
  - Cowlitz County
  - PacifiCorp
  - Washington Department of Natural Resources.
- **Agency Notification**—The following agencies were kept apprised of planning milestones and invited to participate in the plan development through steering committee meeting reminders and monthly updates:
  - Cascade Volcano Observatory
  - Clark County Sheriff's Office
  - Columbia County Emergency Management
  - Cowlitz County Department of Emergency Management
  - Evergreen Public Schools
  - FEMA Region X
  - Multnomah County Emergency Management
  - Northwest Natural
  - PeaceHealth Southwest Medical Center
  - Portland Bureau of Emergency Management
  - Skamania County Department of Emergency Management
  - U.S. Forest Service
  - Washington County Emergency Management
  - Washington Department of Ecology
  - Washington Department of Natural Resources
  - Washington Emergency Management Division
  - Washington State Department of Commerce
  - Washington State Department of Transportation.

  These agencies received notices that included meeting announcements and meeting agenda. Many of these agencies supported the effort by attending meetings.
- **Pre-Adoption Review**—All the agencies listed above were provided an opportunity to review and comment on this plan, primarily through the hazard mitigation plan website (see Section 3.5). Each agency was sent an e-mail message informing them that draft portions of the plan were available for review. In addition, the complete draft plan was sent to FEMA's Community Rating System contractor, the Insurance Services Office, Inc., for a pre-adoption review to ensure CRS program compliance.

Distribution lists for agency coordination are available upon request.

3.5 PUBLIC INVOLVEMENT

Broad public participation in the planning process helps ensure that diverse points of view about the planning area's needs are considered and addressed. The public must have opportunities to comment on disaster mitigation plans during the drafting stages and prior to plan approval (44 CFR, Section 201.6(b)(1)). The Community Rating System (CRS) expands on these requirements by making CRS credits available for optional public involvement activities.

3.5.1 Strategy

The COVID-19 Pandemic required the mitigation planning team to rethink public outreach. Limited pre-planned outreach activities and in-person presentations required the team to focus on virtual meeting platforms and outreach opportunities. The outreach strategy leaned heavily on partners sharing on their websites, social media, and press releases to get public draft feedback.

Press Releases and Media Coverage

This Press release was distributed as the public review draft was posted in order for regional partners and the public to provide feedback and comments to the plan.

CRESA SEEKS COMMENT ON UPDATED HAZARD MITIGATION PLANS
News Release from Clark Regional Emergency Services (CRESA)
Posted on FlashAlert: November 8th, 2022 12:21 PM
For the past year CRESA has been working with 17 local agencies and jurisdictions to update our 2017 Natural Hazard Mitigation Plan.
These plans are usually updated annually as needed with a full review every five years. Due to COVID-19, this cycle was extended for 1 year.
Now it's your opportunity to share your thoughts on the plan. Please visit: cresa911.org/emergency-management/mitigation/ to read the updated plans.
Comments and feedback can be sent to: scott.johnson@clark.wa.gov

The press release generated an article in the local newspaper that can be found at https://www.columbian.com/news/2022/nov/09/clark-regional-emergency-services-agency-seeks-feedback-on-hazard-mitigation-plan/

Social Media

Examples of outreach using social media are shown in Figure 3-1.

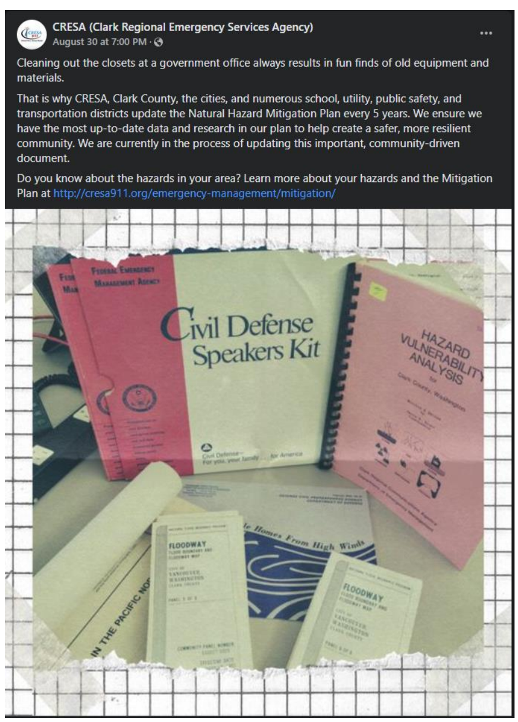

Figure 3-1. Hazard Mitigation Planning Information on Social Media

Project and Partner Websites

Since the creation of the 2017 plan, CRESA has maintained a mitigation page http://cresa911.org/emergency-management/mitigation/ on the CRESA website to keep the public posted on plan development milestones (see Figure 3-2):

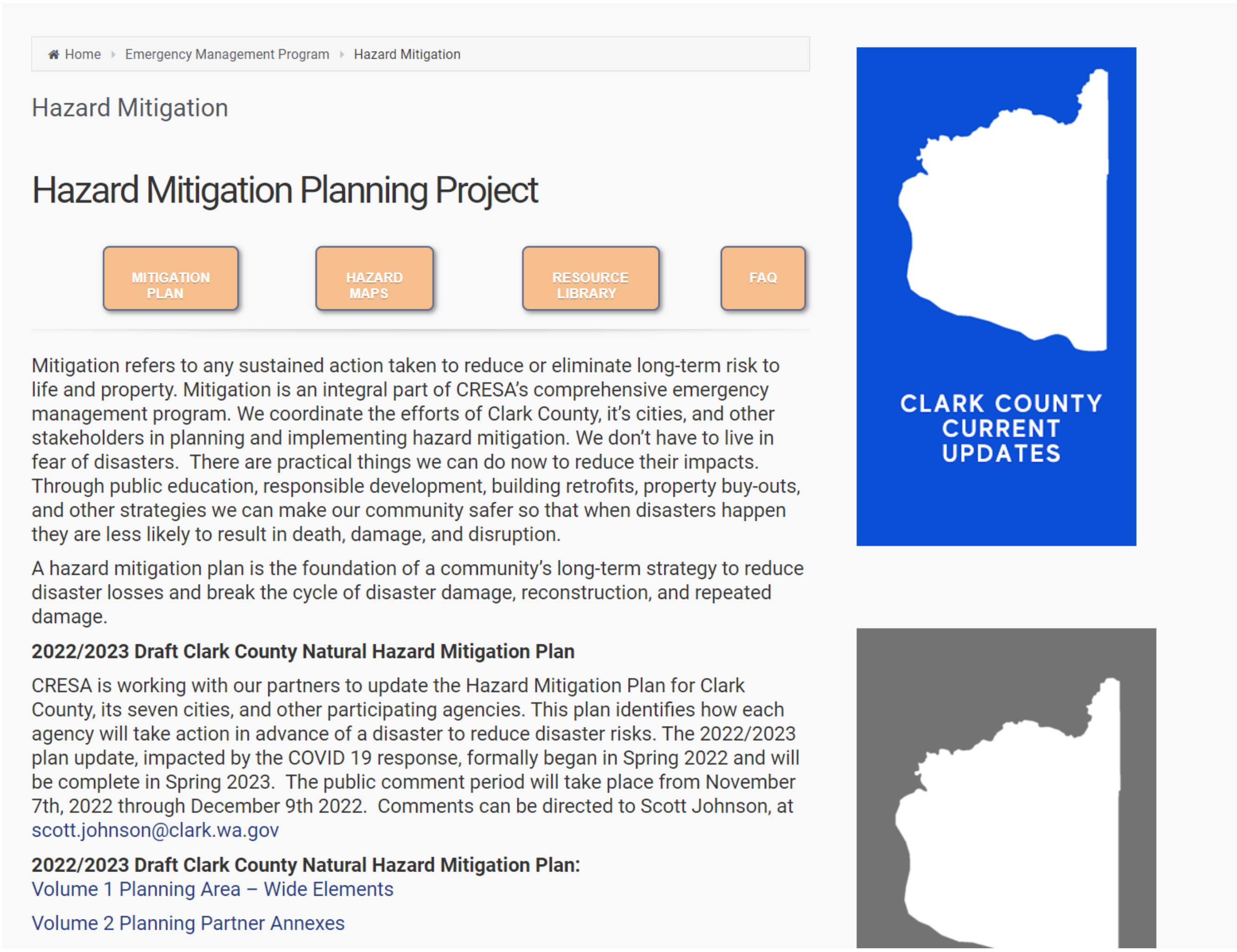

Figure 3-2. Sample Page from Hazard Mitigation Plan Web Site

In addition to the CRESA website, some partner agencies have also posted notices on their community facing websites to showcase both their participation in the planning process and to facilitate community members commenting. (See Table 3-1)

Clark Regional Waste Water District
Vancouver Public Schools
Battle Ground Public Schools
City of Ridgefield
Town of Yacolt

Table 3-1. Sample of partner agency websites notifying public of comment opportunities

Public Involvement Results

Public Comment Period

A 30 day public comment period was held from November 7 2022 to December 9 2022. No public comments were received. Partner comments we of an administrative nature and included website updates and agency name changes.

3.6 PLAN DEVELOPMENT CHRONOLOGY/MILESTONES

Table 3-3 summarizes important milestones in the development of the plan. Most of the planning process was conducted over email and utilizing a collaborative virtual work environment called Mural. For this reason, meetings were kept to a minimum in order to assist planning partners who were working on pandemic response and with smaller workforces.

Table 3-3. Plan Development Milestones

Date	Event	Description
2021		
9/28	Planning partner kickoff meeting	Attendees were advised of planning partner expectations and asked to formally commit to the process.
2022		
1/13	Planning Team Meeting	Introduced the collaborative planning platform and discussed the Annex development process
11/7	Public outreach	Public comment period opens
12/9	Public outreach	Public comment period closes
12/12	Regulatory review submittal	Final draft plan submitted to Washington State for review and approval
2023		
X/X	Adoption	Adoption window of final plan opens
X/X	Plan approval	Final plan approved by FEMA

4. CLARK COUNTY PROFILE

4.1 PLANNING AREA OVERVIEW

Clark County is located in southwest Washington, in the northern portion of the Portland metropolitan area. The county borders the relatively rural Washington counties of Cowlitz to the north and Skamania to the east. The Columbia River makes up the county's western and southern borders, with the State of Oregon across the river. Clark County is the fifth smallest of Washington's 39 counties by area (656 square miles) but the fifth largest by population (503,311 in 2020).

Seven incorporated cities lie entirely within the county, and the City of Woodland lies partly in Clark County and partly in Cowlitz County. The City of Vancouver is the county seat. The other incorporated cities in the county are Battle Ground, Camas, La Center, Ridgefield, Washougal, and Yacolt. The planning area for this hazard mitigation plan consists of all incorporated and unincorporated areas of Clark County, as well as the portion of the City of Woodland that lies in Cowlitz County. All partners to this plan have jurisdictional authority within this planning area.

The Cowlitz Indian Tribe is the only tribe with land in the county; the Tribe also has land in Cowlitz County (Washington State, 2015). The Tribe's reservation was established in March 2015 along Interstate 5, west of La Center, when a U.S. District Court judge approved 152 acres in Clark County to be set aside for it (Cowlitz Tribe, 2015).

4.2 PHYSICAL SETTING

4.2.1 Topography and Geology

Elevations in Clark County range from 50 feet in downtown Vancouver to over 3,500 feet in the foothills in the northeast. The Cascade Mountain Range, crossing the eastern half of the county, was formed 4 to 7 million years ago as a result of the steep descent of the Juan De Fuca plate below the continental margin. The friction of this descent created two folds that formed the Cascade and Olympic Mountain Ranges. (Townsend and Figge, 2002).

In addition to tectonic movements, repeated glacier movement across the region over the past 2 million years affected the geological features of the western portion of Clark County. The most recent period of glaciation was the Vashon period, which occurred during the late Pleistocene. Glaciers in this period advanced into Washington from Canada about 18,000 years ago and retreated 10,000 to 12,000 years ago (Townsend and Figge, 2002).

4.2.2 Seismic and Volcanic Features

The Washington portion of the Portland metropolitan area is the second most seismically active area in Washington, after the Puget Sound area. Clark County lies between the Lacamas Lake Fault in the eastern part of the county and the Portland Hills Fault in Oregon. Earthquakes in this area present what may be the worst-case scenario for Clark County because the epicenters may be quite close. Geologists theorize there may be faults directly underneath the cities of Portland and Vancouver. Recent studies suggest that the epicenter for the Magnitude 5.5 earthquake on November 5, 1962 was located underneath the City of Vancouver (CRESA, 2011).

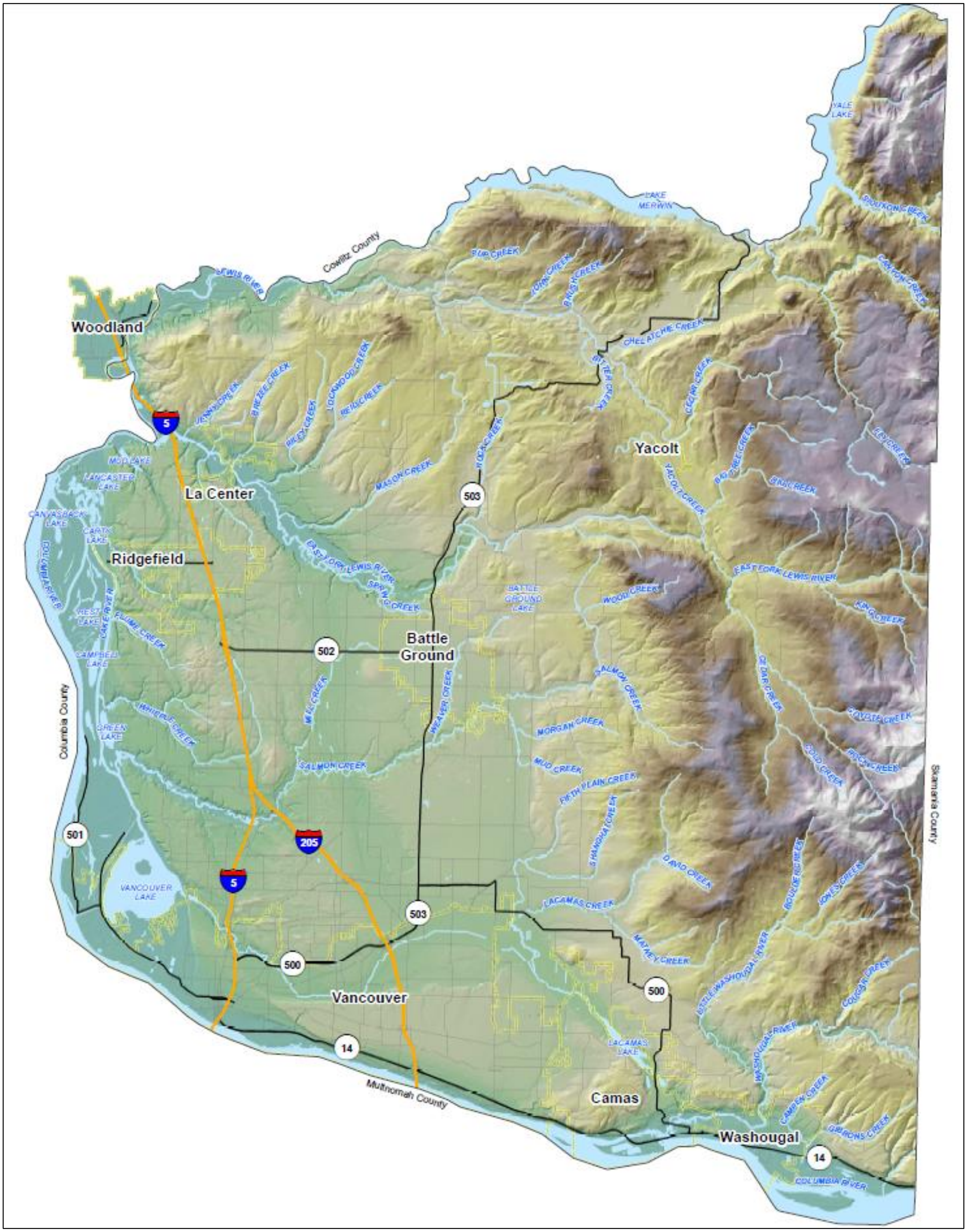

Figure 4-1. Main Features of the Planning Area

All of western Washington also is located on the Pacific “Ring of Fire”—a geological area known for volcanic activity and frequent seismic activity. Washington is near the convergence of several tectonic plates, including the Pacific, North American, and Juan de Fuca. In general earthquakes in the area arise from three sources:

- The oblique subduction of the Juan de Fuca plate can produce events as large as magnitude 7.
- Faults on the North American plate can produce moderate to large events on either side of the Cascades.
- Great earthquakes, which can have magnitudes of 9.0 or greater, can occur at the boundaries of these plates generally referred to as the Cascadia Subduction Zone (USGS, 2012a).

Mount St. Helens, Mount Hood and Mount Adams are nearby volcanoes associated with the Cascade range. Active volcanoes have been present in the Cascades for millions of years, and the remnants of former volcanoes make up the bedrock of the current Cascade range. Volcanoes in the range are still active, although their presence as a result of the fold is merely incidental to the older chain (Townsend and Figge, 2002).

4.2.3 Soils

Clark County is located within the Willamette-Puget trough, a structural low between the Coast Range to the west and the Cascade Range to the east. The regional geology of Clark County is generally divided into four major physiographic categories (CRESA, 2004):

- The Lowland Valley area, adjacent to the Columbia River, consists primarily of recent floodplain and stream deposits of semi-consolidated silt, clay, sand, and gravel.
- Alluvial deposits of thickness ranging from a few feet to about 200 feet overlying the Troutdale Formation define the Fourth Plains area.
- The Troutdale bench is the highest in a series of flat plains rising step-like from the Columbia River and is predominately composed of cemented sandy gravel and fine sand, silt and clay.
- The Foothills area rising to the east is a mixture of older, mostly volcanic, consolidated rocks underlying local sedimentary deposits.

4.2.4 Surface Waters

Major waterways in or surrounding Clark County are the Columbia River, the Lewis River, and the East Fork of the Lewis River. Smaller waterways include Cedar Creek, Canyon Creek, Chelatchie Creek, Dugan Creek, Gee Creek, Salmon Creek, Mill Creek, the Washougal River, the North Fork of the Washougal River, Weaver Creek, Burnt Creek, and Lacamas Creek (CRESA, 2004).

4.2.5 Climate

The climate of the county is greatly influenced by its geography. Moist air flows up the Columbia River bringing rain and moderate temperatures. It is seasonally mild, with relatively cool, dry summers and warm, wet winters. Average temperatures range from 40ºF in January to 65 or 70ºF in August. Annual rainfall is variable, ranging from about 37 to more than 110 inches in various parts of the county. Precipitation tends to be greatest in the more mountainous (northeast) portions of the county. Concentrated rainfall events are relatively common, especially during winter (CRESA, 2004). Average climate conditions at two National Oceanic and Atmospheric Administration (NOAA) weather stations in Clark County are shown in Table 4-1.

Table 4-1. Normal Precipitation and Temperatures

	Precipitation (inches)		Temperature (ºF)					
			Minimum		Average		Maximum	
	1981 – 2010	1991 – 2020	1981 – 2010	1991 – 2020	1981 – 2010	1991 – 2020	1981 – 2010	1991 – 2020
NOAA Weather Station: Battle Ground, WA US								
January	7.19	7.20	32.6	31.9	39.7	39.0	46.8	46.1
February	5.42	5.32	32.6	31.7	41.9	41.1	51.2	50.4
March	5.54	5.59	36.0	34.6	45.9	44.7	55.8	54.7
April	4.35	4.54	39.0	37.9	49.6	48.8	60.2	59.7
May	3.43	3.36	44.1	43.3	55.2	54.9	66.4	66.5
June	2.51	2.31	48.2	49.3	59.8	59.2	71.4	71.1
July	0.87	0.63	51.2	50.6	64.7	64.6	78.2	78.6
August	0.95	0.80	50.6	50.2	65.0	64.9	79.4	79.6
September	2.24	2.20	45.9	45.6	60.3	60.0	74.6	74.5
October	4.40	4.82	40.0	39.9	51.6	51.2	63.1	62.5
November	8.14	7.91	36.5	35.4	44.2	43.5	51.9	51.5
December	7.56	7.99	32.0	31.9	38.5	38.5	45.0	45.1
Annual	52.60	52.37	40.7	40.0	51.4	50.9	62.0	61.7
NOAA Weather Station: Vancouver Pearson Airport, WA US								
January	5.50	5.34	35.4	34.4	41.6	40.7	47.7	47.0
February	4.03	3.77	35.3	35.1	43.5	43.1	51.7	51.0
March	3.57	3.95	39.1	38.4	48.0	47.2	56.9	56.1
April	3.01	2.93	42.6	42.2	52.1	51.7	61.5	61.2
May	2.47	2.51	48.2	48.2	58.1	58.3	68.1	68.3
June	1.79	1.61	53.3	53.0	63.3	63.3	73.4	73.5
July	0.69	0.42	56.9	57.1	68.4	69.0	80.0	80.9
August	0.77	0.52	56.9	57.2	69.2	69.4	81.5	81.6
September	1.56	1.43	51.6	52.0	63.6	63.9	75.7	75.8
October	3.07	3.41	44.1	44.8	53.8	54.2	63.4	63.7
November	5.91	5.51	39.8	39.4	46.4	46.2	53.1	53.0
December	6.77	6.07	34.5	35.0	40.6	40.8	46.7	46.5
Annual	39.14	37.47	44.8	44.7	54.1	54.0	63.3	63.2

Source: NOAA, 2015. NOAA, 2022.

4.3 MAJOR PAST HAZARD EVENTS

Presidential disaster declarations are typically issued for hazard events that cause more damage than state and local governments can handle without assistance from the federal government, although no specific dollar loss threshold has been established for these declarations. A presidential disaster declaration puts federal recovery programs into motion to help disaster victims, businesses and public entities. Some of the programs are matched by state programs. The planning area has experienced 11 events since 1956 for which presidential disaster declarations were issued. These events are listed in Table 4-2.

Review of these events helps identify ways to increase a community's capability to avoid large-scale events in the future. Still, many natural hazard events do not trigger federal disaster declaration protocol but have significant impacts on their communities. These events are also important to consider in establishing recurrence intervals for hazards of concern and are addressed in more detail in Part 2 of this document.

Table 4-2. Federal Disaster Declarations for Events Affecting Clark County

Disaster Number[a]	Incident Description	Event Begin Date
DR-185	Heavy Rains and Flooding	December 29, 1964
DR-545	Severe Storms, Mudslides, Flooding	December 10, 1977
DR-623	Volcanic Eruption, Mount St. Helens	May 21, 1980
DR-1079	Storms, High Winds, Floods	November 7, 1995
DR-1100	Severe Storms, Flooding	January 26, 1996
DR-1159	Severe Winter Storms, Flooding	December 26, 1996
DR-1361	Earthquake	February 28, 2001
EM-3227	Hurricane Katrina Evacuation	August 29, 2005
DR-1671	Severe Storms, Flooding, Landslides, and Mudslides	November 2, 2006
DR-1682	Severe Winter Storm, Landslides, and Mudslides	December 14, 2006
DR-1825	Severe Winter Storm and Record and Near Record Snow	December 12, 2008
DR-4253	Severe Winter Storm, Straight Line Winds, Flooding, Landslides, Mudslides, Tornado	December 1, 2015

a. DR = major disaster; EM = emergency
Source: Federal Emergency Management Agency, 2015.

4.4 DEVELOPMENT PROFILE

4.4.1 Historical Development

The Clark County area was inhabited by multiple indigenous peoples, predominately the Cowlitz and Chinook Indians. While historic population estimate are difficult to find, the Lower Cowlitz were said to occupy 30 villages dotting the Cowlitz River. Currently, there are an estimated 1,400 tribal members living in the area. (Irwin, 1994) The Cowlitz Indian Tribe was federally recognized in 2000 and the Cowlitz Reservation was established in 2010 near Ridgefield, WA. The Chinook Indians' population was estimated to be several thousand in 1806 by the Lewis and Clark expedition, from The Dalles to the coast. Later, the British Hudson's Bay Company estimated the Chinook population in 1825 to be 2,500. An illness—most likely malaria or influenza—later destroyed most of the local population (Hanable, 2004).

The area that is now Clark County was an early trading center and an agriculture market. The Hudson's Bay Company established Fort Vancouver in 1825, the oldest permanent, non-native settlement in the Pacific Northwest. Fort Vancouver, named for British naval captain and explorer George Vancouver, provided access to the Columbia River, facilitating easier trade of local products. The Hudson's Bay Company's agricultural investments stretched for 30 miles along the Columbia (Hanable, 2004).

The County was incorporated as the District of Vancouver on June 27, 1844, by the Oregon Provisional Government. The name was changed to County of Vancouver in 1845 and to County of Clarke in 1849. Clarke County became a political subdivision of Washington Territory upon that territory's establishment in 1853. The state legislature corrected the spelling of the county's name in 1925. The City of Vancouver incorporated in 1857 as a jurisdiction in the Washington Territory (Hanable, 2004).

While Clark County's economy originally centered on agriculture, Vancouver eventually acquired lumber and paper mills, docks, grain elevators, and canneries. Local growth was enhanced by the West Coast gold rush, and in 1870 the Northern Pacific Railroad connected Vancouver to Puget Sound (Hanable, 2004).

World Wars I and II brought additional industries to the county, including the world’s largest spruce mill and the west’s first aluminum manufacturing plant. Tourism became a much more important economic driver for Clark County after World War I; this change was enabled by the construction of the Pacific Highway, US 99, in the 1920s. Fort Vancouver’s designation as a National Historic Monument and the reconstruction of the Hudson Bay’s Company post facilitated tourist interest. Today, a large number of sites (64 total) are recorded on both the National Historic Register and the Clark County Heritage Register (CRESA, 2004).

4.4.2 Current Land Use

Clark County land use has remained relatively unchanged since 2007. It consists of predominantly forest lands in the eastern side of the county, and scattered agriculture, parks/open space, and rural lands throughout the remaining portions of Clark County. Commercial, residential, and industrial land uses are the predominant land uses within the County’s incorporated cities and towns (Clark County, 2016b). For recreation, residents and visitors can access the Gifford Pinchot National Forest and Lewis River, and municipal park systems also abound.

Land use information is analyzed in this plan for each identified hazard that has a defined spatial extent and location. For hazards that lack this spatial reference, land use summary information in Table 4-3 serves as a baseline estimate of land use and exposure for the planning area. Future trends in development are discussed in Section 4.4.4.

Table 4-4 shows the type and distribution of structures throughout the planning area. This data was not updated in the 2022 update due to the inability to utilize Hazus in this update. The comprehensive growth plan has not changed since the previous plan, but an increase in developed lands and a decrease in vacant or uncategorized lands is assumed.

Table 4-3. Present Land Use in Planning Area[a]

Present Use Classification[b]	Area (acres) [c, d]	% of total
Agriculture/Resource Land	112,261	24.1%
Commercial	20,261	4.4%
Education	2,923	0.6%
Governmental Services	3,742	0.8%
Industrial	2,535	0.5%
Religious Services	1,062	0.2%
Residential	291,365	62.7%
Vacant or uncategorized	30,710	6.6%
Total	**464,858**	**100%**

a. Present land use information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Present use classification provided by Clark and Cowlitz County assessor's data assigned to best fit occupancy classes in FEMA's Hazus model (see Section 6.3.1). Parcels for which conflicting information on current development was available were assumed to be improved. Some designated resource land may also be included in the vacant or uncategorized category.
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage includes Clark County and the incorporated areas of the City of Woodland.

Table 4-4. Structure Type in the Planning Area

	Number of Structures[a]							
	Residential	Commercial	Industrial	Agriculture/ Forestry	Religion	Government	Education	Total
Battle Ground	5,558	237	4	10	17	3	25	5,854
Camas	7,109	272	19	26	47	15	25	7,513
La Center	1,051	39	1	5	1	7	6	1,110
Ridgefield	2,176	106	12	8	5	13	8	2,328
Vancouver	47,275	2,387	53	60	167	43	113	50,098
Washougal	5,212	248	7	15	25	19	13	5,539
Woodland	1,642	170	26	1	16	4	5	1,864
Yacolt	489	24		8	7	4	1	533
Unincorporated County	72,392	1,424	29	708	184	54	111	74,902
Total	**142,904**	**4,907**	**151**	**841**	**469**	**162**	**307**	**149,741**

a. Structure type assigned to best fit Hazus occupancy classes based on present use classifications provided by Clark and Cowlitz County assessor's data. Where conflicting information was present in the available data, parcels were assumed to be improved.

4.4.3 Critical Facilities and Infrastructure

The Steering Committee selected the following definition of critical facilities and infrastructure:

> Facilities and infrastructure that are critical to the health and welfare of the population and that are especially important following hazard events.

For this planning process, critical facilities and infrastructure meeting this definition were inventoried from the best available databases under the following sectors:

- Communication facilities
- Dams
- Emergency services
- Energy
- Government facilities
- Hazardous materials
- Healthcare and public health
- Information technology
- Schools
- Transportation systems
- Water and sanitation systems.

Information on data sources for these facilities can be found in Chapter 6 of this volume. The location of critical facilities and infrastructure within the unincorporated areas and cities participating in this plan are shown in Figure 4-2 and summarized in Table 4-5

Due to the sensitivity of this information, a detailed list of facilities is not provided. The list is on file with each planning partner.

Table 4-5. Critical Facilities and Infrastructure by Jurisdiction and Category

	Communication Facilities	Dams	Emergency Services	Energy	Government Facilities	Hazardous Materials	Health Care & Public Health	Information Technology	Schools	Transportation Systems	Water & Sanitation Systems	Total
Battle Ground			2	2	4	6	5		9	2	18	**48**
Camas	1	2	4	6	3	8	9		17	10	57	**117**
La Center	1		2	1	2		1		3	1	7	**18**
Ridgefield	0	0	3	1	2	4	1	0	4	3	12	**30**
Vancouver	4	0	13	24	37	62	165	0	60	126	54	**545**
Washougal	0	0	3	2	3	11	7	0	5	3	28	**62**
Woodland	0	0	3	1	0	2	0	0	5	0	0	**11**
Yacolt	2	0	2	0	1	1	0	0	1	0	0	**7**
Unincorporated	1	2	29	35	8	21	163	0	53	125	217	**654**
Total	**9**	**4**	**61**	**72**	**60**	**115**	**351**	**0**	**157**	**270**	**393**	**1,492**

Critical Facilities & Infrastructure

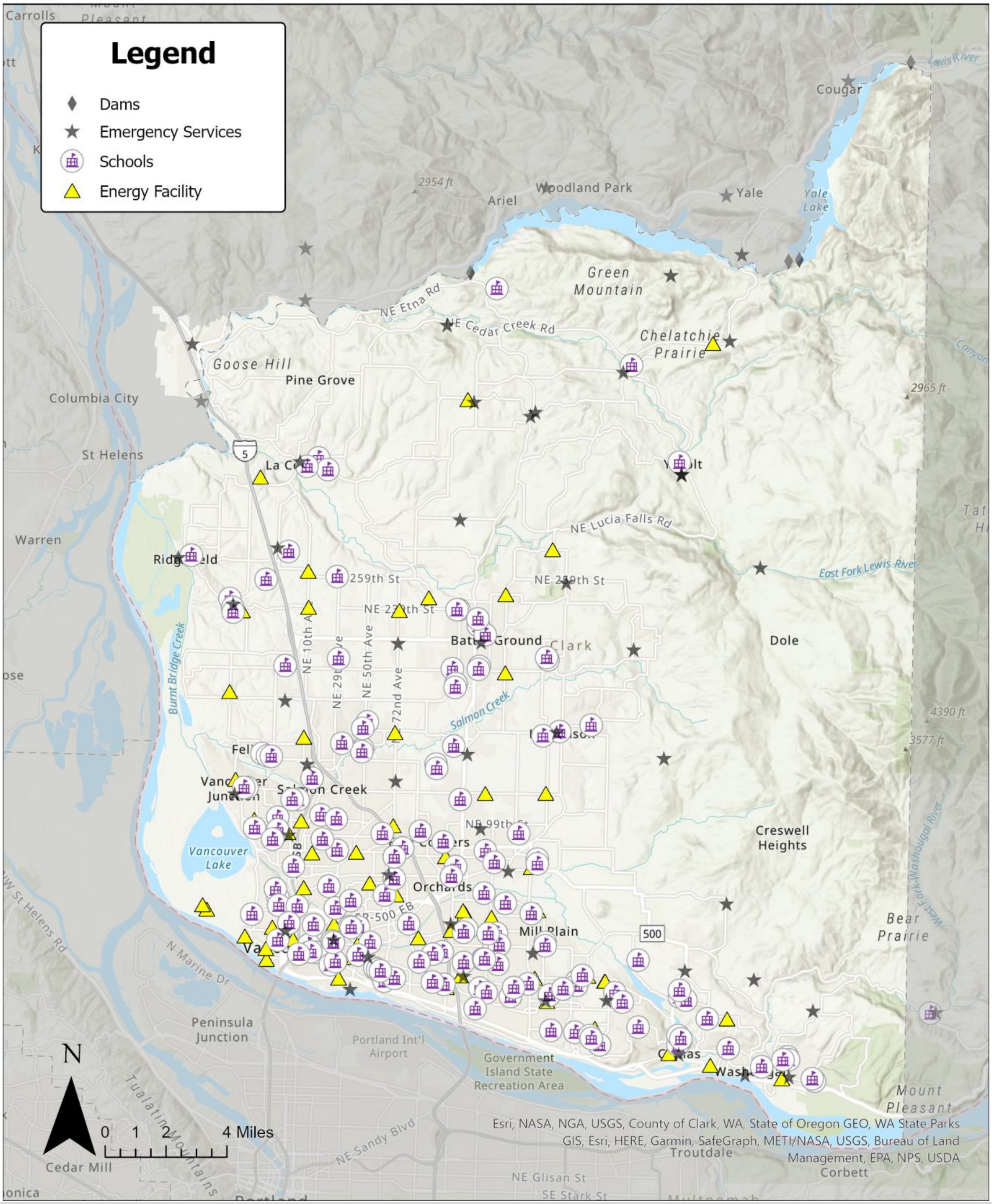

Figure 4-2. Critical Facilities and Infrastructure

4.4.4 Future Trends in Development

The municipal planning partners have adopted comprehensive plans that govern land-use decision-making and policy-making in their jurisdictions. The Community Framework Plan adopted in 1993 as Clark County's long-term vision of what the county could become guides the development of each jurisdiction's growth management comprehensive plan. It embodies countywide planning policies and envisions urban growth areas (UGAs) with specific boundaries and rural centers within larger natural resource and rural areas (Clark County, 2016b).

The Framework Plan emphasizes distinctions between urban, rural and resource lands. It encourages growth in UGAs and rural centers, with each center of development distinct from the others. These centers of development are of different sizes; they contain different combinations of housing, shopping, and employment areas. Each provides places to live and work. The centers are oriented and developed around neighborhoods to create a distinct sense of community (Clark County, 2016b).
In order to achieve this development pattern, each UGA designates a mix of land uses with housing, businesses, and services appropriate to its character and location. Residential development appropriate to the needs of workers and residents is encouraged nearby. Outside of UGAs, the land is predominantly rural with farms, forests, open space, and large lot residences. Shopping and businesses are located in rural centers. Most of northern Clark County remains in rural use, with some resource-based industries (Clark County, 2016b).

This hazard mitigation plan will work together with local programs to support wise land use in the future by providing vital information on the risk associated with natural hazards in the planning area. All municipal planning partners will incorporate this hazard mitigation plan update in their comprehensive plans by reference. This will ensure that future development trends can be established with the benefits of the information on risk and vulnerability to natural hazards identified in this plan.
Risks to future development are analyzed in this plan for each identified hazard that has a defined spatial extent and location. For hazards that lack this spatial reference, buildable lands summary information in Table 4-6 summarizes buildable land area by use category for the planning area.

Table 4-6. Buildable Lands in Planning Area Urban Growth Areas[a]

Urban Growth Area Name	Residential (acres)	Commercial (acres)	Industrial (acres)	Total (acres)
Battle Ground	1,070	412	188	1,670
Camas	891	337	495	1,724
La Center	373	44	49	466
Ridgefield	1,009	192	542	1,743
Vancouver	3,620	971	2,414	7,005
Washougal	477	88	268	833
Woodland	25	0	0	25
Yacolt	44	11	29	83
Total	**7,509**	**2,055**	**3,984**	**13,548**

a. Buildable lands information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Unincorporated areas outside of urban growth areas are excluded from this assessment. Development in these areas consists largely of rural lands, open space and large residential lots. Changes in development can be assessed through
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage includes Clark County and the incorporated areas of the City of Woodland.

4.5 DEMOGRAPHICS

Some populations are at greater risk from hazard events because of decreased resources or physical abilities. Research has shown that people living near or below the poverty line, the elderly, socially-isolated persons, people with disabilities, women, children, ethnic minorities and renters all experience, to some degree, more severe effects from disasters than the general population. They may vary from the general population in risk perception, living conditions, access to information, capabilities during a hazard event, and access to resources for post-disaster recovery. These populations often overlap spatially and live in the most vulnerable locations. Detailed spatial analysis to locate areas where there are higher concentrations of vulnerable community members would assist the County in extending focused public outreach and education to these most vulnerable residents.

4.5.1 Population Characteristics

Information about the composition of the population and how it has changed in the past and how it may change in the future is a critical part of planning because it directly relates to land needs such as housing, industry, public services, and transportation. The Washington Office of Financial Management estimated the total Clark County population at 503,311 as of the 2020 Census (WSOFM, 2022). Table 4-7 presents current and recent population estimates for the county as a whole and for individual jurisdictions within it. Most of the population resides in the incorporated cities, which are mostly along the banks of the Columbia River. The City of Vancouver far surpasses the rest of the cities in population, with over 190,000 residents, although the unincorporated county has a larger total population, with about 233,000 (WSOFM, 2022).

Table 4-7. Clark County City and Unincorporated Area Population, 1990 - 2020

	Population Estimate			
	1990	2000	2010	2020
Battle Ground	3,758	9,322	17,571	20,743
Camas	6,798	12,534	19,355	26,065
La Center	483	1,654	2,800	3,424
Ridgefield	1,332	2,147	4,763	10,319
Vancouver	46,380	143,560	161,791	190,915
Washougal	4,764	8,595	14,095	17,039
Woodland	2,500	3,780	5,509	6,531
Yacolt	600	1,055	1,566	1,668
Unincorporated	173,844	166,279	203,339	233,054
Clark County Total[a]	**238,053**	**345,238**	**425,363**	**503,311**

a. County total is less than the sum of jurisdictions because Woodland includes population outside Clark County.
Source: WSOFM, 2022

Population change is also an important socio-economic indicators. A growing population generally indicates a growing economy, while a decreasing population signifies economic decline. Both incorporated and unincorporated areas in Clark County have continued to grow, as shown in Table 4-7 and Figure 4-3. Unincorporated-area population declined from 1990 to 2000, largely due to annexation of unincorporated areas; since then, unincorporated population has grown, remaining about 48 percent of the total county population.

Source: Washington OFM, 2022

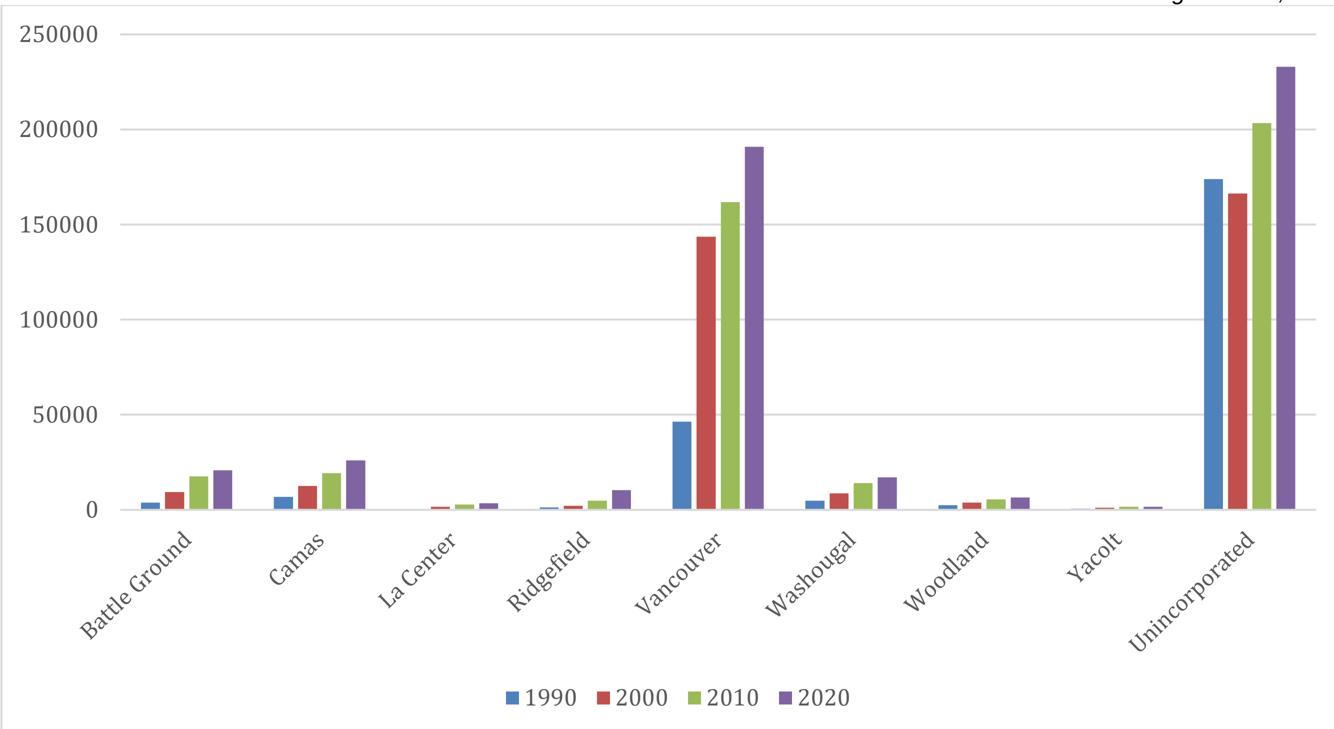

Figure 4-3. Clark County City and Unincorporated Area Population, 1990 - 2022

Overall, Clark County has experienced significant population growth recently. The State of Washington notes that Clark County was the fastest growing county with 1.9% growth between 2020-2021 (State of Washington 2015). Figure 4-4 shows the overall population growth rate in the planning area from 1910 to 2010 compared to that of the State of Washington. Clark County's 10-year growth rate has been slightly higher than the statewide rate, except for the 1950s.

4.5.2 Age Distribution

As a group, the elderly are more likely than the general population to lack the physical and economic resources to respond to hazard events and are more likely to suffer health-related consequences. They are more likely to be vision, hearing, and/or mobility impaired, and more likely to experience mental impairment. The elderly are more likely to live in assisted-living facilities where emergency preparedness occurs at the discretion of facility operators. These facilities are typically identified as "critical facilities" by emergency managers, and they require extra notice to implement evacuation. Elderly residents living in their own homes may have more difficulty evacuating and could be stranded in hazard events. This population is more likely to need medical attention, which may not be readily available during natural disasters due to isolation caused by the event. Specific planning attention for the elderly is an important consideration given the current aging of the American population.

Children are vulnerable to disaster events because of their young age and dependence on others for basic necessities. Very young children may additionally be vulnerable to injury or sickness; this vulnerability can be worsened during a natural disaster because they may not understand the measures that need to be taken to protect themselves from hazards.

The age distribution for the planning area is shown in Figure 4-5. Based on U.S. Census estimates, 12.1 percent of the county's population is 65 or older and 21.6 percent is 14 or younger (U.S. Census Bureau, 2015).

Source: WSOFM, 2022

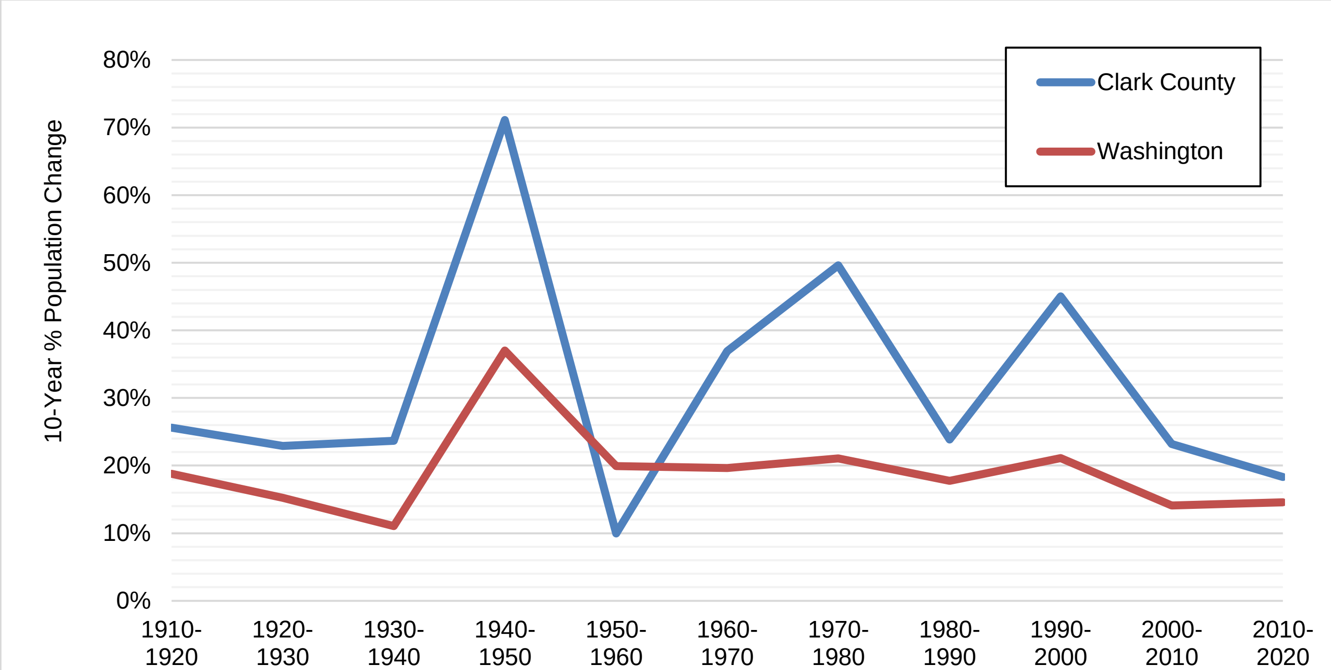

Figure 4-4. Washington and Clark County Population Growth

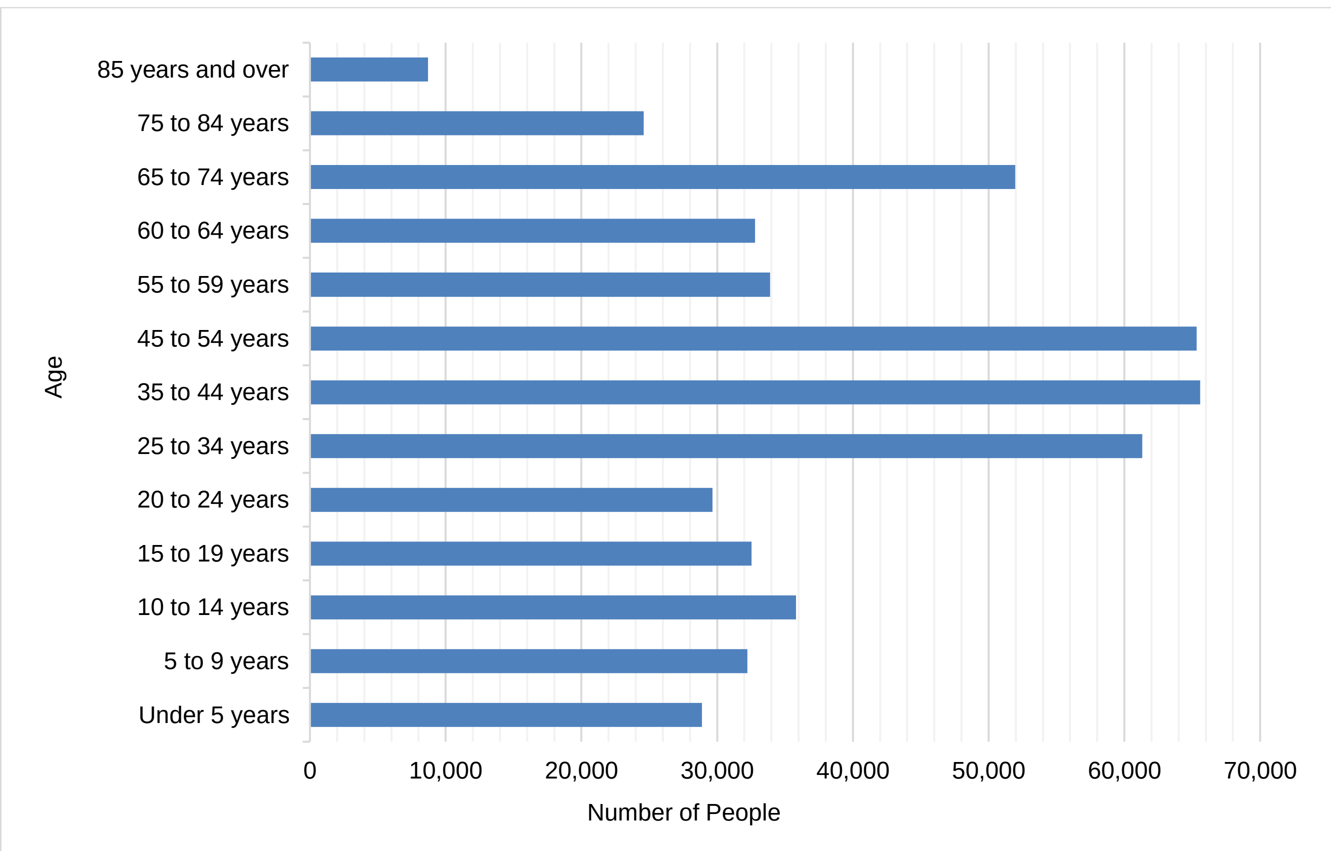

Figure 4-5. Planning Area Age Distribution

4.5.3 Race, Ethnicity and Language

Research shows that minorities are less likely to be involved in pre-disaster planning and experience higher mortality rates during a disaster event. Post-disaster recovery can be ineffective and is often characterized by cultural insensitivity. Higher proportions of ethnic minorities live below the poverty line than the majority white population, and poverty can compound vulnerability. According to the U.S. Census, the racial composition of the planning area is predominantly white, at 85.7 percent. The largest minority populations are Asian at 4.09 percent, “Two or More Races” at 4.12 percent, and “Some Other Race” at 2.67 percent. Figure 4-6 shows the racial distribution in the planning area (U.S. Census Bureau, 2015).

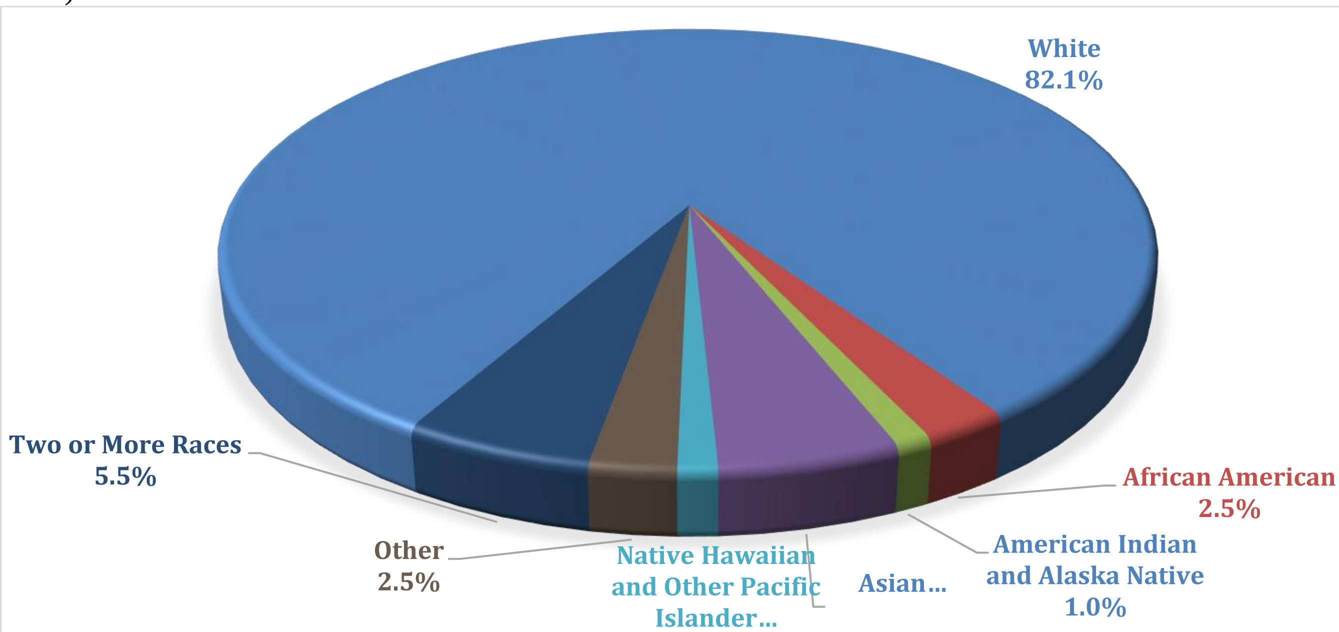

Figure 4-6. Planning Area Race Distribution

The planning area has a 9.95-percent foreign-born population. Other than English, the most commonly spoken languages in the planning area are Indo-European languages. The census estimates 6 percent of residents speak English “less than very well” (U.S. Census Bureau, 2022).

4.5.4 Persons with Disabilities or with Access and Functional Needs

Persons with disabilities or others with access and functional needs are more likely to have difficulty responding to a hazard event than the general population. Local government is the first level of response to assist these individuals, and coordination of efforts to meet their access and functional needs is paramount to life safety efforts. It is important for emergency managers to distinguish between functional and medical needs in order to plan for incidents that require evacuation and sheltering. Knowing the percentage of population with a disability will allow emergency management personnel and first responders to have personnel available who can provide services needed by those with access and functional needs.

According to U.S. Census estimates, 12.1 percent of the Clark County population has some form of disability, including 33.4 percent of those 65 and older (U.S. Census Bureau, 2022).

4.6 ECONOMY

The economy of Clark County is significantly affected by its location within the Portland Metropolitan Area. One-fifth of the county's labor force—nearly 50,000 workers—commutes to Portland on a daily basis; only 9,500 commute in the opposite direction. The lack of a sales tax in Oregon has led to significant leakage of retail sales in Clark County, lowering both retail investment and tax revenues for local governments (Washington ESD, 2014).

4.6.1 Income

In the United States, individual households are expected to use private resources to prepare for, respond to and recover from disasters to some extent. This means that households living in poverty are automatically disadvantaged when confronting hazards. Additionally, the poor typically occupy more poorly built and inadequately maintained housing. Mobile or modular homes, for example, are more susceptible to damage in earthquakes and floods than other types of housing. In urban areas, the poor often live in older houses and apartment complexes, which are more likely to be made of un-reinforced masonry, a building type that is particularly susceptible to damage during earthquakes. Furthermore, residents below the poverty level are less likely to have insurance to compensate for losses incurred from natural disasters. This means that residents below the poverty level have a great deal to lose during an event and are the least prepared to deal with potential losses. Personal household economics significantly impact people's decisions on evacuation. Individuals who cannot afford gas for their cars will likely decide not to evacuate.

Based on U.S. Census Bureau American Community Survey estimates the median household income was $77,184. It is estimated that 37 percent of households receive an annual income of $100,000 or more. An estimated 12 percent of households in the county made less than $25,000 per year in 2020, and 6 percent of families had incomes below the poverty level. The Census Bureau estimates that 2.65 percent of the population under age 18 and 1 percent of the population 65 or older has an income below the poverty line (U.S. Census Bureau, 2020).

4.6.2 Industry, Businesses and Institutions

Major industry sectors in Clark County include healthcare and social assistance (25,000 jobs in 2020), retail trade (24,800 jobs), construction (20,600 jobs) and manufacturing (25,800 jobs). In addition, government employed 23,700, half of which were in public education (Washington ESD, 2014).

Figure 4-7 shows the U.S. Census Bureau breakdown of industry types in Clark County (U.S. Census Bureau, 2015).

4.6.3 Employment Trends and Occupations

Over the past 20 years, Clark County nonfarm employment has grown more than twice as fast as the nation's and much faster than the state's. Pre-recession employment peaked in November 2007. Employment hit bottom in February 2010, when the county had lost 6 percent of its jobs. Unemployment during the recession was exacerbated by higher than average job losses for county residents working in Portland. The recovery was slow in 2011 and 2012, but job growth began accelerating in mid-2013 and has been rapid since then (Washington ESD, 2014).

Clark County's unemployment rate was lower than state and national averages during the 1990s; however, it has been higher than state and national averages since 2000. Figure 4-8 compares Washington and Clark County unemployment trends from 2000 through 2014. In the past 15 years, the county unemployment rate was lowest in 2007, at 5.6 percent. It then rose to 14.0 percent in 2010, and has gradually decreased since then. According to the 2013 American Community Survey, 64.6 percent of Clark County's population age 16 and older is in the labor force (U.S. Census Bureau, 2015).

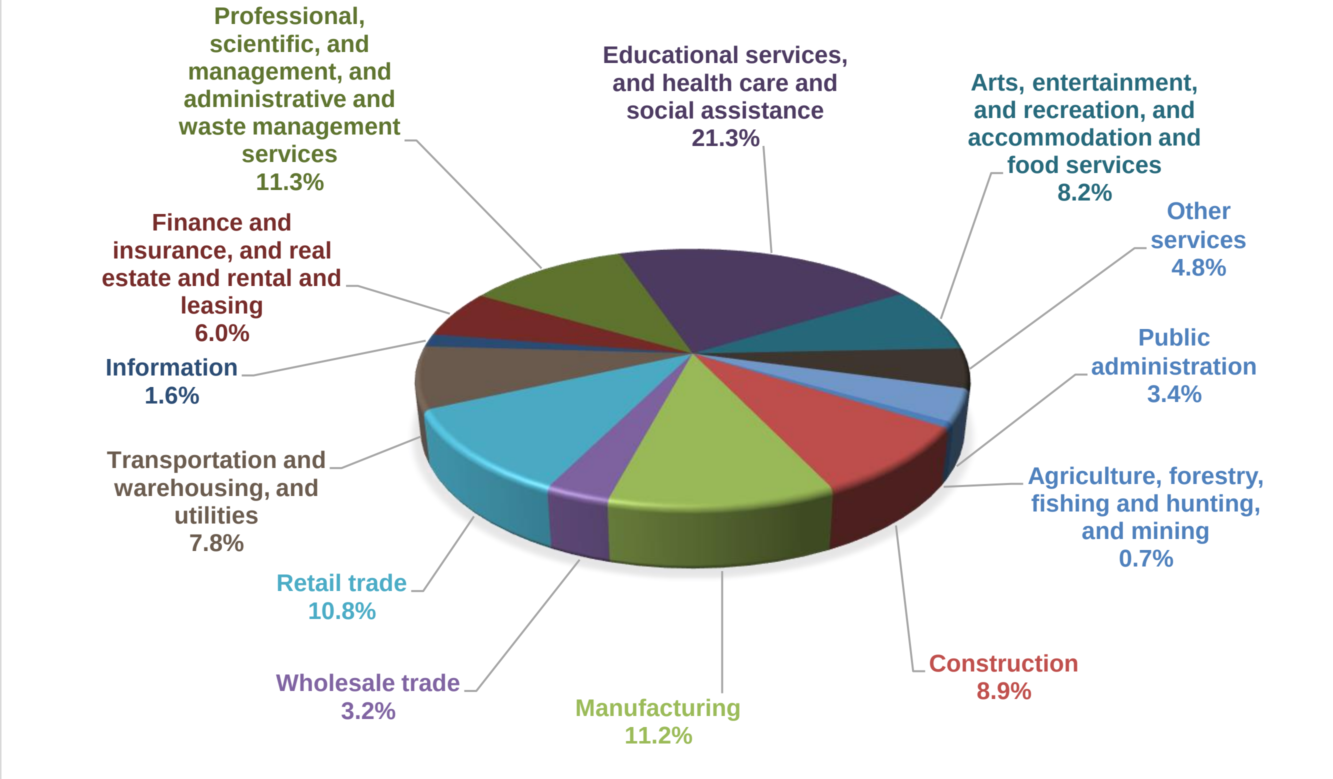

Figure 4-7. Industry in the Planning Area

Source: Washington ESD, 2015

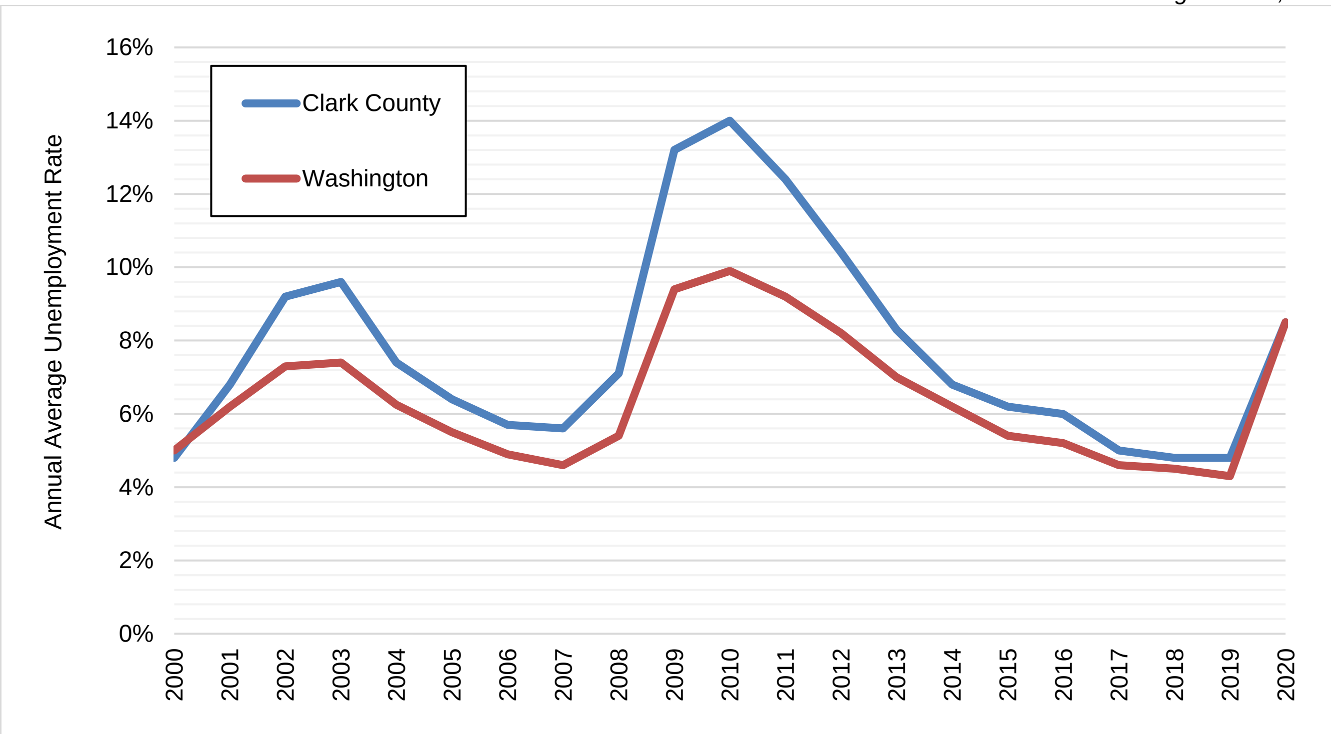

Figure 4-8. Clark County and Washington State Unemployment Rate

Over one-third of employed workers in Clark County (38.3 percent) are in management, business science and arts occupations. Another 21 percent have sales and office jobs, and 16.8 percent are in service occupations (see Figure 4-9) (U.S. Census Bureau, 2020).

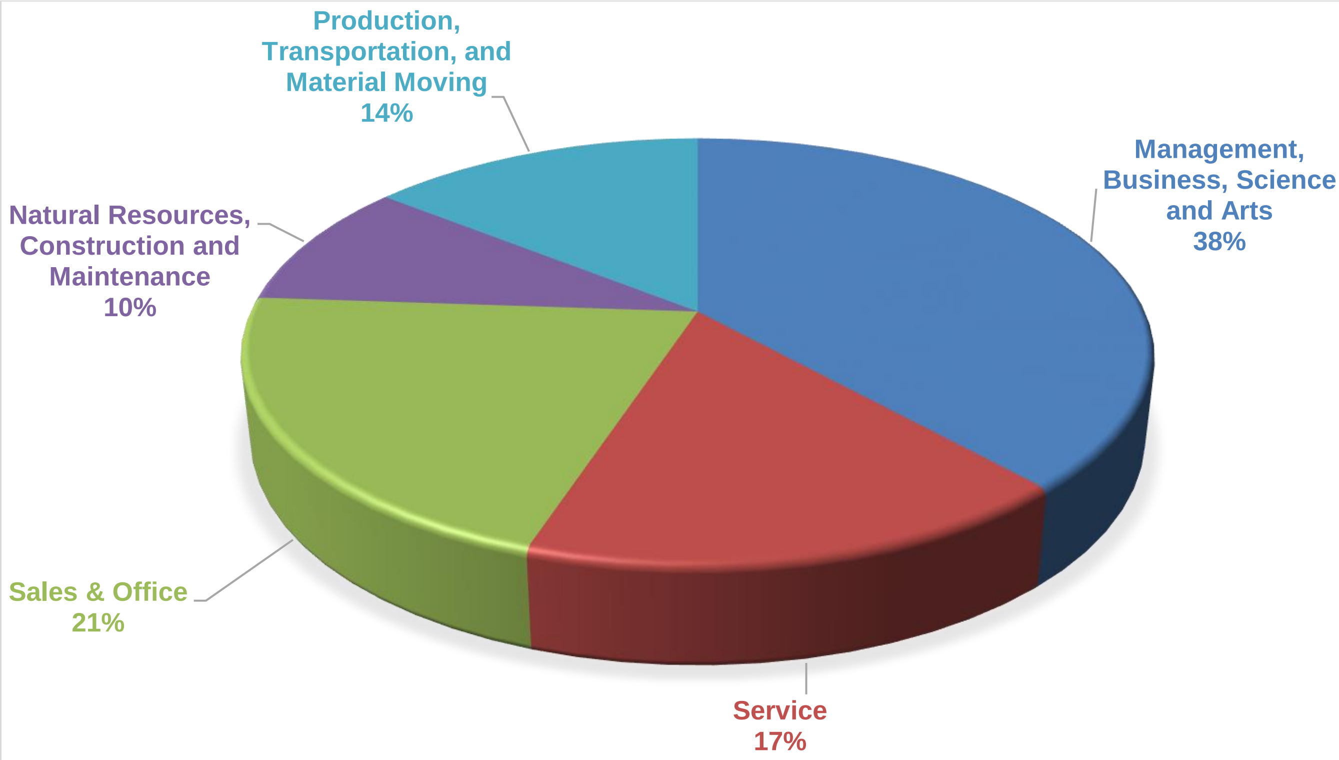

Figure 4-9. Occupations in the Planning Area

The largest employer in Clark County is PeaceHealth (4,374 full time equivalent employees as of 2015), followed by the Bonneville Power Administration (2,946 employees in 2015), and Evergreen Public Schools (2,764 employees as of 2015). Other large employers in the county are Vancouver Public Schools, Fred Meyer Stores, Clark County Government, Battle Ground Public Schools, Legacy Salmon Creek Medical Center, the Vancouver Clinic Inc., and WaferTech LLC (Vancouver Business Journal, 2015).

The U.S. Census estimates that 76.8 percent of Clark County workers commute alone to work (by car, truck or van), and mean travel time to work is 27.4 minutes (U.S. Census Bureau, 2020).

4.7 LAWS, ORDINANCES AND PROGRAMS

Existing laws, ordinances and plans at the federal, state and local level can support or impact hazard mitigation actions identified in this plan. Hazard mitigation planning must include review and incorporation, if appropriate, of existing plans, studies, reports and technical information (44 CFR, Section 201.6(b)(3)). This section provides a review of laws, ordinances and programs in effect within the planning area that can affect hazard mitigation actions. Goals, objectives, policies and actions identified in these programs were reviewed during the development of this plan and used to inform the development of the mitigation strategy. Each planning partner conducted an assessment of its regulatory, technical and financial capabilities to implement hazard mitigation actions (see Volume 2). These jurisdiction-specific capabilities were also used to inform the development of each planning partner's mitigation strategy.

During emergency situations, some Federal, State and Local laws and programs may have emergency protocols that go into effect to waive or expedite certain requirements or procedures. These modifications are limited in scope and duration and all mitigation and recovery projects should be planned for and implemented in ways that they meet all federal, state and local laws.

4.7.1 Federal

Disaster Mitigation Act

The DMA is the current federal legislation addressing hazard mitigation planning. It emphasizes planning for disasters before they occur. It specifically addresses planning at the local level, requiring plans to be in place before Hazard Mitigation Grant Program funds are available to communities. This plan is designed to meet the requirements of DMA, improving the planning partners' eligibility for future hazard mitigation funds.

Endangered Species Act

The federal Endangered Species Act (ESA) was enacted in 1973 to conserve species facing depletion or extinction and the ecosystems that support them. The act sets forth a process for determining which species are threatened and endangered and requires the conservation of the critical habitat in which those species live. The ESA provides broad protection for species of fish, wildlife and plants that are listed as threatened or endangered. Provisions are made for listing species, as well as for recovery plans and the designation of critical habitat for listed species. The ESA outlines procedures for federal agencies to follow when taking actions that may jeopardize listed species and contains exceptions and exemptions. It is the enabling legislation for the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Criminal and civil penalties are provided for violations of the ESA and the Convention. Federal agencies must seek to conserve endangered and threatened species and use their authorities in furtherance of the ESA's purposes. The ESA defines three fundamental terms:

- Endangered means that a species of fish, animal or plant is "in danger of extinction throughout all or a significant portion of its range." (For salmon and other vertebrate species, this may include subspecies and distinct population segments.)
- Threatened means that a species "is likely to become endangered within the foreseeable future." Regulations may be less restrictive for threatened species than for endangered species.
- Critical habitat means "specific geographical areas that are…essential for the conservation and management of a listed species, whether occupied by the species or not."

Five sections of the ESA are of critical importance to understanding it:

- **Section 4: Listing of a Species**—The National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) is responsible for listing marine species; the U.S. Fish and Wildlife Service is responsible for listing terrestrial and freshwater aquatic species. The agencies may initiate reviews for listings, or members of the public may petition for them. A listing must be made "solely on the basis of the best scientific and commercial data available." After a listing has been proposed, agencies receive comment and conduct further scientific reviews for 12 to 18 months, after which they must decide if the listing is warranted. Economic impacts cannot be considered in this decision, but it may include an evaluation of the adequacy of local and state protections. Critical habitat for the species may be designated at the time of listing.
- **Section 7: Consultation**—Federal agencies must ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed or proposed species or adversely modify its critical habitat. This includes private and public actions that require a federal permit. Once a final listing is made, non-federal actions are subject to the same review, termed a "consultation." If the listing agency finds that an action will "take" a species, it must

propose mitigations or "reasonable and prudent" alternatives to the action; if the proponent rejects these, the action cannot proceed.

- **Section 9: Prohibition of Take**—It is unlawful to "take" an endangered species, including killing or injuring it or modifying its habitat in a way that interferes with essential behavioral patterns, including breeding, feeding or sheltering.
- **Section 10: Permitted Take**—Through voluntary agreements with the federal government that provide protections to an endangered species, a non-federal applicant may commit a take that would otherwise be prohibited as long as it is incidental to an otherwise lawful activity (such as developing land or building a road). These agreements often take the form of a "Habitat Conservation Plan."
- **Section 11: Citizen Lawsuits**—Civil actions initiated by any citizen can require the listing agency to enforce the ESA's prohibition of taking or to meet the requirements of the consultation process.

With the listing of salmon and trout species as threatened or endangered, the ESA has impacted most of the Pacific coast states. Some areas have been more impacted by the ESA than others due to the known presence of listed species, but the entire region is impacted by mandates, programs and policies based on the presumption of the presence of listed species. Most West Coast jurisdictions must now take into account the impact of their programs on habitat. According to the Municipal Research Services Center, "Recent court decisions and federal administrative actions connected to the U.S. Endangered Species Act (ESA) have required 122 units of local and tribal governments in the Puget Sound region in Washington State to make changes in how they administer the National Flood Insurance Program (NFIP). This is an ongoing process due to pending litigation and the complexities of determining the needed changes. Although presently limited to the Puget Sound region, future lawsuits or decisions by FEMA may extend the geographic area covered to more areas in Washington." (MRSC, 2016).

According to the U.S. Fish and Wildlife Service, there are a number of threatened or endangered species thought to occur in Clark County, including bull trout, chum, chinook, coho and steelhead. Clark County has established a variety of regulations to protect these species including: development codes; habitat protection; enhancement programs; and education and outreach (Clark County Environmental Services, 2016).

Federally funded projects, such as those awarded pre-disaster mitigation or flood mitigation assistance grants, cannot jeopardize the continued existence of endangered or threatened species or adversely modify critical habitat (FEMA, 2015a).

Clean Water Act

The federal Clean Water Act (CWA) employs regulatory and non-regulatory tools to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's surface waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water."

Evolution of CWA programs over the last decade has included a shift from a program-by-program, source-by-source, pollutant-by-pollutant approach to more holistic watershed-based strategies. Under the watershed approach, equal emphasis is placed on protecting healthy waters and restoring impaired ones. A full array of issues are addressed, not just those subject to CWA regulatory authority. Involvement of stakeholder groups in the development and implementation of strategies for achieving and maintaining water quality and other environmental goals is a hallmark of this approach.

The CWA is important to hazard mitigation in several ways. There are often permitting requirements for any construction within 200 feet of water of the United States, which may have implications for mitigation projects identified by a local jurisdiction. Additionally, CWA requirements apply to wetlands, which serve important functions related to preserving and protecting the natural and beneficial functions of floodplains and are linked with a community's floodplain management program. Finally, the National Pollutant Discharge Elimination System is part of the CWA and addresses local stormwater management programs. Stormwater management plays a critical role in hazard mitigation by addressing urban drainage or localized flooding issues within jurisdictions. In Washington State, the Department of Ecology develops and administers National Pollutant Discharge Elimination System municipal stormwater permits.

National Flood Insurance Program

The National Flood Insurance Program provides federally backed flood insurance in exchange for communities enacting floodplain regulations. Participation in the NFIP is voluntary; however, participation and good standing under NFIP are prerequisites to grant funding eligibility under the Robert T. Stafford Act. The County and most of the partner cities for this plan participate in the NFIP and have adopted regulations that meet the NFIP requirements.

National Incident Management System

The National Incident Management System (NIMS) is a systematic approach for government, nongovernmental organizations, and the private sector to work together to manage incidents involving hazards. The NIMS provides a flexible but standardized set of incident management practices. Incidents typically begin and end locally, and they are managed at the lowest possible geographical, organizational, and jurisdictional level. In some cases, success depends on the involvement of multiple jurisdictions, levels of government, functional agencies, and emergency responder disciplines. These cases necessitate coordination across a spectrum of organizations. Communities using NIMS follow a comprehensive national approach that improves the effectiveness of emergency management and response personnel across the full spectrum of potential hazards (including natural hazards, terrorist activities, and other human-caused disasters) regardless of size or complexity. Although participation is voluntary, Federal departments and agencies are required to make adoption of NIMS by local and state jurisdictions a condition to receive Federal Preparedness grants and awards (Washington Emergency Management Division, 2016).

Americans with Disabilities Act and Amendments

The Americans with Disabilities Act (ADA) seeks to prevent discrimination against people with disabilities in employment, transportation, public accommodation, communications, and government activities. Title II of the ADA deals with compliance with the Act in emergency management and disaster-related programs, services, and activities. It applies to state and local governments as well as third parties, including religious entities and private nonprofit organizations.

The ADA has implications for sheltering requirements and public notifications. During an emergency alert, officials must use a combination of warning methods to ensure that all residents have all necessary information. Those with hearing impairments may not hear radio, television, sirens, or other audible alerts, while those with visual impairments may not see flashing lights or visual alerts. Two technical documents issued for shelter operators address physical accessibility needs of people with disabilities as well as medical needs and service animals.

The ADA intersects with disaster preparedness programs in regards to transportation, social services, temporary housing, and rebuilding. Persons with disabilities may require additional assistance in evacuation and transit (e.g., vehicles with wheelchair lifts or paratransit buses). Evacuation and other response plans should address the unique needs of residents. Local governments may be interested in implementing a special-needs registry to identify the home addresses, contact information, and needs for residents who may require more assistance.

Civil Rights Act of 1964

The Civil Rights Act of 1964 prohibits discrimination based on race, color, religion, sex or nation origin and requires equal access to public places and employment. The Act is relevant to emergency management and hazard mitigation in that it prohibits local governments from favoring the needs of one population group over another. Local government and emergency response must ensure the continued safety and well-being of all residents equally, to the extent possible.

Rural Development Program

The mission of the U.S. Department of Agriculture (USDA) Rural Development Program is to help improve the economy and quality of life in rural America. The program provides project financing and technical assistance to help rural communities provide the infrastructure needed by rural businesses, community facilities, and households. The program addresses rural America's need for basic services, such as clean running water, sewage and waste disposal, electricity, and modern telecommunications and broadband. Loans and competitive grants are offered for various community and economic development projects and programs, such as the development of essential community facilities including fire stations (USDA, 2015b).

Community Development Block Grant Disaster Resilience Program

In response to disasters, Congress may appropriate additional funding for the Community Development Block Grant programs as Disaster Recovery grants (CDBG-DR) to rebuild the affected areas and provide crucial seed money to start the recovery process. Since CDBG-DR assistance may fund a broad range of recovery activities, The U.S. Department of Housing and Urban Development can help communities and neighborhoods that otherwise might not recover due to limited resources. CDBG-DR grants often supplement disaster programs of the Federal Emergency Management Agency, the Small Business Administration, and the U.S. Army Corps of Engineers. Housing and Urban Development generally awards noncompetitive, nonrecurring CDBG-DR grants by a formula that considers disaster recovery needs unmet by other Federal disaster assistance programs. CDBG-DR monies must be used to: address a disaster-related impact (direct or indirect) in a presidentially declared county for the covered disaster; be a CDBG eligible activity (according to regulations and waivers); and meet a national objective. Incorporating preparedness and mitigation into these actions is encouraged as the goal is to rebuild in ways that are safer and stronger.

Emergency Watershed Program

The USDA Natural Resources Conservation Service (NRCS) administers the Emergency Watershed Protection (EWP) Program, which responds to emergencies created by natural disasters. Eligibility for assistance is not dependent on a national emergency declaration. The program is designed to help people and conserve natural resources by relieving imminent hazards to life and property caused by floods, fires, wind-storms, and other natural occurrences. EWP is an emergency recovery program.
EWP eligible activities include providing financial and technical assistance to:

- Remove debris from stream channels, road culverts, and bridges
- Reshape and protect eroded banks
- Correct damaged drainage facilities

- Establish cover on critically eroding lands
- Repair levees and structures
- Repair conservation practices (National Resources Conservation Service, 2016).

Presidential Executive Orders 11988 and 13690

Executive Order 11988 requires federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities" for the following actions:

- Acquiring, managing, and disposing of federal lands and facilities
- Providing federally-undertaken, financed, or assisted construction and improvements
- Conducting federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulation, and licensing activities (FEMA, 2015e).

Executive Order 13690 amends and expands Executive Order 11988 acknowledges that the impacts of flooding are anticipated to increase over time due to the effects of climate change and other threats and mandates a Federal Flood Risk Management Standard, which is a flexible framework to increase resilience against flooding and help preserve the natural values of floodplains. This standard expands management of flood issues from the current base flood level to a higher vertical elevation and corresponding horizontal floodplain to address current and future flood risk and ensure that projects funded with taxpayer dollars last as long as intended (Office of the Press Secretary, 2015).

Presidential Executive Orders 11990

Executive Order 11990 requires federal agencies to provide leadership and take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agency's responsibilities for (1) acquiring, managing, and disposing of Federal lands and facilities; and (2) providing Federally undertaken, financed, or assisted construction and improvements; and (3) conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities (National Archives, 2016).

Emergency Relief for Federally Owned Roads Program

The U.S. Forest Service’s Emergency Relief for Federally Owned Roads Program was established to assist federal agencies with repair or reconstruction of tribal transportation facilities, federal lands transportation facilities, and other federally owned roads that are open to public travel and have suffered serious damage by a natural disaster over a wide area or by a catastrophic failure. The program funds both emergency and permanent repairs (Office of Federal Lands Highway, 2016).

4.7.2 State

Washington State Enhanced Mitigation Plan

The 2018 Washington State Enhanced Hazard Mitigation Plan provides guidance for hazard mitigation throughout Washington (Washington Emergency Management Division, 2018). The plan identifies hazard mitigation goals, objectives, actions and initiatives for state government to reduce injury and damage from natural hazards. By meeting federal requirements for an enhanced state plan (44 CFR parts

201.4 and 201.5), the plan allows the state to seek significantly higher funding from the Hazard Mitigation Grant Program following presidential declared disasters (20 percent of federal disaster expenditures vs. 15 percent with a standard plan).

The *Clark Regional Natural Hazard Mitigation Plan* must be consistent with the Washington State Plan. One major example of this is that the Clark County plan must, at a minimum, address those hazards identified as impacting Clark County in the State Plan.

Growth Management Act

The 1990 Washington State Growth Management Act (Revised Code of Washington (RCW) Chapter 36.70A) mandates that local jurisdictions adopt land use ordinances protect the following critical areas:

- Wetlands
- Critical aquifer recharge areas
- Fish and wildlife habitat conservation areas
- Frequently flooded areas
- Geologically hazardous areas.

The Growth Management Act regulates development in these areas, and therefore has the potential to affect hazard vulnerability and exposure at the local level.

Planning for natural hazards is an integral element of Washington's statewide land use planning program under the Growth Management Act. Other related parts of the planning framework include the Shoreline Master Program rules and guidelines, which now provide for the integration of master programs and comprehensive plans. Natural Hazard Mitigation Elements are an optional element under the Growth Management Act. The continuing challenge faced by local officials and state government is to keep a network of coordinated local plans effective in responding to changing conditions and needs of communities. This is particularly true in the case of planning for natural and technological hazards, where communities must balance development pressures with detailed information on the nature and extent of hazards. Washington's land use program has given its communities and residents a unique opportunity to ensure that natural and technological hazards are addressed in the development and implementation of local comprehensive plans.

Shoreline Management Act

The 1971 Shoreline Management Act (RCW 90.58) was enacted to manage and protect the shorelines of the state by regulating development in the shoreline area. A major goal of the act is to prevent the "inherent harm in an uncoordinated and piecemeal development of the state's shorelines." Its jurisdiction includes the Pacific Ocean shoreline and the shorelines of Puget Sound, the Strait of Juan de Fuca, and rivers, streams and lakes above a certain size. It also regulates wetlands associated with these shorelines.

Shoreline management activities "implement policies and regulations to help protect water quality for our marine waters, lakes and stream systems; increase protection of lives and property from flood and landslide damage; protect critical habitat as well as fish and wildlife; promote recreational opportunities in shoreline areas." Often these policies and programs complement or are critical in mitigation programs for communities. Shoreline management programs are local capabilities relevant to mitigation activities.

Washington State Building Code

The Washington State Building Code Council has adopted the 2015 editions of national model codes, with some amendments. The Council also adopted changes to the Washington State Energy Code and Ventilation and Indoor Air Quality Code. Washington's state-developed codes are mandatory statewide for residential and commercial buildings. The 2015 codes went into effect as the Washington model code on July 1, 2016.

The adoption and enforcement of appropriate building codes is a significant component for hazard mitigation loss avoidance. Using the most up to date and relevant codes reduces risk and increases capability.

Comprehensive Emergency Management Planning

Washington's Comprehensive Emergency Management Planning law (RCW 38.52) establishes parameters to ensure that preparations of the state will be adequate to deal with disasters, to ensure the administration of state and federal programs providing disaster relief to individuals, to ensure adequate support for search and rescue operations, to protect the public peace, health and safety, and to preserve the lives and property of the people of the state. It achieves the following:

- Provides for emergency management by the state, and authorizes the creation of local organizations for emergency management in political subdivisions of the state.
- Confers emergency powers upon the governor and upon the executive heads of political subdivisions of the state.
- Provides for the rendering of mutual aid among political subdivisions of the state and with other states and for cooperation with the federal government with respect to the carrying out of emergency management functions.
- Provides a means of compensating emergency management workers who may suffer any injury or death, who suffer economic harm including personal property damage or loss, or who incur expenses for transportation, telephone or other methods of communication, and the use of personal supplies as a result of participation in emergency management activities.
- Provides programs, with intergovernmental cooperation, to educate and train the public to be prepared for emergencies.

It is policy under this law that emergency management functions of the state and its political subdivisions be coordinated to the maximum extent with comparable functions of the federal government and agencies of other states and localities, and of private agencies of every type, to the end that the most effective preparation and use may be made of manpower, resources, and facilities for dealing with disasters.

Washington Administrative Code 118-30-060(1)

Washington Administrative Code (WAC) 118-30-060 (1) requires each political subdivision to base its comprehensive emergency management plan on a hazard analysis, and makes the following definitions related to hazards:

- Hazards are conditions that can threaten human life as the result of three main factors:
  - Natural conditions, such as weather and seismic activity
  - Human interference with natural processes, such as a levee that displaces the natural flow of floodwaters
  - Human activity and its products, such as homes on a floodplain.
- The definitions for hazard, hazard event, hazard identification, and flood hazard include related concepts:
  - A hazard may be connected to human activity.
  - Hazards are extreme events.

Hazards generally pose a risk of damage, loss, or harm to people and/or their property

Washington State Floodplain Management Law

Washington's floodplain management law (RCW 86.16, implemented through WAC 173-158) states that prevention of flood damage is a matter of statewide public concern and places regulatory control with the Department of Ecology. RCW 86.16 is cited in floodplain management literature, including FEMA's national assessment, as one of the first and strongest in the nation. A major challenge to the law in 1978, Maple Leaf Investors v. Ecology, is cited in legal references to floodplain management issues. The court upheld the law, declaring that denial of a permit to build residential structures in the floodway is a valid exercise of police power and did not constitute a taking. RCW Chapter 86.12 (Flood Control by Counties) authorizes county governments to levy taxes, condemn properties and undertake flood control activities directed toward a public purpose.

This provision also task Counties to develop comprehensive flood control management plans. Following adoption by the county, city, or town, a comprehensive flood control management plan shall be binding on each jurisdiction and special district that is located within an area included in the plan. If within one hundred twenty days of the county's adoption, a city or town does not adopt the comprehensive flood control management plan, the city or county shall request arbitration on the issue or issues in dispute. If parties cannot agree to the selection of an arbitrator, the arbitrator shall be selected according to the process described in *RCW 7.04.050.

Washington State/Ecology Grant Sources

Washington's first flood control maintenance program was passed in 1951, and was called the Flood Control Maintenance Program. In 1984, the state Legislature established the Flood Control Assistance Account Program (FCAAP) (RCW 86.26; State Participation in Flood Control Maintenance) to assist local jurisdictions in comprehensive planning and flood control maintenance efforts. FCAAP rules are found in WAC 173-145. This is one of very few state programs in the country that provides grant funding to local governments for flood plain management planning and implementation actions. The account is funded at $4 million per state biennium, unless modified by the state legislature. Projects include comprehensive flood hazard management planning, maintenance projects, feasibility studies, purchase of flood prone properties, match for federal projects, and emergency projects. FCAAP grants for non-emergency projects may not exceed $500,000 per county. However, applications are not currently being accepted for this program due to funding cuts, with the exception of emergency projects.

Floodplains by Design (FbD) is an emerging partnership of local, state, federal and private organizations focused on coordinating investment in and strengthening the integrated management of floodplain areas through Washington State. In 2013, the Washington State Legislature authorized $44 million in new funding for integrated projects consistent with Floodplains by Design; and a similar level of funding was also authorized in the 2015-17 Biennium. The Washington State Department of Ecology's Floods and Floodplain Management Division administers the Floodplains by Design grant program under a biennial funding cycle. Ecology awards grants on a competitive basis to eligible entities for collaborative and innovative projects throughout Washington State that support the integration of flood hazard reduction with ecological preservation and restoration. Proposed projects may also address other community needs, such as preservation of agriculture, improvements in water quality, or increased recreational opportunities provided they are part of a larger strategy to restore ecological functions and reduce flood hazards.

Washington Silver Jackets

The Washington Silver Jackets team was formed in 2010 and is a mix of Federal and State agencies that work together to address state flood risk priorities in the State. Federal agencies include the U.S. Army Corps of Engineers Seattle District, which facilitates coordination within the group, and individuals from FEMA, NOAA, and USGS. Participating state agencies include the Department of Ecology, Emergency Management Division, and Department of Transportation. The team has been awarded three interagency projects over the last three years. Each project and routine coordination and communication between Silver Jackets agencies is intended to address state needs and ultimately improve flood risk management throughout the full flood life cycle (Silver Jackets, 2016).

Land and Water Conservation Fund

The Land and Water Conservation Fund provides funding to preserve and develop outdoor recreation resources, including parks, trails, and wildlife lands. Congress established the fund in 1965 with the passage of the Land and Water Conservation Fund Act that authorizes the Secretary of the Interior to provide financial assistance to the states for the acquisition and development of public outdoor recreation areas. Funding comes from a portion of federal revenue from selling and leasing off-shore oil and gas resources. Eligible projects include land acquisition and development or renovation projects, such as natural areas and open space. The Washington State Recreation and Conservation Office administers the program (Washington State Recreation and Conservation Office, 2016a).

Salmon Recovery Fund

In 1999, the Washington State Legislature created the Salmon Recovery Funding Board. The board provides grants to protect or restore salmon habitat and assist related activities. Funded projects may include activities that protect existing, high quality habitats for salmon, and that restore degraded habitat to increase overall habitat health and biological productivity; undertake feasibility assessments to determine future projects and for other salmon related activities. Projects may include the actual habitat used by salmon and the land and water that support ecosystem functions and processes important to salmon (Washington State Recreation and Conservation Office, 2016b).

State Environmental Policy Act

The State Environmental Policy Act (SEPA) provides a way to identify possible environmental impacts that may result from governmental decisions. These decisions may be related to issuing permits for private projects, constructing public facilities, or adopting regulations, policies, or plans. Information provided during the SEPA review process helps agency decision-makers, applicants, and the public understand how a proposal will affect the environment. This information can be used to change a proposal to reduce likely impacts, or to condition or deny a proposal when adverse environmental impacts are identified. Actions identified in hazard mitigation plans are frequently subject to SEPA review requirements before implementation (Washington Department of Ecology, 2016b).

4.7.3 Local Programs

Each planning partner has prepared a jurisdiction-specific annex to this plan (see Volume 2). In preparing these annexes, each partner completed a capability assessment that looked at its regulatory, technical and financial capability to carry out proactive hazard mitigation. Refer to these annexes for a review of regulatory codes and ordinances applicable to each planning partner. This section provides an overview of programs in Clark County that can support or enhance the initiatives identified in this plan and apply countywide.

Clark County Comprehensive Plan Update

Clark County is in the process of updating its Comprehensive Growth Management Plan. The County has completed a draft Supplemental Environmental Impact Statement (DSEIS) for the plan (Clark County, 2016b) and is currently developing the update. The draft plan and other relevant documents will be made available as completed on the project website. The DSEIS assesses the impact of various growth management alternatives on potential hazard areas, including waterways, open spaces, liquefiable soils, landslide hazard areas, and wildlife habitat. The DSEIS evaluates how these areas may have changed since the last update in 2007.

The Land Use and Shoreline Use Elements of the County's comprehensive plan determine the general distribution, location and extent of land uses—agriculture, timber production, housing, commerce, industry, recreation, open spaces, public utilities, public facilities, and other uses, as well as transitions between rural and urban areas. These comprehensive plan elements include population densities, building intensities, and estimates of future population growth inside and outside the UGAs. The Environmental Element of the comprehensive plan contains policies to protect shoreline and critical areas and to develop regulations addressing land use issues such as protection of groundwater, stormwater runoff, flooding, and drainage problems (Clark County, 2016b).

Hazard Impact and Vulnerability Analysis

In 2011, CRESA developed a guidance document to assess hazards and vulnerabilities for the County and its cities (not including Woodland). The analysis identified vulnerability to the following natural and technological hazards (CRESA, 2011):

- Flooding
- Windstorm and tornado
- Severe winter weather
- Earthquake
- Landslide
- Drought
- Chemical emergency
- Terrorism
- Transportation accidents
- Dam failure
- Volcano
- Wildfire.

Each hazard analysis includes a description of the hazard and its potential range of impact and history in the County.

Clark Regional Comprehensive Emergency Management Plan

CRESA prepared a plan in 2018 to identify how it, along with the seven incorporated cities in Clark County (not including Woodland) and partnering agencies, would prepare for, respond to, recover from, and mitigate against hazard events (CRESA, 2018). The plan consists of appendices that delineate authorities, responsibilities, and appropriate references, along with emergency support function and incident annexes, which primarily focus on manmade hazard events.

Region IV Public Health Emergency Response Plan

In 2013, the Counties of Clark, Cowlitz, Skamania, and Wahkiakum (Region IV Public Health) coordinated to develop a regional public health emergency response plan (Region IV Public Health, 2013). Under this plan, the four local health departments in southwest Washington (Clark County Public Health, Cowlitz County Health Department, Skamania County Community Health and Wahkiakum County Health & Human Services), together with the Cowlitz Indian Tribe, have combined efforts and resources to ensure adequate response capacity to events affecting single or multiple jurisdictions. The plan provides each department guidance in ensuring appropriate response according to state, federal, and tribal agency requirements.

Vacant Buildable Lands Model Maps and Data

Clark County uses its Vacant Buildable Lands Model (Clark County, 2015b) as a planning tool to analyze residential, commercial, and industrial lands in urban growth areas. The model is used to monitor growth patterns for comprehensive growth management plan updates and interim periods. It models residential and employment capacity for each urban growth area, based on underutilized and vacant properties. Reports and maps are available free of charge for the County and for its eight incorporated cities (including Woodland).

Hazard mitigation plans must describe current and future risk to the hazards of concern. The Vacant Buildable Lands Model allows for the analysis of areas where future development may occur that may overlap with identified risk areas.

Clark County Local Emergency Planning Committee

CRESA's Local Emergency Planning Committee works closely with the business community to form a safety net around the chemical industry in order to protect the general population from hazardous material incidents. The following committee activities demonstrate its ability to support County emergency management and preparedness initiatives (CRESA, 2015a):

- Clark County Hazardous Materials Response Plan maintenance
- Making chemical inventory information available to the public
- Industrial and transportation-related chemical hazard analysis
- Training and exercise development and coordination
- Public-private preparedness partnerships
- Public education on chemical hazard preparedness and response.

Clark County Volunteer Programs

CRESA promotes several volunteer response organizations to offer local residents a way to safely become involved in disaster management. These programs include the following (CRESA, 2015b):

- Clark Citizen Corps Council—Maintains the Community Emergency Response Teams, Medical Reserve Corps, American Red Cross, Neighbors on Watch, and Volunteer Connections
- Search and Rescue—Volunteers must belong to a recognized and qualified search and rescue team.
- Amateur Radio
- Trauma Intervention Program
- Emergency Operations Center Training and Volunteering.

5. HAZARDS OF CONCERN FOR RISK ASSESSMENT

Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazards. The DMA requires hazard mitigation planning to include risk assessment (44 CFR, Section 201.6(c)(2)). The risk assessment for the *Clark Regional Natural Hazard Mitigation Plan* evaluates all natural hazards that are prevalent in the defined planning area. The first step in the process was to identify which hazards to include in the assessment. This chapter describes the process of identifying these hazards of concern.

5.1 FOCUS ON NATURAL HAZARDS

Natural hazards are naturally occurring severe events that have the potential to result in the loss of life and property. Technological or human-caused hazards also have the potential to result in the loss of life and property, but originate from human activities. Federal hazard mitigation planning guidelines require risk assessment for all natural hazards of concern; risk assessment of non-natural hazards (technological and/or human-caused) is optional. The Steering Committee decided that this plan will focus on natural hazards of concern, based on several factors:

- The federal funding streams for which this plan creates eligibility are focused on natural hazards of concern.
- Clark County already has several plans and programs that address non-natural hazards of concern such as the Hazard Identification and Vulnerability Assessment (CRESA, 2011) and the Comprehensive Emergency Response Plan (CRESA, 2013).
- The expertise needed to identify and implement appropriate mitigation actions for non-natural hazards of concern differs from the expertise needed for assessing natural hazards. The Steering Committee was formed with an emphasis on knowledge of and experience with natural hazards.
- It is difficult to develop a relative ranking of the risk of natural and non-natural hazards because of differences between the two types of hazard in probabilities, consequences and spatial extent.

Clark County's 2004 hazard mitigation plan addressed two non-natural hazards: terrorism and hazardous materials release. Terrorism was not addressed in the 2016 plan update, but the potential for hazardous material releases is discussed for each natural hazard profile as a potential secondary impact.

5.2 IDENTIFIED HAZARDS OF CONCERN

The Steering Committee considered the full range of natural hazards that could impact the planning area and selected those that present the greatest concern. The process incorporated review of state and local hazard planning documents, as well as information on the frequency, magnitude and costs associated with hazards that have impacted or could impact the planning area. Anecdotal information regarding the perceived vulnerability of planning area assets to natural hazards was used as appropriate. Based on the review, this plan addresses the following hazards of concern (in alphabetical order; this listing does not indicate relative risk):

- Dam failure
- Drought
- Earthquake
- Flood
- Landslide
- Severe weather
- Volcano
- Wildfire

All natural hazards identified in the 2004 plan were included in the 2016 plan, and two hazards of concern were added:

- Dam failure—Although dams and the reservoirs behind them are human-constructed, the dam failure hazard shares many characteristics with natural hazards. Inundation resulting from a dam failure has a defined extent and results in damage similar to damage from natural flooding that can be modeled using existing software. Additionally, dam failure is considered to be a flooding hazard that should be addressed in plans seeking approval under the Community Rating System (see Section 10.1.3). The dam failure risk assessment for this plan focuses on impacts on people and property, not the impacts on dam operations.
- Drought—The 2013 Washington State Enhanced Hazard Mitigation Plan (Washington Emergency Management Division, 2014) identifies drought as a hazard of concern and the 2011 Clark County Hazard Identification and Vulnerability Assessment (CRESA, 2011) identifies drought as a moderate risk hazard.

5.3 OTHER HAZARDS NOT ASSESSED

In addition to the hazards of concern listed above, the 2013 Washington State Enhanced Hazard Mitigation Plan identifies avalanche and tsunami as hazards of concern in Washington. Clark County is not identified in the state plan as a jurisdiction vulnerable to either of these hazards. The state plan does not list any major transportation systems in the County as transportation routes threatened by avalanche.

6. Risk Assessment Methodology

6.1 OVERALL RISK ASSESSMENT APPROACH

The risk assessments in Chapter 7 through Chapter 14 describe the risks associated with each identified hazard of concern. Each chapter describes the hazard, the planning area's exposure and vulnerability, and probable event scenarios. The planning team reviewed existing studies, reports and technical information to determine the best available data to utilize in the risk assessment (44 CFR, Section 201.6(b)(3)). Information from these sources was incorporated into the hazard profiles and forms the basis of the exposure and vulnerability assessment (see Section 6.6). The following steps were used to define the risk of each hazard:

- Profile each hazard—The following information is given for each hazard:
  - Summary of past events
  - Geographic area most affected by the hazard
  - Event frequency estimates
  - Severity estimates
  - Warning time likely to be available for response
  - Secondary hazards associated with or resulting from the hazard of concern
  - Future trends that may impact risk, including future development and climate trends
  - Worst-case event scenario
  - Key issues related to mitigation of the hazard in the planning area.
- Determine exposure to each hazard—Exposure was determined by overlaying hazard maps with demographic information and an inventory of structures, facilities and systems to determine which of them would be exposed to each hazard. For each hazard of concern, the best available existing data was used to delineate the hazard area, based on scale, age and source. Data available in a GIS-compatible format with coverage of the full extent of the planning area was preferred when available.
- Assess the vulnerability of exposed facilities—Vulnerability of exposed structures and infrastructure was determined by interpreting the probability of occurrence of each event and assessing structures, facilities, and systems that are exposed to each hazard. FEMA's hazard-modeling program, Hazus-MH was used to perform this assessment for some hazards; GIS-based spatial analysis or qualitative assessments were used for others.

6.2 MAPPING

National, state and county databases were reviewed to locate spatially based data relevant to this planning effort. Maps were produced using GIS software to show the spatial extent and location of identified hazards when such data was available. These maps are included in the hazard profile chapters of this document and many of them are available on the CRESA Hazard Mitigation Plan Project website. Additionally, municipal planning partners have jurisdiction-scale maps included in their annexes in Volume 2 of this plan. Information on the data sources and methodologies used for hazard mapping is provided in Appendix E.

6.3 DAM FAILURE, EARTHQUAKE AND FLOOD

6.3.1 Overview of FEMA's Hazus-MH Software

- FEMA developed the Hazards U.S., or Hazus, model in 1997 to estimate losses caused by earthquakes and identify areas that face the highest risk and potential for loss. Hazus was later expanded into a multi-hazard methodology, Hazus-MH, with new models for estimating potential losses from hurricanes and floods. The use of Hazus-MH for hazard mitigation planning offers numerous advantages:
  - Provides a consistent methodology for assessing risk across geographic and political entities.
  - Provides a way to save data so that it can readily be updated as population, inventory, and other factors change and as mitigation planning efforts evolve.
  - Facilitates the review of mitigation plans because it helps to ensure that FEMA methodologies are incorporated.
  - Supports grant applications by calculating benefits using FEMA definitions and terminology.
  - Produces hazard data and loss estimates that can be used in communication with local stakeholders.
  - Is administered by the local government and can be used to manage and update a hazard mitigation plan throughout its implementation.

Hazus-MH is a GIS-based software program used to support risk assessments, mitigation planning, and emergency planning and response. It provides a wide range of inventory data, such as demographics, building stock, critical facilities, transportation and utility lifeline, and multiple models to estimate potential losses from natural disasters. The program can be used to map hazard data and the results of damage and economic loss estimates for buildings and infrastructure.

6.3.2 Levels of Detail for Evaluation

Hazus-MH provides default data for inventory, vulnerability and hazards; this default data can be supplemented with local data to provide a more refined analysis. The model can carry out three levels of analysis, depending on the format and level of detail of information about the planning area:

- **Level 1**—All of the information needed to produce an estimate of losses is included in the software's default data. This data is derived from national databases and describes in general terms the characteristic parameters of the planning area.
- **Level 2**—More accurate estimates of losses require more detailed information about the planning area. To produce Level 2 estimates of losses, detailed information is required about local geology, hydrology, hydraulics and building inventory, as well as data about utilities and critical facilities. This information is needed in a GIS format.
- **Level 3**—This level of analysis generates the most accurate estimate of losses. It requires detailed engineering and geotechnical information to customize it for the planning area.

6.3.3 Application for This Plan

The Hazus model was used as follows for the hazards evaluated in this plan:

- **Flood**—A Level 2, user-defined analysis was performed for general building stock and for critical facilities and infrastructure. GIS building and assessor data (replacement cost values and detailed structure information) were loaded into Hazus-MH. Critical facility default data was updated whenever possible with locally available datasets. Current planning area flood mapping was used to delineate flood hazard areas and estimate potential losses from the 100- and 500-year flood events. To estimate damage that would result from a flood, Hazus uses pre-defined relationships between flood depth at a structure and resulting damage, with damage given as a percent of total replacement value. Curves defining these relationships have been developed for damage to structures and for damage to typical contents within a structure. By inputting flood depth data and known property replacement cost values, dollar-value estimates of damage were generated.

- **Dam Failure**—The basis for this analysis was the Lewis River Projects dam failure inundation mapping for the Merwin, Swift and Yale dams. This data was imported into Hazus-MH and a Level 2 analysis was run using the flood methodology described above.
- **Earthquake**—A Level 2 analysis was performed to assess earthquake risk and exposure. Earthquake shake maps and probabilistic data prepared by the U.S. Geological Survey (USGS) were used for the analysis of this hazard. An updated general building stock inventory was developed using replacement cost values and detailed structure information from assessor tables. Critical facility default data was updated whenever possible with locally available datasets. Two scenario events and two probabilistic events were modeled:
  - The scenario events were a Magnitude-9.0 event on the Cascadia Subduction Zone and a Magnitude-6.5 event on the Portland Hills Fault.
  - The standard Hazus analysis was run for the 100- and 500-year probabilistic events.

6.4 LANDSLIDE, SEVERE WEATHER, WILDFIRE AND VOLCANO

For landslide, severe weather, volcano and wildfire, historical data was not adequate to model future losses. However, areas and inventory susceptible to some of the hazards of concern were mapped by other means and exposure was evaluated. For other hazards, a qualitative analysis was conducted using the best available data and professional judgment.

6.5 DROUGHT

The risk assessment methodologies used for this plan focus on damage to structures. Because drought does not impact structures to the same degree as other hazards, the risk assessment for drought was more limited and qualitative than the assessment for the other hazards of concern.

6.6 SOURCES OF DATA USED IN RISK ASSESSMENT

6.6.1 Building Count and Replacement Cost Value

GIS building and assessor data (replacement cost values and detailed structure information) were loaded into Hazus-MH and utilized in GIS spatial analysis. When available, an updated inventory was used in place of the Hazus-MH defaults for critical facilities and infrastructure.

Replacement cost is the cost to replace the entire structure with one of equal quality and utility. Replacement cost is based on industry-standard cost-estimation models published in *RS Means Square Foot Costs* (RS Means, 2015). It is calculated using the estimated cost for a structure based on the Hazus occupancy class (e.g., multi-family residential, commercial retail trade) and the square footage of the structure from tax assessor data. For single-family residential, the construction class and number of stories also factor into the square foot costs.

6.6.2 Data Used for Spatial Analysis

Table 6-1 describes the data used for spatially based exposure and vulnerability assessments. If no database was available, it was noted as a gap.

Table 6-1. Summary of Data Used for Spatial Analysis

Data	Source
Base Map Data	County and city boundaries, roads, water features, district boundaries from Clark County GIS.
	Aerial photos from Clark County GIS.
	Base map data for City of Woodland from Cowlitz County.
General Building Stock Update	Building footprints, tax lots, address points from Clark County GIS.
	Parcel data and assessor data extract from Cowlitz County for City of Woodland.
	Assessor data extract from Clark County GIS.
Critical Facility Database Update[a,b]	Communication facilities from Clark County Assessor and Hazus Comprehensive Data Management System.
	Dams from U.S. Army Corps National Inventory of Dams.
	Emergency services from Clark County GIS.
	Energy from Clark County GIS and Hazus Comprehensive Data Management System.
	Government facilities from Clark County GIS.
	Hazardous materials from Clark County GIS.
	Healthcare and public health from Clark County GIS.
	Information technology was not available.
	Schools from Clark County GIS, Camas School District and Battle Ground School District.
	Transportation systems from Clark County GIS, Port of Vancouver, and Hazus Comprehensive Data Management System.
	Water and sanitation systems from Clark County GIS, Clark Regional Wastewater District, Clark Public Utilities, City of Vancouver, City of Battleground and City of Camas.
Flood	Effective digital Flood Insurance Rate Maps downloaded from FEMA website.
	2002 10-foot resolution digital elevation model from Clark County GIS.
	Washington State levee inventory data downloaded from Washington Department of Ecology website.
	Repetitive loss data acquired from FEMA.
	3-meter resolution digital elevation model for City of Woodland area downloaded from USGS website.
Earthquake	Shake maps for Cascadia M-9.0 and Portland Hills M-6.5 downloaded from USGS website.
	Liquefaction susceptibility and National Earthquake Hazard Reduction Program soils data downloaded from Washington Department of Natural Resources website. https://www.dnr.wa.gov/geologyportal
	Earthquake hazard areas data from Clark County GIS.
	Faults data downloaded from Washington Department of Natural Resources website.
Landslide	Landslide and soil erosion hazard data from Clark County GIS.
	Landslides and landforms data downloaded from Washington Department of Natural Resources website. https://www.dnr.wa.gov/geologyportal

Dam Failure	Lewis River Projects inundation data from CRESA (includes inundation areas for Merwin, Swift, and Yale dams).
	Dams data from Clark County GIS.
Wildfire	Wildland urban interface data from Clark County GIS.
	Wildland urban interface data from the City of Vancouver.
Volcano	Mt. Hood Region, Mount St. Helens, and Mount Adams Region volcano hazards data downloaded from USGS CVO website.
Demographics	2010 Census block boundaries available in Hazus database.
	2010 Census statistical data downloaded from the U.S. Census Bureau website.
Current and Future Land Use	Land use, zoning, comprehensive plan designations, urban growth area boundary, vacant buildable lands and critical lands (environmental constraints) data from Clark County GIS.

Note: Additional information on hazard data can be found in Appendix E.
a. Hazus-MH default data was used as appropriate for the City of Woodland.
b. Not all requested data was received, so gaps in the database are present. Future planning efforts will work to address these gaps.

6.7 LIMITATIONS

6.7.1 General Limitations

Loss estimates, exposure assessments and hazard-specific vulnerability evaluations rely on the best available data and methodologies. However, results are subject to uncertainties associated with the following factors:

- Incomplete scientific knowledge about natural hazards and their effects on the built environment
- Approximations and simplifications necessary to conduct a study
- Incomplete or outdated inventory, demographic or economic parameter data
- The unique nature, geographic extent and severity of each hazard
- Mitigation measures already employed
- The amount of advance notice residents have to prepare for a specific hazard event.

Hazus-MH currently represents the industry best management practice for assessing risk in support of hazard mitigation planning. However, Hazus and other models used for this risk assessment are limited by the availability of data to support their working components. Such models must assumptions where firm data are not available. Assumptions are used, for example, to estimate ground deformation caused by liquefaction. These model limitations can lead to an understatement or overstatement of risk. These factors can affect loss estimates by a factor of two or more. Therefore, potential exposure and loss estimates are approximate and should be used only to understand relative risk. Over the long term, Clark County and its planning partners will collect additional data to assist in estimating potential losses associated with other hazards.

6.7.2 Specific Limitations Noted During the Planning Process

The following are limitations specific to the datasets used in this planning process:

- Clark County assessor data lacked detailed information on building and foundation type (e.g. masonry construction and slab-on-grade, respectively). Default information was used, which impacts the accuracy of vulnerability estimates because building and foundation type play a major role in how structures will behave during hazard events.

- Model data input requirements necessitate the conversion of building footprints into single point features. Building locations are represented by single points located in the centroid of the building footprint.
- Data used in the wildfire assessment is dated and does not cover the entire planning area.
- Not all critical facility data was available in a digital format. Best available datasets were used.

6.7.3 How Climate Change Affects Hazard Mitigation

An essential aspect of hazard mitigation is predicting the likelihood of hazard events in a planning area. Typically, predictions are based on statistical projections from records of past events. This approach assumes that the likelihood of hazard events remains essentially unchanged over time. Thus, averages based on the past frequencies of, for example, floods are used to estimate future frequencies: if a river has flooded an average of once every five years for the past 100 years, then it can be expected to continue to flood an average of once every five years.

For hazards affected by climate conditions, the assumption that future behavior will be equivalent to past behavior is not valid if climate conditions are changing. As flooding is generally associated with precipitation frequency and quantity, for example, the frequency of flooding will not remain constant if broad precipitation patterns change over time. The risks of landslide, severe weather, and wildfire are all affected by climate patterns as well. Changing risk from climate change to the volcano and earthquake hazard is less understood at this time, but may also be significant.

For this reason, an understanding of climate change is pertinent to efforts to mitigate natural hazards. Information about how climate patterns are changing provides insight on the reliability of future hazard projections used in mitigation analysis. Information pertaining to the likely or expected impacts of climate change on each of hazard of concern is discussed in the hazard profiles.

Part 2. RISK ASSESSMENT

7. DAM FAILURE

7.1 GENERAL BACKGROUND

7.1.1 Causes of Dam Failure

Dam failures in the United States typically occur in one of four ways:

- Overtopping of the primary dam structure, which accounts for 34 percent of all dam failures, can occur due to inadequate spillway design, settlement of the dam crest, blockage of spillways, and other factors.
- Foundation defects due to differential settlement, slides, slope instability, uplift pressures, and foundation seepage can also cause dam failure. These account for 30 percent of all dam failures.
- Failure due to piping and seepage accounts for 20 percent of all failures. These are caused by internal erosion, erosion along hydraulic structures such as spillways, erosion due to animal burrows, and cracks in the dam structure.
- Failure due to problems with conduits and valves, typically caused by the piping of embankment material into conduits through joints or cracks, constitutes 10 percent of all failures.

The remaining 6 percent of U.S. dam failures are due to miscellaneous causes. Many dam failures in the United States have been secondary results of other disasters. The prominent causes are earthquakes, landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, and sabotage (ASDSO, 2016).

Poor construction, lack of maintenance and repair, and deficient operational procedures are preventable or correctable by a program of regular inspections. Terrorism and vandalism are serious concerns that all operators of public facilities must plan for; these threats are under continuous review by public safety agencies.

7.1.2 Regulatory Oversight

The dam failure risk assessment and mitigation strategies developed for this plan focus on impacts on people and property once a dam failure has occurred. The focus is not on dam operations to prevent dam failures from occurring, although a brief synopsis of regulatory programs impacting dam operations is included for reference.

National Dam Safety Act

The potential for catastrophic flooding due to dam failures led to passage of the National Dam Safety Act (Public Law 92-367). The National Dam Safety Program requires a periodic engineering analysis of every major dam in the country. The goal of this FEMA-monitored effort is to identify and mitigate the risk of dam failure so as to protect the lives and property of the public. The program is a partnership between states, federal agencies, and other stakeholders that encourages individual and community responsibility for dam safety. State assistance funds have allowed participating states to improve their programs through increased inspections, emergency action planning, and the purchase of needed equipment. FEMA has also expanded existing and initiated new training programs. Grant assistance from FEMA provides support for improvement of dam safety programs that regulate most of the dams in the United States (FEMA, 2013b).

Washington Department of Ecology Dam Safety Program

The Dam Safety Office (DSO) of the Washington Department of Ecology regulates over 1,000 dams in the state that impound at least 10 acre-feet of water. The DSO has developed dam safety guidelines to provide dam owners, operators, and design engineers with information on activities, procedures, and requirements involved in the planning, design, construction, operation and maintenance of dams in Washington. The authority to regulate dams in Washington and to provide for public safety is contained in the following laws:

- State Water Code (1917)—RCW 90.03
- Flood Control Act (1935)—RCW 86.16
- Department of Ecology (1970)—RCW 43.21A.

Where water projects involve dams and reservoirs with a storage volume of 10 acre-feet or more, the laws provide for the Department of Ecology to conduct engineering review of the construction plans and specifications, to inspect the dams, and to require remedial action as necessary to ensure proper operation, maintenance, and safe performance. The DSO was established within Ecology's Water Resources Program to carry out these responsibilities.

The DSO's five-year periodic inspection program for dams with high and significant hazard classifications achieves the following purposes (Washington Department of Ecology, 2022):

- Assess the structural integrity and stability of project elements.
- Identify obvious defects, especially due to aging.
- Assess the stability of the structure under earthquake conditions.
- Determine the adequacy of the spillways to accommodate major floods.
- Evaluate project operation and maintenance.

The inspections, performed by professional engineers from the DSO, consist of the following elements (Washington Department of Ecology, 2022):

- Review and analysis of available data on the design, construction, operation and maintenance of the dam and its appurtenances
- Visual inspection of the dam and its appurtenances
- Evaluation of the safety of the dam and its appurtenances, which may include an assessment of hydrological and hydraulic capabilities, structural stabilities, seismic stabilities, and any other condition that could constitute a hazard to the integrity of the structure
- Evaluation of the downstream hazard classification
- Evaluation of the operation, maintenance and inspection procedures employed by the owner and/or operator
- Review of the emergency action plan for the dam, including review or update of the dam-breach inundation map.

The DSO provides assurance that impoundment facilities will not pose a threat to lives and property, but dam owners bear primary responsibility for the safety of their structures, through proper design, construction, operation, and maintenance.

U.S. Army Corps of Engineers Dam Safety Program

The U.S. Army Corps of Engineers is responsible for safety inspections of some federal and non-federal dams in the United States that meet the size and storage limitations specified in the National Dam Safety

Act. The Corps has inventoried dams; surveyed each state and federal agency's capabilities, practices and regulations regarding design, construction, operation and maintenance of the dams; and developed guidelines for inspection and evaluation of dam safety (U.S. Army Corps of Engineers, 2011). The Corps' National Inventory of Dams lists the following dates of the most recent inspection dates for Clark County dams:

- Anderson Dam: N/A
- Binford Reservoir Dam: N/A
- Cadman Lewisville S&G Pit: February 14, 2020
- Crisman Reservoir Dam: N/A
- Curtis Dam: July 24, 2017
- Elmer Dam: October 25, 2020
- Erickson Dam: June 31, 2018
- Fargher Lake Dam: N/A
- Green Mountain Pond: N/A
- Haigh Reservoir Dam: July 8, 2019
- Jones Dam: N/A
- Lacamas and Round Lakes, Lower Dam: September 14, 2017
- Lacamas and Round Lakes, Upper Dam: September 14, 2017
- Malar Dam: N/A
- Merwin Dam: September 30, 2020
- North Aeration Stabilization Basin Lady Island: May 17, 2017
- Shillapoo Lake Dikes: N/A
- Swift No 2 Hydroelectric Project: August 23, 2019
- Tri-Mountain Estates Dam: July 25, 2020
- Warman Waterski Lake Dam: N/A
- Yale Dam: September 30, 2020

Federal Energy Regulatory Commission Dam Safety Program

The Federal Energy Regulatory Commission (FERC) cooperates with a large number of federal and state agencies to ensure and promote dam safety. More than 3,000 dams are part of regulated hydroelectric projects in the FERC program. Two-thirds of these are more than 50 years old. As dams age, concern about their safety and integrity grows, so oversight and regular inspection are important. FERC inspects hydroelectric projects on an unscheduled basis to investigate the following:

- Potential dam safety problems
- Complaints about constructing and operating a project
- Safety concerns related to natural disasters
- Issues concerning compliance with the terms and conditions of a license.

Every five years, an independent FERC-approved engineer must inspect and evaluate projects with dams higher than 32.8 feet (10 meters), or with a total storage capacity of more than 2,000 acre-feet.

FERC monitors and evaluates seismic research and applies it in structural analyses of hydroelectric projects. FERC also evaluates the effects of potential and actual large floods on the safety of dams. During and following floods, FERC visits dams and licensed projects, determines the extent of damage, if any, and directs any necessary studies or remedial measures the licensee must undertake. The FERC publication *Engineering Guidelines for the Evaluation of Hydropower Projects* guides the FERC engineering staff and licensees in evaluating dam safety. The publication is frequently revised to reflect current information and methodologies.

FERC requires licensees to prepare emergency action plans and conducts training sessions on how to develop and test these plans. The plans outline an early warning system if there is an actual or potential sudden release of water from a dam due to failure. The plans include operational procedures that may be used, such as reducing reservoir levels and reducing downstream flows, as well as procedures for notifying affected residents and agencies responsible for emergency management. These plans are frequently updated and tested to ensure that everyone knows what to do in emergency situations (FERC, 2005).

7.2 HAZARD PROFILE

7.2.1 Past Events

Dam failures can occur suddenly and without warning. They may occur during normal operating conditions or during a large storm event. Significant rainfall can quickly inundate an area and cause floodwaters to overwhelm a reservoir. If the spillway of the dam cannot safely pass the resulting flows, water will begin flowing in areas not designed for such flows, and a failure may occur.

According to the Association of State Dam Safety Officials, there have been no recorded dam incidents in Clark County (ASDSO, 2020). Between 1954 and 2020, FEMA has not included the State of Washington in any dam/levee break-related disaster declarations. One incident has been recorded in Skamania County, near the border of Clark County. On April 21, 2002, the retention structure at the west end of Swift Canal catastrophically failed. While there were no injuries, State Route (SR) 503 was completely washed out (CRESA, 2011).

7.2.2 Location

In Clark County, there are 29 dams that impound 10 acre-feet of water or more. Table 7-1 lists the dams in Clark County that the Dam Safety Office rates as High Hazard Class (1A, 1B, 1C). In addition to the dams located in Clark County, dams located on the Lewis River upstream of the County could impact residents. These dams are regularly inspected, well-staffed, and well-maintained (CRESA, 2011). The location of dams within the County can be seen on Figure 4-2.

Table 7-1. High Hazard Class Dams in Clark County (1A, 1B, 1C)

	Hazard Category	National ID #	Water Course	Owner	Year Built	Dam Type[a]	Crest Length (feet)	Height (feet)	Storage Capacity (acre-feet)	Drainage area (sq. mi.)
Merwin Dam	1A	WA00474	Lewis River	PacifiCorp	1931	Concrete single arch	1,250	313	423,000	731
Curtis Dam	1C	WA01980	Not available	Curtis Dam	1978	Earth Fill	Not available	15	24	1.37

Erikson Dam	1B	WA00102	Tributary – Rock Creek	Adrian Navarro	1968	Earth fill	500	22	210	2.03
Tri Mountain Estates Dam	1C	WA00103	Tributary – Mason Creek	Tri-Mountain Estates LLC	1953	Earth fill	180	30	102	0.22
Haight Reservoir Dam	1C	WA01039	Tributary – Columbia River	Camas City Public Works	1951	Earth Fill	480	12	20	0.02
Yale Dam (Cowlitz County)	1A	WA00148	Lewis River	PacifiCorp	1953	Earth Fill	1500	323	402,000	600
Yale Saddle Dam (Cowlitz County)	1A	WA00135	Lewis River	PacifiCorp	1953	Earth Fill	1600	42	129,000	596

Source: Washington Department of Ecology 2020

7.2.3 Frequency

Dam failure events are infrequent and often coincide with other hazard events that cause them, such as earthquakes, landslides and excessive rainfall and snowmelt. There is a "residual risk" associated with dams. Residual risk is the risk that remains after safeguards have been implemented. For dams, the residual risk is associated with events beyond those that the facility was designed to withstand. However, the probability of any type of dam failure is low in today's dam safety oversight environment.

7.2.4 Severity

The DSO classifies regulated dams in Washington by hazard class, based on the at-risk population living in the area that could be inundated if the dam fails. The hazard class definitions and number of Clark County dams in each class are as follows (Washington Department of Ecology, 2020):

- 1 Hazard Class 1A (High - a downstream at-risk population of more than 300)
- 0 Hazard Class 1B (High - a downstream at-risk population of 31 to 300)
- 3 Hazard Class 1C (High -a downstream at-risk population of 7 to 30)
- 3 Hazard Class 2 (Significant - a downstream at-risk population of 1 to 6)
- 22 Hazard Class 3 (Low - no downstream at-risk population).

Four high-hazard dams and three significant hazard dams are located in Clark County—on the Lewis River, Rock Creek, Mason Creek, and Lacamas Creek (CRESA, 2011). These dams could cause a countywide concern were they to fail Localized problems could occur if one of the minor dams in the county failed.

The U.S. Army Corps of Engineers developed the classification system shown in Table 7-2 for the hazard potential of dam failures. The DSO and Corps of Engineers hazard rating systems are based only on the potential consequences of a dam failure; they do not take into account the probability of such failures.

Table 7-2. Corps of Engineers Hazard Potential Classification

Hazard Category[a]	Direct Loss of Life[b]	Lifeline Losses[c]	Property Losses[d]	Environmental Losses[e]
Low	None (rural location, no permanent structures for human habitation)	No disruption of services (cosmetic or rapidly repairable damage)	Private agricultural lands, equipment, and isolated buildings	Minimal incremental damage
Significant	Rural location, only transient or day-use facilities	Disruption of essential facilities and access	Major public and private facilities	Major mitigation required
High	Certain (one or more) extensive residential, commercial, or industrial development	Disruption of essential facilities and access	Extensive public and private facilities	Extensive mitigation cost or impossible to mitigate

a. Categories are assigned to overall projects, not individual structures at a project.
b. Loss of life potential based on inundation mapping of area downstream of the project. Analyses of loss of life potential should take into account the population at risk, time of flood wave travel, and warning time.
c. Indirect threats to life caused by the interruption of lifeline services due to project failure or operational disruption; for example, loss of critical medical facilities or access to them.
d. Damage to project facilities and downstream property and indirect impact due to loss of project services, such as impact due to loss of a dam and navigation pool, or impact due to loss of water or power supply.
e. Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond what would normally be expected for the magnitude flood event under which the failure occurs.

Source: U.S. Army Corps of Engineers, 1995

7.2.5 Warning Time

Warning time for dam failure varies depending on the cause of the failure. In events of extreme precipitation or massive snowmelt, evacuations can be planned with sufficient time. In the event of a structural failure due to earthquake, there may be no warning time. A dam’s structural type also affects warning time. Earthen dams do not tend to fail completely or instantaneously. Once a breach is initiated, discharging water erodes the breach until either the reservoir water is depleted or the breach resists further erosion. Concrete gravity dams also tend to have a partial breach as one or more monolith sections are forced apart by escaping water. The time of breach formation ranges from a few minutes to a few hours (U.S. Army Corps of Engineers, 1997).

7.3 SECONDARY HAZARDS

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure are landslides around the reservoir perimeter, bank erosion on the downstream watercourse, and destruction of downstream habitat. Hazardous materials spills are also a potential secondary hazard of dam failure if storage tanks rupture and spill.

7.4 EXPOSURE

The flood module of Hazus-MH was used for a Level 2 assessment of dam failurein 2016. Hazus-MH uses census data at the block level, which has a level of accuracy acceptable for planning purposes. Where possible, the Hazus-MH data was enhanced for this risk assessment using GIS data from county, state and federal sources. The exposure and vulnerability analyses use inundation mapping for a cascading failure of the Swift, Yale and Merwin dams, which are part of the PacifiCorp Lewis River project. The mapping used a risk-based approach to establish the inflow design flood, which allows for the evaluation of downstream consequences for a range of hydrologic dam failure events. This assessment does not capture all risk from all dams in the county, but was selected because of the substantial impacts and available data. Inundation maps were prepared for this analysis, but are not included in the publicly available version of this plan due to security concerns.

7.4.1 Population

All populations in a dam failure inundation zone would be exposed to the risk of a dam failure. The potential for loss of life is affected by the capacity and number of evacuation routes available to populations living in areas of potential inundation. The estimated population living in the mapped inundation areas within the planning area is 34,346 or 7.6 percent of the county's population. Table 7-3 summarizes the at-risk population in the planning area by jurisdiction.

Table 7-3. Population within Dam Failure Inundation Areas[c]

	Population Exposed[a]	% of Total Population
Battle Ground	0	0.0%
Camas	2,304	10.9%
La Center	165	5.3%
Ridgefield	1,262	19.7%
Vancouver	9,031	5.3%
Washougal	1,183	7.8%
Woodland	5,839	99.9%
Yacolt	0	0.0%
Unincorporated	14,562	6.8%
Total	**34,346**	**7.6%b**

a. Represents the percent of total buildings that are exposed multiplied by the estimated 2015 per-household population
b. Represents the total affected population as a percent of total Clark County population.
c. These estimates are derived from the planning scenario event, not for all possible dam failure risk in the county.

7.4.2 Property

Table 7-4 summarizes the value of planning area buildings in the mapped inundation area. Over 10 percent of the total replacement value of the planning area is exposed to the dam failure hazard. Table 7-5 lists the structure type of buildings in the inundation areas. Residential properties make up over 90 percent of this exposure. The distribution of land uses in dam inundation area is in Table 7-6.

Table 7-4. Value of Structures in Dam Failure Inundation Area[b]

	Value Exposed			% of Total Replacement Value[a]
	Building	Contents	Total	
Battle Ground	$0	$0	$0	0.0%
Camas	$651,757,000	$596,720,000	$1,248,477,000	16.5%
La Center	$53,074,000	$48,780,000	$101,854,000	12.7%
Ridgefield	$206,190,000	$152,250,000	$358,440,000	17.3%
Vancouver	$2,741,206,000	$2,423,901,000	$5,165,107,000	10.8%
Washougal	$447,433,000	$390,519,000	$837,952,000	20.1%
Woodland	$948,973,000	$827,704,000	$1,776,677,000	99.9%
Yacolt	$0	$0	$0	0.0%
Unincorporated	$1,553,548,000	$976,661,000	$2,530,209,000	5.6%

	Value Exposed			% of Total Replacement Value[a]
	Building	Contents	Total	
Total	$6,602,181,000	$5,416,535,000	$12,018,716,000	**10.6%**

a. Percentages are based on the total replacement value for individual jurisdictions, not for the planning area as a whole. The "total" percentage shown is based on the sum of replacement values for jurisdictions in this table.
b. These estimates are derived from the planning scenario event, not for all possible dam failure risk in the county.
Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 7-5. Structure Type in Dam Failure Inundation Areas[b]

	Number of Structures[a]							
	Residential	Commercial	Industrial	Agriculture/ Forestry	Religion	Government	Education	Total
Battle Ground	0	0	0	0	0	0	0	0
Camas	726	67	11	4	5	3	0	816
La Center	49	5	0	3	0	1	1	59
Ridgefield	434	13	5	2	1	4	0	459
Vancouver	2,349	262	17	17	1	5	4	2,655
Washougal	340	79	3	2	5	3	0	432
Woodland	1,641	169	26	1	16	4	5	1,862
Yacolt	0	0	0	0	0	0	0	0
Unincorporated County	4,939	44	1	88	9	2	0	5,083
Total	**10,478**	**639**	**63**	**117**	**37**	**22**	**10**	**11,366**

a. Structure type assigned to best fit Hazus occupancy classes based on present use classifications provided by Clark and Cowlitz County assessor's data. Where conflicting information was present in the available data, parcels were assumed to be improved.
b. These estimates are derived from the planning scenario event, not for all possible dam failure risk in the county.

Table 7-6. Present Land Use in Planning Area[a]

Present Use Classification[b]	Area in Dam Inundation Hazard Areas (acres)[c, d]	% of total exposed acreage
Agriculture/Resource Land	9,216.29	18.2%
Commercial	5,926.12	11.7%
Education	134.08	0.3%
Governmental Services	241.08	0.5%
Industrial	1,259.56	2.5%
Religious Services	57.81	0.1%
Residential	27,997.70	55.1%
Vacant or uncategorized	5,938.74	11.7%
Total	50,771.38	**100%**

a. Present land use information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Present use classification provided by Clark and Cowlitz County assessor's data assigned to best fit occupancy classes in the Hazus model (see Section 6.3.1). Parcels for which conflicting information on current development was available were assumed to be improved. Some designated resource land may also be included in the vacant or uncategorized category.
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage includes Clark County and the incorporated areas of the City of Woodland.

7.4.3 Critical Facilities

GIS analysis determined that there are 167 critical facilities in the mapped inundation area (see Table 7-7). In addition, the following linear features are exposed to the dam failure hazard:

- Interstate 5
- Interstate 205
- State Route 14
- State Route 500
- State Route 501
- State Route 503
- Northwest Pipeline
- Olympic Pipeline
- All watercourse levees.

Additional critical facilities and infrastructure are likely to be located in inundation areas where mapping was not available.

Table 7-7. Critical Facilities and Infrastructure in the Swift Dam Inundation Area

	Communication Facilities	Dams	Emergency Services	Energy	Government Facilities	Hazardous Materials	Health Care & Public Health	Information Technology	Schools	Transportation Systems	Water & Sanitation Systems	Total
Battle Ground	0	0	0	0	0	0	0	0	0	0	0	**0**
Camas	0	0	0	0	0	0	0	0	0	4	13	**17**
La Center	0	0	0	0	0	0	0	0	0	0	0	**0**
Ridgefield	0	0	0	0	0	0	0	0	0	0	2	**2**
Vancouver	0	0	0	6	0	20	1	0	0	66	20	**113**
Washougal	0	0	2	0	0	1	0	0	0	0	2	**5**
Woodland	0	0	3	1	0	2	0	0	5	0	0	**11**
Yacolt	0	0	0	0	0	0	0	0	0	0	0	**0**
Unincorporated	0	2	0	1	0	0	0	0	0	11	5	**19**
Total	**0**	**2**	**5**	**8**	**0**	**23**	**1**	**0**	**5**	**81**	**42**	**167**

7.4.4 Environment

The environment would be exposed to a number of risks in the event of dam failure. The inundation could introduce many foreign elements into local waterways, including hazardous materials. This could result in destruction of downstream habitat and could have detrimental effects on many species of animals, especially endangered species, such as salmon.

7.5 VULNERABILITY

7.5.1 Population

Vulnerable populations are all populations downstream from dam failures that are incapable of escaping the area within the allowable time frame. This includes the elderly and young, who may be unable to get themselves out of the inundation area. Vulnerable populations also include those who would not have adequate warning from a television or radio emergency warning system. Impacts on persons and households in the planning area were estimated for dam failure events through the Level 2 Hazus-MH analysis. Table 7-8 summarizes the results.

Table 7-8. Estimated Dam Failure Impact on Persons and Households[a, c]

	Displaced Households		Persons Requiring Short-Term Shelter	
	Number	% of Population	Persons	% of Population
Battle Ground	0	0.0%	0	0.0%
Camas	702	3.3%	556	2.6%
La Center	30	1.0%	15	0.5%
Ridgefield	58	0.9%	27	0.4%

	Displaced Households		Persons Requiring Short-Term Shelter	
	Number	% of Population	Persons	% of Population
Vancouver	2,241	1.3%	1,996	1.2%
Washougal	410	2.7%	322	2.1%
Woodland[b]	5,839	99.9%	4,788	81.9%
Yacolt	0	0.0%	0	0.0%
Unincorporated	1,968	0.9%	1,515	0.7%
Total	**11,248**	**2.5%**	**9,219**	**2.0%**

a. Displaced population and shelter need estimates were based on updated general building stock dataset at a census block analysis level.
b. Due to the way Hazus calculates results inside each county, the City of Woodland results for displaced population and short-term shelter needs using Cowlitz County data were higher than total population. To compensate, the displaced population for the City of Woodland was calculated by multiplying the estimated 2015 population by the percentage of population exposed. The short-term shelter requirements were determined by calculating the percentage of total scenario short-term shelter requirements over displaced population and applying it to the City of Woodland displaced population.
c. These estimates are derived from the planning scenario event, not for all possible dam failure risk in the county.

7.5.2 Property

Vulnerable properties are those closest to the dam inundation area. These properties would experience the largest, most destructive surge of water. Low-lying areas are also vulnerable since they are where the dam waters would collect. Table 7-9 summarizes estimated losses associated with planning area buildings in the mapped inundation area. About 2.5 percent of the total replacement value of the planning area is vulnerable to the dam failure hazard.

Table 7-9. Loss Estimates for Structures in Dam Failure Inundation Area[a]

	Estimated Loss Associated with Dam Failure			% of Total Replacement Value
	Building	Contents	Total	
Battle Ground	$0	$0	$0	0.00%
Camas	$84,485,000	$127,631,000	$212,116,000	2.80%
La Center	$2,514,000	$4,111,000	$6,625,000	0.82%
Ridgefield	$37,402,000	$46,564,000	$83,966,000	4.05%
Vancouver	$396,975,000	$589,260,000	$986,235,000	2.05%
Washougal	$17,267,000	$29,195,000	$46,462,000	1.12%
Woodland	$607,581,000	$628,226,000	$1,235,807,000	69.51%
Yacolt	$0	$0	$0	0.00%
Unincorporated	$161,955,000	$128,100,000	$290,055,000	0.65%
Total	**$1,308,179,000**	**$1,553,087,000**	**$2,861,266,000**	**2.52%**

a. These estimates are derived from the planning scenario event, not for all possible dam failure risk in the county.
Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

7.5.3 Critical Facilities

On average, critical facilities expected to sustain damage during a dam failure event would receive 42.9 percent damage to the structure and 96.5 percent damage to the contents during a dam failure event. The estimated time to restore these facilities to 100 percent of their functionality is 846 days. In addition, transportation routes are vulnerable to dam inundation and have the potential to be wiped out, creating isolation issues. This includes all roads, railroads and bridges in the path of the dam inundation. Those that are most vulnerable are those that are already in poor condition and would not be able to withstand a large water surge. Utilities such as overhead power lines, cable and phone lines could also be vulnerable. Loss of these utilities could create additional isolation issues for the inundation areas. Estimated damage to critical facilities and infrastructure in the dam inundation area is summarized in Table 7-10.

Table 7-10. Estimated Damage to Critical Facilities and Infrastructure from Dam Failure

	Number of Facilities Affected	Average % of Total Value Damaged		Days to 100% Functionality
		Building	Content	
Communication Facilities	0	--	--	--
Dams	0	--	--	--
Emergency Services	5	59.8%	93.0%	792
Energy	5	18.7%	--	--
Government Facilities	0	--	--	--
Hazardous Materials	17	22.8%	--	--
Health Care & Public Health	0	--	--	--
Information Technology	0	--	--	--
Schools	5	94.0%	100.0%	900
Transportation Systems[a]	27	N/A	N/A	N/A
Water & Sanitation Systems	31	19.1%	--	--
Total	**90**	**42.9%**	**96.5%**	**846**

a. Due to an issue with the Hazus software, analysis of transportation facilities was not able to be conducted for this scenario. It expected that there would be extensive impacts to many of the facilities in the inundation area.

7.5.4 Environment

The extent of the vulnerability of the environment is the same as the exposure of the environment. As with any significant natural hazard event, large of amounts of debris generated from the damaged buildings and infrastructure could have significant environmental impacts. These impacts were estimated for the dam failure event through the Level 2 Hazus-MH analysis. Table 7-11 summarizes the results.

Table 7-11. Estimated Dam Failure-Caused Debris

	Debris to Be Removed (tons) [a]	Truck Loads[b]
Battle Ground	0	0
Camas	31,791,450	1,271,658
La Center	179,750	7,190
Ridgefield	6,175,230	247,009
Vancouver	80,547,430	3,221,897
Washougal	1,586,430	63,457
Woodland	68,553,860	2,742,154
Yacolt	0	0
Unincorporated	24,637,680	985,507
Total	**213,471,830**	**8,538,873**

a. Debris generation estimates were based on updated general building stock dataset at a Census Block analysis level.
b. Hazus assumes 25 tons per truck.
Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

7.5.5 Economic Impact

In general, dam failure presents the potential for significant disruption, including loss of life, massive property damage, and other long-term consequences. All of these are likely to impact the local economy, directly and indirectly. Economic losses can include the cost to rebuild structures and properties, the cost of response, and recovery, downstream damage, and long-term costs to repair environmental damage. It can also have a hidden impact, by reducing public morale and confidence, resulting in decreased spending in local stores and businesses near the event's occurrence. Such indirect and cascading impacts, however, are difficult to quantify, even though FEMA recognizes their significance and probability. FEMA provides resources to assist jurisdictions in estimating both direct and indirect economic consequences after a dam failure (Homeland Security, 2011).

7.6 FUTURE TRENDS

7.6.1 Development

Land use in the planning area will be directed by local comprehensive plans adopted under state law. The planning partners have established comprehensive policies regarding sound land use in identified flood hazard areas. While some of the areas vulnerable to the more severe impacts from dam failure intersect the mapped flood hazard areas, the inundation areas from a dam failure cover a much larger portion of the planning area.

Flood-related policies in these comprehensive plans and in the local municipal code will help to reduce the risk associated with the dam failure hazard for development in the planning area, but will be unlikely to help reduce risk to all structures within the dam inundation area. Table 7-12 shows the land acreage identified as underutilized or vacant in urban growth areas in the County that intersect the dam failure inundation areas.

Table 7-12. Buildable Lands in Planning Area Urban Growth Areas that Intersect Dam Inundation Areas[a]

Urban Growth Area Name[b]	Residential		Commercial (acres)	Industrial (acres)	Total (acres) [c]
	Acres	Units			
Battle Ground	0	0	0	0	**0**
Camas	19.03	114	2.54	28.35	**49.92**
La Center	13.10	52	1.97	0	**15.06**
Ridgefield	28.94	174	0.27	0	**29.21**
Vancouver	114.27	914	26.63	674.78	**815.68**
Washougal	4.42	26	20.67	33.29	**58.37**
Woodland[d]	25.24	101	0	0	**25.24**
Yacolt	0	0	0	0	**0**
Total	**205.00**	**1,381**	**52.08**	**736.42**	**993.48**

a. Buildable lands information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Unincorporated areas outside of urban growth areas are excluded from this assessment. Development in these areas consists largely of rural lands, open space and large residential lots.
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage estimates exclude the portions of the City of Woodland in Cowlitz County and thus may be underestimated.

7.6.2 Climate Change

Dams are designed partly based on assumptions about a river's flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or all of its designed margin of safety, also known as freeboard. If freeboard is reduced, dam operators may be forced to release increased volumes earlier in a storm cycle in order to maintain the required margins of safety. Such early releases of increased volumes can increase flood potential downstream.

Dams are constructed with safety features known as “spillways.” Spillways are put in place on dams as a safety measure in the event of the reservoir filling too quickly. Spillway overflow events, often referred to as “design failures,” result in increased discharges downstream and increased flooding potential. Although climate change will not increase the probability of catastrophic dam failure, it may increase the probability of design failures.

The climate of Washington state is already changing and will continue to change over the course of this century. The number of extreme weather events is increasing, and warmer temperatures are resulting in greater amounts of rain (as opposed to snow) during winter months. This results in higher winter stream flows and more frequent floods, earlier spring snowmelt, and earlier peak spring stream flow (already 10-30 days earlier than in 1948) (Washington Department of Ecology, 2015). While most of these predicted concerns relate to limited water supply, the potential increase in flooding could impact dams’ capacities to contain excess water.

7.7 SCENARIO

An earthquake in the region could lead to liquefaction of soils around a dam. This could occur without warning during any time of the day. Failure of a high hazard dam in the county would likely result in the loss of life, roadways, structures and property and cause severe impacts on the local economy. While the possibility of failure is remote, results of such an event would be devastating.

While the probability of dam failure is very low, the probability of flooding associated with changes to dam operational parameters in response to climate change is higher. Dam designs and operations are developed based on hydrographs from historical records. If these hydrographs experience significant changes over time due to the impacts of climate change, the dam design and operations may no longer be valid for the changed condition. Specified release rates and impound thresholds may have to be changed. This would result in increased discharges downstream of these facilities, thus increasing the probability and severity of flooding.

7.8 ISSUES

In the late 1980s, the Department of Ecology DSO was reorganized to better use its resources to minimize public safety problems. The DSO has recognized the key role of other government agencies in carrying out its public safety charge. For example, the dam approval process now requires that dams located above populated areas develop emergency action plans in conjunction with local and county emergency management agencies.

The most significant issue associated with dam failure involves properties and populations in the inundation zones. Flooding as a result of a dam failure would significantly impact these areas. In certain scenarios there would be little or no warning time. Dam failure events are frequently associated with other natural hazard events such as earthquakes, landslides or severe weather, which limits their predictability and compounds the hazard. Important issues associated with dam failure hazards include the following:

- The dam failure scenario utilized in the risk assessment brings forward the following issues:
  - More than 11,000 people would be displaced and more than 9,000 people would require short term shelter following the scenario event.

- More than $2.8 billion (2.5 percent) in damages to the expected building stock would be expected. More than half of this damage would be expected within the City of Woodland.
- More than 213 million tons of debris from structures impacted would be expected.
- There are estimated to be more than 11,300 structures located within inundation areas. More than 92 percent are residential structures.
  - It is unclear whether dam failure warning and notification strategies will be viable if dam failure occurs as a result of a significant earthquake that interrupts communication systems.
  - Changes in hydrographs in the region as a result of climate change are likely to include more instances of winter flooding. This could alter dam operations and increase the potential for design failures.
  - Downstream populations are often not aware that they are located in a dam failure inundation area and do not know the risks associated with probable dam failure.
  - Balancing the need to address security concerns and the need to inform the public of the risk associated with dam failure is a challenge for public officials.
  - Dam failure inundation areas are often located outside of special flood hazard areas under the National Flood Insurance Program, so flood insurance coverage in these areas is not common.
  - Most dam failure mapping required at federal levels requires determination of the probable maximum flood. While the probable maximum flood represents a worst-case scenario, it is generally the event with the lowest probability of occurrence. For non-federal-regulated dams, mapping of dam failure scenarios that are less extreme than the probable maximum flood but have a higher probability of occurrence can be valuable to emergency managers and community officials downstream of these facilities. This type of mapping can show areas potentially impacted by more frequent events, to be used in support of emergency response and preparedness measures.
  - Limited financial resources for dam maintenance during economic downturns result in decreased attention to dam structure operational integrity, because available funding is often directed to more urgent needs. This could increase the potential for maintenance failures.
  - Unpermitted dams may exist within the planning area. These dams may present risks to people and property. In 2008 Washington DOE inspected 95 unpermitted dams, 30 of which were classified as high hazard. Eleven of these high hazard dams (36.6 percent) were determined to need immediate repairs (Washington Department of Ecology, 2016).
  - Model results indicate that more than 90 critical facilities would sustain damages from the dam failure scenario modeled for this assessment. Some of these facilities may require almost 2.5 years to regain full functionality after the event.
  - Exposure to the dam failure hazard may increase in the planning area. It is anticipated that new development will occur within the mapped inundation area, including up to 1,381 residential units.

8. DROUGHT

8.1 GENERAL BACKGROUND

Drought is a normal phase in the climatic cycle of most geographical regions. Drought originates from a deficiency of precipitation over an extended period of time, usually a season or more, and results in a water shortage for some activity, group or environmental sector. Unlike most disasters, droughts normally occur slowly but last a long time. There are four generally accepted operational definitions of drought (National Drought Mitigation Center, 2006):

- **Meteorological drought** is an expression of precipitation's departure from normal over some period of time. Meteorological measurements are the first indicators of drought. Definitions are usually region-specific, and based on an understanding of regional climatology. A definition of drought developed in one part of the world may not apply to another, given the wide range of meteorological definitions.
- **Agricultural drought** occurs when there is not enough soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought happens after meteorological drought but before hydrological drought. Agriculture is usually the first economic sector to be affected by drought.
- **Hydrological drought** refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow and as lake, reservoir and groundwater levels. There is a time lag between lack of rain and less water in streams, rivers, lakes and reservoirs, so hydrological measurements are not the earliest indicators of drought. After precipitation has been reduced or deficient over an extended period of time, this shortage is reflected in declining surface and subsurface water levels. Water supply is controlled not only by precipitation, but also by other factors, including evaporation (which is increased by higher than normal heat and winds), transpiration (the use of water by plants), and human use.
- **Socioeconomic drought** occurs when a physical water shortage starts to affect people, individually and collectively. Most socioeconomic definitions of drought associate it with the supply and demand of an economic good.

Defining when drought begins is a function of the impacts of drought on water users, and includes consideration of the supplies available to local water users as well as the stored water they may have available in surface reservoirs or groundwater basins. Different local water agencies have different criteria for defining drought conditions in their jurisdictions. Some agencies issue drought watch or drought warning announcements to their customers. Determinations of regional or statewide drought conditions are usually based on a combination of hydrologic and water supply factors. Washington has a statutory definition of drought (RCW 43.83B.400), defining an area as being in a drought condition when the water supply for the area is below 75 percent of normal and water uses and users in the area are likely to incur undue hardships because of the water shortage.

8.2 HAZARD PROFILE

Droughts originate from a deficiency of precipitation resulting from an unusual weather pattern. If the weather pattern lasts a short time (a few weeks or months), the drought is considered short-term. If the weather pattern becomes entrenched and the precipitation deficits last for several months or years, the drought is considered to be long-term. It is possible for a region to experience a long-term circulation pattern that produces drought, and to have short-term changes in this long-term pattern that result in short-term wet spells. Likewise, it is possible for a long-term wet circulation pattern to be interrupted by short-term weather spells that result in short-term drought. According to the Washington State Emergency Management Division, drought in Washington usually results from low snow accumulation (from low precipitation or warm winter temperatures) or early melt of the snowpack due to warm weather in late winter or early spring (Washington Emergency Management Division, 2014).

8.2.1 Past Events

In the past century, Washington has experienced a number of droughts, including several that lasted for more than a single season—1928 to 1932, 1992 to 1994, and 1996 to 1997. The most recent droughts in the state occurred in 2005, 2015, 2019, 2021, and 2022 (Washington Emergency Management Division, 2013; Washington Department of Ecology, 2015). NOAA's National Climatic Data Center does not list any drought events impacting Clark County between 1950 and 2020.

Between 1954 and 2015, Washington experienced one FEMA-declared drought-related emergency (EM-3037). This was the 1977 event, which has been identified as the worst drought in state history; however, Clark County was not included in the declaration (FEMA, 2022). The U.S. Secretary of Agriculture is authorized to designate counties as disaster areas to make emergency loans to agricultural producers suffering losses due to drought. One-half to two-thirds of the counties in the U.S. have been designated as drought disaster areas in each of the past several years. Between 2012 and 2021, Washington has been included in 246 USDA drought declarations. Clark County has been included in 6 of these declarations (USDA, 2022).

8.2.2 Location

NOAA has developed several indices to measure drought impacts and severity and to map their extent and locations. These indices change regularly depending on local weather patterns and are snapshots of drought impacts at a specific point in time:

- The ***Palmer Crop Moisture Index*** measures short-term drought on a weekly scale and is used to quantify drought's impacts on agriculture during the growing season. Figure 8-1 shows this index for the week ending January 30, 2016.
- The ***Palmer Z Index*** measures short-term drought on a monthly scale. Figure 8-2 shows this index for December 2015.
- The ***Palmer Drought Index*** measures the duration and intensity of long-term drought-inducing circulation patterns. Long-term drought is cumulative, so the intensity of drought during a given month is dependent on the current weather patterns plus the cumulative patterns of previous months. Weather patterns can change quickly from a long-term drought pattern to a long-term wet pattern, and the Palmer Drought Index can respond fairly rapidly. Figure 8-3 shows this index for December 2015.
- The hydrological impacts of drought (e.g., reservoir levels, groundwater levels, etc.) take longer to develop and it takes longer to recover from them. The ***Palmer Hydrological Drought Index***, another long-term index, was developed to quantify hydrological effects. The Palmer Hydrological Drought Index responds more slowly to changing conditions than the Palmer Drought Index. Figure 8-4 shows this index for August 2015.

- While the Palmer indices consider precipitation, evapotranspiration and runoff, the ***Standardized Precipitation Index*** considers only precipitation. In the Standardized Precipitation Index, an index of zero indicates the median precipitation amount; the index is negative for drought and positive for wet conditions. The Standardized Precipitation Index is computed for time scales ranging from one month to 72 months. Figure 8-5 shows the 12-month Standardized Precipitation Index map for December 2014 to December 2015.

Source: Climate Prediction Center, NOAA

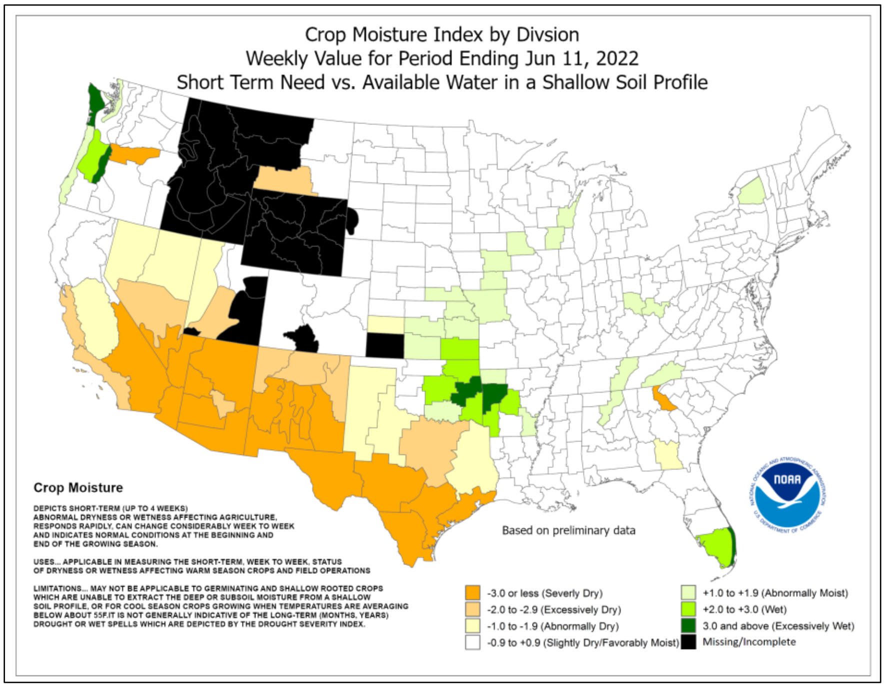

Figure 8-1. Crop Moisture Index for Week Ending June 11, 2022

Source: National Centers for Environmental Information, NOAA

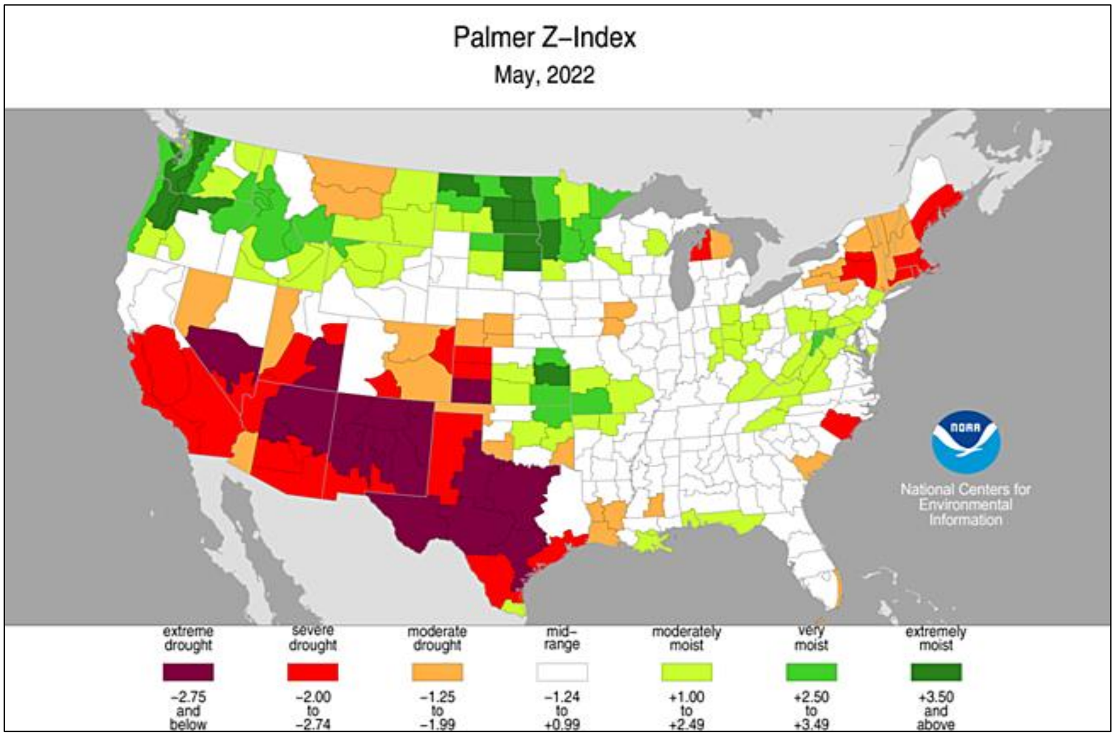

Figure 8-2. Palmer Z Index Short-Term Drought Conditions (May 2022)

Source: National Centers for Environmental Information, NOAA

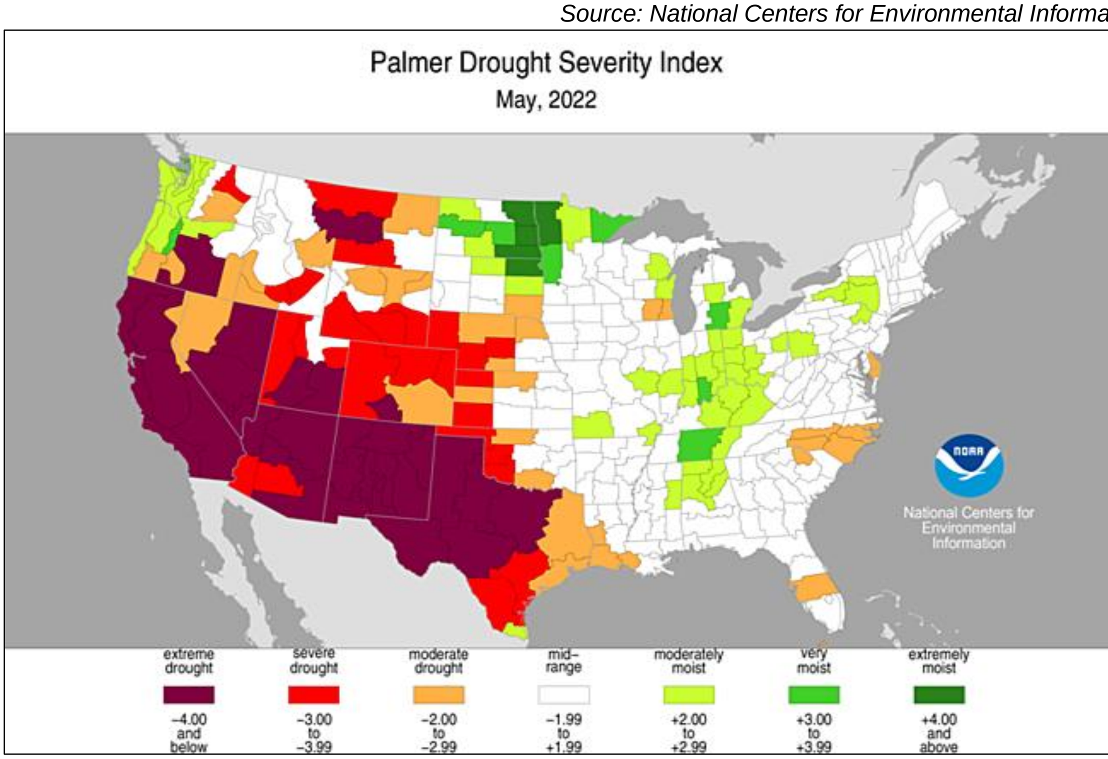

Figure 8-3. Palmer Drought Severity Index (May 2022)

Source: National Centers for Environmental Information, NOAA

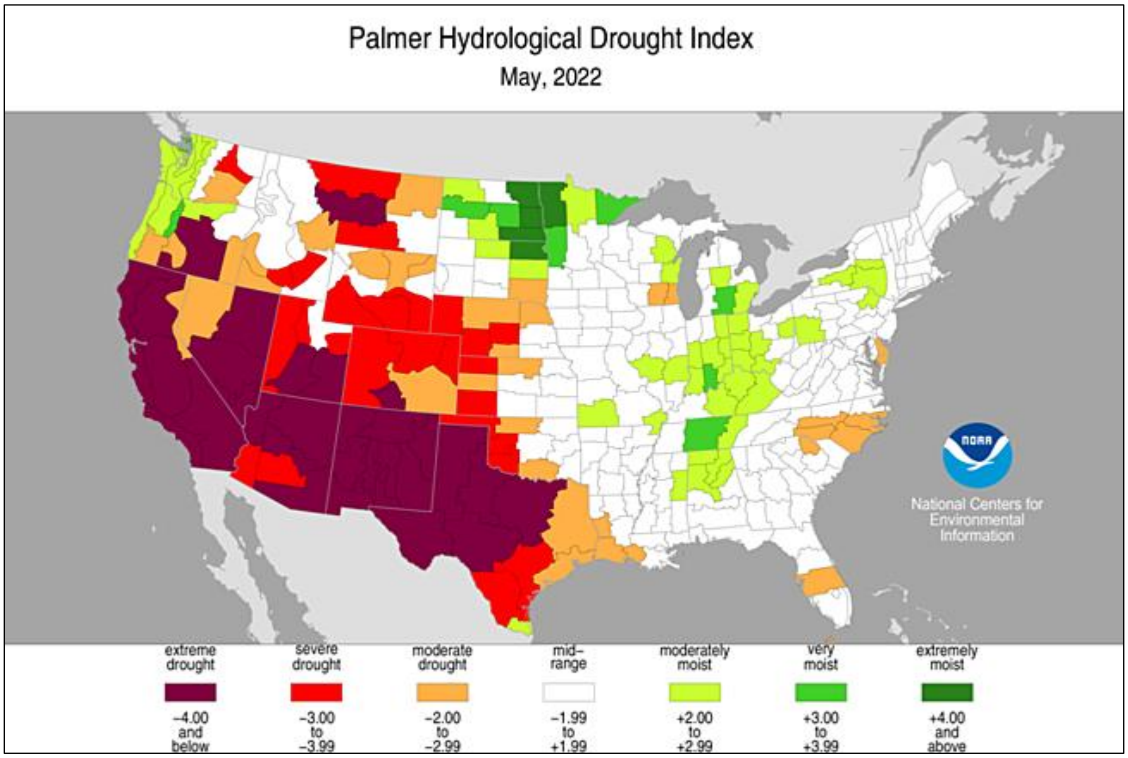

Figure 8-4. Palmer Hydrological Drought Index Long-Term Hydrologic Conditions (May 2022)

Source: Western Regional Climate Center

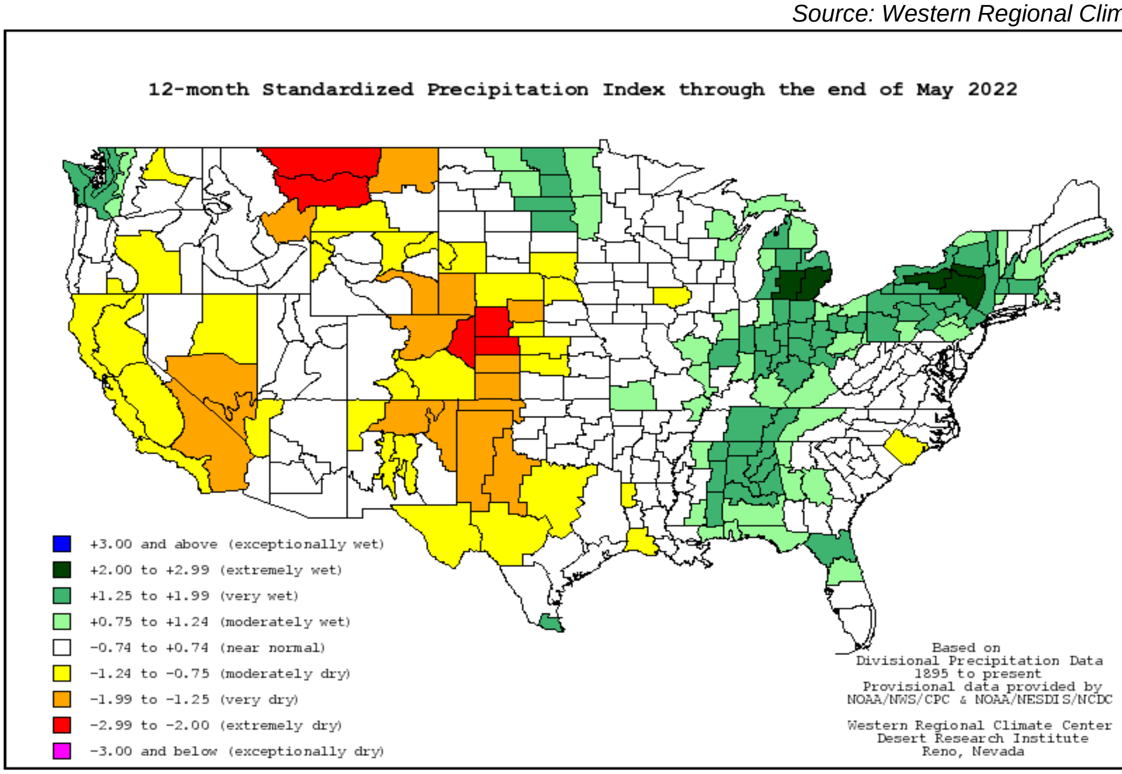

Figure 8-5. 12-Month Standardized Precipitation Index (May 2022)

8.2.3 Frequency

According to the Washington State Emergency Management Division, the numbers of variables required to determine drought frequency make it extremely difficult to predict future drought events, though drought forecasting continues to improve (Washington Emergency Management Division, 2020). Climate change is expected to contribute to increasing drought risk in the future (Washington Department of Ecology, 2016a).

8.2.4 Severity

Drought can have a widespread impact on the environment and the economy, depending upon its severity, although it typically does not result in loss of life or damage to property, as do other natural disasters. The severity of a drought depends on the degree of moisture deficiency, the duration, and the size and location of the affected area. The longer the drought and the larger the area impacted, the more severe the potential impacts. From 1980 to 2021 there have been 29 drought events in the United States with losses exceeding $1 billion. Of these, nine included losses in the State of Washington (NOAA, 2022b).

When measuring the severity of droughts, analysts typically look at economic impacts on a planning area. A drought directly or indirectly impacts all people in affected areas. All people could pay more for water if utilities increase their rates due to shortages. Agricultural impacts can result in loss of work for farm workers and those in related food processing jobs. Other water- or electricity-dependent industries are commonly forced to shut down all or a portion of their facilities, resulting in further layoffs. A drought can harm recreational companies that use water (e.g., swimming pools, water parks and river rafting companies) as well as landscape and nursery businesses because people will not invest in new plants if water is not available to sustain them. In Washington, where hydroelectric power plants generate nearly three-quarters of the electricity produced, drought also threatens the supply of electricity, with the potential to affect the cost of power.

8.2.5 Warning Time

Droughts are climatic patterns that occur over long periods of time. Predicting drought depends on the ability to forecast precipitation and temperature. Anomalies of precipitation and temperature may last from several months to several decades. How long they last depends on interactions between the atmosphere and the oceans, soil moisture and land surface processes, topography, internal dynamics, and the accumulated influence of weather systems on the global scale.

Because drought conditions in Washington State are often related to deficiencies in snowpack accumulation, some warning is available through monitoring snowpack accumulation through the winter. The U.S. Natural Resources Conservation Service’s snow survey and water supply forecasting program conducts snow surveys to develop accurate and reliable water supply forecasts (USDA, 2014). The system, called SNOTEL (short for Snow Telemetry) provides information for local governments, water consumers and providers and the general public on snowpack conditions that may impact water resources in future months. When snowpack levels are below average, communities may make changes to their water management programs and practices to reduce impacts from a possible future drought. NOAA’s National Integrated Drought Information System launched a Drought Early Warning System for the Pacific Northwest in February 2016. The early warning system draws upon new and existing federal, tribal, state, local and academic partner networks to make climate and drought science readily available, easily understandable and usable for decision makers. The system improves stakeholders’ abilities to monitor, forecast, plan for and cope with the impacts of drought (NIDIS, 2016).

8.3 SECONDARY HAZARDS

The secondary hazard most commonly associated with drought is wildfire. A prolonged lack of precipitation dries out vegetation, which becomes increasingly susceptible to ignition as the duration of the drought extends.

Drought also is often accompanied by extreme heat. When temperatures reach 90ºF and above, people are vulnerable to sunstroke, heat cramps and heat exhaustion. Pets and livestock are also vulnerable to heat-related injuries, and agricultural crops can suffer.

Due to the prevalence of hydroelectric power generation in Washington State, Clark County businesses and residents may also experience a decrease in power supply or an increase in electric supply costs as the result of a prolonged drought. In extreme cases, planned power outages throughout the region may be implemented.

8.4 EXPOSURE

All people, property and environments in the planning area would be exposed to some degree to the impacts of moderate to extreme drought conditions.

8.5 VULNERABILITY

Drought produces a complex web of impacts that spans many sectors of the economy and reaches well beyond the area experiencing physical drought. This complexity exists because water is integral to the ability to produce goods and provide services. Drought can affect a wide range of economic, environmental and social activities. The vulnerability of an activity to the effects of drought usually depends on its water demand, how the demand is met, and what water supplies are available to meet the demand.

8.5.1 Population

No significant life or health impacts are anticipated as a result of drought within the planning area.

8.5.2 Property

No structures are likely to be directly affected by drought conditions, though some structures may become vulnerable to wildfires, which are more likely following years of drought. Droughts can also have significant impacts on landscapes, which could cause a financial burden on property owners. However, these impacts are not considered critical in planning for impacts from the drought hazard.

8.5.3 Critical Facilities

Critical facilities as defined for this plan will continue to be operational during a drought. Local water providers have plans in place including alternate water sources and memorandums of agreement to ensure operations continue during severe drought conditions. The risk to critical facilities will be largely aesthetic. For example, when water conservation measures are in place, landscaped areas will not be watered and may die. These aesthetic impacts are not considered significant.

8.5.4 Environment

Although environmental losses are difficult to quantify, growing public awareness and concern for environmental quality has led public officials to focus greater attention and resources on these effects. Environmental losses from drought are associated with damage to plants, animals, wildlife habitat, and air and water quality; forest and range fires; degradation of landscape quality; loss of biodiversity; and soil erosion. Some of the effects are short-term and conditions quickly return to normal following the end of the drought. Other environmental effects linger for a longer time or may even become permanent. Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes and vegetation.

However, many species will eventually recover from this temporary aberration. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological productivity. Reductions in groundwater replenishment can impact streams, especially during the summer when precipitation is sparse and all snowmelt has occurred. During these times, much of stream flow comes from groundwater sources. This means that reductions to groundwater can reduce stream flow when it is already low (Washington Emergency Management Division, 2014).

8.5.5 Economic Impact

The economic impact of drought is largely associated with industries that use water or depend on water for their business. For example, landscaping businesses are affected as the demand for their service significantly declines because landscaping is not being watered. Livestock owners experience increased expenses for watering their herds. Agricultural industries are impacted if water usage is restricted for irrigation. Drought can lead to a reduction in power-generating capacity in hydroelectric-dominated systems, such as those found in Washington. Reductions in capacity can lead to interruptions in the power supply that may have economic impacts in the region.

8.6 FUTURE TRENDS

8.6.1 Development

Clark County is updating its Comprehensive Plan, with the goal of completing the draft plan by December 2015 and adopting the plan no later than June 2016. The Comprehensive Plan will include policies directing land use and dealing with water supply issues and water resource protection. The Environmental Element, where these concerns will be addressed, also will prioritizes the regulation of development in a manner that protects water quality and quantity (Clark County, 2016b).

8.6.2 Climate Change

Although there is still some uncertainty regarding climate change impacts on the water cycle, most current models project increases in precipitation in winter, spring and fall and decreases in precipitation in summer. This decrease in precipitation, coupled with higher average summer temperatures, may contribute to an increase in the frequency, severity and duration of droughts in the region (Dalton et al., 2013). More frequent extreme events such as droughts could end up being more cause for concern than the long-term change in temperature and precipitation averages. According to the Washington State Department of Ecology, Washington has experienced unusually dry periods almost every year since 2000 (Washington Department of Ecology, 2007).

The potential for water shortages may increase as the timing and duration of precipitation events change. Winter snowpack is crucial to water resource management strategies in Washington and much of the west. Some projections indicate that snowpack in the Cascade Mountain range may decrease as much as 40 percent by the 2040s (Payne et al., 2004). The Washington State Department of Ecology reports that the average mountain snowpack in the North Cascades has declined at 73 percent of mountain sites studied (Washington Department of Ecology, 2007). These declines impact social, natural and built systems within and surrounding Clark County. For example, summer hydropower production may decline 9 to 11 percent by the 2020s, while summer demand for energy increases, due to higher electricity needs from an increase in cooling days coupled with population growth (Washington Department of Ecology, 2012). Additionally, snowmelt is pivotal for the recharge of underground water supply. A decreased snowpack and increased winter rain could create greater stormwater runoff (as opposed to a slow recharge). Increased temperatures in the summer, along with less summer rainfall, would then lead to drier soil. This could lead to wells going dry, as well as potential conflicts over senior water rights and new water rights (Washington Department of Ecology, 2016a).

Historically, drought patterns in the West are related to large-scale climate patterns in the Pacific and Atlantic oceans. The El Niño–Southern Oscillation in the Pacific varies on a 5- to 7-year cycle, the Pacific Decadal Oscillation varies on a 20- to 30-year cycle, and the Atlantic Multidecadal Oscillation varies on a 65- to 80-year cycle. As these large-scale ocean climate patterns vary in relation to each other, drought conditions in the U.S. shift from region to region. El Niño years bring drier conditions to the Pacific Northwest.

Water resource managers need to start addressing current stresses on water supplies and build flexibility and robustness into existing systems. Flexibility helps to ensure a quick response to changing conditions, and robustness helps people prepare for and survive the worst conditions. Washington State's Integrated Climate Response Strategy identifies five strategies for water resource management in response to a changing climate (Washington Department of Ecology, 2016a):

- Use integrated water resource management approaches in highly vulnerable basins.
- Involve decision-makers and communities in finding balanced sustainable solutions.
- Improve water supply and water quality in vulnerable basins.
- Apply water conservation and efficiency programs to reduce the amount of water needed for irrigation, municipal, and industrial users.
- Build the capacity of state and local governments, tribes, watershed groups, water managers, and communities to identify risks and reduce vulnerability to climate impacts.

With this approach to planning, water system managers will be better able to adapt to the impacts of climate change.

8.7 SCENARIO

The worst-case scenario is an extreme multiyear drought impacting the region. Combinations of low summer precipitation and low winter snowpack accumulation could stretch water resources, resulting in increased pressures to meet all users' needs. Intensified by such conditions, wildfires could threaten the planning area, increasing the need for water. Surrounding communities, also in drought conditions, could increase their demand for water supplies relied upon by Clark County, causing social and political conflicts. If such conditions persist for several years, the local economy could experience setbacks, especially in water-dependent industries and on local farms.

8.8 ISSUES

The planning team identified the following drought-related issues:

- Changes in the timing, frequency and duration of precipitation events may present challenges for current water storage and management practices in the region. Climate change may also increase the frequency and duration of meteorological drought conditions.
- Water resource management strategies have changed significantly over the last several decades. Managers must now consider the needs of communities, industries, power-generating facilities and the environment. Issues associated with meeting the needs of these competing demands with limited resources will likely increase as population growth continues and the impacts of climate change intensify.
- The use and promotion of water-saving and reclamation technologies even during non-drought periods may decrease the effects of drought in the planning area.
- Recent droughts have resulted in the need to stop pumping from some water courses due to limited stream flow.

- Predicting droughts can be challenging, although warning systems are currently under development.

9. EARTHQUAKE

9.1 GENERAL BACKGROUND

9.1.1 How Earthquakes Happen

An earthquake is the vibration of the earth's surface following a release of energy in the earth's crust. This energy can be generated by a sudden dislocation of the crust or by a volcanic eruption. Most destructive quakes are caused by dislocations of the crust. The crust may first bend and then, when the stress exceeds the strength of the rocks, break and snap to a new position. In the process of breaking, vibrations called "seismic waves" are generated. These waves travel outward from the source of the earthquake at varying speeds.

Earthquakes tend to reoccur along faults, which are zones of weakness in the crust. Even if a fault zone has recently experienced an earthquake, there is no guarantee that all the stress has been relieved. Another earthquake could still occur.

9.1.2 Types of Earthquakes

The earth's crust is divided into eight major pieces (or plates) and many minor plates. In Western Washington, the primary plates of interest are the Juan De Fuca and North American plates. The Juan De Fuca plate moves northeastward with respect to the North America plate at a rate of about 3 to 4 centimeters per year. The boundary where these two plates converge, the Cascadia Subduction Zone, lies approximately 50 miles offshore and extends from the middle of Vancouver Island in British Columbia to northern California. As it collides with North America, the Juan De Fuca plate slides beneath the continent and sinks into the earth's mantle. The collision of the Juan De Fuca and North America plates produces three types of earthquakes, as shown on Figure 9-1 and described below.

Subduction Zone Earthquakes

Subduction Zone earthquakes occur at the interface between tectonic plates. A subduction zone earthquake affecting Clark County would be centered in the Cascadia Subduction zone off the coast of Washington or Oregon. Such earthquakes typically have a minute or more of strong ground shaking, and are quickly followed by damaging tsunamis and numerous large aftershocks. The potential exists for large earthquakes along the Cascadia Subduction Zone, up to an earthquake measuring 9 or more on the Richter scale. This could cause coastal areas to drop up to 6 feet in minutes and could produce a tsunami all along the fault line from British Columbia to Mendocino, California. Such an earthquake would last several minutes and produce catastrophic damage in the region.

Source: USGS

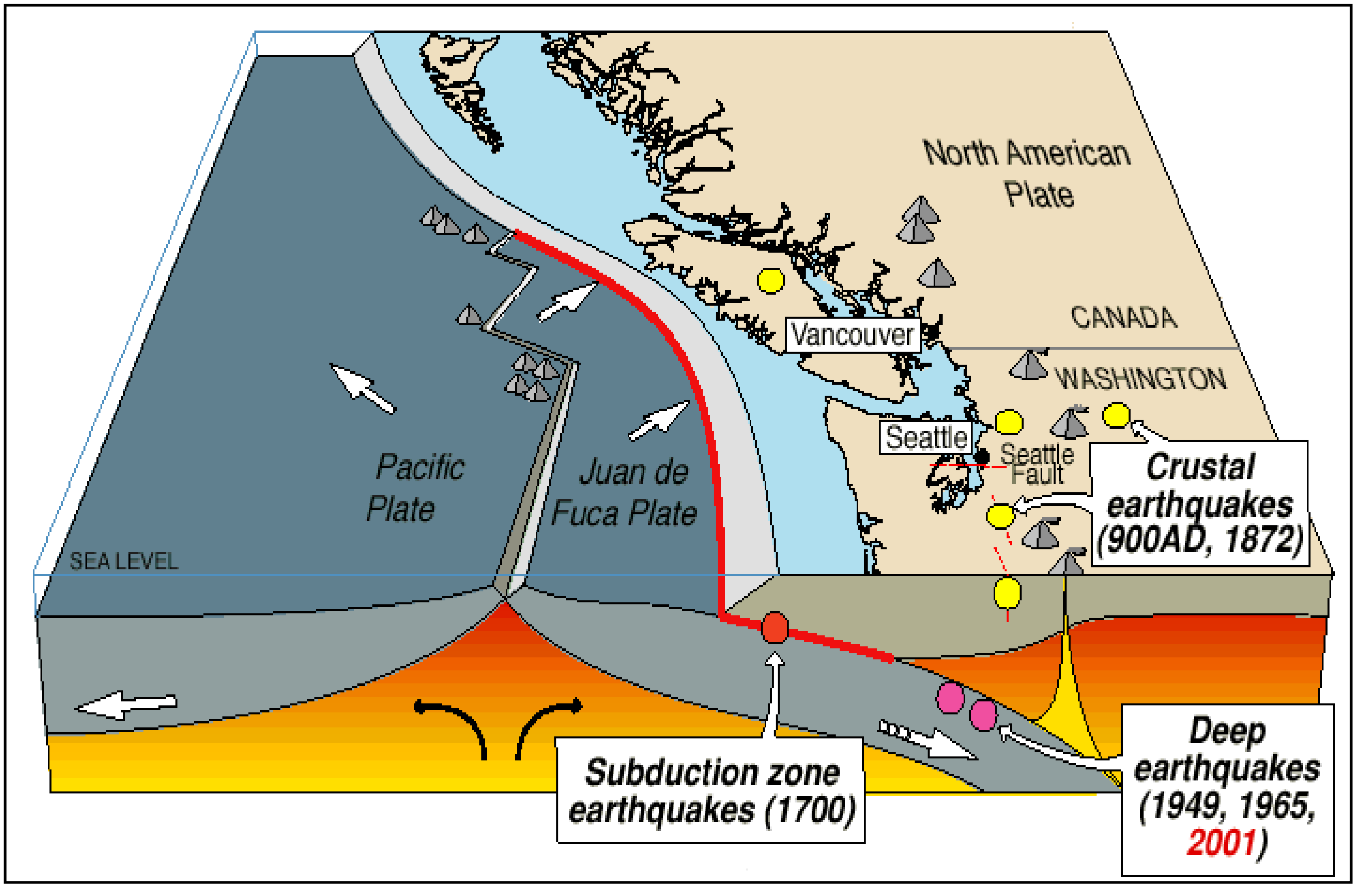

Figure 9-1. Earthquake Types in the Pacific Northwest

Benioff Zone (Deep) Earthquakes

Benioff Zone earthquakes occur within the Juan De Fuca plate as it sinks into the Earth's mantle. These are primarily deep earthquakes, 25 to 100 kilometers in depth. Due to their depth, aftershocks are typically not felt in association with these earthquakes. These earthquakes are caused by mineral changes as the plate moves deeper into the mantle. Minerals that make up the plates are altered to denser, more stable forms as temperature and pressure increase. This results in a decrease in the size of the plate, and stresses build up that pull the plate apart (Washington Department of Natural Resources, 2014). Deep earthquakes generally last 20 to 30 seconds and have the potential of reaching 7.5 on the Richter scale. Geologists have concluded that Benioff earthquakes are a phenomenon centered in the Puget Sound basin and as such their epicenters are at a considerable distance from Clark County. Their impact on Clark County is expected to be minimal to moderate (CRESA 2004).

Shallow Crustal Earthquakes

Shallow crustal earthquakes occur within the North America plate at depths of 30 kilometers or less. Shallow earthquakes within the North America plate account for most of the earthquakes in the region around Clark County. Most are relatively small but the potential exists for major shallow earthquakes as well. Generally, these earthquakes are expected to have magnitudes less than 8 and last from 20 to 60 seconds. Of the three types of earthquake, crustal events are the least understood.

9.1.3 Faults

Geologists classify faults by their relative hazards. Active faults, which represent the highest hazard, are those that have ruptured to the ground surface within the last 11,000 years. Potentially active faults are those that displaced layers of rock within the last 1,800,000 years. Determining if a fault is “active” or “potentially active” depends on geologic evidence, which may not be available for every fault. Additionally, earthquakes may occur on faults that have not been mapped and identified.

Faults are more likely to have earthquakes on them if they have more rapid rates of movement, have had recent earthquakes along them, experience greater total displacements, and are aligned so that movement can relieve accumulating tectonic stresses. A direct relationship exists between a fault’s length and location and its ability to generate damaging ground motion at a given site. In some areas, smaller, local faults produce lower magnitude quakes, but ground shaking can be strong, and damage can be significant as a result of the fault’s proximity to the area. In contrast, large regional faults can generate great magnitudes but, because of their distance and depth, may result in only moderate shaking in the area.

9.1.4 Earthquake Classifications

Earthquakes are typically classified in one of two ways: By the amount of energy released, measured as **magnitude**; or by the impact on people and structures, measured as **intensity**. Magnitude describes the size at the focus of an earthquake and intensity describes the overall felt severity of shaking during the event.

Magnitude

An earthquake’s magnitude is a measure of the energy released at the source of the earthquake. It is expressed by ratings on the Richter scale or the moment magnitude scale. Currently the most commonly used magnitude scale is the moment magnitude (M_w) scale, with the follow classifications of magnitude:

- Great—$M_w \geq 8$
- Major—$M_w = 7.0 - 7.9$
- Strong—$M_w = 6.0 - 6.9$
- Moderate—$M_w = 5.0 - 5.9$
- Light—$M_w = 4.0 - 4.9$
- Minor—$M_w = 3.0 - 3.9$
- Micro—$M_w < 3$

Estimates of moment magnitude roughly match the local magnitude scale (ML) commonly called the Richter scale. One advantage of the moment magnitude scale is that, unlike other magnitude scales, it does not saturate at the upper end. That is, there is no value beyond which all large earthquakes have about the same magnitude. For this reason, moment magnitude is now the most often used estimate of large earthquake magnitudes.

Intensity

The intensity of an earthquake is based on the observed effects of ground shaking on people, buildings and natural features. Intensity of a given earthquake varies with location. The Modified Mercalli (MMI) scale expresses intensity of an earthquake and describes how strong a shock was felt at a particular location. Table 9-1 summarizes earthquake intensity as expressed by the Modified Mercalli scale.

Table 9-1. Mercalli Scale and Peak Ground Acceleration Comparison

Modified Mercalli Scale	Perceived Shaking	Potential Structure Damage		Estimated PGA[a] (%g)
		Resistant Buildings	Vulnerable Buildings	
I	Not Felt	None	None	<0.17%
II-III	Weak	None	None	0.17% - 1.4%
IV	Light	None	None	1.4% - 3.9%
V	Moderate	Very Light	Light	3.9% - 9.2%
VI	Strong	Light	Moderate	9.2% - 18%
VII	Very Strong	Moderate	Moderate/Heavy	18% - 34%
VIII	Severe	Moderate/Heavy	Heavy	34% - 65%
IX	Violent	Heavy	Very Heavy	65% - 124%
X – XII	Extreme	Very Heavy	Very Heavy	>124%

a. PGA measured in percent of g, where g is the acceleration of gravity

Sources: USGS, 2008; USGS, 2010

9.1.5 Ground Motion

Earthquake hazard assessment is also based on expected ground motion. This involves determining the annual probability that certain ground motion accelerations will be exceeded, then summing the annual probabilities over the time period of interest. The most commonly mapped ground motion parameters are the horizontal and vertical peak ground accelerations (PGA) for a given soil or rock type. Instruments called accelerographs record levels of ground motion due to earthquakes at stations throughout a region. These readings are recorded by state and federal agencies that monitor and predict seismic activity.

Maps of PGA values form the basis of seismic zone maps that are included in building codes such as the International Building Code. Building codes that include seismic provisions specify the horizontal force due to lateral acceleration that a building should be able to withstand during an earthquake. PGA values are directly related to these lateral forces that could damage “short period structures” (e.g. single-family dwellings). Longer period response components determine the lateral forces that damage larger structures with longer natural periods (apartment buildings, factories, high-rises, bridges). Table 9-1 lists damage potential and perceived shaking by PGA factors, compared to the Mercalli scale.

9.1.6 Effect of Soil Types

The impact of an earthquake on structures and infrastructure is largely a function of ground shaking, distance from the source of the quake, and liquefaction, a secondary effect of an earthquake in which soils lose their shear strength and flow or behave as liquid, thereby damaging structures that derive their support from the soil. Liquefaction generally occurs in soft sedimentary soils. A program called the National Earthquake Hazard Reduction Program (NEHRP) creates maps based on soil characteristics to help identify locations subject to liquefaction. Table 9-2 summarizes NEHRP soil classifications. NEHRP Soils B and C typically can sustain ground shaking without much effect, dependent on the earthquake magnitude. The areas that are commonly most affected by ground shaking have NEHRP Soils D, E and F. In general, these areas are also most susceptible to liquefaction.

Table 9-2. NEHRP Soil Classification System

NEHRP Soil Type	Description	Mean Shear Velocity to 30 m (m/s)
A	Hard Rock	1,500
B	Firm to Hard Rock	760-1,500
C	Dense Soil/Soft Rock	360-760
D	Stiff Soil	180-360
E	Soft Clays	< 180
F	Special Study Soils (liquefiable soils, sensitive clays, organic soils, soft clays >36 m thick)	

9.2 HAZARD PROFILE

9.2.1 Past Events

Like most of the northwestern coast of the United States, Clark County is susceptible to Cascadia Subduction Zone events, which are generally major in scale. On January 26, 1700, an approximate Magnitude 9 Cascadia Subduction Zone earthquake occurred. This earthquake inundated coastal areas from British Columbia to northern California and lowered coastal land elevations by as much as 6 feet (CRESA 2004).

Clark County has also been susceptible to shallow, crustal earthquakes. The 1872 earthquake in the North Cascades was the largest crustal earthquake in the recorded history of Washington and Oregon. It had an estimated magnitude of 7.4 and was followed by many aftershocks. In 1993, a Magnitude 5.6 earthquake in the Willamette Valley of Oregon caused $28 million in damage, including damage to the Oregon State capital building in Salem. A pair of earthquakes near Klamath Falls, Oregon of Magnitude 5.9 and 6.0 caused two fatalities and $7 million in damage (CRESA 2004).

The two most damaging Benioff earthquakes in Washington occurred in 1949 and 1965. The 1949 earthquake occurred near Olympia and had a magnitude of 7.1. The earthquake of 1965 occurred between Seattle and Tacoma with a magnitude of 6.5. These were centered in the Puget Sound region and had little impact on Clark County (CRESA 2004).

On February 28, 2001, the Nisqually earthquake, with a magnitude of 6.8, occurred northeast of Olympia, Washington. Most of the damage was concentrated in localized areas in central Puget Sound with poor site conditions and older construction. This earthquake caused minor damage in some areas of Clark County as well (CRESA 2004).

The USGS notes a moderately strong earthquake on November 5, 1962. This earthquake reportedly caused minor damage in Vancouver, Washington and nearby towns. The Magnitude 4.75 event was felt over an approximately 20,000-square-mile area (USGS, 1978).

Figure 9-2 is a Washington State map of historical earthquakes in the state. Most of the events were well north of Clark County, though some smaller magnitude events occurred in the county. Larger magnitude events that occurred in the surrounding region may also have been felt by Clark County residents.

Source: USGS, 2022

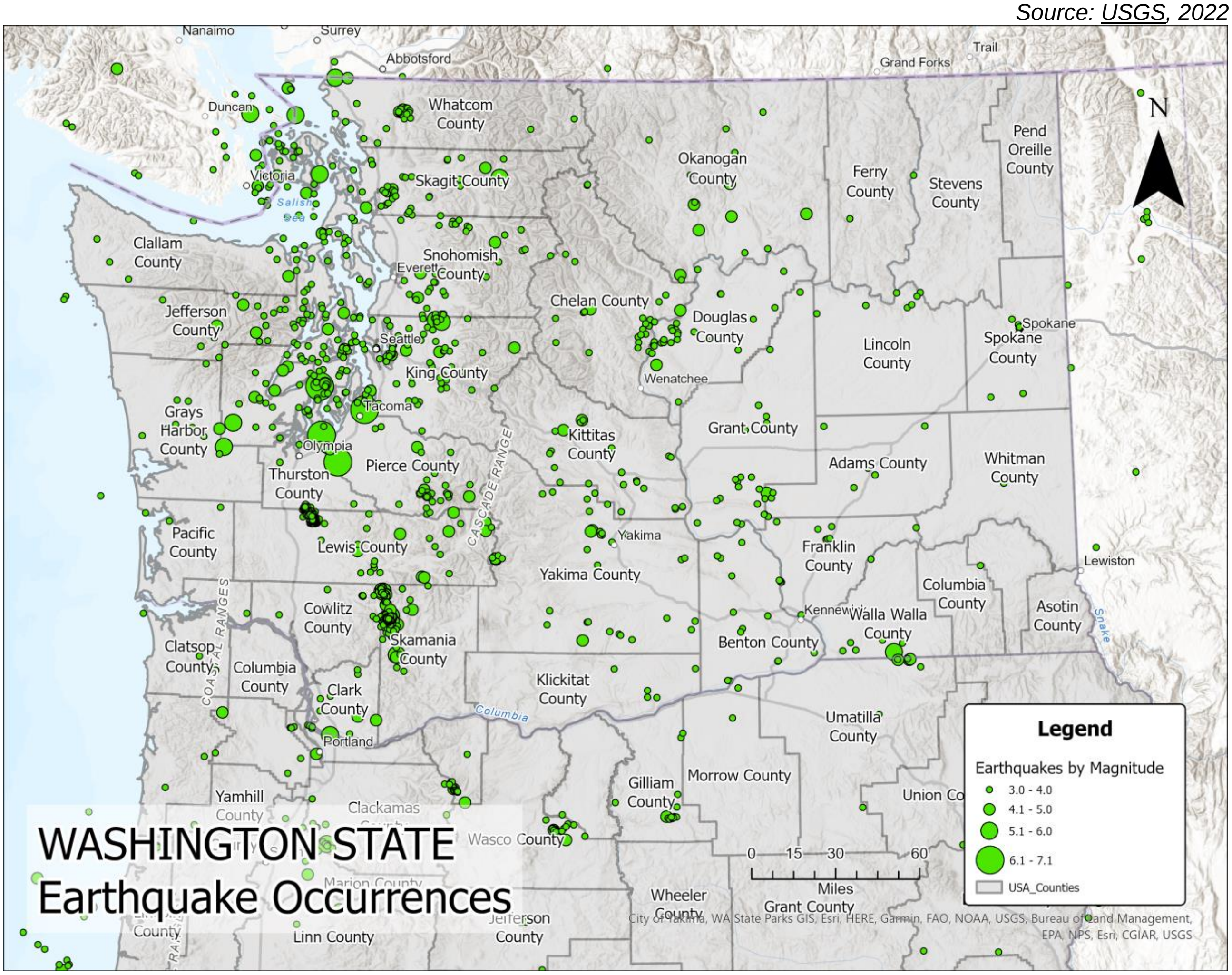

Figure 9-2. Historic Earthquakes in Washington State

9.2.2 Location

Identifying the extent and location of an earthquake is not as simple as it is for hazards such as flood, landslide or wildfire. The impact of an earthquake is largely a function of the following components:

- Ground shaking (ground motion accelerations)
- Liquefaction (soil instability)
- Distance from the source (both horizontally and vertically).

Mapping that shows the impacts of these components was used to assess the risk of earthquakes within the planning area as described below. While the impacts from each of these components can build upon each other during an earthquake, the mapping looks at each component individually.

Identified Faults

In 1993, the U.S. Geological Survey began developing a database of Quaternary faults and folds in the United States. The database includes information on geographic, geologic, and seismic parameters for making assessments of seismic hazards. There is only one known fault within Clark County: the Lacamas Lake Fault. The geologic age of the fault is estimated to be greater than 750,000 years (mid- to late-Quaternary) and the magnitude of an event on the fault is likely to be about 6.5 (USGS, 2014).

Faults outside the planning area but nearby, such as the Portland Hills fault in northern Oregon, may also cause damage in Clark County. The Portland Hills fault is about 30-miles long and runs northwest to southeast through Portland (CRESA 2004). Geophysical studies suggest that earthquakes of Magnitude 6 or larger should occur in the Portland region every 300 to 350 years, and an event of Magnitude 6.5 or larger every 800 to 900 years (CRESA, 2011). Figure 9-3 shows the identified faults in and near the planning area.

Source: http://earthquake.usgs.gov/hazards/qfaults/map/

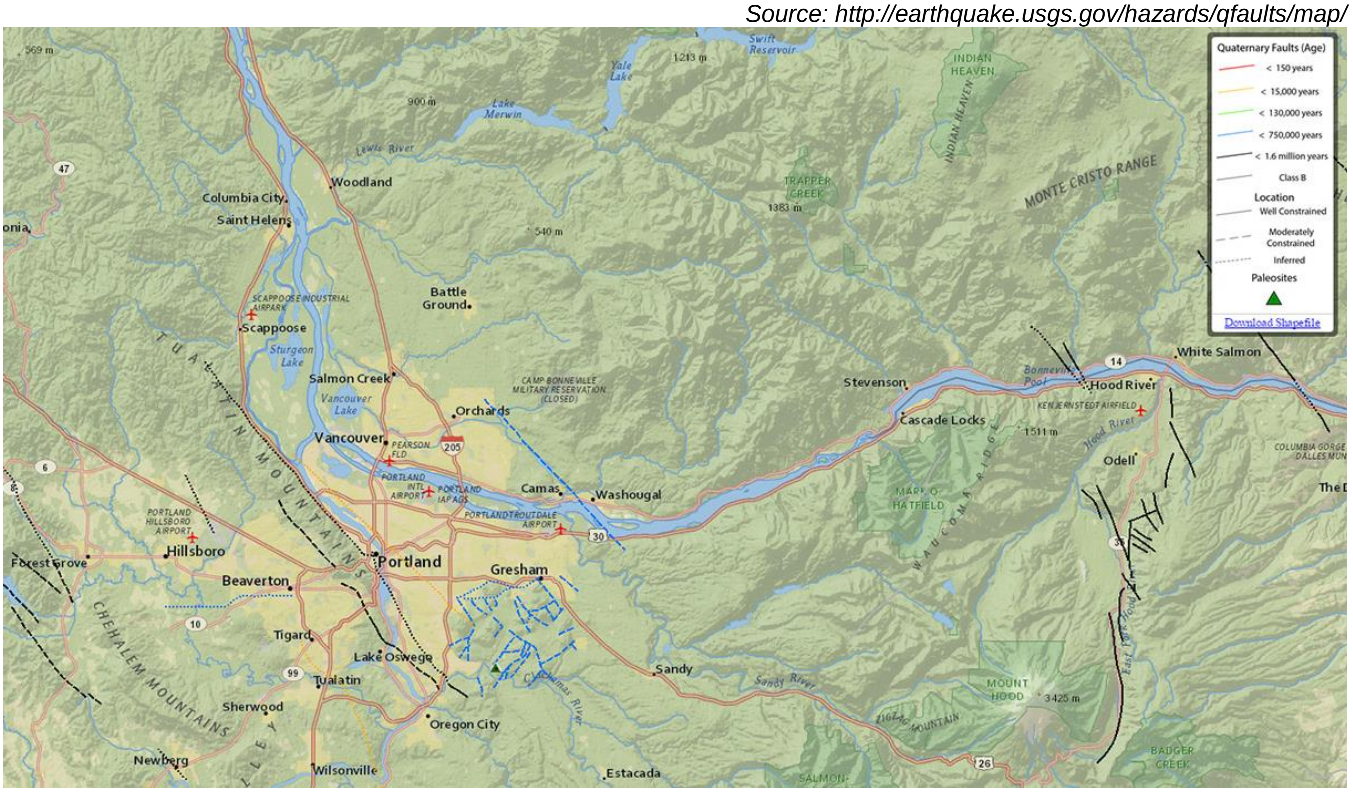

Figure 9-3. Planning Area Active Faults and Folds

Shake Maps

A shake map is a representation of ground shaking produced by an earthquake. The information it presents is different from the earthquake magnitude and epicenter that are released after an earthquake because shake maps focus on the ground shaking resulting from the earthquake, rather than the parameters describing the earthquake source. An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region, depending on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth's crust. A shake map shows the extent and variation of ground shaking in a region immediately following significant earthquakes. Ground motion and intensity maps are derived from peak ground motion amplitudes recorded on seismic sensors (accelerometers), with interpolation based on estimated amplitudes where data are lacking, and site amplification corrections. Color-coded instrumental intensity maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity. Two types of shake map are typically generated from the data:

- A probabilistic seismic hazard map shows the hazard from earthquakes that geologists and seismologists agree could occur. The maps are expressed in terms of probability of exceeding a certain ground motion, such as the 10-percent probability of exceedance in 50 years. This level of ground shaking has been used for designing buildings in high seismic areas. **Error! Reference source not found.** and **Error! Reference source not found.** show the estimated ground motion for the 100-year and 500-year probabilistic earthquakes in the planning area

- Earthquake scenario maps describe the expected ground motions and effects of hypothetical large earthquakes for a region. Maps of these scenarios can be used to support all phases of emergency management. Two scenarios were chosen for this plan:
  - Cascadia Subduction Zone Scenario—A Magnitude 9.0 event off the Pacific Coast. See Figure 9-4.
  - Portland Hills Fault Scenario—A Magnitude 6.5 event with the epicenter southwest of the planning area, near the border of Washington and Oregon. See Figure 9-5.

NEHRP Soil Maps

NEHRP soil types define locations that will be significantly impacted by an earthquake. NEHRP Soils B and C typically can sustain low-magnitude ground shaking without much effect. The areas most commonly affected by ground shaking have NEHRP Soils D, E and F. Figure 9-6 shows NEHRP soil classifications in Clark County.

Liquefaction Maps

Soil liquefaction maps are useful tools to assess potential damage from earthquakes. When the ground liquefies, sandy or silty materials saturated with water behave like a liquid, causing pipes to leak, roads and airport runways to buckle, and building foundations to be damaged. In general, areas with NEHRP Soils D, E and F are also susceptible to liquefaction. If there is a dry soil crust, excess water will sometimes come to the surface through cracks in the confining layer, bringing liquefied sand with it, creating sand boils. Figure 9-7 shows the liquefaction susceptibility in the planning area.

9.2.3 Frequency

Earthquake events occurring along the Cascadia Subduction Zone reoccur on average every 500 to 600 years, although the recurrence interval appears to be irregular. The intervals between earthquakes in this subduction zone have ranged from 200 years to more than 1,000 years. The probability of a magnitude 9.0 earthquake occurring along the subduction zone is estimated to be about 10 percent in the next 50 years (Cascadia Region Earthquake Workgroup, 2013).

A Portland Hills earthquake is a surface event with lower likelihood of occurrence, about 2 percent in the next 50 years (CRESA, 2004).

9.2.4 Severity

The severity of an earthquake can be expressed in terms of intensity or magnitude. Intensity represents the observed effects of ground shaking on people, buildings, and natural features. The USGS has created ground motion maps based on current information about several fault zones. These maps show the PGA that has a certain probability (2 percent or 10 percent) of being exceeded in a 50-year period. The PGA is measured in numbers of g’s (the acceleration associated with gravity). Figure 9-8 shows the PGAs with a 2-percent exceedance chance in 50 years in the United States.

Magnitude is related to the amount of seismic energy released at the hypocenter of an earthquake. It is determined by the amplitude of the earthquake waves recorded on instruments. Whereas intensity varies depending on location with respect to the earthquake epicenter, magnitude is represented by a single, instrumentally determined value for each earthquake event.

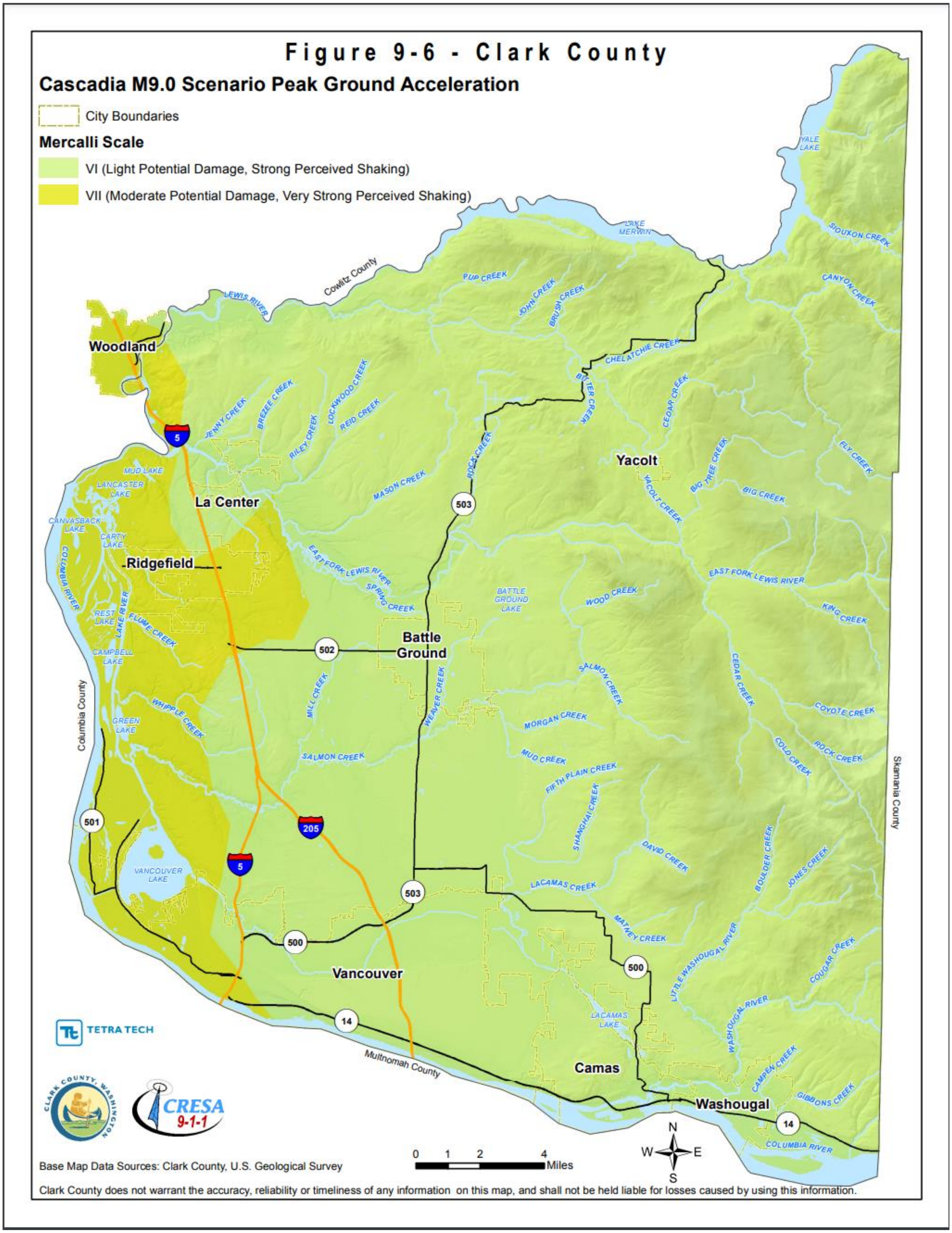

Figure 9-4. Cascadia M9.0 Scenario Peak Ground Acceleration

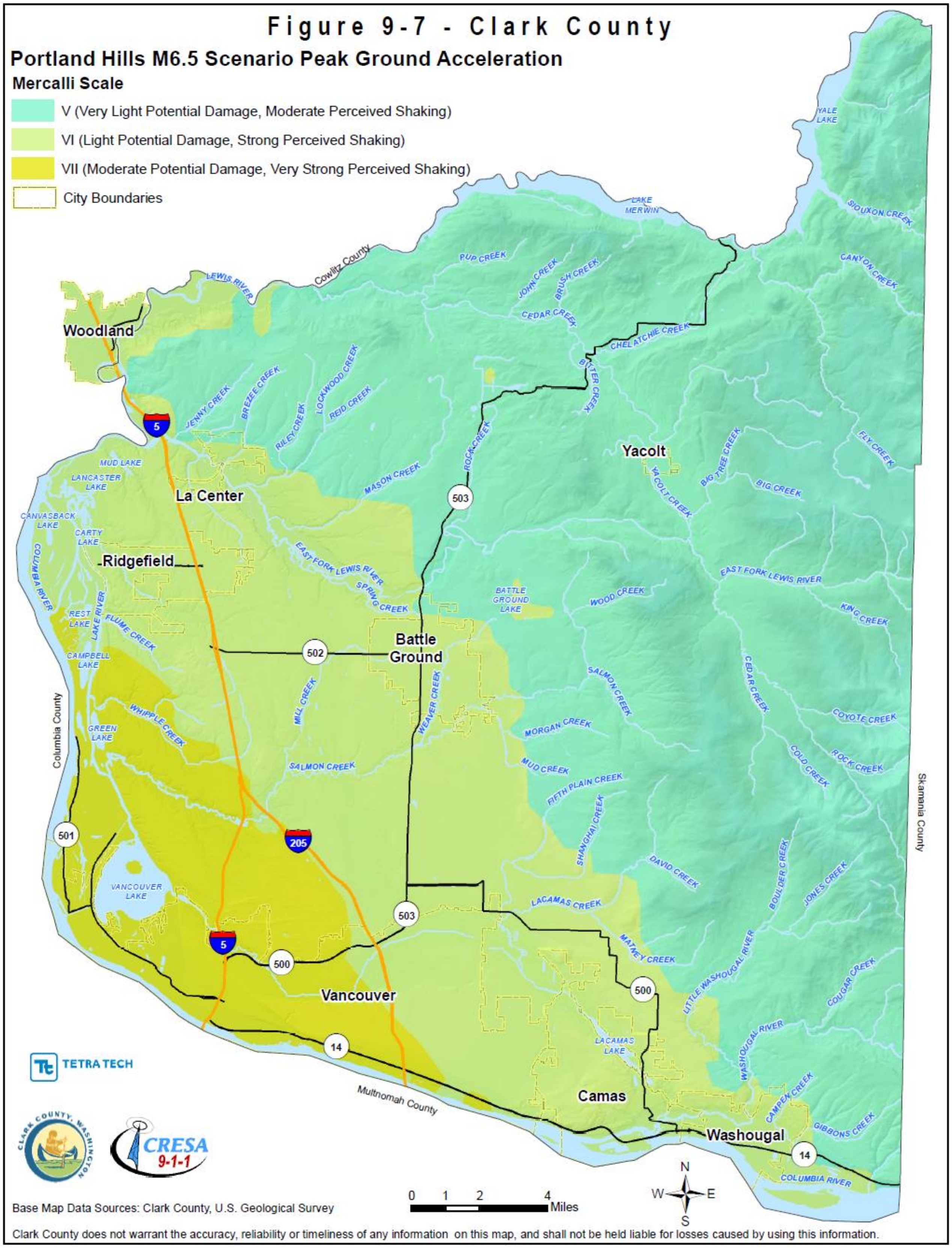

Figure 9-5. Portland Hills M6.5 Scenario Peak Ground Acceleration

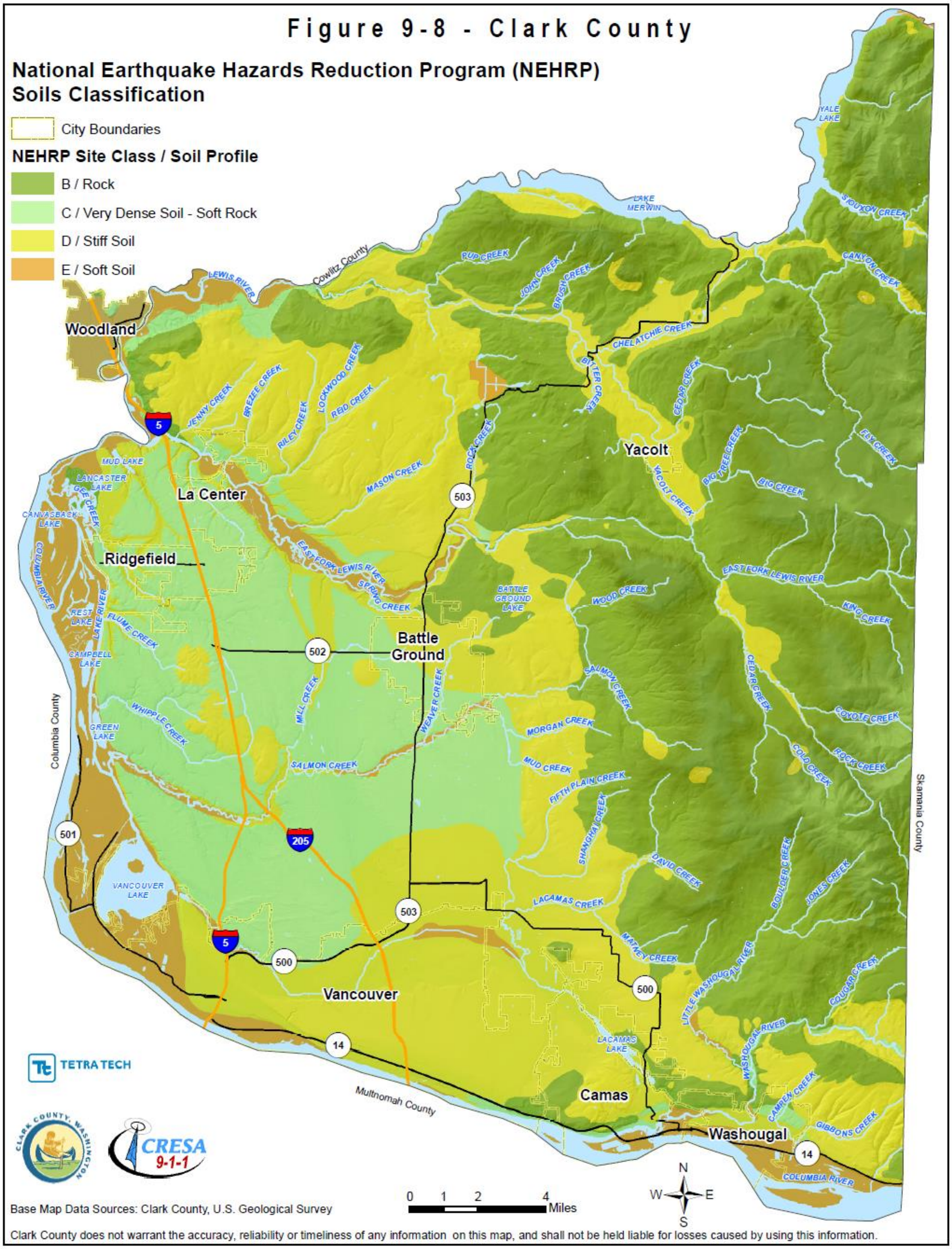

Figure 9-6. National Earthquake Hazard Reduction Program Soils Classification

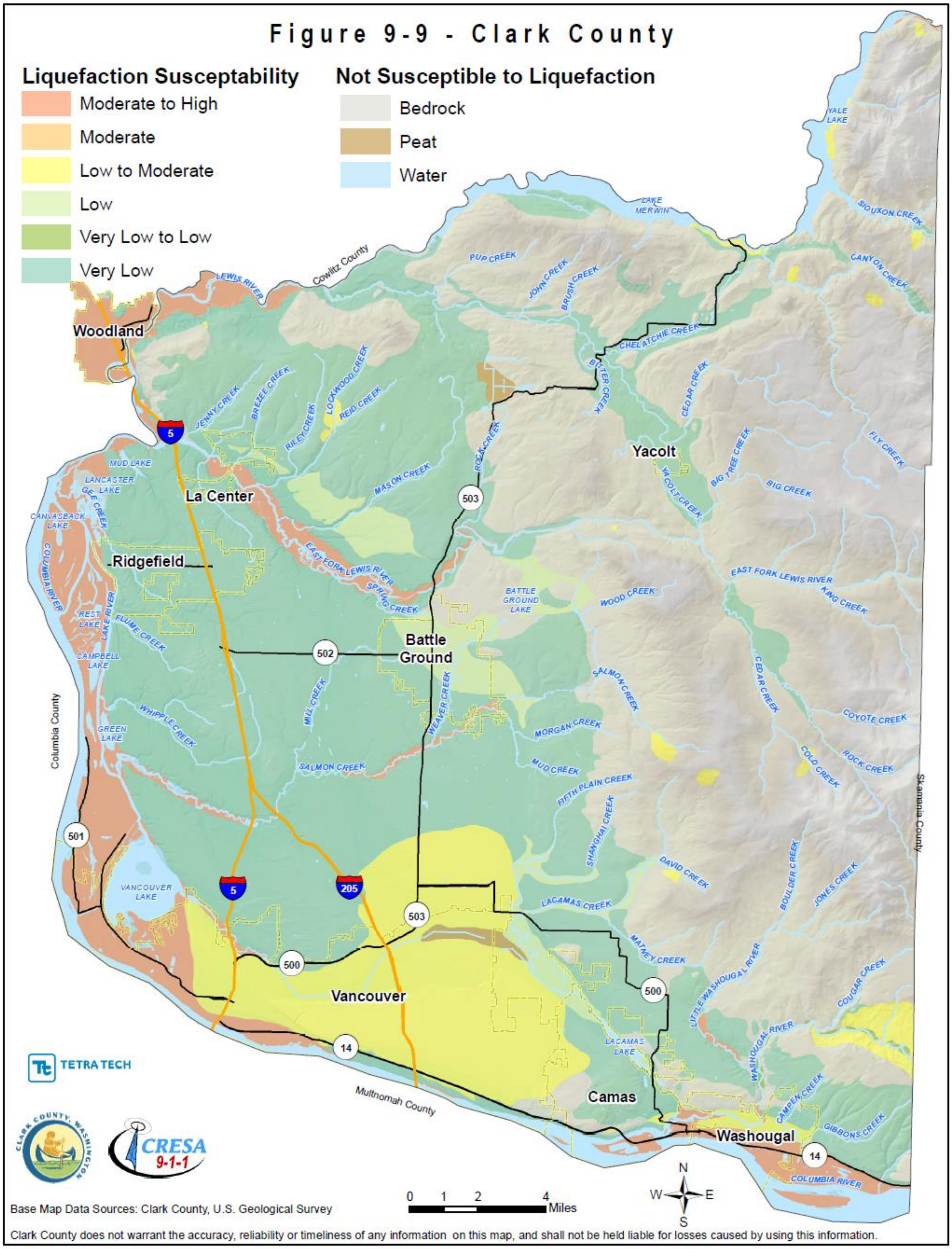

Figure 9-7. Liquefaction Susceptibility

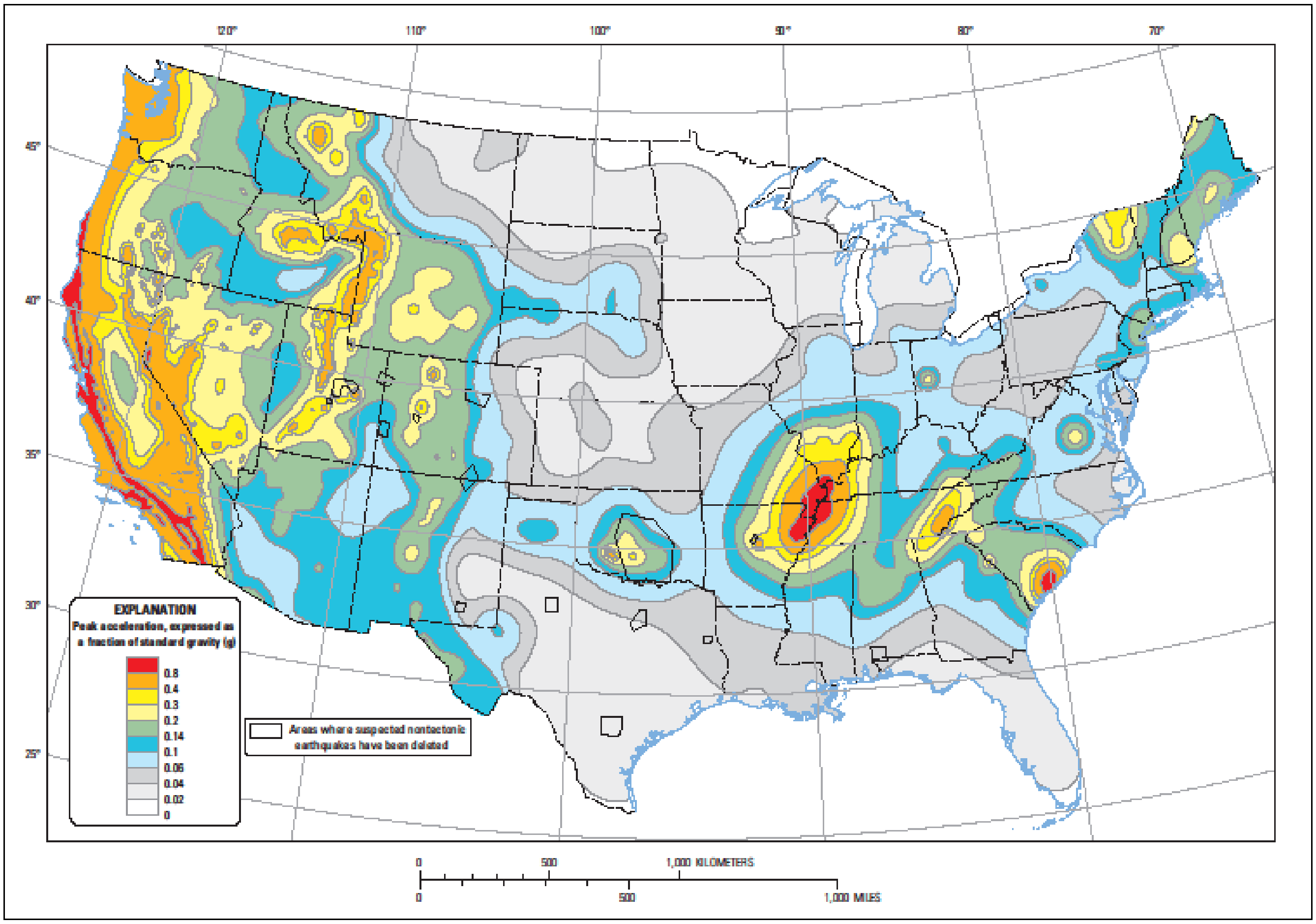

Figure 9-8. PGA with 2-Percent Probability of Exceedance in 50 Years

In simplistic terms, the severity of an earthquake event can be measured in the following terms:

- How hard did the ground shake?
- How did the ground move? (Horizontally or vertically)
- How stable was the soil?
- What is the fragility of the built environment in the area of impact?

9.2.5 Warning Time

There is currently no reliable way to predict the day or month that an earthquake will occur at any given location. An earthquake early warning system has been implemented in Washington State, Oregon, and California that uses the low energy waves that precede major earthquakes to provide warning of ground movement. The USGS and university partners have developed an early warning system called ShakeAlert for the West Coast of the United States. The potential warning ranges from a few seconds to tens of seconds notice that a major earthquake is about to occur (Earthquake Early Warning, 2022). The warning time is very short but it could allow for someone to get under a desk, step away from a hazardous material they are working with, or shut down a computer system.

It is known that fore- and aftershocks are likely to precede and follow both subduction and Portland Hills events, so there might be some preparation for these. It is likely that aftershocks may be close in timing to the actual earthquake event (CRESA, 2004).

9.3 SECONDARY HAZARDS

Earthquakes can cause large and sometimes disastrous landslides and mudslides. River valleys are vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction occurs when water-saturated sands, silts or gravelly soils are shaken so violently that the individual grains lose contact with one another and float freely in the water, turning the ground into a pudding-like liquid. Building and road foundations lose load-bearing strength and may sink into what was previously solid ground. Unless properly secured, hazardous materials can be released, causing significant damage to the environment and people. Earthen dams and levees are highly susceptible to seismic events and the impacts of their eventual failures can be considered secondary risks for earthquakes. Disruptions in utility services, including power, communication, gas, wastewater and potable water, may also occur. Structure fires also pose a significant hazard after earthquake events.

9.4 EXPOSURE

9.4.1 Population

The entire population of Clark County is potentially exposed to direct and indirect impacts from earthquakes. The degree of exposure is dependent on many factors, including the age and construction type of the structures people live in, the soil type their homes are constructed on, their proximity to fault location, etc. Whether directly impacted or indirectly impacted, the entire population will have to deal with the consequences of earthquakes to some degree. Business interruption could keep people from working, road closures could isolate populations, and loss of functions of utilities could impact populations that suffered no direct damage from an event itself.

9.4.2 Property

According to County Assessor records, there are 149,741 buildings in the planning area, with a total replacement value of $113.5 billion. Since all structures in the planning area are susceptible to earthquake impacts to varying degrees, this total represents the countywide property exposure to seismic events. Most of the buildings (approximately 95 percent) are residential.

9.4.3 Critical Facilities and Infrastructure

All critical facilities in the planning area are exposed to the earthquake hazard.

Table 4-5 lists the number of each type of facility by jurisdiction.

9.4.4 Environment

Secondary hazards associated with earthquakes will likely have some of the most damaging effects on the environment. Earthquake-induced landslides can significantly impact surrounding habitat. It is also possible for streams to be rerouted after an earthquake. This can change water quality, possibly damaging habitat and feeding areas. There is a possibility of streams fed by groundwater drying up because of changes in underlying geology or that new flows may be released. Major concentrations of hazardous materials on port industrial lands along the Columbia River shoreline upriver of the Lake Vancouver wetland area and the Ridgefield National Wildlife Refuge create significant exposure for the natural environment (CRESA 2004).

9.5 VULNERABILITY

Earthquake vulnerability data was evaluated using a Level 2 Hazus-MH analysis by Tetra Tech in 2017. A follow-up analysis was conducted at a regional level by the Oregon Department of Geology and Mineral Industries (DOGAMI). The vulnerability was updated with DOGAMI's data where applicable throughout this section. Once the location and size of a hypothetical earthquake are identified, Hazus-MH estimates the intensity of the ground shaking, the number of buildings damaged, the damage to critical facilities and infrastructure, the number of people displaced from their homes, and additional information that can be used to estimate the costs of repair and cleanup.

9.5.1 Population

DOGAMI estimated there to be (307,471) people in over (114,988) households living on soils with moderate to high liquefaction potential or peat soils in the planning area. This was substantially higher than Tetra Tech's analysis of 13,093 households. DOGAMI Attributes this to differences in modeling techniques (DOGAMI, 2020). Two groups are particularly vulnerable to earthquake hazards:

- **Population Below Poverty Level**—Tetra Tech estimated 2,265 households in the planning area census blocks with moderate to high liquefaction potential or peat soils have household incomes less than $20,000 per year. This is about 17 percent of all households located on moderate to high liquefaction potential or peat soils. These households may lack the financial resources to improve their homes to prevent or mitigate earthquake damage. Economically disadvantaged residents are also less likely to have insurance to compensate for losses in earthquakes.
- **Population Over 65 Years Old**—Tetra Tech estimated 4,316 residents in the planning area census blocks with moderate to high liquefaction potential or peat soils are over 65 years old. This is about 12 percent of all residents in these census blocks. This population group is vulnerable because they are more likely to need special medical attention, which may not be available due to isolation caused by earthquakes. Elderly residents also have more difficulty leaving their homes during earthquake events and could be stranded in dangerous situations.

Impacts on persons and households in the planning area were estimated for the 100-year and 500-year earthquakes and the two scenario events through the Level 2 Hazus-MH analysis. Table 9-3 summarizes the results.

Table 9-3. Estimated Earthquake Impact on Persons and Households

	Number of Displaced Households/ Persons	Number of Persons Requiring Short-Term Shelter
100-Year Earthquake	23 Households	14
500-Year Earthquake	1,350 Households	822
Cascadia Fault, M9.0 Scenario	3,801 (Dry) – 24,695 (Wet) Persons[1]	215

Portland Hills Fault, M6.5 Scenario	2,819 (Dry) – 28, 986 (Wet) Persons[1]	91

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.
[1] – Analysis conducted by DOGAMI. All others conducted by Tetra Tech.

9.5.2 Property

Building Age

Table 9-4 identifies significant milestones in building and seismic code requirements that directly affect the structural integrity of development. Using these time periods, the planning team used Clark County and Cowlitz County assessor's data to identify the number of structures in the planning area by date of construction. The number of structures does not reflect the number of total housing units, as many multi-family units and attached housing units are reported as one structure. Approximately 23.8 percent of the planning area's structures were constructed before there were state minimums regarding residential seismic construction standards. Approximately 41.8 percent were built after seismic Zone 3 standards were required.

Table 9-4. Age of Structures in Planning Area

Time Period	Number of Current Planning Area Structures Built in Period[a]	Significance of Time Frame
Pre-1972	33,339	Adoption of building codes was at the discretion of individual cities and counties. There were no state minimums regarding residential construction, although newly constructed schools, hospitals and places of assembly were required to withstand a lateral force of 5 percent of the building weight.
1972-1993	48,623	Houses built after 1972 are in compliance with the 1970 Uniform Building Code, which required that all structures be constructed to Zone 2 seismic standards.
1994-2003	37,148	Zone 3 standards of the Uniform Building Code went into effect in western Washington in 1994, requiring all new construction to be capable of withstanding the effects of 0.3 times the force of gravity.
2004-2006	12,532	Adoption of new codes that became effective in July of 2004 brought Washington State's building codes to the highest level nationwide addressing the state's seismic hazard.
2007-present	32,155	Amendments to the International Building Code that took effect in July of 2007 included provisions for structural design for earthquake loads and flood hazards. The code applies to all building permits in the state of Washington. The codes are driven in part by soil and liquefaction maps prepared.
Total	**163,797**	

a. Year built information was collected from Clark and Cowlitz County tax assessor data. When year built information was unavailable, it was estimated based on census block or county-wide average year built dates.
Source: Western States Seismic Policy Council, 2016

Liquefaction Potential

Table 9-5 shows the estimated number of structures located on moderate to high potential liquefaction areas or peat soils based on the analysis by Tetra Tech. There are estimated to be 2,234 such structures in the planning area that were built before 1972 (32.9 percent). An estimated 429 structures on liquefiable soils have been built since 2007 (6.3 percent).

Table 9-5. Structures Located on Moderate to High Liquefaction Potential

Jurisdiction	Structures on Liquefiable Soils	Total Structures	Percent of Total Structures
Battle Ground	0	5,854	0.0%
Camas	349	7,513	4.6%
La Center	0	1,110	0.0%

Jurisdiction	Structures on Liquefiable Soils	Total Structures	Percent of Total Structures
Ridgefield	54	2,328	2.3%
Vancouver	2,209	50,098	4.4%
Washougal	1,416	5,539	25.6%
Woodland	1,849	1,864	99.2%
Yacolt	0	533	0.0%
Unincorporated	894	74,902	1.2%
Total	**6,771**	**149,741**	**4.5%**

Loss Potential

Structural and Non-Structural Loss

Property losses were estimated through the Level 2 Hazus-MH analysis for the 100-year and 500-year earthquakes and the two scenario events. Table 9-6 and Table 9-7 show the results for two types of property loss: structural loss (damage to building structures); and non-structural loss (the value of lost contents).

Table 9-6. Loss Estimates for Probabilistic Earthquakes

	Estimated Loss Associated with Earthquake							
	100- Year Earthquake				500- Year Earthquake			
Jurisdiction	Structure	Contents	Total	% of Total Value	Structure	Contents	Total	% of Total Value
Battle Ground	$7,702,384	$2,504,623	$10,207,007	0.3%	$126,603,887	$36,962,449	$163,566,336	4.1%
Camas	$21,150,784	$7,508,475	$28,659,259	0.4%	$434,388,396	$141,940,597	$576,328,993	7.6%
La Center	$1,669,746	$557,716	$2,227,461	0.3%	$23,089,793	$7,439,052	$30,528,845	3.8%
Ridgefield	$4,508,121	$1,506,279	$6,014,400	0.3%	$81,460,429	$25,484,320	$106,944,749	5.2%
Vancouver	$129,170,801	$44,902,228	$174,073,029	0.4%	$2,883,634,647	$871,943,387	$3,755,578,034	7.8%
Washougal	$15,754,583	$5,214,119	$20,968,702	0.5%	$346,332,544	$105,512,514	$451,845,057	10.9%
Woodland	$12,468,825	$4,592,914	$17,061,739	1.0%	$247,836,758	$89,373,231	$337,209,990	19.0%
Yacolt	$123,362	$33,080	$156,443	0.1%	$1,973,430	$755,599	$2,729,028	0.9%
Unincorporated	$60,313,915	$18,209,930	$78,523,845	0.2%	$984,008,141	$306,616,992	$1,290,625,133	2.9%
Total	**$252,862,521**	**$85,029,364**	**$337,891,885**	**0.3%**	**$5,129,328,025**	**$1,586,028,142**	**$6,715,356,166**	**5.9%**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 9-7. Loss Estimates for Cascadia and Portland Hills Fault Scenario Earthquakes

	Estimated Loss Associated with Earthquake							
	Cascadia Fault, M9.0				Portland Hills Fault, M6.5			
Jurisdiction	Structure	Contents	Total	% of Total	Structure	Contents	Total	% of Total
Battle Ground	$55,961,241	$15,037,033	$70,998,274	1.8%	$12,565,086	$6,270,833	$18,835,919	0.5%
Camas	$78,513,607	$24,461,975	$102,975,582	1.4%	$28,095,911	$13,994,049	$42,089,959	0.6%
La Center	$5,933,361	$2,373,416	$8,306,776	1.0%	$626,988	$386,700	$1,013,688	0.1%
Ridgefield	$50,081,043	$13,081,752	$63,162,795	3.0%	$5,690,364	$3,278,681	$8,969,044	0.4%
Vancouver	$1,096,996,587	$262,385,378	$1,359,381,965	2.8%	$639,121,124	$232,439,643	$871,560,767	1.8%
Washougal	$30,283,011	$8,453,341	$38,736,351	0.9%	$10,958,868	$5,712,285	$16,671,153	0.4%
Woodland	$87,133,236	$23,773,277	$110,906,513	6.2%	$10,177,446	$3,846,130	$14,023,576	0.8%
Yacolt	$949,658	$455,241	$1,404,899	0.5%	$118,443	$85,610	$204,053	0.1%
Unincorporated	$544,728,735	$155,275,222	$700,003,957	1.6%	$325,936,412	$133,643,686	$459,580,098	1.0%
Total	**$1,950,580,479**	**$505,296,633**	**$2,455,877,112**	**2.2%**	**$1,033,290,641**	**$399,657,617**	**$1,432,948,257**	**1.3%**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

A summary of the property-related loss results is as follows:

- For a 100-year probabilistic earthquake, the estimated damage potential is $337.9 million, or 0.3 percent of the total replacement value for the planning area.
- For a 500-year probabilistic earthquake, the estimated damage potential is $6.7 billion or 5.9 percent of the total replacement value for the planning area.
- For a 9.0-magnitude Cascadia Fault event, the estimated damage potential is $2.5 billion, or 2.2 percent of the total replacement value for the planning area.
- For a 6.5-magnitude Portland Hills Fault event, the estimated damage potential is $1.4 billion, or 1.3 percent of the total replacement value for the planning area.

Building Damage

Damage states vary for each type of structure. Moderate to very heavy damage will occur in older residential neighborhoods, business districts, communities with concentrations of non-seismically designed buildings, and areas built on soft soils. Particularly vulnerable are homes built before 1950, turn of the century un-reinforced masonry buildings, homes that were built prior to the 1970 Uniform Building Code that required anchoring to foundations, pre-1980 tilt-up buildings, and buildings with large windows or parking doors that weaken the first floor. Least vulnerable are structures built since 1994 when the earthquake Zone 3 standards of the Uniform Building Code were applied (CRESA 2004). The Hazus-MH analysis estimated the expected building damage by occupancy for the least damaging and most damaging earthquake events—the 100-year and 500-year events, respectively.

- For a 100-year probabilistic earthquake, about 1 percent (1,267) of planning area buildings are expected to be at least moderately damaged. Less than 0.1 percent are expected to be damaged beyond repair.
- For a 500-year probabilistic earthquake, about 12.5 percent (almost 19,000) of planning area buildings are expected to be at least moderately damaged. Less than 1 percent (753) are expected to be damaged beyond repair, including more than 270 residential structures.

Damage would be especially severe in taller buildings, which would experience large displacements. The movement of taller buildings may damage adjacent buildings by pounding against them, causing significant damage to buildings that otherwise would have been undamaged (CRESA 2004).

Earthquake-Caused Debris

The Hazus-MH analysis estimated the amount of earthquake-caused debris in the planning area for the 100-year and 500-year earthquakes and the two scenario events, as summarized in Table 9-8.

Table 9-8. Estimated Earthquake-Caused Debris

	Debris to Be Removed (tons)[a]	Estimated Number of Truckloads[b]
100-Year Earthquake	94,070	3,763
500-Year Earthquake	2,416,280	96,651
Cascadia Fault, M9.0 Scenario	1,827,000	73,080
Portland Hills Fault, M6.5 Scenario	1,795,000	71,800

a. Debris generation estimates were based on updated general building stock dataset at a Census Tract analysis level.
b. Hazus-MH assumes 25 tons/trucks
Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

9.5.3 Critical Facilities and Infrastructure

Level of Damage

Hazus-MH classifies the vulnerability of critical facilities to earthquake damage in five categories: no damage, slight damage, moderate damage, extensive damage, or complete damage. The model was used to assign a vulnerability category to each critical facility in the planning area. The analysis was performed for the Cascadia M9.0 scenario and 500-year probabilistic events. Results are summarized in Table 9-9 and Table 9-10.

Table 9-9. Estimated Damage to Critical Facilities from Cascadia M9.0 Scenario Earthquake

Category[a]	Damage Extent				
	None	Slight	Moderate	Extensive	Complete
Communication Facilities	8	1	0	0	0
Dams[b]	--	--	--	--	--
Emergency Services	61	0	0	0	0
Energy	56	16	0	0	0
Government Facilities	0	60	0	0	0
Hazardous Materials	0	116	0	0	0
Health Care & Public Health	5	345	0	0	0
Information Technology	--	--	--	--	--
Schools	157	0	0	0	0
Transportation Systems	211	54	0	0	0
Water & Sanitation Systems	337	56	0	0	0
Total	**835**	**648**	**0**	**0**	**0**

a. Damage extent was determined by selecting the highest probability damage state for each facility.
b. Hazus-MH does not produce damage estimates for dams. It is likely that owner/operators have already performed in depth, site-specific seismic hazard analysis.

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 9-10. Estimated Damage to Critical Facilities from 500-Year Earthquake

Category[a]	Damage Extent				
	None	Slight	Moderate	Extensive	Complete
Communication Facilities	0	9	0	0	0
Dams	--	--	--	--	--
Emergency Services	61	0	0	0	0
Energy	1	59	12	0	0
Government Facilities	0	56	0	0	4
Hazardous Materials	0	73	0	0	43
Health Care & Public Health	5	343	0	0	2
Information Technology	--	--	--	--	--
Schools	157	0	0	0	0
Transportation Systems	256	4	0	0	5
Water & Sanitation Systems	78	254	57	0	4
Total	**558**	**798**	**69**	**0**	**58**

a. Damage extent was determined by selecting the highest probability damage state for each facility.
b. Hazus-MH does not produce damage estimates for dams. It is likely that owner/operators have already performed in depth, site-specific seismic hazard analysis.

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Time to Return to Functionality

Hazus-MH estimates the time to restore critical facilities to fully functional use. Results are presented as probability of being functional at specified time increments: 1, 3, 7, 14, 30 and 90 days after the event. For example, Hazus-MH may estimate that a facility has 5 percent chance of being fully functional at Day 3, and a 95-percent chance of being fully functional at Day 90. Results from the 100-year probability event and the 500-year probability event are summarized in Table 9-11 and Table 9-12.

Table 9-11. Functionality of Critical Facilities for Cascadia M9.0 Scenario Earthquake

	# of Critical Facilities	Probability of Being Fully Functional (%)[a]					
		at Day 1	at Day 3	at Day 7	at Day 14	at Day 30	at Day 90
Communication Facilities	9	92	99	99	100	100	100
Dams[a]	3	--	--	--	--	--	--
Emergency Services	61	88	88	98	98	99	99
Energy	72	67	88	94	97	99	100
Government Facilities	60	4	6	55	55	81	94
Hazardous Materials	115	4	7	56	56	81	92
Health Care & Public Health	350	5	8	59	59	84	96
Information Technology	0	--	--	--	--	--	--
Schools	157	87	88	99	99	99	99
Transportation Systems	265	93	95	96	97	97	98
Water & Sanitation Systems	393	37	50	78	78	90	96
Total/Average	**1,485**	**53**	**59**	**82**	**82**	**92**	**97**

a. Hazus-MH does not produce functionality estimates for dams. It is likely that owner/operators have already performed in depth, site-specific seismic hazard analysis.

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 9-12. Functionality of Critical Facilities for 500-Year Earthquake

	# of Critical Facilities	Probability of Being Fully Functional (%)[a]					
		at Day 1	at Day 3	at Day 7	at Day 14	at Day 30	at Day 90
Communication Facilities	9	82	95	97	99	100	100
Dams[a]	3	--	--	--	--	--	--
Emergency Services	61	65	65	87	88	95	95
Energy	72	47	70	83	90	95	99
Government Facilities	60	2	4	44	44	71	88
Hazardous Materials	116	2	3	37	37	63	81
Health Care & Public Health	350	3	6	49	49	76	91
Information Technology	0	--	--	--	--	--	--
Schools	157	66	67	90	90	96	96
Transportation Systems	265	83	88	90	90	91	94
Water & Sanitation Systems	393	27	43	64	64	79	89
Total/Average	**1,485**	**42**	**49**	**71**	**72**	**85**	**93**

a. Hazus-MH does not produce functionality estimates for dams. It is likely that owner/operators have already performed in depth, site-specific seismic hazard analysis.

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Liquefaction Potential

Structures located with the Port of Vancouver facilities and containing hazardous materials are particularly susceptible to liquefaction and flow into the Columbia impacting down river wetlands. When liquefaction occurs, the ground loses the capability to support structures, resulting in subsidence and/or tipping of buildings and bridge supports. Lateral spreading pulls apart some types of buildings and rupture pipelines. Several tall grain elevators could potentially fail. (CRESA 2004).

In addition other facilities located on liquefiable soil may be particularly vulnerable to the earthquake hazards. The following infrastructure is located on or passes through these areas:

- Interstate 5
- State Route 500
- Northwest Pipeline
- Interstate 205
- State Route 501
- Olympic Pipeline
- State Route 14
- State Route 503
- All watercourse levees.

9.5.4 . Environment

The environment vulnerable to earthquake hazard is the same as the environment exposed to the hazard.

9.5.5 Economic Impact

Economic impact will be largely associated with the disruption of services caused by an earthquake event. In general, significant events may cause damage to land, buildings, transportation infrastructure, and businesses. With an event of such significance, economic recovery could take years depending on available recovery funds.

9.6 FUTURE TRENDS

9.6.1 Development

Land use in the planning area will be directed by comprehensive plans adopted under Washington's Growth Management Act. The information in this plan provides the participating partners a tool to ensure that there is no increase in exposure in areas of high seismic risk. Development in the planning area will be regulated through building standards and performance measures so that the degree of risk will be reduced. The geologic hazard portions of the planning area are regulated under each jurisdiction's critical areas ordinances. The most recently adopted building codes take liquefaction and soil mapping into account in their standards.

Areas targeted for future growth and development have been identified across the County. It is anticipated that the human exposure and vulnerability to earthquake impacts in newly developed areas will be similar to those that currently exist within the County. New development in areas with softer NEHRP soil classes, liquefaction and landslide-susceptible areas may be more vulnerable to the earthquake hazard. Table 9-13 shows the area identified as underutilized or vacant in urban growth areas in the County that intersect moderate to high liquefaction potential or peat soils. Development in these areas has the potential to increase vulnerability to the earthquake hazard if proper structural measures are not taken. Critical areas ordinances in the planning area may restrict development in portions of these parcels where liquefaction is likely.

9.6.2 Climate Change

The impacts of global climate change on earthquake probability are unknown. Some scientists say that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity, according to research into prehistoric earthquakes and volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska may be opening the way for future earthquakes (NASA, 2004).

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could experience liquefaction or an increased propensity for slides during seismic activity due to the increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. There are currently no models available to estimate climate-change related impacts on the earthquake hazard.

Table 9-13. Buildable Lands in Planning Area Urban Growth Areas that Intersect Liquefaction Areas[a]

Urban Growth Area Name[b]	Residential Acres	Residential Units	Commercial (acres)	Industrial (acres)	Total (acres)[c]
Battle Ground	22.8	137	2.1	0	24.9
Camas	17.3	104	3.1	19.2	39.6
La Center	0	0	0	0	0
Ridgefield	0		0	0	0
Vancouver	141.6	1,132	35.0	830.6	1,007.1
Washougal	51.4	308	51.1	73.1	175.5
Woodland[d]	25.2	101	0	0	25.2
Yacolt	0	0	0	0	0
Total	**258.2**	**1,782**	**91.2**	**922.9**	**1,272.3**

a. Buildable lands information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Unincorporated areas outside of urban growth areas are excluded from this assessment. Development in these areas consists largely of rural lands, open space and large residential lots. Changes in development can be assessed through an increase in structures located outside of incorporated areas.
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage estimates exclude the portions of the City of Woodland in Cowlitz County and thus may be underestimated.

9.7 SCENARIO

Any seismic activity of 6.0 or greater on faults within the planning area's general region would have significant impacts throughout the planning area. An earthquake in the Cascadia subduction zone would have disastrous consequences for the entire state and the region. Potential warning systems could give a few seconds' notice that a major earthquake is about to occur. This would not provide adequate time for preparation.

Large magnitude earthquakes in the region could lead to massive structural failure of property on liquefiable soils. Structural failure may be intensified if the earthquake occurs during winter when soils are saturated. Heavy damage would also occur in areas with poor site conditions, older construction, or construction especially vulnerable to long duration, long period ground motions (CRESA, 2004). Dams, levees and revetments built on poor soils would likely fail, representing a loss of critical infrastructure. Access to and from the County would be challenging, given the likelihood that bridges and major transportation routes may be impassable. These events could cause secondary hazards, including landslides and mudslides that would further damage structures.

9.8 ISSUES

Important issues associated with an earthquake include the following:

- It is estimated that up to 60% percent of the total population in the planning area resides on soils with moderate to high liquefaction potential or peat soils.

- Approximately 17 percent of households living in moderate to high liquefaction potential areas have household incomes less than $20,000 per year.
- Approximately 12 percent of the population living in moderate to high liquefaction potential areas are 65 years or older and may require special medical attention or be unable to evacuate without assistance.
- The results of the earthquake scenario events chosen for analysis indicate that between 23 and 1,350 households will be displaced and that between 14 and 822 residents may require short term shelter.
- Over 58 percent of the planning area's building stock was built prior to 1994, when Zone 3 seismic standards were incorporated into the building code.
- Critical facility owners should be encouraged to create or enhance continuity of operations plans using the information on risk and vulnerability contained in this plan.
- Geotechnical standards should be established that take into account the probable impacts from earthquakes in the design and construction of new or enhanced facilities.
- Earthquakes could trigger other natural hazard events such as dam failures, levee failures and landslides, which could severely impact the planning area or regional critical facilities.
- There are likely additional faults in or around Clark County that have not yet been discovered.
- After a major seismic event, Clark County is likely to experience disruptions in the flow of goods and services due to the destruction of major transportation infrastructure across the broader region.
- Major arterials in the planning area cross liquefiable soils and could be impassable after an event.
- The county vehicular intra-county transportation system is generally characterized by the lack of redundancy and dependency on bridges. The County north/south vehicular corridors include Interstate 5 (I-5) and Interstate 205 (I-205). There is limited north/south redundancy via a series of local roads. east/west traffic is restricted to Route 14 along the Washington side of the Columbia River and Route 30 on the Oregon side. Limited East/West redundancies are possible along East Mill Plain Boulevard, NE Fourth Plain, NE 76th Street, and SR 500. Most corridors include numerous bridges (CRESA, 2004).
- Residents are expected to be self-sufficient up to three days following a major earthquake without government response agencies, utilities, private sector services and infrastructure components. Education programs are currently in place to facilitate the development of individual, family, neighborhood and business earthquake preparedness. Government alone can never make this region fully prepared. It takes individuals, families, and communities working in concert with one another to truly be prepared for disaster.
- Natural hazards have a devastating impact on businesses. Of all businesses that close following a disaster, more than 43 percent never reopen, and an additional 29 percent close for good within the next two years. The Institute of Business and Home Safety has developed "Open for Business," which is a disaster planning toolkit to help guide businesses in preparing for and dealing with the adverse effects of natural hazards. The kit integrates protection from natural disasters into companies' risk reduction measures to safeguard employees, customers, and the investment itself. The guide helps businesses secure human and physical resources during disasters, and helps to develop strategies to maintain business continuity before, during, and after a disaster occurs.
- An early warning system, ShakeAlert, is currently under development, but is not ready for public use.

- County government buildings, including the Clark Regional Emergency Services Agency, which contains the Emergency Operation Center where all response activities are coordinated, are located within a consolidated campus in Vancouver. Because many government functions are located close together, serious damage in that area could be devastating.
- Many city offices are older and located with their respective jurisdictions (CRESA, 2004).
- Masonry construction is scattered throughout the county. Un-reinforced masonry structures are most common, though not predominant, in downtown Vancouver, downtown Camas, and the Walnut Grove area (CRESA, 2004).
- Model estimates indicate that debris removal from earthquake events would require approximately 3,700 to almost 100,000 truckloads, depending on the event scenario.

10. FLOOD

10.1 GENERAL BACKGROUND

A floodplain is the area adjacent to a river, creek or lake that becomes inundated during a flood. Floodplains may be broad, as when a river crosses an extensive flat landscape, or narrow, as when a river is confined in a canyon.

Connections between a river and its floodplain are most apparent during and after major flood events. These areas form a complex physical and biological system that not only supports a variety of natural resources but also provides natural flood and erosion control. When a river is separated from its floodplain with levees and other flood control facilities, natural, built-in benefits can be lost, altered, or significantly reduced.

10.1.1 Measuring Floods and Floodplains

The frequency and severity of flooding are measured using a discharge probability, which is the probability that a certain river discharge (flow) level will be equaled or exceeded in a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels. The flood frequency equals 100 divided by the discharge probability. For example, the 100-year discharge has a 1-percent chance of being equaled or exceeded in any given year. The “annual flood” is the greatest flood event expected to occur in a typical year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. The same flood can have different recurrence intervals at different points on a river. For example, the December 1977 flood event exceeded a 500-year flood (0.2 percent annual chance) on the Washougal River at USGS Gage # WASW1 but was less than a 100-year flood on some of its tributaries.

The extent of flooding associated with a 1-percent annual probability of occurrence (the base flood or 100-year flood) is used as the regulatory boundary by many agencies. Also referred to as the special flood hazard area, this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities. Many communities have maps that show the extent and likely depth of flooding for the base flood. Corresponding water-surface elevations describe the elevation of water that will result from a given discharge level, which is one of the most important factors used in estimating flood damage.

10.1.2 Effects of Human Activities

Because they border water bodies, floodplains have historically been popular sites to establish settlements. Human activities tend to concentrate in floodplains for a number of reasons: water is readily available; land is fertile and suitable for farming; transportation by water is easily accessible; and land is flatter and easier to develop. But human activity in floodplains frequently interferes with the natural function of floodplains. It can affect the distribution and timing of drainage, thereby increasing flood problems. Human development can create local flooding problems by altering or confining drainage channels. This increases flood potential in two ways: it reduces the stream’s capacity to contain flows, and it increases flow rates or velocities downstream during flood events. Human activities can interface effectively with a floodplain as long as steps are taken to mitigate the activities' adverse impacts on floodplain functions.

10.1.3 Federal Flood Programs

National Flood Insurance Program

The NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in participating communities. For most participating communities, FEMA has prepared a detailed Flood Insurance Study. The study presents water surface elevations for floods of various magnitudes, including the 1-percent annual chance flood and the 0.2-percent annual chance flood (the 500-year flood). Base flood elevations and the boundaries of the 1-percent and 0.2-percent annual chance floodplains are shown on Flood Insurance Rate Maps (FIRMs), which are the principle tool for identifying the extent and location of the flood hazard. FIRMs are the most detailed and consistent data source available, and they represent the minimum area of oversight for many communities' floodplain management programs.

Participants in the NFIP must, at a minimum, regulate development in floodplain areas in accordance with NFIP criteria. Before issuing a permit to build in a floodplain, participating jurisdictions must ensure that the following criteria are met:

- New buildings and those undergoing substantial improvements must, at a minimum, be elevated to protect against damage by the base flood.
- New floodplain development must not aggravate existing flood problems or increase damage to other properties.
- New floodplain development must exercise a reasonable and prudent effort to reduce its adverse impacts on listed threatened/endangered species.

Communities participating in the NFIP may adopt regulations that are more stringent than those contained in 44 CFR 60.3, but not less stringent. The Washington State Building Code Act requires new construction to be elevated to 1 foot above the base flood elevation or to the design flood elevation, whichever is higher. Some communities in Clark County have adopted more stringent standards. For example, a 1-foot freeboard (height above the base flood elevation) is standard for most structures in unincorporated Clark County.

In NFIP participating communities, structures permitted or built in the planning area before NFIP and related building code regulations went into effect are called "pre-FIRM" structures, and structures built afterwards are called "post-FIRM." Historically, the insurance rate has been different for the two types of structures. However, recent flood insurance reform legislation (Biggert-Waters Flood Insurance Reform Act of 2012) changes the way flood insurance is rated, with a move to full actuarial rates based on flood risk.

Clark County and all cities and towns in it except La Center are participants in NFIP. All participating communities are currently in good standing with the provisions of the NFIP. All cities and towns have identified actions to regain or maintain continued compliance with the provisions of the NFIP. The current effective FIRM for Clark County is dated September 5, 2012. The City of Woodland lies in both Clark and Cowlitz Counties, and most of its floodplain is in Cowlitz County. The preliminary FIRM for Cowlitz County was issued August 16, 2013.

In Washington, the Department of Ecology is the coordinating agency for floodplain management. Ecology works with FEMA and local governments by providing grants and technical assistance, evaluating community floodplain management programs, reviewing local floodplain ordinances, and participating in statewide flood hazard mitigation planning. Compliance is monitored by FEMA regional staff and by Ecology. Maintaining compliance under the NFIP is an important component of flood risk reduction. All planning partners that participate in the NFIP have identified actions to maintain their compliance and good standing. Planning partners who do not currently participate have identified actions to consider re-enrollment in the program.

The Community Rating System

The CRS is a voluntary program within the NFIP that encourages floodplain management activities that exceed the minimum NFIP requirements. Flood insurance premiums are discounted to reflect the reduced flood risk resulting from community actions meeting the following three goals of the CRS:

- Reduce flood losses.
- Facilitate accurate insurance rating.
- Promote awareness of flood insurance.

For participating communities, flood insurance premium rates are discounted in increments of 5 percent. Class 1 communities receive a 45-percent premium discount, and Class 9 communities receive a 5-percent discount. (Class 10 communities are those that do not participate in the CRS; they receive no discount.) The CRS classes are based on 18 creditable activities in the following categories:

- Public information
- Mapping and regulations
- Flood damage reduction
- Flood preparedness.

Figure 10-1 shows the nationwide number of CRS communities by class as of October 1, 2015, when there were 1,368 communities receiving flood insurance premium discounts under the CRS program. In Washington there are 36 CRS communities. Although CRS communities represent only 6 percent of the over 22,000 communities participating in the NFIP, more than 70 percent of all flood insurance policies are written in CRS communities. CRS activities can help to save lives and reduce property damage.

Source: FEMA, 2015

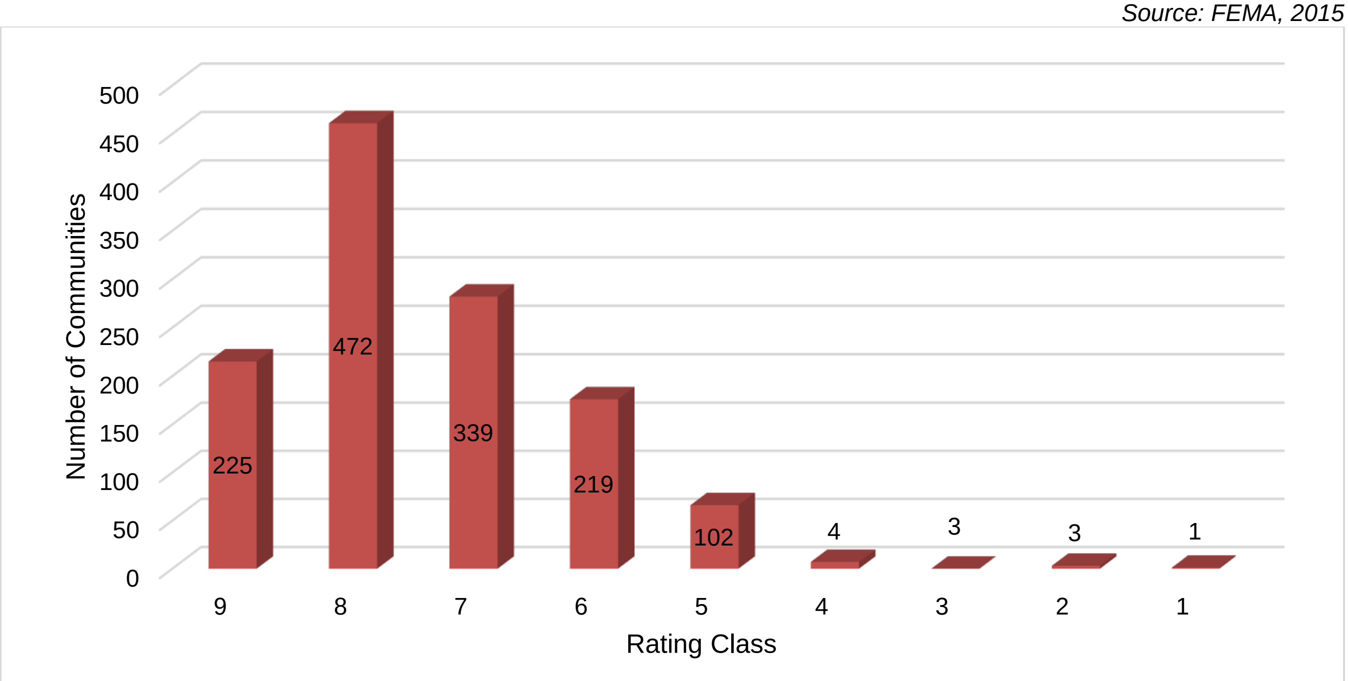

Figure 10-1. CRS Communities by Class Nationwide as of October 1, 2015

Clark County, the only CRS participant in the planning area, has participated in the program since 2004. The County has a Class 5 rating, so citizens who live in a special flood hazard area can receive a 25-percent discount on flood insurance; outside the 1-percent annual chance flood hazard area they receive a 10-percent discount. This equates to a savings of $56 to $314 per policy, for a total county-wide premium savings of $93,393. To maintain or improve its rating, the County goes through an annual recertification and a re-verification every five years. The County is among 12 Washington CRS communities with a Class 5 rating; 21 have a better (lower) rating and three have a worse (higher) rating.

10.1.4 The Value of Floodplains

Floodplains are a natural component of the Clark County environment. Understanding and protecting their natural function can reduce flood damage and protect people and property. The benefits of preserving floodplains include the following:

- Flood and erosion control. Floodplains are natural sponges, storing and slowly releasing floodwaters. This reduces the height of a flood and the speed of a river. When a river is cut off from its floodplain by levees and dikes, flood heights often increase and downstream damage can be greater.
- Water quality improvement. As water travels through floodplains, plants serve as natural filters, trapping sediments and capturing pollutants. Floodplains help to moderate temperature fluctuations that can harm aquatic life. They also reduce sedimentation (soil and pollutants in the water) that can harm aquatic life.
- Groundwater recharge. Floodplains promote infiltration and recharge of underlying aquifers.
- Fish and wildlife habitat. Floodplains maintain biodiversity. They provide breeding and feeding grounds, create and enhance waterfowl areas, and protect habitat for rare and endangered species.

The natural processes of flooding add sediment and nutrients to fertile floodplain areas. When floodwaters recede after a flood event, they leave behind layers of rock and mud. These gradually build up to create a new floor of the floodplain. Floodplains generally contain accumulations of sand, gravel, loam, silt, and/or clay, often extending below the bed of the stream. These sediments provide a natural filtering system, with water percolating back into the ground and replenishing groundwater. These are often important aquifers, the water drawn from them being filtered compared to the water in the stream. Fertile, flat reclaimed floodplain lands are commonly used for agriculture, commerce and residential development.

As buildable land becomes scarce with ongoing urban development, pressure builds to develop in floodplains. Building homes and businesses in floodplains not only puts people in harm's way, but it also reduces the environmental benefits of floodplains (Clark County, 2016b).

10.2 HAZARD PROFILE

10.2.1 Types of Flood Related Hazards

Riverine Flooding

Riverine flooding is the overbank flooding of rivers and streams. Flooding in large river systems typically results from large-scale weather systems that generate prolonged rainfall over a wide geographic area, causing flooding in hundreds of smaller streams, which then drain into the major rivers. Shallow area flooding is a special type of riverine flooding. FEMA defines shallow flood hazards as areas that are inundated by the base flood with flood depths of only 1 to 3 feet. These areas are generally flooded by low velocity sheet flows of water. Two types of flood hazards are generally associated with riverine flooding:

- **Inundation**—Inundation occurs when there is floodwater and debris flowing through an area that is not normally covered by water. Such events cause minor to severe damage, depending on the velocity and depth of flows, the duration of the flood event, the quantity of logs and other debris carried by the flows, and the amount and type of development and personal property along the floodwater's path.
- **Channel Migration**—Channel migration results when erosion to flowing water wears away banks and soils due. This erosion, combined with sediment deposition, causes the migration or lateral movement of a river channel across a floodplain. A channel can also move by abrupt change in location, called avulsion, which can shift the channel location a large distance in as short a time as one flood event.

Urban Flooding

In urbanized areas, localized or urban flooding not associated with stream overflow can occur where there are no drainage facilities to control flows or when runoff volumes exceed the design capacity of drainage facilities. As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Urbanization of a watershed changes the hydrologic systems of the basin. Heavy rainfall collects and flows faster on impervious concrete and asphalt surfaces. The water moves from the clouds to the ground and then into streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in floodwaters that rise rapidly and peak with violent force. During periods of urban flooding, streets can become swiftly moving rivers and basements can fill with water. Storm drains often back up with vegetative debris, causing additional, localized flooding. Urban flooding issues are generally addressed through stormwater management plans at the local level.

10.2.2 Principal Flooding Sources

Floods occur in Clark County every few years, and major events occur with some frequency. There have been seven major events since 1964. In Clark County, flooding is most likely to occur due to a severe winter storm that brings snow to higher elevations, followed by warmer weather and rain. The sudden influx of new rain and melting snow can overwhelm both natural and man-made water drainage systems (CRESA 2004). Floods in Clark County can generally be classified into four different types (CRESA 2004):

- Flooding resulting from overflow of the Columbia River, distinct from general riverine flooding both because of the magnitude of flooding possible and because of the slow rising nature of these floods.
- Riverine flooding, which occurs primarily in designated floodplains in the interior of the county and side drains to the Columbia River.
- Shallow flooding or ponding in "sink areas," which may occur well outside of mapped floodplains and generally results either from areas of very high water table (which can oversaturate during storm events), or from areas of poor soil percolation (where rain water does not drain effectively during storm events).
- Isolated urban flooding from clogged or overflowing storm drainage systems and culverts.

Columbia River Flooding

Historically, most development in Clark County has been along the Columbia River, which forms the southern and western boundaries of the county. The river is the major inland waterway in the northwestern United States. It drains approximately 241,000 square miles of southwestern Canada and the northwestern United States upstream of Vancouver. Although many large Columbia River floods have occurred in Clark County, existing flood control storage structures (reservoirs and dams) reduce flood elevations and provide increased warning time for those who live in the flood's path (CRESA 2004).

The entire Columbia River Basin includes more than 50 storage projects, significantly reducing flood levels. The following Clark County flood control structures provide varying levels of flood protection (CRESA 2004; FEMA 2012a):

- The drainage districts along the Columbia River in Clark County have levees of varying flood protection capacities. Thus, safe water levels have been established by the Corps of Engineers. The safe water level is the highest flood elevation, considering surveillance and minor remedial work, for which reasonable assurance can be given that a levee system will not fail. The determination of the levee safe water level was based on need for freeboard, structural deficiencies observed in the field, knowledge of levee and foundation materials, and flood fighting records. Although the perimeter levee of a particular drainage district may be capable of withstanding large floods, major rainstorms could cause extensive interior ponding in low areas if runoff exceeds the capacity of the dewatering-drainage pumps.
- In the vicinity of Vancouver, some protection from Columbia River flooding is provided by levees along the Lower River Road and at Fruit Valley. However, known deficiencies in their design and maintenance limit the degree of protection to below the 1-percent-annual-chance flood level for the Lower River Road area and below the 0.2-percent-annual-chance flood level for the Fruit Valley area.
- Two projects southwest of Ridgefield at Lake River Delta and Bachelor Island include levees, pumping stations, tide boxes, and interior drainage canals. However, known deficiencies limit the degree of protection they provide to well below 1-percent-annual-chance flood levels.
- The Washougal Area Drainage District, constructed by the Corps of Engineers in 1965 and 1966, extends 5.5 miles along the Columbia River from Lawton Creek west to Camas and includes levee embankment, revetment, tide box, and freshwater inlets, and a pumping plant with interior drainage canals.

These flood control structures have reduced the frequency and severity of flooding along the Columbia River. The floodplain is well defined and residents have experienced several weeks' notice of approaching floodwaters. However, continued maintenance is crucial if these structures are to remain successful. Should they be ignored, the severity of the impact of a future flood would be greater than if the structures had not been built to begin with (CRESA 2004).

Riverine Flooding

Clark County watercourses generally flow west and south from sources in the steep timberland watershed, pass through lower reaches of gently sloping agricultural and developing residential lands, and flow into the Columbia River. Flooding along these rivers and streams differs from Columbia River flooding in two ways (CRESA 2004):

- The rivers have less capacity for carrying water, so the flooding, while no less severe for those experiencing it, affects a smaller number of homes.
- There are fewer dams and reservoirs along the interior rivers, making flooding less predictable.

In general, minor flooding occurs along the banks of the upper reaches of most streams. However, when two streams merge, floodwaters can back up into the smaller stream, creating a backwater that can mean more severe and more frequent flooding for residents near the confluence. In the 1995 floods, this scenario was the principle cause of flooding along the Lewis River. Floodwaters from the Columbia backed up into the Lewis, flooding the area. Salmon Creek, the East Fork of the Lewis River, the Washougal River, Burnt Bridge Creek, and Mill Creek all follow this pattern of flooding (CRESA 2004).

Washougal River

The largest flood on the Washougal River since a USGS stream gauge was installed in 1944 was in December 1977, 6 miles upstream of the City of Washougal. There was little damage however, largely because at that time there was limited development along that stretch of the river. As development increased over time, damage from future floods may be more likely (CRESA 2004).

Lewis River

The Lewis River is regulated by three storage projects: Swift Reservoir, Yale Reservoir and Lake Merwin Reservoir, all of which are operated by Pacific Power and Light (PP&L). The largest flood on the Lewis River occurred in 1933 before these were built. Under the present Federal Energy Regulatory Commission license, PP&L is not required to reserve storage for flood protection. However, on August 18, 1983, FEMA and PP&L agreed to make approximately 70,000 acre-feet available for flood control storage on the Lewis River System at Merwin Dam, thus reducing the 100-year discharge at Woodland from 128,000 cubic feet per second to 102 cubic feet per second, further reducing the risk of flooding to Woodland residents (CRESA 2004). PP&L has prepared emergency operation procedures for three danger conditions:

- Non-failure emergency (high flows)
- Potentially hazardous conditions
- Failure is imminent or has occurred.

PP&L has not established the risk of each condition occurring, but states that the dams are in very good condition as certified by independent consultants (CRESA 2004). Chapter 7 provides additional discussion on the dam failure hazard.

Shallow Flooding and Urban Flooding

Much of the south and western urban growth area has poorly to moderately drained soils, a condition that leads to the ponding of water in lower elevations. During heavy rainstorms, water neither seeps into the soil nor drains off, instead collecting into ponds and potentially flooding homes (CRESA, 2004). An analysis after the 1995 floods showed drainage structures to be a major contributor to ponding and flooding during the event. Many culverts and drainages were judged to have been inadequate to efficiently move the rainwater that fell onto urban infrastructures (road, roofs, sidewalks, etc.) into rivers. This led to urban flooding distant from mapped floodplains and floodways. According to this post-1995 flood engineering report, a lack of well-functioning storm sewer structures and increasing runoff from urbanization had led to an increasing number of drainage problems during storms. Limited resources meant that maintenance crews were unable to respond to flooding problems in many areas in a timely manner. The report commented that maintenance crews can manage some drainage problems, such as plugged inlets, but capacity problems (under-designed subdivision storm systems) require significantly more complex solutions. Operations crews were unable to prevent flooding in these situations (CRESA, 2004).

In rural counties, drainage problems tend to be minimal and are manageable within the limits of a rural public services budget. However, Clark County has experienced significant growth in recent decades and County funding may not be sufficient to provide a reasonable level of drainage and flood control services to county citizens. Significant capital funding may need to be developed to provide drainage and flood control infrastructure extensions and improvements within the County. Alternatively, the use of “softer structures” such as contouring, engineered swales and introduced vegetation, may present opportunities for improved stormwater management (CRESA, 2004).

In some cases, blocked drainage structures can provide important retention functions, and actually slow the process of water moving downstream in the same way that a natural system, such as a wetland, might. Basin-wide analysis is necessary to determine which drainages should be improved to speed the flow of stormwater, and which should be maintained (CRESA, 2004).

10.2.3 Past Events

Seven federal flood-related disaster declarations have affected Clark County since 1964 (see Table 10-1). An example of the type of flooding typical throughout the county is the event that occurred on November 29, 1995. It resulted from an extended series of rainstorms generated over the Pacific Ocean that moved north and east across California, Oregon and Washington. Flooding in Clark County occurred when relatively intense rain fell on saturated ground surfaces and already swollen creeks and rivers. Runoff from snowmelt also contributed to high flows in the North and East Forks of the Lewis River, and the Little Washougal and Washougal Rivers. Peak flows in county streams ranged from approximately a 2-year flood in Burnt Bridge Creek to a 25-year flood in Salmon Creek (CRESA, 2004).

Table 10-1. History of Flood Events

Date	Declaration #	Type of event	Estimated Damage
December 29, 1964	DR-185	Heavy Rains and Flooding	N/A
December 10, 1977	DR-545	Severe Storms, Mudslides, Flooding	N/A
November 7, 1995	DR-1079	Storms, High Winds, Floods	$862,992[a]
January 26, 1996	DR-1100	Severe Storms, Flooding	N/A
December 26, 1996	DR-1159	Severe Winter Storms, Flooding	N/A
November 2, 2006	DR-1671	Severe Storms, Flooding, Landslides, and Mudslides	N/A
December 1, 2015	DR-4253	Severe Winter Storm, Straight Line Winds, Flooding, Landslides, Mudslides, Tornado	N/A

a. Data obtained from Spatial Hazard Events and Losses Database for the United States
N/A = Information is not available

The storm of November 1995 was not considered to be a major flood-producing storm for the Columbia River. However, relatively high stream base flows and tides did combine to produce river levels exceeding flood stage within the portion of the Columbia River flowing through Clark County. Ten houseboats were evacuated at Ridgefield due to sewer problems caused by high river elevations. Higher Columbia River elevations also produced backwater in the lower reaches of Salmon Creek, requiring evacuation of 15 additional houses. Some condominiums and restaurants also experienced flooding along the Columbia River (CRESA, 2004).

10.2.4 Location

Flooding in Clark County has been documented by gage records, high water marks, damage surveys and personal accounts. This documentation was the basis for the September 5, 2012, Flood Insurance Study that is incorporated in the currently effective FIRMs for Clark County and the preliminary FIRMs (issued August 8, 2016) for the City of Woodland. The FIRMs are the most detailed and consistent data source available for determining flood extent. The 2012 and 2013 Flood Insurance Studies are the sole source of data used in this risk assessment to map the extent and location of the flood hazard, as shown in Figure 10-2. Mapped 1-percent annual chance flood hazard areas cover about 2.5 percent of the planning area.

10.2.5 Frequency

Based on the seven flood declarations affecting Clark County since 1964 (see Table 10-1), major floods in Clark County can be expected on average about once every seven years. The County also typically experiences one episode of minor river flooding each winter. Urban portions of the county annually experience nuisance flooding related to drainage issues.

Figure 10-2. FEMA DFIRM Flood Hazard Areas

10.2.6 Severity

The principal factors affecting flood damage are flood depth and velocity. The deeper and faster flood flows become, the more damage they can cause. Shallow flooding with high velocities can cause as much damage as deep flooding with slow velocity. This is especially true when a channel migrates over a broad floodplain, redirecting high velocity flows and transporting debris and sediment. Flood severity is often evaluated by examining peak discharges; Table 10-2 lists peak flows used by FEMA to map the floodplains of Clark County.

Table 10-2. Summary of Peak Discharges in Clark County

Source/Location	Drainage area (sq. mi.)	Discharge (cubic feet/second)			
		10-Year	50-Year	100-Year	500-Year
Burnt Bridge Creek					
At Mouth	22.5	115	220	255	330
At USGS Gage	19.8	120	230	270	340
At N.E. 112th Ave	5.0	55	110	135	180
China Ditch					
At Mouth	8.9	495	665	740	915
Curtin Creek					
At Mouth	11.0	335	460	520	670
At N.E. 109th St	4.5	225	360	405	530
At N. E. 83rd St	1.0	60	85	95	130
E. Fork Lewis River					
At Mouth	212.0	19,200	24,400	26,900	32,000
Upstream of confluence with Lockwood Creek	185.0	17,000	21,700	23,800	28,300
Approximately 17,000' downstream of Daybreak Rd.	165.0	20,650	28,630	32,200	40,900
At Daybreak Rd.	152.0	18,600	26,050	29,300	37,210
At Lewisville Park	150.0	15,300	19,400	21,400	25,400
Fifth Plain Creek					
At Mouth	20.2	1,280	1,750	1,960	2,460
Upstream of China Ditch	9.0	650	895	1,000	1,260
Upstream of Shanghai Creek	4.6	360	495	555	700
At 119th St.	2.6	225	315	330	445
Gee Creek					
At Burlington Northern Railroad	13	850	1,010	1,080	1,260
At County Rd.	9	580	695	745	870
Lacamas Creek					
At Goodwin Rd.	52.8	4,170	5,740	6,430	8,080
At Fourth Plain Rd.	22.7	1,990	2,740	3,060	3,850
Lewis River					
At Mouth	1,046	75,000[a]	114,000[a]	132,700[a]	181,000[a]
At Woodland	820	54,400[a]	86,300[a]	102,000[a]	142,000[a]
At USGS Gage near Ariel	731	49,000[a]	79,000[a]	94,000[a]	132,000[a]
Mill Creek					
At Mouth	11.5	670	985	1,140	1,570
Downstream of unnamed tributary (RM 0.85)	11.0	595	860	1,000	1,370
Upstream of unnamed tributary (RM 0.85)	9.1	510	780	915	1,300
At confluence with unnamed tributary (RM 3.12)	6.7	285	585	685	975
At N.E. 199th St.	4.8	290	415	480	655
Packard Creek					

Source/Location	Drainage area (sq. mi.)	Discharge (cubic feet/second)			
		10-Year	50-Year	100-Year	500-Year
At Mouth	2.4	135	180	200	250
Upstream of unnamed tributary (RM 1.0)	0.6	43	58	64	79
Padden Creek					
At confluence with Curtin Creek	1.0	39	45	48	53
Downstream of N.E. 76th St.	0.8	21 2	21 2	22 2	22[b]
At Interstate 205	0.7	43	57	64	79
Salmon Creek					
At Mouth	88	3,230	4,460	5,020	6,490
At County gage SMN020, Klineline Park	80	2,970	4,100	4,620	5,970
Below Mill Creek	72	2,710	3,730	4,210	5,430
Downstream of confluence with Curtin Creek	60	2,330	3,250	3,700	4,860
At County gage SMN045, N.E. 156th St.	45	1,960	2,740	3,110	4,090
Downstream of confluence with Morgan Creek	31	1,290	1,920	2,240	3,140
At County gage S-01, Battle Ground, WA	18.0	1,130	1,770	2,110	3,120
Spring Branch Creek					
At Mouth	1.8	105	140	155	190
Unnamed Tributary to Gee Creek					
At Mouth	1.7	85	100	105	125
Washougal River					
At Mouth	168	29,800	39,000	43,000	51,900
At USGS gage (RM 9.2)	108	21,500	28,400	31,300	38,000
Weaver Creek					
At Mouth	7.1	350	495	565	755
At N.E. 199th St.	5.9	310	440	500	665
Upstream of unnamed tributary (RM 3.45)	4.4	225	330	385	535
At N.E. 167th Ave.	1.5	85	125	150	205
Whipple Creek					
At mouth Upstream of unnamed tributary (RM 1.19)	11.1	510	685	755	925
Upstream of unnamed tributary (RM 1.19)	9.5	450	600	665	815
Upstream of Packard Creek (RM 2.47)	6.4	320	430	475	580
Upstream of N.E. 157th Ave. (RM 4.53)	4.5	240	320	355	430
Upstream of Interstate 5 Freeway (RM 6.45)	1.9	115	150	170	210
Upstream of NE 179th Street (RM 7.74)	0.9	55	75	85	110
Lewis River[c]					
At confluence with Columbia River	1,046	75,000[a]	114,100[a]	132,700[a]	181,000[a]
At CC Street Bridge	820	54,400[a]	86,300[a]	102,000[a]	142,000[a]
At USGS Gage No. 14220500	731	49,000[a]	79,000[a]	94,000[a]	132,000[a]

Source: FEMA, 2012a and FEMA, 2013a

a. Regulated by Merwin Dam
b. Maximum flow passing NE 76th Street Culvert. Additional flow is diverted out of the basin by NE 76th Street
c. Cowlitz County Flood Insurance Study

10.2.7 Warning Time

Due to the sequential pattern of meteorological conditions needed to cause serious flooding, it is unusual for a flood to occur without warning. Warning times for floods can be between 24 and 48 hours. Flash flooding can be less predictable, but potential hazard areas can be warned in advanced of potential flash flooding danger.

The National Oceanic and Atmospheric Administration and the Washington State Department of Ecology operate river gauges. NOAA stations also provide 4-10 day trend forecasts of near-term river levels. These gauges allow residents to monitor river levels before, during and after a flood. Clark County provides links to seven gauge stations at: https://www.clark.wa.gov/public-works/river-gauge-data.

The National Weather Service Seattle Forecast Office provides weather observations and forecasts for western Washington and issues warnings for many types of hazards, including floods, severe weather, windstorms, snowstorms and fire conditions. The National Weather Service issues a statement when heavy rain is expected to cause flooding or aggravate existing flood conditions. These statements are generally issued two to three days before the potential event. Flood watches for specific areas and rivers are issued one to two days before an event. Flood warnings are issued up to one day in advance when flooding is imminent. This applies to a specific river forecast point that is expected to exceed a flood stage based on predictive computer river modeling output, including dam operation information, and to other streams and urban areas. For large storms and major floods, the National Weather Service conducts direct internet briefings and uses follow-up phone calls to Clark County. National Weather Service statements and information are communicated to other government agencies and the public via NOAA Weather Radio, radio and television, the Internet, telephone recordings and media outlets.

10.3 SECONDARY HAZARDS

The main secondary hazard for flooding is bank erosion, which in some cases can be more harmful than actual flooding. This is especially true in the upper courses of rivers with steep gradients, where floodwaters may pass quickly and without much damage but scour the banks, edging properties closer to the floodplain or causing them to fall in. Flooding is also responsible for hazards such as landslides when high flows over-saturate soils on steep slopes, causing them to fail. Hazardous materials spills are also a secondary hazard of flooding if storage tanks rupture and spill into streams, rivers or storm sewers. Septic systems may cause additional water contamination.

10.4 EXPOSURE

The Level 2 (user-defined) Hazus-MH protocol was used to assess the risk and vulnerability to flooding in the planning area. The model used census data at the block level and FEMA floodplain data, which has a level of accuracy acceptable for planning purposes. Where possible, the Hazus-MH default data was enhanced using local GIS data from county, state and federal sources.

10.4.1 Population

Population counts of those living in the floodplain in the planning area were generated by estimating the percent of the total buildings in each jurisdiction within the 1 percent and 0.2 percent annual chance flood hazard areas and multiplying this percentage by the total population in the planning area. Using this approach, it was estimated that the exposed population for the entire county is 6,720 persons within the 1-percent annual chance flood hazard area (1.5 percent of the total county population) and 12,199 within the 0.2-percent annual chance flood hazard area (2.7 percent of the total). For unincorporated portions of the county, it is estimated that the exposed population is 2,702 within the 1 percent annual chance flood hazard area (1.3 percent of the total unincorporated county population) and 4,028 within the 0.2 percent annual chance flood hazard area (1.9 percent of the total). Table 10-3 shows the population estimates by jurisdiction.

Table 10-3. Population within Flood Hazard Areas

	1-Percent Annual Flood Hazard		0.2-Percent Annual flood hazard	
	Population Exposed[a]	% of Total Population	Population Exposed[a]	% of Total Population
Battle Ground	72	0.4%	112	0.6%
Camas	133	0.6%	342	1.6%
La Center	8	0.3%	8	0.3%
Ridgefield	159	2.5%	162	2.5%
Vancouver	616	0.4%	4,449	2.6%
Washougal	159	1.0%	299	2.0%
Woodland	2,758	47.2%	2,935	50.2%
Yacolt	49	3.0%	49	3.0%
Unincorporated	2,702	1.3%	4,028	1.9%
Total	**6,656**	**1.5%**[b]	**12,199**	**2.7%**[b]

a. Represents the percent of total buildings that are exposed multiplied by the estimated 2015 per-household population
b. Represents the total affected population as a percent of total Clark County population.

10.4.2 Property

Structures in the Floodplain

Table 10-4 and Table 10-5 summarize the total area and number of structures in the floodplain by municipality. Spatial analysis determined that there are 2,199 structures within the 1-percent annual chance flood hazard area and 3,992 structures within the 0.2-percent annual chance flood hazard area. In the 1-percent annual chance flood hazard area, about 40 percent of the structures are in the City of Woodland and 43 percent are in unincorporated County areas. It is assumed that 92 percent (2,023) of the structures in the 1-percent annual chance flood hazard area are residential.

Table 10-4. Area and Structures in the 1-Percent Annual Chance Flood Hazard Area

	Area in Floodplain (Acres)	Number of Structures in Floodplain							
		Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
Battle Ground	144	16	6	0	0	0	0	0	22
Camas	1,885	39	6	0	0	2	0	0	47
La Center	34	2	0	0	1	0	0	0	3
Ridgefield	163	53	5	0	0	0	0	0	58
Vancouver	5,901	134	43	2	2	0	0	0	181
Washougal	960	37	17	4	0	0	0	0	58
Woodland	533	859	5	1	0	5	1	0	871
Yacolt	17	14	0	0	2	0	0	0	16
Unincorporated	35,218	869	25	0	41	4	3	1	943
Total	**44,855**	**2,023**	**107**	**7**	**46**	**11**	**4**	**1**	**2,199**

Table 10-5. Area and Structures in the 0.2-Percent Annual Chance Flood Hazard Area

	Area in Floodplain (Acres)	Number of Structures in Floodplain							
		Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
Battle Ground	171	20	14	0	0	0	0	0	34

	Area in Floodplain (Acres)	Number of Structures in Floodplain							
		Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
Camas	2,114	101	11	5	1	2	1	0	121
La Center	35	2	0	0	1	0	0	0	3
Ridgefield	186	54	5	0	0	0	0	0	59
Vancouver	7,124	1,173	123	7	5	0	0	0	1,308
Washougal	992	88	17	4	0	0	0	0	109
Woodland	585	923	5	1	0	5	1	1	936
Yacolt	17	14	0	0	2	0	0	0	16
Unincorporated	36,873	1,302	46	2	42	6	5	3	1,406
Total	**48,098**	**3,677**	**221**	**19**	**51**	**13**	**7**	**4**	**3,992**

Exposed Value

Table 10-6 and Table 10-7 summarize the estimated value of exposed buildings in the planning area. This methodology estimated $2 billion worth of building-and-contents exposed to the 1-percent annual chance flood, representing 1.8 percent of the total replacement value of the planning area, and $4.65 billion worth of building-and-contents exposed to the 0.2-percent annual chance flood, representing 4.1 percent of the total.

Land Use in the Floodplain

Some land uses, such as single-family homes, are more vulnerable to flooding than others, such as agricultural land or parks. Table 10-8 shows the existing land use of parcels that intersect the 1-percent annual chance flood hazard area and 0.2-percent annual chance flood hazard area. More than 21 percent of the parcels that intersect the 1-percent annual chance flood hazard area are estimated to be agriculture, vacant, or uncategorized uses. These are favorable, lower-risk uses for the floodplain. The majority of the acreage of land area in the floodplain is categorized as residential, although, much of this acreage is likely to be zoned for low densities given that most floodplain acreage in the County is located in the unincorporated areas.

10.4.3 Critical Facilities and Infrastructure

Critical facilities and infrastructure in the 1-percent annual chance flood hazard area and 0.2-percent annual chance flood hazard area of the planning area are summarized in Table 10-9 and Table 10-10. Details are provided in the following sections.

Hazardous Material Facilities

Tier II facilities are those that use or store materials that can harm the environment if damaged by a flood. The planning area includes 7 businesses in the 1-percent annual chance flood hazard area and 18 businesses in the 0.2-percent annual chance flood hazard area that report having Tier II hazardous materials. During a flood event, containers holding these materials can rupture and leak into the surrounding area, having a disastrous effect on the environment as well as residents.

Table 10-6. Value of Structures in 1-Percent Annual Chance Flood Hazard Area

	Value Exposed			% of Total Replacement value
	Structure	Contents	Total	
Battle Ground	$18,084,598	$16,738,872	$34,823,470	0.9%
Camas	$80,316,052	$71,731,971	$152,048,023	2.0%
La Center	$3,462,254	$3,342,247	$6,804,500	0.8%

	Value Exposed			% of Total Replacement value
	Structure	Contents	Total	
Ridgefield	$9,204,301	$5,923,557	$15,127,858	0.7%
Vancouver	$278,749,595	$265,720,572	$544,470,168	1.1%
Washougal	$86,686,255	$88,425,937	$175,112,192	4.2%
Woodland	$188,416,451	$110,077,142	$298,493,593	16.8%
Yacolt	$8,640,290	$7,542,385	$16,182,674	5.3%
Unincorporated County	$435,510,126	$329,454,660	$764,964,787	1.7%
Total	**$1,109,069,922**	**$898,957,343**	**$2,008,027,265**	**1.8%**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 10-7. Value of Structures in 0.2-Percent Annual Chance Flood Hazard Area

	Value Exposed			% of Total Replacement value
	Structure	Contents	Total	
Battle Ground	$35,145,967	$34,400,310	$69,546,277	1.7%
Camas	$225,726,464	$260,645,291	$486,371,755	6.4%
La Center	$3,462,254	$3,342,247	$6,804,500	0.8%
Ridgefield	$9,356,528	$5,999,671	$15,356,199	0.7%
Vancouver	$1,201,876,649	$1,135,344,038	$2,337,220,687	4.9%
Washougal	$100,510,404	$95,338,012	$195,848,415	4.7%
Woodland	$209,535,680	$124,872,914	$334,408,594	18.8%
Yacolt	$8,640,290	$7,542,385	$16,182,674	5.3%
Unincorporated County	$679,908,753	$510,421,979	$1,190,330,732	2.7%
Total	**$2,474,162,989**	**$2,177,906,847**	**$4,652,069,833**	**4.1%**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 10-8. Present Land Use Within Parcels Intersecting the Floodplain[a]

Land Use[b]	1-Percent Annual Chance Flood Hazard Area		0.2-Percent Annual Chance Flood Hazard Area	
	Area (acres)[c]	% of Total Area	Area (acres)[c]	% of Total Area
Agriculture/Resource Land	9,561	12.8%	10,216	12.6%
Commercial	7,726	10.3%	8,406	10.4%
Education	423	0.6%	319	0.4%
Governmental Services	311	0.4%	346	0.4%
Industrial	1,130	1.5%	1,142	1.4%
Religious Services	88	0.1%	93	0.1%
Residential	49,133	65.6%	53,684	66.4%
Vacant or uncategorized	6,823	9.1%	6,987	8.6%
Total	**75,195**	**100%**	**81,193**	**100%**

a. Present land use information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Present use classification provided by Clark and Cowlitz County assessor's data assigned to best fit occupancy classes in the Hazus model (see Section 6.3.1). Parcels for which conflicting information on current development was available were assumed to be improved. Some designated resource land may also be included in the vacant or uncategorized category.
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features. Acreage includes Clark County and the incorporated areas of the City of Woodland.

Table 10-9. Critical Facilities in 1-Percent Annual Chance Flood Hazard Area

	Communication Facilities	Dams	Emergency Services	Energy	Government Facilities	Hazardous Materials	Health Care & Public Health	Information Technology	Schools	Transportation Systems	Water & Sanitation Systems	Total
Battle Ground	0	0	0	0	0	0	0	0	0	1	1	**2**
Camas	0	2	0	1	0	0	0	0	0	5	6	**14**
La Center	0	0	0	0	0	0	0	0	0	0	0	**0**
Ridgefield	0	0	0	0	0	0	0	0	0	1	1	**2**
Vancouver	0	0	0	2	0	4	0	0	0	18	2	**26**
Washougal	0	0	0	0	0	3	0	0	0	0	3	**6**
Woodland	0	0	1	1	0	0	0	0	0	0	0	**2**
Yacolt	0	0	0	0	0	0	0	0	0	0	0	**0**
Unincorporated	0	1	0	2	0	0	0	0	0	38	9	**50**
Total	**0**	**3**	**1**	**6**	**0**	**7**	**0**	**0**	**0**	**63**	**22**	**102**

Table 10-10. Critical Facilities in 0.2-Percent Annual Chance Flood Hazard Area

	Communication Facilities	Dams	Emergency Services	Energy	Government Facilities	Hazardous Materials	Health Care & Public Health	Information Technology	Schools	Transportation Systems	Water & Sanitation Systems	Total
Battle Ground	0	0	0	0	0	0	0	0	0	1	1	**2**
Camas	0	2	0	4	0	0	0	0	0	5	7	**18**
La Center	0	0	0	0	0	0	0	0	0	0	0	**0**
Ridgefield	0	0	0	0	0	0	0	0	0	1	1	**2**
Vancouver	0	0	0	3	0	13	0	0	0	37	14	**67**
Washougal	0	0	0	0	0	3	0	0	0	0	3	**6**

Woodland	0	0	1	1	0	0	0	0	1	0	0	**3**
Yacolt	0	0	0	0	0	0	0	0	0	0	0	**0**
Unincorporated	0	1	0	2	0	2	0	0	1	40	13	**59**
Total	**0**	**3**	**1**	**10**	**0**	**18**	**0**	**0**	**2**	**84**	**39**	**157**

Utilities and Infrastructure

Flood damage to infrastructure presents numerous risks. Roads or railroads that are blocked or damaged can isolate residents and can prevent access throughout the county, including for emergency service providers needing to get to vulnerable populations or to make repairs. Bridges washed out or blocked by floods or debris also can cause isolation. Floodwaters can back up drainage systems, causing localized flooding. Culverts can be blocked by debris from flood events, also causing localized urban flooding. Floodwaters can get into drinking water supplies, causing contamination. Sewer systems can be backed up, causing waste to spill into homes, neighborhoods, rivers and streams. Underground utilities can also be damaged. Dikes and levees can fail or be overtopped, inundating the land that they protect.

Roads and Bridges

The following major roads pass through the 1-percent annual chance flood hazard area and thus are exposed to flooding:

- Interstate 205
- Interstate 5
- State Road 500
- State Route 501
- State Route 502
- State Road 503
- State Road 14.

Some of these roads are built above the flood level, and others function as levees to prevent flooding. Still, in severe flood events these roads can be blocked or damaged, preventing access to some areas. Flooding can affect bridges that provide access to neighborhoods. There are 39 bridges in or over the 1-percent annual chance flood hazard area and 41 bridges in or over the 0.2-percent annual chance flood hazard area.

Levees

Clark County's flood protection system includes more than 49 miles of levees. Levee locations can be seen in Figure 10-2. The mileage on each watercourse is as follows (FEMA, 2012a):

- Bachelor Island Slough—6.79 miles
- Columbia River —29.97 miles
- East Fork Lewis River—1.33 miles
- Lake River—3.66 miles
- Lewis River—0.38 miles.

10.4.4 Environment

Flooding is a natural event, and floodplains provide many natural and beneficial functions. Nonetheless, with human development factored in, flooding can impact the environment in negative ways. Migrating fish can wash into roads or over dikes into flooded fields, with no possibility of escape. Pollution from roads, such as oil, and hazardous materials can wash into rivers and streams. During floods, these can settle onto normally dry soils, polluting them for agricultural uses. Human development such as bridge abutments and levees, and logjams from timber harvesting can increase stream bank erosion, causing rivers and streams to migrate into non-natural courses.

Many species of mammals, birds, reptiles, amphibians and fish live in Clark County in plant communities that are dependent upon streams, wetlands and floodplains. Changes in hydrologic conditions can result in a change in the plant community. Wildlife and fish are impacted when plant communities are eliminated or fundamentally altered to reduce habitat. Wildlife populations are limited by shelter, space, food and water. Since water supply is a major limiting factor for many animals, riparian communities are of special importance. Riparian areas are the zones along the edge of a river or stream that are influenced by or are an influence upon the water body. Human disturbance to riparian areas can limit wildlife's access to water, remove breeding or nesting sites, and eliminate suitable areas for rearing young. Wildlife relies on riparian areas and is associated with the flood hazard in the following ways:

- Mammals depend upon a supply of water for their existence. Riparian communities have a greater diversity and structure of vegetation than other upland areas. Beavers and muskrats are now recolonizing streams, wetlands and fallow farm fields, which are converted wetlands. As residences are built in rural areas, there is an increasing concern with beaver dams causing flooding of low-lying areas and abandoned farm ditches being filled in, which can lead to localized flooding.
- A great number of birds are associated with riparian areas. They swim, dive, feed along the shoreline, or snatch food from above. Rivers, lakes and wetlands are important feeding and resting areas for migratory and resident waterfowl. Other threatened or endangered species (such as the bald eagle or the peregrine falcon) eat prey from these riparian areas.
- Amphibians and reptiles are some of the least common forms of wildlife in riparian areas. However, some state threatened species, such as the western pond turtle and the spotted frog, are known to inhabit the waterways and wetlands.
- Fish habitat throughout the county varies widely based on natural conditions and human influence. Many ditches were dug throughout the county to make low, wet ground better for farming. As the water drained away and the wetlands were converted to farm fields, natural stream conditions were altered throughout the county. Agriculture along many rivers extends to the water's edge and smaller side channels have been tiled to drain better. Within developing areas, small streams were placed in pipes and wetland was filled in to support urban development. While salmonids prefer clear, free-flowing streams, other species like the Olympic mud-minnow inhabit the calm, backwater areas of sloughs and wetlands.

10.5 VULNERABILITY

10.5.1 Columbia River Vulnerabilities

Few residential structures are directly exposed to flooding from the Columbia River, in part because much of the area along the river is not residentially zoned. Residential structures that are impacted by high water when the Columbia River floods are generally flooded as a result of the restricted flows of rivers and streams draining into the Columbia (CRESA, 2004).

The commercial development vulnerable to the flooding of the Columbia River includes primarily hotels and restaurants. During the 1995 flood, most commercial uses along the river were interrupted. Newer commercial development is appropriately elevated above the 1-percent annual chance flood level. Since these floodplain fringe areas did not experience high floodwater velocities or large debris in the flows, the elevated structures fared well in the floods. Older structures, however, are more vulnerable (CRESA, 2004).

Industrial development along the floodplain is largely protected through a combination of building elevation and fill (as at the Port of Vancouver), or by levees. Perimeter levees of a drainage district may be capable of withstanding large floods, yet major rainstorms could cause extensive interior ponding in lower areas if runoff exceeds the capacity of the dewatering-drainage pumps. Without regular maintenance, the functionality of any levee will decline (CRESA, 2004).

Port facilities are protected by levee systems and fill and ring dikes around vulnerable structures, but an extreme flood on the Columbia River could breach dikes and lead to flooding in port areas. The port is a major employer and a regional economic driver. Any loss of function at the port would impact the entire region (CRESA, 2004).

The Vancouver water treatment facility is located in the floodplain and protected by a series of ring dikes. These were not severely damaged during the 1995 floods and operation was not interrupted (CRESA, 2004).

The Ridgefield National Wildlife Refuge, which lies downriver from the Port of Vancouver and the Vancouver sewage treatment facilities, is potentially vulnerable to floods and the pollution they may carry. During the 1995 event, floodwaters flowed over port lands and onto these critical areas. However, because the port chemical storage tanks and the Vancouver sewage treatment facilities remained intact, the sanctuary was not severely impacted (CRESA, 2004).

10.5.2 Riverine Flooding Vulnerabilities

The major issue related to riverine flooding in Clark County is the large number of new homes that could be constructed in floodplains. Any new development built in a floodplain increases the number of residences and other structures exposed to flooding, increasing risk to life and property along with the damage figures from any flood event. Large numbers of additional homes in the floodplain mean that even floods that are now considered minor could cause large amount of damage in the future (CRESA, 2004).

While new construction in Clark County floodplains exceeds the development standards required by the National Flood Insurance Program, risk is not entirely eliminated. Development, even when compliant with NFIP standards, is served by infrastructure that is vulnerable to flooding. Individual homes may be resistant to flooding, but the roads and drainage systems that serve them could flood, leading to isolation and property damage. Almost 80 percent of all of the structures insured through the NFIP cover structures constructed since 1980, and 60 percent have been built since 1990. Since flood insurance is required on new development if it falls within the floodplain, this figure evidences the increasing number of structures in flood-prone areas (CRESA, 2004).

10.5.3 Stormwater Problems and Shallow Flooding Areas

Much of southwestern Clark County is relatively flat, with poorly drained soils. During heavy rainstorms, water ponds in this area. In 1995, many homeowners suffered water damage that was not directly associated with flooding in a river (CRESA, 2004). This type of flooding is more than a nuisance to homeowners. Severe structural damage can result from wet shifting soils, and damp foundations can allow mildew and related harmful agents. These shallow flooding areas, while causing challenging building environments, often provide excellent natural habitat (CRESA, 2004).

Increased development and the accompanying built land cover are causing increased flood elevations and increased runoff in the stormwater system. With increased development, the vulnerability of local road and drainage systems would increase from overland flow and blocked culverts. These impacts could isolate some residents from emergency services during a major event (CRESA, 2004).

10.5.4 Population

Vulnerable Populations

A geographic analysis of demographics using the Hazus-MH model identified populations vulnerable to the flood hazard as follows:

- **Economically Disadvantaged Populations**—An estimated 14 percent (543) of households within the 1-percent annual chance flood hazard area are economically disadvantaged, defined as having household incomes of $20,000 or less.
- **Population over 65 Years Old**—An estimated 13 percent (1,390) of the population in the census blocks that intersect the 1-percent annual chance flood hazard area are over 65 years old.
- **Population under 16 Years Old**—An estimated 26 percent (2,717) of the population within census blocks located in or near the 1-percent annual chance flood hazard area are under 16 years of age.

Impacts on Persons and Households

Table 10-11 summarizes estimated impacts on persons in the planning area for the 1-percent annual chance and 0.2-percent annual chance flood events.

Table 10-11. Estimated Flood Impact on Persons[a]

	1 Percent Annual Chance		0.2 Percent Annual Chance	
	Displaced Persons	Persons Requiring Short-Term Shelter	Displaced Persons	Persons Requiring Short-Term Shelter
Battle Ground	235	95	304	153
Camas	459	360	546	456
La Center	30	18	30	19
Ridgefield	93	18	121	30
Vancouver	2,195	1,899	3,622	3,209
Washougal	302	226	405	336
Woodland	2,236	2,169	2,445	2,369
Yacolt	82	17	76	14
Unincorporated	4,433	2,491	6,191	3,846
Total	**10,065**	**7,293**	**13,740**	**10,432**

a. Hazus-MH results in this table are not intended to be precise estimates of damage after a hazard event. They represent generalized estimates of damage that may occur as the result of the modeled scenario, based on the available data.

Public Health and Safety

Floods and their aftermath present the following threats to public health and safety:

- **Unsafe food—**Floodwaters contain disease-causing bacteria, dirt, oil, human and animal waste, and farm and industrial chemicals. They carry away whatever lies on the ground and upstream. Their contact with food items, including food crops in agricultural lands, can make that food unsafe to eat and hazardous to human health. Power failures caused by floods damage stored food. Refrigerated and frozen foods are affected during the outage periods, and must be carefully monitored and examined prior to consumption. Foods kept inside cardboard, plastic bags, jars, bottles, and paper packaging are subject to disposal if contaminated by floodwaters. Even though the packages do not appear to be wet, they may be unhygienic with mold contamination and deteriorate rapidly.

- **Contaminated drinking and washing water and poor sanitation—**Flooding impairs clean water sources with pollutants. Contact with the contaminants—whether through direct food intake, vector insects such as flies, unclean hands, or dirty plates and utensils—can result in waterborne illnesses and life-threatening infectious disease. The pollutants also saturate into the groundwater or can infiltrate into sanitary sewer lines through the ground. Wastewater treatment plants, if flooded and caused to malfunction, can be overloaded with polluted runoff waters and sewage beyond their disposal capacity, resulting in backflows of raw sewage to homes and low-lying grounds. Private wells can be contaminated or damaged severely by floodwaters, while private sewage disposal systems can become a cause of infection if they are broken or overflow. Unclean drinking and washing water and sanitation, coupled with lack of adequate sewage treatment, can lead to disease outbreaks.
- **Mosquitoes and animals—**Prolonged rainfall and floods provide new breeding grounds for mosquitoes—wet areas and stagnant pools—and can lead to an increase in the number of mosquito-borne diseases such as malaria and dengue and West Nile fevers. Rats and other rodents and wild animals also can carry viruses and diseases. The public should avoid such animals and should dispose of dead animals in accordance with guidelines issued by local animal control authorities. Leptospirosis—a bacterial disease associated predominantly with rats—often accompanies floods in developing countries, although the risk is low in industrialized regions unless cuts or wounds have direct contact with disease-contaminated floodwaters or animals.
- **Mold and mildew—**Excessive exposure to mold and mildew can cause flood victims—especially those with allergies and asthma—to contract upper respiratory diseases, triggering cold-like symptoms. Molds grow in as short a period as 24 to 48 hours in wet and damp areas of buildings and homes that have not been cleaned after flooding, such as water-infiltrated walls, floors, carpets, toilets and bathrooms. Very small mold spores can be easily inhaled by human bodies and, in large enough quantities, cause allergic reactions, asthma episodes, and other respiratory problems. Infants, children, elderly people and pregnant women are considered most vulnerable to mold-induced health problems.
- **Carbon monoxide poisoning—**Carbon monoxide poisoning is as a potential hazard after major floods. In the event of power outages following floods, flood victims tend to use alternative sources of fuels for heating or cooking inside enclosed or partly enclosed houses, garages or buildings without an adequate level of air ventilation. Carbon monoxide can be found in combustion fumes such as those generated by small gasoline engines, stoves, generators, lanterns, gas ranges, or the burning of charcoal or wood. Built-up carbon monoxide from these sources can poison people and animals.
- **Hazards when reentering and cleaning flooded homes and buildings—**Flooded buildings can pose significant health hazards to people entering and cleaning damaged buildings or working to restore utility service after floodwaters recede. Electrical power systems, including fallen power lines, can become hazardous. Gas leaks from pipelines or propane tanks can trigger fire and explosion. Flood debris—such as broken bottles, wood, stones and walls—may cause wounds and injuries to those removing contaminated mud and cleaning damaged buildings. Containers of hazardous chemicals, including pesticides, insecticides, fertilizers, car batteries, propane tanks and other industrial chemicals, may be hidden or buried under flood debris. A health hazard can also occur when hazardous dust and mold in ducts, fans and ventilators of air-conditioning and heating equipment are circulated through a building and inhaled by those engaged in cleanup and restoration.

- **Mental stress and fatigue**—Having experienced a devastating flood and seen loved ones lost or injured and homes damaged or destroyed, flood victims can experience long-term psychological impact. The expense and effort required to repair flood-damaged homes places severe financial and psychological burdens on the people affected, in particular the unprepared and uninsured. Post-flood recovery—especially when it becomes prolonged—can cause mental disorders, anxiety, anger, depression, lethargy, hyperactivity, sleeplessness, and, in an extreme case, suicide. Behavior changes may also occur in children such as an increase in bed-wetting and aggression. There is also a long-term concern among the affected that their homes can be flooded again in the future.

Current loss estimation models such as Hazus are not equipped to measure public health impacts such as these. The best level of mitigation for these impacts is to be aware that they can occur, educate the public on prevention, and be prepared to deal with them in responding to flood events.

10.5.5 Property

Hazus-MH calculates flood losses to structures based on flooding depth and structure type. Using historical flood insurance claim data, Hazus-MH estimates the percentage of damage to structures and their contents by applying established damage functions to an inventory. For this analysis, local data on facilities was used instead of the default inventory data provided with Hazus-MH. The analysis is summarized in Table 10-12 and Table 10-13 for the 1-percent annual chance and 0.2-percent annual chance flood events, respectively.

Table 10-12. Loss Estimates for 1-Percent Annual Chance Flood Event

	Structures Impacted[a]	Estimated Loss Associated with Flood			% of Total Replacement value
		Structure	Contents	Total	
Battle Ground	22	$3,549,389	$10,326,798	$13,876,187	0.3%
Camas	38	$23,742,188	$27,038,281	$50,780,469	0.7%
La Center	3	$882,359	$2,187,192	$3,069,551	0.4%
Ridgefield	55	$1,531,604	$2,112,225	$3,643,828	0.2%
Vancouver	144	$15,911,588	$28,909,855	$44,821,442	0.1%
Washougal	41	$13,545,721	$23,465,441	$37,011,162	0.9%
Woodland	789	$24,378,452	$18,152,121	$42,530,573	2.4%
Yacolt	8	$254,442	$222,024	$476,466	0.2%
Unincorporated	813	$60,179,196	$78,011,896	$138,191,093	0.3%
Total	**1913**	**$143,974,939**	**$190,425,833**	**$334,400,771**	**0.3%**

a. Impacted structures are those structures with finished floor elevations below the 100-year water surface elevation. These structures are the most likely to receive significant damage in a 1-percent annual chance flood event

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 10-13. Loss Estimates for 0.2-Percent Annual Chance Flood Event

	Structures Impacted[a]	Estimated Loss Associated with Flood			% of Total Replacement value
		Structure	Contents	Total	
Battle Ground	32	$6,591,957	$21,942,920	$28,534,877	0.7%
Camas	114	$65,196,208	$122,131,590	$187,327,798	2.5%
La Center	3	$1,289,064	$2,252,823	$3,541,886	0.4%
Ridgefield	57	$2,952,044	$3,788,517	$6,740,561	0.3%
Vancouver	1,176	$301,910,535	$527,418,002	$829,328,537	1.7%
Washougal	91	$18,005,170	$28,734,345	$46,739,516	1.1%
Woodland	925	$58,559,688	$51,536,180	$110,095,867	6.2%
Yacolt	7	$184,226	$197,653	$381,878	0.1%

	Structures Impacted[a]	Estimated Loss Associated with Flood			% of Total Replacement value
		Structure	Contents	Total	
Unincorporated	1,231	$99,413,476	$138,695,856	$238,109,333	0.5%
Total	**3,636**	**$554,102,368**	**$896,697,886**	**$1,450,800,253**	**1.3%**

a. Impacted structures are those structures with finished floor elevations below the 500-year water surface elevation. These structures are the most likely to receive significant damage in a 0.2-percent annual chance flood event

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

It is estimated that there would more than $334.4 million of flood loss from a 1-percent annual chance flood event in the planning area. This represents 16.7 percent of the total exposure to the 1-percent annual chance flood and 0.3 percent of the total replacement value for the planning area. It is estimated that there would be $1.45 billion of flood loss from a 0.2-percent annual chance flood event, representing 31 percent of the total exposure to a 0.2-percent annual chance flood event and 1.3 percent of the total replacement value.

National Flood Insurance Program

Table 10-14 lists flood insurance statistics for the jurisdictions in the planning area that participate in the NFIP. In these jurisdictions, 1,519 flood insurance policies provide $414.7 million in insurance coverage. According to FEMA, 145 flood insurance claims were paid between January 1, 1978 and November 30, 2015, for a total $2.84 million, an average of $19,618 per claim (FEMA, 2015b). During this time, 55 claims were closed without payment.

Table 10-14. Flood Insurance Statistics

Jurisdiction	Date of Entry Initial FIRM Effective Date	# of Flood Insurance Policies as of 3/28/2022	Insurance In Force	Total Annual Premium	Total Claims, 11/1978 to 3/28/2022	Value of Claims paid, 11/1978 to 3/28/2022
Battle Ground	04/15/81	17	$4,579,000	$9,025	3	$3,265
Camas	02/18/81	59	$18,212,900	$42,184	6	$13,710
La Center[a]	N/A	0	$0	$0	0	$0
Ridgefield	05/19/81	7	$2,312,000	$3,239	0	$0
Vancouver	08/17/81	401	$120,901,200	$332,621	12	$113,938
Washougal	03/02/81	64	$19,979,000	$41,289	13	$93,962
Woodland[b]	02/01/78	489	$130,721,100	$363,714	72	$962,920
Yacolt	09/05/12	4	$683,200	$7,719	0	$0
Unincorporated	08/02/82	432	$127,113,000	$336,931	113	$1,924,727
Total		**1,473**	**$424,501,400**	**$1,136,722**	**219**	**$3,112,522**

a. La Center has been suspended from the NFIP program as of September 6, 2012.
b. This number represents all of woodland, though only a portion of it is in Clark County.

Source: FEMA, 2015b and FEMA, 2015d

Repetitive Loss

A repetitive loss property is defined by FEMA as an NFIP-insured property that has experienced any of the following since 1978, regardless of any changes in ownership:

- Four or more paid losses in excess of $1,000
- Two paid losses in excess of $1,000 within any rolling 10-year period
- Three or more paid losses that equal or exceed the current value of the insured property.

Repetitive loss properties represent only 1 percent of all flood insurance policies, but historically they account for nearly one-third of the claim payments (National Wildlife Federation, 2006). The government has instituted programs encouraging communities to identify and mitigate the causes of repetitive losses. A report on repetitive losses by the National Wildlife Federation found that 20 percent of these properties are outside any mapped 1-percent annual chance flood hazard area (National Wildlife Federation, 1998). The key identifiers for repetitive loss properties are the existence of flood insurance policies and claims paid by the policies. With the potential for minor flood events every year and major events every five to seven years, the County and its planning partners consider all of the mapped floodplain areas as susceptible to repetitive flooding.

FEMA has identified 10 repetitive loss properties in the planning area as of March 28, 2022. FEMA records indicate that these properties fall in several communities within the County. A further review of the properties determined that 6 are in the 1-percent annual chance flood hazard area. The remaining property is located outside of the 1-percent and 0.2-percent annual chance flood hazard areas and is not located near any mapped flood hazard areas. The dates and amounts of loss were not provided by FEMA, so they cannot be correlated to any known flood or storm events. Based on this information, it is assumed that the repetitive losses are a result of localized drainage issues. All of the properties are single-family residential structures.

A repetitive loss area is the portion of a floodplain holding structures that FEMA has identified as meeting the definition of repetitive loss. The CRS requires participating communities to identify repetitive loss areas. Identifying the broader area helps to identify structures that are at risk but are not on FEMA's list of repetitive loss structures because no flood insurance policy was in force at the time of loss.

10.5.6 Critical Facilities and Infrastructure

Hazus-MH was used to estimate potential flood damage to critical facilities exposed to the flood risk. Using depth/damage function curves to estimate the percent of damage to the building and contents of critical facilities, Hazus-MH correlates these estimates into an estimate of functional down-time (the estimated time it will take to restore a facility to 100 percent of its functionality). This helps to gauge how long the planning area could have limited usage of facilities deemed critical to flood response and recovery. The Hazus critical facility results are shown in Table 10-15 and Table 10-16:

- **1-percent annual chance flood event**—On average, critical facilities would receive 22 percent damage to the structure and 70 percent damage to the contents during a 1-percent annual chance flood.
- **0.2-percent annual chance flood**—A 0.2-percent annual chance flood event would damage the structures an average of 22 percent and the contents an average 67 percent.

Table 10-15. Estimated Damage to Critical Facilities and Infrastructure from 1-Percent Annual Chance Flood

	Number of Facilities Affected	Average % of Total Value Damaged		Days to 100% Functionality
		Building	Content	
Communication Facilities	0	--	--	--
Dams[a]	N/A	N/A	N/A	N/A
Emergency Services	1	15%	70%	630
Energy	3	22%	N/A	N/A
Government Facilities	0	--	--	--
Hazardous Materials	7	28%	N/A	N/A
Health Care & Public Health	0	--	--	--
Information Technology	--	--	--	--

	Number of Facilities Affected	Average % of Total Value Damaged		Days to 100% Functionality
		Building	Content	
Schools	0	--	--	--
Transportation Systems	49	21%	N/A	N/A
Water & Sanitation Systems	22	23%	N/A	N/A
Total	**82**	**22%**	**70%**	**630**

a. Hazus-MH does not produce damage estimates for dams.

Table 10-16. Estimated Damage to Critical Facilities and Infrastructure from 0.2-Percent Annual Chance Flood

	Number of Facilities Affected	Average % of Total Value Damaged		Days to 100% Functionality
		Building	Content	
Communication Facilities	0	--	--	--
Dams[a]	N/A	N/A	N/A	N/A
Emergency Services	1	27%	100%	720
Energy	5	25%	--	--
Government Facilities	0	--	--	--
Hazardous Materials	16	25%	--	--
Health Care & Public Health	0	--	--	--
Information Technology	0	--	--	--
Schools	1	6%	33%	480
Transportation Systems	71	24%	--	--
Water & Sanitation Systems	33	26%	--	--
Total	**127**	**22%**	**67%**	**600**

a. Hazus-MH does not produce damage estimates for dams.

10.5.7 Environment

The environment vulnerable to flood hazard is the same as the environment exposed to the hazard. As with any significant natural hazard event, large of amounts of debris generated from the damaged buildings and infrastructure could have significant environmental impacts. These impacts were estimated for the flood hazard events through the Level 2 Hazus-MH analysis. Table 10-17 summarizes the results.

Table 10-17. Estimated Flood-Caused Debris

	1-percent annual chance event		0.2 percent annual chance event	
	Debris to Be Removed (tons) [a]	Truck Loads[b]	Debris to Be Removed (tons) [a]	Truck Loads[b]
Battle Ground	300.34	12	392.09	16
Camas	31,223.38	1,249	38,173.52	1,527
La Center	1,513.84	61	1,564.54	63
Ridgefield	1,126.04	45	3,050.12	122
Vancouver	74,823.08	2,993	141,288.97	5,652
Washougal	8,348.10	334	10,315.27	413
Woodland	2,447.70	98	4,634.97	185
Yacolt	45.39	2	45.44	2
Unincorporated	31,501.58	1,260	38,887.05	1,555

Total	151,329.47	6,053	238,351.97	9,534

a. Debris generation estimates were based on updated general building stock dataset at a Census Block analysis level.
b. Hazus assumes 25 tons per truck.
Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

At this time this is the best approximation available to measure environmental impacts of flood hazards. The best gauge of vulnerability of the environment would be a review of damage from past flood events. Loss data that segregates damage to the environment was not available at the time of this plan. Capturing this data from future events could be beneficial in measuring the vulnerability of the environment for future updates.

10.5.8 Economic Impact

Economic impact will be largely associated with the location in which flooding occurred. In such areas, commercial buildings may need to be renovated, causing a disruption in associated services. Additionally, many of the port facilities lie within flood hazard areas, which could cause significant economic disruption.

10.6 FUTURE TRENDS

10.6.1 Development

Municipal comprehensive plans guide development in the planning area. The County's Comprehensive Plan sets goals, objectives, policies and actions for frequently flooded areas. The County has developed several plans and initiatives to promote healthy watersheds and to manage stormwater runoff by directing future development away from flood risk areas. Clark County's critical areas regulations regulate how development and redevelopment can safely occur on lands that contain critical areas. Additionally, Clark County and all but one of the municipal planning partners participate in the NFIP and have adopted flood damage prevention regulations in response to its requirements.

Clark County's population increased an average of 1.7% per year between 2010 and 2020, a total of 16.98%. County plans and regulations will reduce the impacts of this future growth on floodplains and critical areas and lessen the impacts of flooding on future development. State-mandated growth management, stormwater management and critical areas regulations have been effective in limiting an increase in flood risk throughout Washington.

Table 10-18 shows the area identified as underutilized or vacant in urban growth areas in the County that intersect the 0.2 percent annual flood hazard, but are outside of the 1 percent annual flood hazard areas generally regulated pursuant to critical areas ordinances and the NFIP.

Table 10-18. Buildable Lands in Urban Growth Areas Intersecting the 0.2-Percent Annual Flood Hazard[a]

	Buildable Area[c] (acres)				
	Residential				
Urban Growth Area[b]	Acres	Units	Commercial	Industrial	Total
Battle Ground	60.59	364	54.10	0	**114.69**
Camas	21.18	127	12.62	55.97	**89.77**
La Center	4.92	20	0.29	0	**5.21**
Ridgefield	98.21	589	0	7.13	**105.33**
Vancouver	374.00	2,992	61.37	865.79	**2,991.99**
Washougal	13.96	84	3.36	0	**17.31**
Woodland[d]	24.97	100	0	0	**24.97**

	Buildable Area[c] (acres)				
	Residential				
Urban Growth Area[b]	Acres	Units	Commercial	Industrial	Total
Yacolt	0	0	0	0	**0**
Total	**597.83**	**4,276.00**	**131.74**	**928.89**	**3,349.27**

a. Buildable lands information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Unincorporated areas outside of urban growth areas are excluded from this assessment. Development in these areas consists largely of rural lands, open space and large residential lots. Changes in development can be assessed through
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage estimates exclude the portions of the City of Woodland in Cowlitz County and thus may be underestimated.

10.6.2 Climate Change

According to the University of Washington Climate Impacts Group, floods are expected to be more extreme and occur more often as a result of climate change. Warmer temperatures result in more winter precipitation falling as rain rather than snow throughout much of the Pacific Northwest. This change will result in the following (University of Washington Climate Impacts Group, 2013):

- Higher winter stream flows with more floods
- Less winter snow accumulation
- Earlier spring snowmelt.
- Earlier peak spring stream flow (already 10 to 30 days earlier than 1948)
- Lower summer stream flows.

Future floods are expected to exceed the capacity and protective abilities of existing flood protection facilities, threatening lives, property, major transportation corridors, communities and regional economic centers.

Changes in Hydrology

Use of historical hydrologic data has long been the standard of practice for designing and operating water supply and flood protection projects. For example, historical data are used for flood forecasting models and to forecast snowmelt runoff for water supply. This method of forecasting assumes that the climate of the future will be similar to that of the period of historical record. However, the hydrologic record cannot be used to predict changes in frequency and severity of extreme climate events such as floods. Going forward, model calibration or statistical relation development must happen more frequently, new forecast-based tools must be developed, and a standard of practice that explicitly considers climate change must be adopted. Climate change is already impacting water resources, and resource managers have observed the following:

- Historical hydrologic patterns can no longer be solely relied upon to forecast the water future.
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management and ecosystem functions.
- Extreme climatic events will become more frequent, necessitating improvement in flood protection, drought preparedness and emergency response.

The amount of snow is critical for water supply and environmental needs, but so is the timing of snowmelt runoff into rivers and streams. Rising snowlines caused by climate change will allow more mountain area to contribute to peak storm runoff. High frequency flood events (e.g. 10-year floods) in particular will likely increase with a changing climate. Along with reductions in the amount of the snowpack and accelerated snowmelt, scientists project greater storm intensity, resulting in more direct runoff and flooding. Changes in watershed vegetation and soil moisture conditions will likewise change runoff and recharge patterns. As stream flows and velocities change, erosion patterns will also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality. With potential increases in the frequency and intensity of wildfires due to climate change, there is potential for more floods following fire, which increase sediment loads and water quality impacts.

As hydrology changes, what is currently considered a 1-percent annual chance flood may strike more often, leaving many communities at greater risk. Planners will need to factor a new level of safety into the design, operation, and regulation of flood protection facilities such as dams, bypass channels and levees, as well as the design of local sewers and storm drains.

10.7 SCENARIO

A likely flooding event would be one similar to the winter 1995 flood. A rainy and cold winter would be broken by warm weather, causing mountain snow to melt and stream runoff to increase. A severe winter storm with strong winds and heavy precipitation would accompany the flooding. Creeks would be overwhelmed at the same time that soil would be less permeable because of frozen ground. The combination would lead to watersheds draining water at overcapacity. Streams would rise above their natural banks, flooding homes and streets in the floodplains. Drainage structures would be overwhelmed, a situation further complicated by blockage from branches downed by the wind. Water would pond and stagnate in flat areas and areas with already-high water tables. Continued warm, rainy weather in the larger Columbia watershed would result in flood stages along the Columbia River. Water would penetrate the levee system in several areas leading to ponding in low-lying industrial areas (CRESA, 2004).

This scenario could be more costly in the future. There would be increased development in mapped floodplains, meaning greater exposure as well as increased flood levels due to increased impervious surfaces. Flood stages would be higher. Ponding would occur for longer periods of time and be more extensive. More human debris would block a greater number of culverts. Existing ring dikes that had protected sewage treatment structures and chemical storage structures might fail, impacting downriver wildland sanctuaries and other critical habitat (CRESA, 2004).

More homes would be present on vulnerable slopes, leading to increased numbers of landslides, with potential to destroy homes and damage roadways. The county emergency services response operations could be over-taxed by such an event. Residents, especially those in the more rural parts of the county, would experience isolation (CRESA, 2004).

10.8 ISSUES

The planning team has identified the following flood-related issues relevant to the planning area:

- The following are issues associated with a 1-percent annual chance flood event:
  - More than 6,650 people are estimated to live within the special flood hazard area.
  - There may be more than 150 million tons of debris following a 1-percent annual chance flood.
  - More than $334 million in damage to building structure and contents would be expected.
  - More than 2,100 structures are within the special flood hazard area. Of these, 92 percent are residential.
- The following are issues associated with a 0.2-percent annual chance flood event:
  - More than 12,100 people are estimated to live within the special flood hazard area.

    - There may be more than 238 million tons of debris following a 0.2-percent annual chance flood.
    - More than $1.45 billion in damage to building structure and contents would be expected.
    - Almost 4,000 structures are within the special flood hazard area. Of these, 92 percent are residential structures.
- There are 10 repetitive loss properties in the planning area.
- A sustained effort should be made to gather historical damage data, such as high water marks on structures and damage reports. The collection of this information will assist with determining the cost-effectiveness of future mitigation projects and will provide more information on the nature of the hazard.
- Ongoing flood hazard mitigation will require funding from multiple sources.
- Flood hazards do not recognize jurisdictional boundaries, and actions in jurisdictions can impact upstream or downstream neighbors. Coordination is necessary to ensure that these connections are understood and hazards are effectively mitigated.
- Floodplain residents need to continue to be educated about flood preparedness and the resources available during and after floods. Flood preparedness can help residents reduce risk to property and lives. Resources that are made available after flood events can help residents make informed decisions that may mitigate future risk to lives and property.
- The risk associated with the flood hazard overlaps the risk associated with other hazards, such as earthquake and landslide. This provides an opportunity to seek mitigation alternatives that can reduce risk for multiple hazards.
- The location of hazardous materials within the floodplain could result in secondary hazards during or after a flood event. Additional risk analysis should be performed on any hazardous-material facilities in the County.
- FEMA maps do not recognize residual risk outside the mapped area. Where levees are accredited, there may be a misperception that there is no flood risk. Public outreach and awareness efforts should emphasize the residual risk behind levees.
- The concept of residual risk should be considered in the design of future capital flood control projects and should be communicated with residents living in the floodplain.
- The impacts of climate change on flooding in the planning area are uncertain.
- The promotion of flood insurance as a means of protecting private property owners from the economic impacts of frequent flood events should continue.
- Existing floodplain-compatible uses such as agricultural and open space need to be maintained. There is constant pressure to convert these existing uses to more intense uses within the planning area during times of moderate to high growth.

11. LANDSLIDE

11.1 GENERAL BACKGROUND

A landslide is a mass of rock, earth or debris moving down a slope. Landslides may be minor or very large, and can move at slow to very high speeds. They can be initiated by storms, earthquakes, fires, volcanic eruptions or human modification of the land. For more information see the Washington Geological Survey (WGS) landslide information page at https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/landslides

Mudslides (or mudflows or debris flows) are rivers of rock, earth, organic matter and other soil materials saturated with water. They develop in the soil overlying bedrock on sloping surfaces when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt. Water pressure in the pore spaces of the material increases to the point that the internal strength of the soil is drastically weakened. The soil's reduced resistance can then easily be overcome by gravity, changing the earth into a flowing river of mud. A mudflow can move rapidly down slopes or through channels and can strike with little or no warning. The material can travel miles from its source, growing as it descends, picking up trees, boulders, cars and anything else in its path. Although these slides behave as fluids, they pack many times the hydraulic force of water due to the mass of material included in them.

Landslides can be some of the most destructive events in nature, posing a serious hazard to properties on or below hillsides. When landslides occur—in response to such changes as increased water content, earthquake shaking, addition of load, or removal of downslope support—they deform and tilt the ground surface. The result can be destruction of foundations, offset of roads, breaking of underground pipes, or overriding of downslope property and structures.

11.1.1 Landslide Failure Types and Runout

Landslides are commonly categorized by the type of initial ground failure. Figure 11-1 through Figure 11-4 show common types of slides (Washington Department of Ecology, 2014). The most common is the shallow colluvial slide, occurring particularly in response to intense, short-duration storms. The largest and most destructive are deep-seated slides, although they are less common than other types.

In addition to the failure type, landslide risk assessment evaluates the post-failure movement of loosened material, called "runout." Runout is assessed for its travel distance and velocity. Mapping of landslide risk areas generally indicates the location of the potential failure, but mapping of areas that would be affected by the runout after the failure is not currently well-developed.

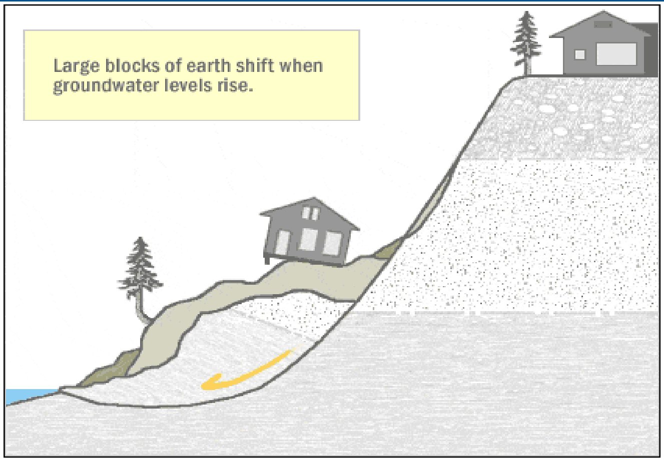

Figure 11-1. Deep Seated Slide

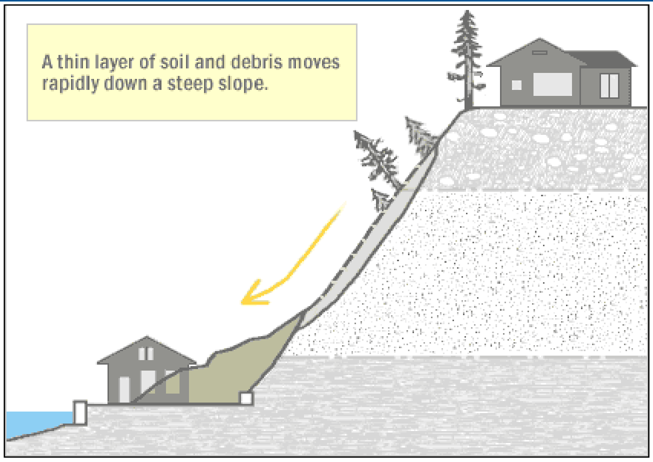

Figure 11-2. Shallow Colluvial Slide

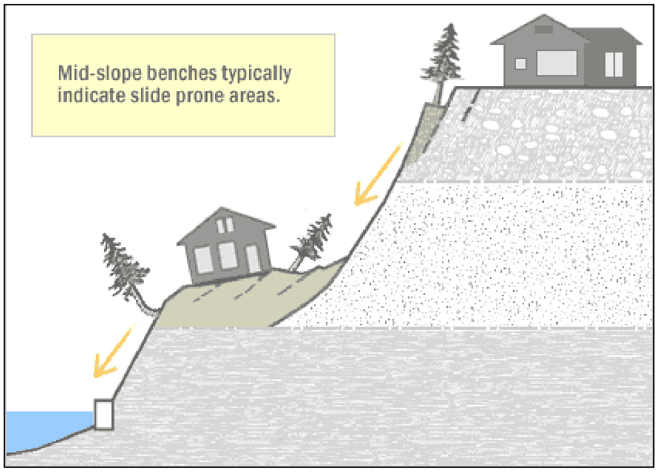

Figure 11-3. Bench Slide

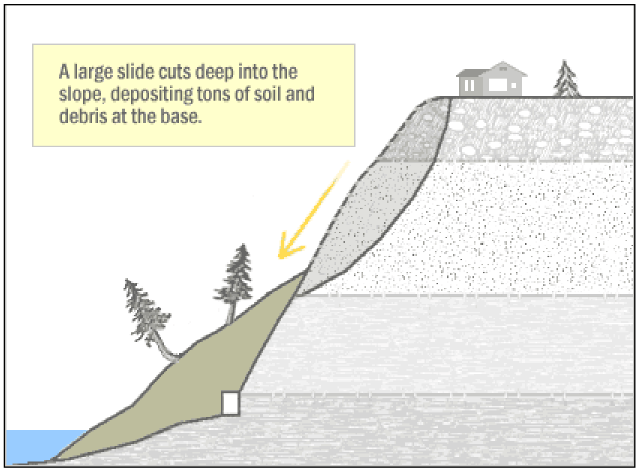

Figure 11-4. Large Slide

11.1.2 Landslide Causes

Mass movements are caused by a combination of geological and climate conditions, as well as the encroaching influence of urbanization. Vulnerable natural conditions are affected by human residential, agricultural, commercial and industrial development and the infrastructure that supports it. The following factors can contribute to landslide:

- Change in slope of the terrain
- Increased load on the land
- Shocks and vibrations
- Change in water content
- Groundwater movement
- Frost action
- Weathering of rocks
- Removing or changing the type of vegetation covering slopes.

Soil composition is also a factor, with many slides occurring on a slope at the contact between a permeable soil such as sand and an underlying impervious material such as clay. The Missoula flood deposits over much of central Clark County are characterized by alternating sand and clay layers (CRESA 2004).

Excavation and Grading

Slope excavation is common in the development of home sites or roads on sloping terrain. Grading can result in some slopes that are steeper than the pre-existing natural slopes. Since slope steepness is a major factor in landslides, these steeper slopes can be at an increased risk for landslides. The added weight of fill placed on slopes can also result in an increased landslide hazard. Small landslides can be fairly common along roads, in either the road cut or the road fill. Landslides occurring below new construction sites are indicators of the potential impacts stemming from excavation. In addition, historical landslide areas are more susceptible to construction-triggered sliding than are undisturbed slopes (CRESA 2004).

A study conducted by Burns and others (1998) at Portland State University found that changes to the slope through cutting or filling increased the risk of 76 percent of inventoried landslides in the Portland Metro region. The study documented 48 landslides that occurred in Oregon City in February 1996 and found that only about half the slides were considered natural. A Seattle landslide study found that human influence played some role in 84 percent of recorded slides (Winters 2015).

Drainage and Groundwater Alterations

Water flowing through or above ground is often the trigger for landslides. Any activity that increases the amount of water flowing into landslide-prone slopes can increase landslide hazards. Broken or leaking water or sewer lines can be especially problematic, as can water retention facilities that direct water onto slopes. However, even lawn irrigation and minor alterations to small streams in landslide prone locations can result in damaging landslides. Ineffective stormwater management and excess runoff can also cause erosion and increase the risk of landslide hazards. Drainage can be affected naturally by the geology and topography of an area. Development that results in an increase in impervious surface impairs the ability of the land to absorb water and may redirect water to other areas. Channels, streams, flooding, and erosion on slopes all indicate potential slope problems.

Road and driveway drains, gutters, downspouts, and other constructed drainage facilities can concentrate and accelerate flow. Ground saturation and concentrated velocity flow are major causes of slope problems and may trigger landslides.

Changes in Vegetation

Removing vegetation from very steep slopes can increase landslide hazards. A study by the Oregon Department of Forestry found that landslide hazards in three out of four steeply sloped areas were highest for a period of roughly 10 years after timber harvesting (Oregon Department of Forestry, 1999). A more recent study of a heavy rain event on Vancouver Island, Canada found that low forest density, indicating regrowth areas, and proximity to forest service roads were jointly associated with a 6- to 9-fold increase in the odds of a landslide (Goetz et al 2015). Areas that have experienced wildfire and land clearing for development may have long periods of increased landslide hazard. In addition, woody debris in stream channels (both natural and man-made from logging) may cause the impacts of debris flows to be more severe.

11.1.3 Landslide Management

While small landslides are often a result of human activity, the largest landslides are often naturally occurring phenomena with little or no human contribution. The sites of large landslides are typically areas of previous landslide movement that are periodically reactivated by significant precipitation or seismic events. Such naturally occurring landslides can disrupt roadways and other infrastructure lifelines, destroy private property, and cause flooding, bank erosion and rapid channel migration. Landslides can create immediate, critical threats to public safety, and engineering solutions to protect structures from large active landslides are often prohibitively expensive.

In spite of their destructive potential, landslides can serve beneficial functions to the natural environment. They supply sediment and large wood to a stream network, contributing to complexity and dynamic channel behavior critical for aquatic and riparian ecological diversity. Effective landslide management should include the following elements:

- Continuing investigation to identify natural landslides, understand their mechanics, assess their risk to public health and welfare, and understand their role in ecological systems
- Regulation of development in or near existing landslides or areas of natural instability.
- Preparation for emergency response to landslides to facilitate rapid, coordinated action among local government and state and federal agencies, and to provide emergency assistance to affected or at-risk residents.
- Evaluation of options including landslide stabilization or structure relocation where landslides are identified that threaten critical public structures or infrastructure.

Critical area ordinances at the local level reduce the impacts of human alterations on critical areas, which include geologically hazardous areas such as areas prone to landslide, erosion, mass-wasting, debris flows and rock falls. The designation of critical areas, including geologically hazardous areas, is a requirement of the Washington State Growth Management Act (WAC 365-190-080(4) and WAC 365-190-120 Geologically Hazardous Areas . The Clark County Title 40 Unified Development Code discourages development in landslide hazard areas; however, development may be allowed when certain requirements are met. In this same chapter, Chapter 40.430 – Geologic Hazard Areas, the County also establishes regulations for development on slopes greater than 40 percent (Clark County Code, 2015). In general, development in a landslide hazard area requires the following:

- A minimum buffer of 50 feet from the edge of the hazard area,
- Designation of the hazard areas and buffers as landslide protection areas,
- No decrease in slope stability on contiguous properties,
- Promotion of mitigation using best-available engineering
- Certification of all clearing and alteration by a registered geotechnical engineer or geologist licensed in the state.

11.2 HAZARD PROFILE

Clark County is topographically level to gently rolling in the southwestern areas, but the eastern and northern areas of the county contain steep, forested foothills and mountains of the Cascade Range. The elevation ranges from sea level to over 3,500 feet in the foothills in the eastern portion of the county. Historically, Clark County has experienced landslides as a result of slope instability, foundation distress, and poor drainage (Dames and Moore 2000). Landslides have become more common in the last decade and may be attributed to the rapid population growth and development, combined with the intense rainfall that occurs in this area (CRESA 2004).

11.2.1 Past Events

Most significant slide events in Clark County have occurred during or shortly after storm events. Four federal disaster declarations with listed landslide or mudslide impacts have affected Clark County since 1977. The Washington State Hazard Mitigation Plan lists the following landslide events as having impacted Clark County (FEMA, 2022; Washington Emergency Management Division 2020; CRESA 2004):

- **December 10, 1977—**Clark County was included in FEMA DR-545 for the Washington Severe Storms, Mudslides, Flooding.
- **1996-1997—**Heavy rains from a series of strong Pacific storms during the last week of December loosened hillsides throughout Southwest Washington. Numerous mudslides cut roads

and threatened homes during the first week of January. One major landslide occurred 2 miles north of Woodland (outside of Clark County) in which 32,000 cubic yards of material fell across all lanes of Interstate 5, blocking traffic for several hours. A large slide near Battle Ground slowly flowed down a hillside and threatened nearby homes through the month of January. A slide occurred near Jenny Creek in Northwest Clark County.

- **December 23, 2002—**A landslide blocked a portion of the Washougal River Road, producing traffic problems.
- **November 2-11, 2006—**Clark County was included in FEMA DR-1671 for the Washington Severe Storms, Flooding, Landslides, and Mudslides.
- **December 14-15, 2006—**Clark County was included in FEMA DR-1682 for the Washington Severe Storm, Landslides, and Mudslides.
- **January 2009—**A warm wet storm from the Pacific Ocean brought significant amounts of rainfall, flooding, and soil saturation to the state, causing over 1,500 landslides greater than 5,000 square feet in size. The landslides in Clark County were primarily along the Interstate 5 corridor, in the Kelso and Longview areas, and on or near Highway 504.
- **December 1, 2015—**Clark County was included in FEMA DR-4253 for the Washington Severe Winter Storms, Straight Line Winds, Flooding, Landslides, Mudslides and a Tornado. Northbound Interstate 5 was closed due to a slide near Woodland.

11.2.2 Location

Slides can occur in urban and rural areas throughout the County. In general, landslide hazard areas are where the land has characteristics that contribute to the risk of the downhill movement of material, such as the following (Washington Department of Community, Trade and Economic Development, 2007):

- Areas of historical failures
- Areas with all three of the following characteristics:
  - Slopes steeper than 15 percent
  - Hillsides intersecting geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock
  - Springs or groundwater seepage
- Areas that have shown movement within the last 11,000 years or that are underlain or covered by mass wastage debris of that time period
- Slopes that are parallel or subparallel to planes of weakness (such as bedding planes, joint systems, and fault planes) in subsurface materials
- Slopes with gradients steeper than 80 percent subject to rock-fall during seismic shaking
- Areas potentially unstable as a result of rapid stream incision, stream bank erosion, and undercutting by wave action
- Areas that show evidence of, or that are at risk from, snow avalanches
- Areas in a canyon or on an active alluvial fan, presently or potentially subject to inundation by debris flows or catastrophic flooding
- Any area with a slope of 40 percent or steeper and with a vertical relief of 10 or more feet, except areas composed of consolidated rock.

According to the Washington State Hazard Mitigation Plan, the state has six major landslide provinces. Clark County is in the Southwest Washington landslide province, although the County has a lower frequency of major landslides than elsewhere in the state. Southwest Washington is primarily characterized by a lack of glaciation and local exposure to glacial melt water. Much of this area has deeply dissected terrain and areas of mid-slope benches and gentle slopes. The State Hazard Mitigation Plan notes that Crescent and similar intrusive rocks are the dominant lithology where shallow landslides occur. Deep-seated landslides are found more in surrounding marine and nearshore sediments (Washington Emergency Management Division, 2014).

Landslide hazard areas and steep slopes within the planning area are shown on Figure 11-5. The landslide areas presented are a combination of Clark County and Washington Department of Natural Resources datasets that show historical, potential or active landslide hazard areas compiled from a variety of landslide databases.

11.2.3 Frequency

Landslides are an annual event in Clark County, and significant events occur every five years on average. Landslides are often triggered by other natural hazards such as earthquakes, heavy rain, floods or wildfires, so landslide frequency is often related to the frequency of these other hazards.

Slides can occur at any time, although most occur during the rainy season. All of the significant landslides in Clark County have occurred in November, December or January. These landslides typically occur during and after major storms, so the potential for landslides largely coincides with the potential for sequential severe storms that saturate steep, vulnerable soils. Precipitation influences the timing of landslides on three scales: total annual rainfall, monthly rainfall, and single precipitation events. In general, landslides are most likely during periods of higher than average rainfall.

11.2.4 Severity

Landslides destroy property and infrastructure and can take the lives of people. Landslides in Clark County are typically not sudden releases of material and are a function of saturation from heavy rain and snowmelt (CRESA 2004). Landslide events often occur concurrently with other hazard events, so damage estimates specifically related to landslide are difficult to obtain. There are no records of fatalities attributed to mass movement in the County. However, deaths have occurred in neighboring Washington counties and across the west coast as a result of slides and slope collapses.

The State Road 530 landslide that occurred in Oso, Washington showed the devastating damage that can be caused by landslides. On March 22, 2014, the slide traveled over 60 mph, covering over a square mile of land and depositing a thickness of 15 to 75 feet in some areas. The slide caused 43 fatalities and 12 injuries, destroyed 37 homes, and destroyed State Route 530 for over a mile. The debris blocked the North Fork Stillaguamish River for over 24 hours, backing up a pool of water that flooded the valley about 2 miles upstream and reached approximately 20 feet deep, inundating an additional 6 homes. Total property damage was estimated at $60 million (NOAA 2015). Although Oso is located in the northern part of the state and Clark County in the southern part, the magnitude of this event as well as its occurrence in the same state have heightened the awareness of the severity of this hazard in the planning area.

Landslide Hazard Areas

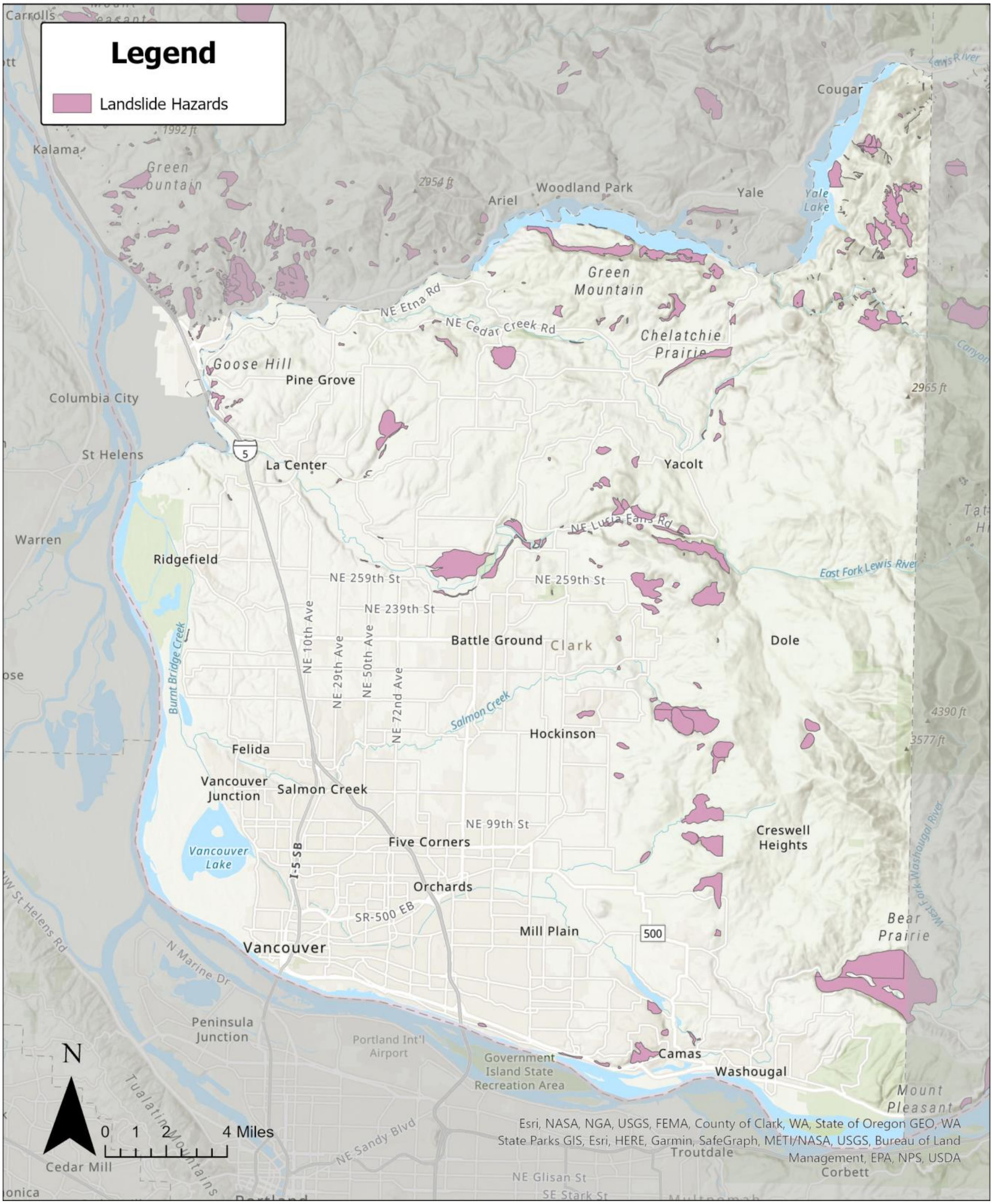

Figure 11-5. Landslide Hazard Areas

11.2.5 Warning Time

Mass movements can occur suddenly or slowly. The velocity of movement may range from inches per year to many feet per second, depending on slope angle, material and water content. Generally accepted warning signs for landslide activity include the following:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements or sidewalks
- Soil moving away from foundations
- Ancillary structures such as decks and patios tilting and/or moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still falling or just recently stopped
- Sticking doors and windows, and visible open spaces indicating frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together.

Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. Assessing the geology, vegetation and amount of predicted precipitation for an area can help in predictions of what areas are generally at risk. Currently, there is no practical warning system for individual landslides. The standard operating procedure is to monitor situations on a case-by-case basis and respond after an event has occurred.

The Washington Geological Survey, in cooperation with NOAA, has developed a generalized landslide awareness map for shallow landslides.   Located here, WGS Mapped Landslides the forecasting model is based on recent and predicted rainfall data. The awareness map is not intended to forecast individual landslide events before they occur, but it will be a useful system for alerting residents to be more vigilant about landslide risk. The landslide awareness map associated with this system provides additional information by county for residents (Washington Department of Natural Resources, 2016b).

11.3 SECONDARY HAZARDS

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures. Vegetation or poles on slopes can be knocked over, resulting in possible losses to power and communication lines. Landslides also have the potential of destabilizing the foundation of structures, which may result in monetary loss for residents. They also can damage rivers or streams, potentially harming water quality, fisheries and other habitat.

11.4 EXPOSURE

Landslides exposure data is related to the landslide hazard area map shown in Figure 11-5 Landslide Hazard Area.

11.4.1 Population

Population could not be examined by landslide hazard area because census block group areas do not coincide with the hazard areas. A population estimate was made using the structure count of buildings within the landslide hazard areas and applying the census value of 2.7 persons per household for Clark County and 3.17 persons per household for the City of Woodland. Using this approach, the estimated population living in the landslide risk area is 10,580 or 2.3 percent of the total planning area population. This includes only populations within defined landslide risk areas; it does not include persons who may be impacted by landslide runout. Table 11-1 shows the estimated population exposure by city.

Table 11-1. Estimated Population Residing in Landslide Risk Areas

	Population Exposed[a]	% of Total Population
Battle Ground	251	1.3%
Camas	2,084	9.8%
La Center	176	5.7%
Ridgefield	257	4.0%
Vancouver	470	0.3%
Washougal	772	5.1%
Woodland	10	0.2%
Yacolt	162	10.0%
Unincorporated	6,399	3.0%
Total	**10,580**	**2.3%**

a. Value calculated as number of buildings exposed multiplied by 2.7 people (Clark Co) / 3.17 people (Woodland) per building. This multiplier is the number of persons per household per the U.S. Census Bureau, State, County and City Quick Facts 2009-2015.

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

11.4.2 Property

Table 11-2 shows the number and replacement value of structures exposed to the landslide risk. Table 11-3 shows the types of structures in landslide hazard areas. There are an estimated 3,918 structures on parcels in the landslide risk areas, with an estimated value of $1.88 billion. This represents 1.7 percent of the total replacement value for the planning area. Over 98 percent of the exposed structures are estimated to be residential structures. Table 11-4 shows the general land use of parcels exposed to landslides in Clark County. Most of the land area of parcels intersecting landslide hazard areas is residential (56.5 percent); agricultural/resource lands make up 29.3 percent.

Table 11-2. Exposure and Value of Structures in Landslide Risk Areas

	Buildings Exposed	Value Exposed			% of Total Replacement Value
		Structure	Contents	Total	
Battle Ground	93	$27,118,550	$13,559,275	$40,677,825	1.0%
Camas	772	$290,399,860	$179,019,753	$469,419,613	6.2%
La Center	65	$19,576,851	$10,324,107	$29,900,958	3.7%
Ridgefield	95	$28,711,585	$15,871,853	$44,583,438	2.1%
Vancouver	174	$65,356,297	$34,422,777	$99,779,073	0.2%
Washougal	286	$78,247,726	$39,123,863	$117,371,589	2.8%
Woodland	3	$534,793	$267,396	$802,189	0.0%
Yacolt	60	$7,772,765	$3,886,382	$11,659,147	3.8%
Unincorporated	2,370	$662,389,959	$407,534,166	$1,069,924,125	2.4%
Total	**3,918**	**$1,180,108,386**	**$704,009,572**	**$1,884,117,957**	**1.7%**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 11-3. Structures in Landslide Hazard Areas

	Number of Structures in Landslide Hazard Areas							
	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
Battle Ground	93	0	0	0	0	0	0	93
Camas	763	6	0	2	0	0	1	772
La Center	64	1	0	0	0	0	0	65
Ridgefield	94	0	0	0	1	0	0	95
Vancouver	172	0	0	2	0	0	0	174
Washougal	286	0	0	0	0	0	0	286
Woodland	3	0	0	0	0	0	0	3
Yacolt	60	0	0	0	0	0	0	60
Unincorporated	2,317	6	0	41	4	2	0	2,370
Total	**3,852**	**13**	**0**	**45**	**5**	**2**	**1**	**3,918**

Table 11-4. Present Land Use in Parcels Intersecting Landslide Risk Areas[a]

Present Use Classification[b]	Area in Landslide Risk Area (acres)[c, d]	% of total exposed acreage
Agriculture/Resource Land	38,089	29.3%
Commercial	4,034	3.1%
Education	778	0.6%
Governmental Services	2,904	2.2%
Industrial	1,013	0.8%
Religious Services	64	0.0%
Residential	73,433	56.5%
Vacant or uncategorized	9,643	7.4%
Total	**129,957**	**100%**

a. Present land use information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Present use classification provided by Clark and Cowlitz County assessor's data assigned to best fit occupancy classes in FEMA's Hazus model (see Section 6.3.1). Parcels for which conflicting information on current development was available were assumed to be improved. Some designated resource land may also be included in the vacant or uncategorized category.
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage includes Clark County and the incorporated area of the City of Woodland.

11.4.3 Critical Facilities and Infrastructure

Table 11-5 summarizes the critical facilities exposed to the landslide hazard. The following infrastructure can be exposed to mass movements:

- Roads—Roads are frequently partially or completely blocked by landslides. Major roads in the planning area that intersect mapped hazard areas include Interstates 5 and 205 and State Routes 14, 500, 501, 502 and 503.
- Power Lines—Power lines are generally elevated above steep slopes, but a landslide can trigger failure of the soil underneath the towers supporting them, causing collapse and ripping down the lines.
- Rail Lines—The BNSF Railway and the Clark County Railroad cross Clark County. The BNSF Railway passes through Ridgefield along a slope currently classified as potentially unstable. The Lewis and Clark Railway passes between Battleground and Yacolt in an area that is classified as a slope of potential instability. The BNSF Railway also passes along dangerous slopes in Camas and Washougal, as well as areas where old landslide debris was located (CRESA 2004).

- Pipelines— Pipelines can de damaged or buried by landslides. Both the Northwest and Olympic pipelines cross through landslide hazard areas.

Table 11-5. Critical Facilities and Infrastructure Exposed to Landslide Hazard

	Commu-nication Facilities	Dams	Emer-gency Services	Energy	Govern-ment Facilities	Hazardous Materials	Health Care & Public Health	Infor-mation Technol-ogy	Schools	Trans-portation Systems	Water & Sanitation Systems	Total
Battle Ground	0	0	0	0	0	0	0	0	0	0	0	**0**
Camas	0	0	0	0	0	0	3	0	1	1	5	**10**
La Center	0	0	0	0	0	0	0	0	0	0	2	**2**
Ridgefield	0	0	0	0	0	0	0	0	0	0	1	**1**
Vancouver	0	0	0	0	0	0	0	0	0	1	0	**1**
Washougal	0	0	0	0	0	0	0	0	0	0	0	**0**
Woodland	0	0	0	0	0	0	0	0	0	0	0	**0**
Yacolt	0	0	0	0	0	0	0	0	0	0	0	**0**
Unincorporated	0	0	0	0	0	0	0	0	1	12	15	**28**
Total	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**2**	**14**	**23**	**42**

11.4.4 Environment

Landslides that fall into streams may significantly impact fish and wildlife habitat, as well as affecting water quality. Hillsides that provide wildlife habitat can be lost for prolonged periods due to landslides. Topography may shift, and sediment accumulation downslope can block waterways and roadways, impacting the quality of streams and other water bodies. However, landslides also provide resources for many ecosystems. They contribute sediment and wood needed for building complex in-stream habitats, estuarine marshes, and beaches that are important for fisheries, wildlife and recreation (Washington Department of Community, Trade and Economic Development, 2007).

11.5 VULNERABILITY

11.5.1 Population

Due to the nature of census block group data, it is difficult to estimate populations vulnerable to landslides. In general, all of the estimated 10,580 persons exposed to the landslide hazard are considered to be vulnerable. Increasing population, and the fact that many homes are built on view property atop or below bluffs and on steep slopes subject to mass movement, increases the number of lives endangered by this hazard. In addition, people may be impacted if transportation corridors are disrupted by the landslide hazard.

11.5.2 Property

Loss estimations for the landslide hazard are not based on modeling using damage functions, because no such damage functions have been generated. Instead, loss potential was developed representing 10 percent, 30 percent and 50 percent of the replacement value of exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 11-6 shows the general building stock loss estimates in landslide risk areas. It is highly unlikely that all landslide-prone areas would slide at the same time.

Table 11-6. Loss Potential for Landslide

		Estimated Loss Potential from Landslide		
	Exposed Value	10% Damage	30% Damage	50% Damage
Battle Ground	$40,677,825	$46,941,961	$140,825,884	$234,709,807
Camas	$469,419,613	$2,990,096	$8,970,287	$14,950,479
La Center	$29,900,958	$4,458,344	$13,375,031	$22,291,719
Ridgefield	$44,583,438	$9,977,907	$29,933,722	$49,889,537
Vancouver	$99,779,073	$11,737,159	$35,211,477	$58,685,795
Washougal	$117,371,589	$80,219	$240,657	$401,095
Woodland	$802,189	$1,165,915	$3,497,744	$5,829,574
Yacolt	$11,659,147	$46,941,961	$140,825,884	$234,709,807
Unincorporated	$1,069,924,125	$2,990,096	$8,970,287	$14,950,479
Total	**$1,884,117,957**	**$127,283,658**	**$381,850,973**	**$636,418,292**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

11.5.3 Critical Facilities and Infrastructure

There are 42 critical facilities exposed to the landslide hazard to some degree. A more in-depth analysis of mitigation measures taken by these facilities should be done to determine if they could withstand impacts of a mass movement. No loss estimates were developed due to the lack of established damage functions for the landslide hazard.

All infrastructure and transportation corridors identified as exposed to the landslide hazard are considered vulnerable until more information becomes available. Protecting roads from hazards becomes particularly important in situations where they provide the only route into and out of an area. Particular areas of concern include some roads that occur in developments in Camas, Washougal, Ridgefield and La Center (CRESA 2004).

11.5.4 Environment

The environment vulnerable to landslide hazard is the same as the environment exposed to the hazard.

11.5.5 Economic Impact

The economic impact of a landslide depends on its severity and location. Minor landslides may not lead to any economic impact if they occur in the woods or non-populated areas. Minor landslides in more populated areas can have an economic impact, as they can lead to temporary road closures that cause isolation in neighborhoods and traffic delays for public and private transportation. This can result in losses for businesses if employees are unable to make it to work or if customers choose to not shop because of transportation difficulties. Landslide economic losses can be categorized in several ways (USGS 2001):

- Direct or indirect:
  - Direct losses include costs for replacement, repair, rebuilding, and maintenance resulting from landslide damage to property.
  - Indirect losses include the following:
    - Reduced real estate values in areas threatened by landslides
    - Loss of tax revenues on properties devalued by landslides
    - Loss of industrial, agricultural, and forest productivity, and of tourist revenues
    - Loss of human or domestic animal productivity because of death, injury, and psychological trauma
    - Costs of mitigation and prevention activities to reduce landslide risks.
- Private or public costs:

- Private costs are mainly incurred as damage to land and structures, such as private property or industrial facilities.
- Public costs are those borne by government agencies. The largest public cost is the repair or relocation of highways/roads and accessory structures (sidewalks, storm drains, etc.) after an event.

11.6 FUTURE TRENDS

11.6.1 Development

The State of Washington has adopted the International Building Code by reference in its Washington Building Standards Code. The International Building Code includes provisions for geotechnical analyses in steep slope areas that have soil types considered susceptible to landslide hazards. These provisions ensure that new construction is built to standards that reduce vulnerability to the landslide risk. In addition, all municipal planning partners have comprehensive plans that define landslide hazard areas as critical areas and have adopted critical areas ordinances that regulate development in landslide-prone areas. This will facilitate wise land use decisions as future growth impacts landslide hazard areas. It is anticipated that some new development will be exposed to landslide risk, as runout models do not yet exist and it is likely that not all landslide hazard areas have been identified.

Table 11-7 shows the area identified as underutilized or vacant in urban growth areas in the County that intersect identified landslide hazard areas. These estimates do not include area within parcels that have been designated as critical areas and, thus, are believed to be at the greatest risk from landslide hazards.

Table 11-7. Buildable Lands in Planning Area Urban Growth Areas Intersecting Landslide Hazard Areas[a]

Urban Growth Area[b]	Buildable Area[c] (acres)				
	Residential		Commercial	Industrial	Total
	Acres	Units			
Battle Ground	213.81	1,283	23.25	24.35	**261.41**
Camas	271.02	1,626	0.50	7.21	**278.73**
La Center	237.66	951	35.32	46.31	**319.29**
Ridgefield	576.54	3,459	24.65	136.19	**737.38**
Vancouver	451.57	3,612	51.05	80.31	**582.93**
Washougal	131.89	792	5.51	68.20	**206.60**
Woodland[d]	--	--	--	--	**--**
Yacolt	2.50	10	0	5.86	**8.36**
Total	**1,884.99**	**11,733**	**140.28**	**368.43**	**14,126.70**

a. Buildable lands information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Unincorporated areas outside of urban growth areas are excluded from this assessment. Development in these areas consists largely of rural lands, open space and large residential lots. Changes in development can be assessed through
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage estimates exclude the portions of the City of Woodland in Cowlitz County and thus may be underestimated.

11.6.2 Climate Change

Climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Increase in global temperature could affect the snowpack and its ability to hold and store water. Warming temperatures also could increase the occurrence and duration of droughts, which would increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors would increase the probability for landslide occurrences.

11.7 SCENARIO

The worst-case scenario for landslide in the planning area would be a severe storm with heavy rain that pushes precipitation levels above the thresholds identified by USGS, followed by an earthquake. This scenario is most likely to occur during late winter when the water table is high. An earthquake is likely to trigger landslides across the County that would complicate response and recovery efforts to the initial hazard event.

As a standalone event, a major landslide that occurred during a severe storm would create road obstructions and create isolation problems for residents and businesses in the more sparsely developed areas. It is likely that property owners located on steep slopes would suffer damage to property or structures. In addition to this, landslides carrying vegetation, such as shrubs and trees, may cause a break in power or communication lines, cutting off power and communication access to residents. Continued heavy rains and flooding would complicate this problem further. As emergency responders in Clark County attend to problems with flooding, it is possible they may be unavailable to assist with landslides occurring all over the county. This would worsen the problem of isolation for residents and business (CRESA 2004).

11.8 ISSUES

Landslides are often a secondary hazard related to other natural disasters. Landslide-triggering rainstorms often produce damaging floods. Earthquakes often induce landslides that can cause additional damage. The identification of areas susceptible to landslides is necessary to support grading, building, foundation design, housing density, and other land development regulations in reducing the risk of property damage and personal injury. The most significant effect of landslides in Clark County is the disruption of transportation and the destruction of private and public property. Important issues associated with landslides in the planning area include the following:

- It is estimated that more than 10,000 people (2.3 percent of the population) reside within landslide risk areas. This does not include residences that may be in landslide runout areas.
- An estimated 1.7 percent of the replacement value of the planning area ($1.88 million) is located in landslide hazard areas; 80 percent of this is in unincorporated areas of the county and the City of Camas.
- There are more than 3,900 structures in landslide hazard areas. About 98 percent of them are residential.
- Although known landslide hazard areas and steep slopes are subject to regulation under critical area ordinances, continued development pressures could lead to more homes in landslide risk areas. Furthermore, landslides may occur that threaten people and property outside of the mapped risk areas.
- Current maps show areas that might be unstable, but do not offer a complete picture of areas at risk, as they do not indicate runout (where a landslide might go). Mapping and assessment of landslide hazards are constantly evolving. As new data and science become available, assessments of landslide risk should be reevaluated.
- The impact of climate change on landslides is uncertain. Climate change impacts that alter vegetation patterns, increase the occurrence of wildfires, or alter precipitation patterns may increase exposure to landslide risks.
- Landslides may cause negative environmental consequences, including water quality degradation.
- Areas with significant landslide risk should be monitored, to the extent possible, immediately following a possible triggering event. Officials may need to focus the majority of attention on emergency response; however, the possibility for a secondary event should not be disregarded.

- Facilities that contain hazardous materials located in landslide hazard areas may present additional risks.
- Additional studies should be performed that assess the risks from seismically induced landslides.
- Landslides in the County often impact transportation corridors limiting ingress and egress and creating issues of isolation.
- There are 42 critical facilities located in mapped landslide hazard areas in the planning area. Most of these facilities are sanitation system and transportation facilities in Camas and unincorporated County areas.
- Buildable lands analysis indicates that there is the potential for exposure to landslide risk to increase in the planning area. Although the most susceptible areas are regulated through critical areas ordinances, exposure can increase as current regulations may not include run out.

12. SEVERE WEATHER

12.1 GENERAL BACKGROUND

Severe weather refers to any dangerous meteorological phenomena with the potential to cause damage, serious social disruption, or loss of human life. Severe weather, technically, is not the same as extreme weather, which refers to unusual weather events at the extremes of the historical distribution for a given area. It includes thunderstorms, hail storms, damaging winds, tornadoes, excessive heat, snowstorms, ice storms, blizzards, and extreme cold. The most common severe weather events that impact Clark County are winter weather (snowstorms, ice storms or extreme cold) and windstorms. All types of severe weather that affect the planning area are described in the following sections. Flooding issues associated with severe weather are discussed in Chapter 10.

12.1.1 Damaging Winds

Winds exceeding 60 mph are classified as damaging winds. There are seven types of damaging winds:

- **Straight-line winds**—Any thunderstorm wind that is not associated with rotation; this term is used mainly to differentiate from tornado winds. Most thunderstorms produce some straight-line winds as a result of outflow generated by the thunderstorm downdraft.
- **Downdrafts—**A small-scale column of air that rapidly sinks toward the ground.
- **Downbursts—**A strong downdraft with horizontal dimensions larger than 2.5 miles resulting in an outward burst or damaging winds on or near the ground. Downburst winds may begin as a microburst and spread out over a wider area, sometimes producing damage similar to a strong tornado. Although usually associated with thunderstorms, downbursts can occur with showers too weak to produce thunder.
- **Microbursts—**A small concentrated downburst that produces an outward burst of damaging winds at the surface. Microbursts are generally less than 2.5 miles across and short-lived, lasting only 5 to 10 minutes, with maximum wind speeds up to 168 mph. There are two kinds of microbursts: wet and dry. A wet microburst is accompanied by heavy precipitation at the surface. Dry microbursts occur with little or no precipitation reaching the ground.
- **Gust front—**A gust front is the leading edge of rain-cooled air that clashes with warmer thunderstorm inflow. Gust fronts are characterized by a wind shift, temperature drop, and gusty winds out ahead of a thunderstorm. Sometimes the winds push up air above them, forming a shelf cloud or detached roll cloud.
- **Derecho—**A derecho is a widespread thunderstorm wind caused when new thunderstorms form along the leading edge of an outflow boundary (the boundary formed by horizontal spreading of thunderstorm-cooled air). The word "derecho" is Spanish and means "straight ahead." Thunderstorms feed on the boundary and continue to reproduce. Derechos typically occur in summer when complexes of thunderstorms form over plains, producing heavy rain and severe wind. The damaging winds can last a long time and cover a large area.

- **Bow Echo—**A bow echo is a linear wind front bent outward in a bow shape. Damaging straight-line winds often occur near the center of a bow echo. Bow echoes can be 200 miles long, last for several hours, and produce extensive wind damage at the ground.

Damage from winds accounts for half of all severe weather reports in the continental U.S. Winds can reach speeds up to 100 mph and can produce a damage path extending for hundreds of miles. Windstorms in Washington typically occur from October through March (Washington Emergency Management Division, 2014).

12.1.2 Extreme Temperatures

Excessive Heat Events

Excessive heat events are defined by the U.S. EPA as "summertime weather that is substantially hotter and/or more humid than average for a location at that time of year" (U.S. EPA, 2006). Heat waves are excessive heat events that typically last two or more days (CDC, 2014b). Because extreme heat is relative to the usual weather in a region, criteria that define an extreme heat event may differ among jurisdictions and with the time of year. In general, extreme heat events can be characterized by temperatures greater than 90°F, warm stagnant air masses and consecutive nights with higher-than-usual minimum temperatures (CDC, 2009).

Heat Index

Extreme heat events are often a result of more than ambient air temperature. Heat index tables (see Figure 12-1) are commonly used to provide information about how hot it feels based on several meteorological conditions. Heat index values are for shady, light wind conditions; exposure to full sunshine can increase heat index values by up to 15°F. Strong winds with very hot, dry air also can be extremely hazardous (NWS, 2014b).

Source: National Weather Service/NOAA

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution Extreme Caution Danger Extreme Danger

Figure 12-1. Heat Index Chart

Heat Islands

Extreme heat events may be exacerbated in urban areas, where reduced air flow, reduced vegetation and increased generation of waste heat can contribute to temperatures that are several degrees higher than in surrounding rural or less urbanized areas. When urban buildings, roads and other infrastructure replace open land and vegetation, surfaces that were once permeable and moist become impermeable and dry. These changes cause urban areas to become warmer than the surrounding areas, serving as contiguous regions of higher temperatures. This phenomenon is known as urban heat island effect. Heat islands can affect communities by increasing peak summer energy demand, air pollution, greenhouse gas emissions, heat-related illness and death, and water quality degradation.

Extreme Cold and Wind Chill

Weather that constitutes extreme cold varies across different parts of the U.S. In regions relatively unaccustomed to winter weather, near freezing temperatures are considered extreme cold (CDC, 2014a). Extreme cold can often accompany severe winter storms. Wind can exacerbate the effects of cold temperatures by carrying heat away from the body more quickly, thus making it feel colder than is indicated by the temperature. This phenomenon is known as wind chill. Wind chill is the temperature that your body feels when the air temperature is combined with wind speed (CDC, 2014a). Figure 12-2 shows the value of wind chill based on ambient temperature and wind speed.

Source: National Weather Service/NOAA

Temperature (°F)

Wind (mph)	Calm 40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes; 10 minutes; 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Figure 12-2. Wind Chill Chart

12.1.3 Severe Winter Weather

Blizzards and Snowstorms

The National Weather Service defines a winter storm as having significant snowfall, ice and/or freezing rain; the quantity of precipitation varies by elevation. Heavy snowfall is 4 inches or more in a 12-hour period, or 6 inches or more in a 24-hour period in non-mountainous areas; and 12 inches or more in a 12-hour period or 18 inches or more in a 24-hour period in mountainous areas. There are three key ingredients to a severe winter storm:

- Cold Air—Below-freezing temperatures in the clouds and near the ground are necessary to make snow and/or ice.
- Moisture—Moisture is required in order to form clouds and precipitation. Air blowing across a body of water, such as a large lake or the ocean, is a typical source of moisture.
- Lift—Lift is required in order to raise the moist air to form the clouds and cause precipitation. An example of lift is warm air colliding with cold air and being forced to rise over the cold dome. The boundary between the warm and cold air masses is called a front. Another example of lift is air flowing up a mountain side.

Areas most vulnerable to winter storms are those affected by convergence of dry, cold air from the interior of the North American continent and warm, moist air off the Pacific Ocean. When strong storms crossing the Pacific arrive at the coast, if the air is cold enough, snow falls. As the moisture rises into the mountains, heavy snow closes mountain passes and can cause avalanches. Cold air from the north has to filter through mountain canyons into basins and valleys to the south. If the cold air is deep enough, it can spill over a mountain ridge. As the air funnels through canyons and over ridges, wind speeds can reach 100 mph. High winds with snow results in a blizzard.

Ice Storms

The National Weather Service defines an ice storm as a storm that results in the accumulation of at least 0.25 inches of ice on exposed surfaces. Ice storms occur when rain falls from a warm, moist, layer of atmosphere into a below freezing, drier layer near the ground. The rain freezes on contact with the cold ground and exposed surfaces, causing damage to trees, utility wires, and structures (see Figure 12-3).

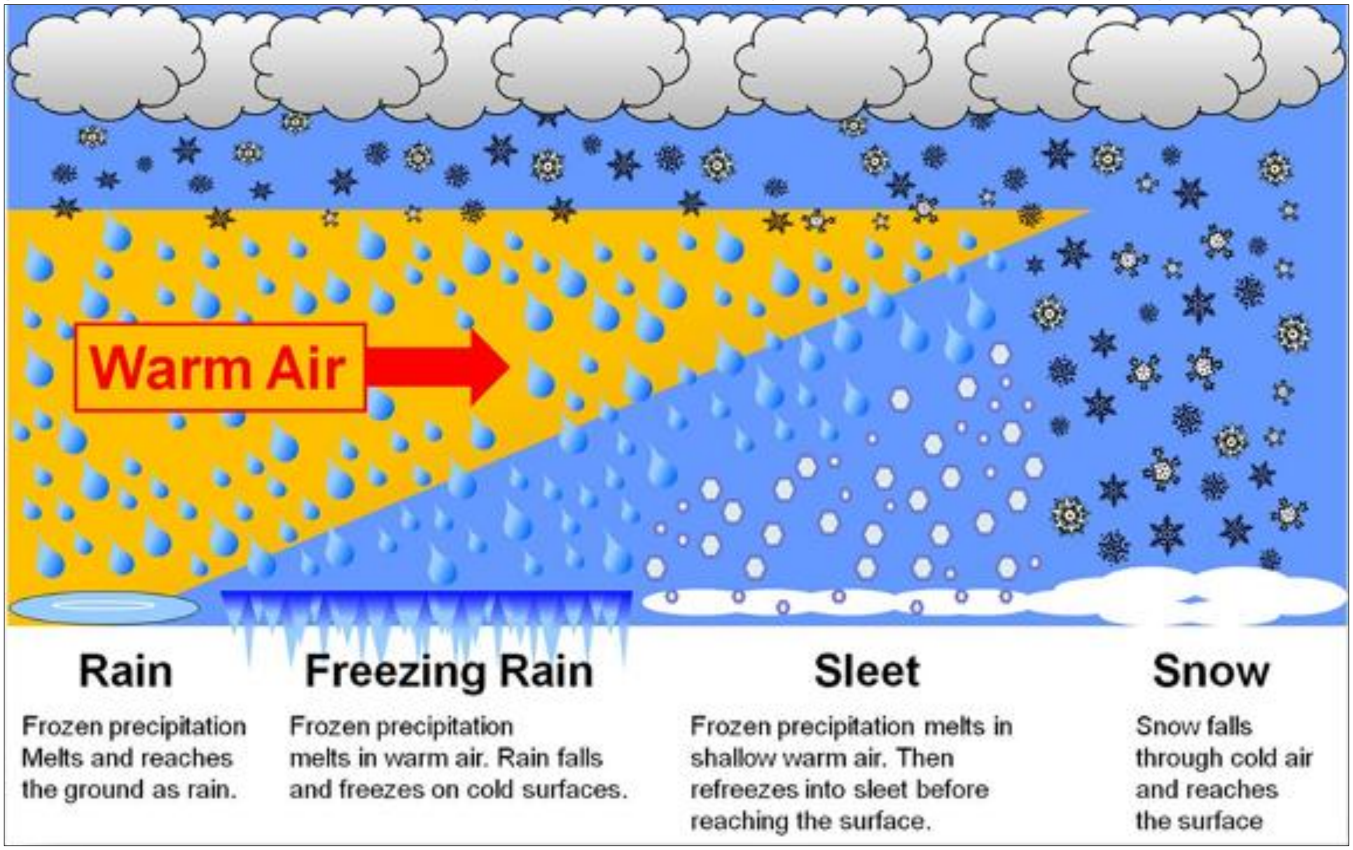

Figure 12-3. The Formation of Different Kinds of Precipitation

Ice accretion generally ranges from a trace to 1 inch. Accumulations between 1/4-inch and 1/2-inch can cause small branch and faulty limb breakage. Accumulations of 1/2-inch to 1 inch can cause significant breakage. Strong winds increase the potential for damage from ice accumulation.

12.1.4 Thunderstorms and Lightning

A thunderstorm is a rain event that includes thunder and lightning. A thunderstorm is classified as "severe" when it contains one or more of the following: hail with a diameter of three-quarter inch or greater, winds gusting in excess of 50 knots (57.5 mph), or tornado. Approximately 10 percent of the 100,000 thunderstorm that occur nationally every year are classified as severe (NOAA, 2014).

Three factors cause thunderstorms to form: moisture, rising unstable air (air that keeps rising when disturbed), and a lifting mechanism to provide the disturbance. The sun heats the surface of the earth, which warms the air above it. If this warm surface air is forced to rise (hills or mountains can cause rising motion, as can the interaction of warm air and cold air or wet air and dry air) it will continue to rise as long as it weighs less and stays warmer than the air around it. As the air rises, it transfers heat from the surface of the earth to the upper levels of the atmosphere (the process of convection). The water vapor it contains begins to cool and it condenses into a cloud. The cloud eventually grows upward into areas where the temperature is below freezing. Some of the water vapor turns to ice and some of it turns into water droplets. Both have electrical charges. Ice particles usually have positive charges, and rain droplets usually have negative charges. When the charges build up enough, they are discharged in a bolt of lightning, which causes the sound waves we hear as thunder. Thunderstorms have three stages (see Figure 12-4):

- The *developing stage* of a thunderstorm is marked by a cumulus cloud being pushed upward by a rising column of air (updraft). The cumulus cloud soon looks like a tower. There is little to no rain during this stage but occasional lightning. The developing stage lasts about 10 minutes.
- As the updraft continues, the thunderstorm enters the *mature stage* when precipitation begins to fall and a downdraft begins (a column of air pushing downward). When the downdraft and rain-cooled air spread out along the ground, they form a gust front, or a line of gusty winds. The mature stage is the most likely time for hail, heavy rain, frequent lightning, strong winds, and tornadoes. The storm occasionally has a black or dark green appearance.
- Eventually, a large amount of precipitation is produced and the updraft is overcome by the downdraft beginning the *dissipating stage*. At the ground, the gust front moves out a long distance from the storm and cuts off the warm moist air that was feeding the thunderstorm. Rainfall decreases in intensity, but lightning remains a danger.

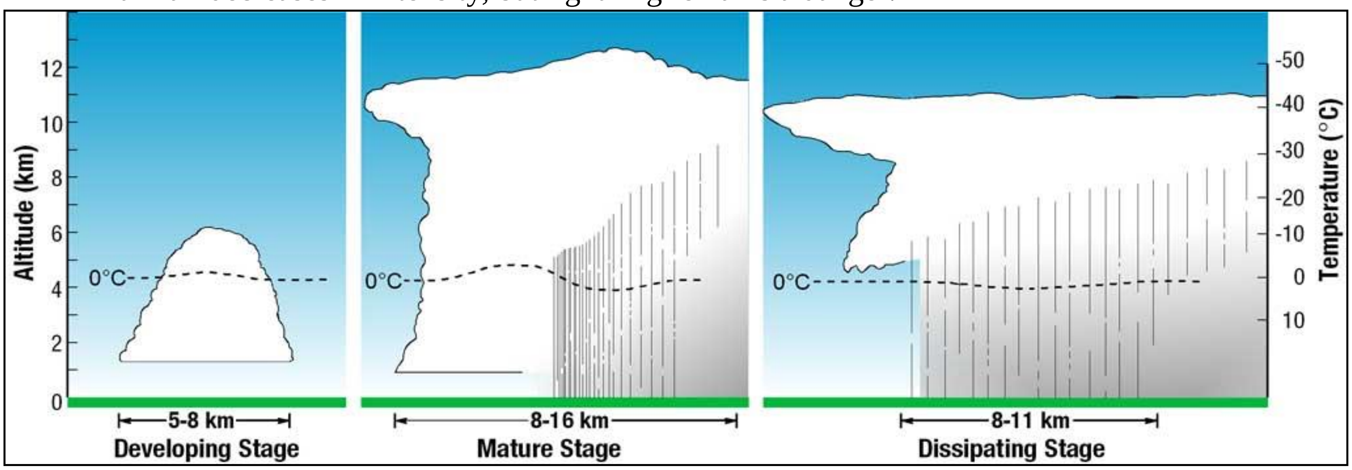

Figure 12-4. The Thunderstorm Life Cycle

There are four types of thunderstorms:

- **Single-Cell Thunderstorms**—Single-cell thunderstorms usually last 20 to 30 minutes. A true single-cell storm is rare, because the gust front of one cell often triggers the growth of another. Most single-cell storms are not usually severe, but a single-cell storm can produce a brief severe weather event. When this happens, it is called a pulse severe storm.
- **Multi-Cell Cluster Storm**—A multi-cell cluster is the most common type of thunderstorm. The multi-cell cluster consists of a group of cells, moving as one unit, with each cell in a different phase of the thunderstorm life cycle. Mature cells are usually found at the center of the cluster and dissipating cells at the downwind edge. Multi-cell cluster storms can produce moderate-size hail, flash floods and weak tornadoes. Each cell in a multi-cell cluster lasts only about 20 minutes; the multi-cell cluster itself may persist for several hours. This type of storm is usually more intense than a single cell storm.
- **Multi-Cell Squall Line**—A multi-cell line storm, or squall line, consists of a long line of storms with a continuous well-developed gust front at the leading edge. The line of storms can be solid, or there can be gaps and breaks in the line. Squall lines can produce hail up to golf-ball size, heavy rainfall, and weak tornadoes, in addition to strong downdrafts. Occasionally, a strong

downburst will accelerate a portion of the squall line ahead of the rest of the line to produce a bow echo. Bow echoes can develop with isolated cells as well as squall lines. Bow echoes are easily detected on radar but are difficult to observe visually.

- **Super-Cell Storm**—A super-cell is a highly organized thunderstorm that poses a high threat to life and property. It is similar to a single-cell storm in that it has one main updraft, but the updraft is extremely strong, reaching speeds of 150 to 175 miles per hour. Super-cells are rare. The main characteristic that sets them apart from other thunderstorms is the presence of rotation. The rotating updraft of a super-cell (called a mesocyclone when visible on radar) helps the super-cell to produce extreme weather events, such as giant hail (more than 2 inches in diameter), strong downbursts of 80 miles an hour or more, and strong to violent tornadoes.

Lightning occurs in all thunderstorms. There are two main types of lightning: intra-cloud lightning and cloud-to-ground lightning (NWS, 2014). More information on lightning can be found in the following section.

Lightning

Lightning is an electrical discharge between positive and negative regions of a thunderstorm. A lightning flash is composed of a series of strokes, with an average of about four. The average duration of each stroke is about 30 microseconds.

Lightning is one of the more dangerous weather hazards in the United States. Each year, lightning is responsible for deaths, injuries, and millions of dollars in property damage, including damage to buildings, communications systems, power lines, and electrical systems. Lightning also causes forest and brush fires and deaths and injuries to livestock and other animals. According to the National Lightning Safety Institute, property damage, increased operating costs, production delays, and lost revenue from lightning and secondary effects exceed $6 billion per year (NLSI, 2008). Impacts can be direct or indirect. People or objects can be directly struck, or damage can occur indirectly when the current passes through or near it.

Intra-cloud lightning is the most common type of discharge. This occurs between oppositely charged centers within the same cloud. Usually it takes place inside the cloud and looks from the outside of the cloud like a diffuse brightening that flickers. However, the flash may exit the boundary of the cloud, and a bright channel can be visible for many miles.

Although not as common, cloud-to-ground lightning is the most damaging and dangerous form of lightning. Most flashes originate near the lower-negative charge center and deliver negative charge to earth. However, many flashes carry positive charge to earth, often during the dissipating stage of a thunderstorm's life. Positive flashes are more common as a percentage of total ground strikes during the winter months. This type of lightning is particularly dangerous for several reasons. It frequently strikes away from the rain core, either ahead or behind the thunderstorm. It can strike as far as 5 or 10 miles from the storm in areas that most people do not consider to be a threat. Positive lightning also has a longer duration, so fires are more easily ignited. And, when positive lightning strikes, it usually carries a high peak electrical current, potentially resulting in greater damage.

The ratio of cloud-to-ground and intra-cloud lightning can vary significantly from storm to storm. Depending upon cloud height above ground and changes in electric field strength between cloud and earth, the discharge stays within the cloud or makes direct contact with the earth. If the field strength is highest in the lower regions of the cloud, a downward flash may occur from cloud to earth. Using a network of lightning detection systems, the United States monitors an average of 25 million strokes of lightning from the cloud-to-ground every year.

U.S. lightning statistics compiled by the National Oceanic and Atmospheric Administration between 1959 and 1994 indicate that most lightning incidents occur in June, July and August and during the afternoon hours from between 2 and 6 p.m.

Hail Storms

Hail occurs when updrafts in thunderstorms carry raindrops upward into extremely cold areas of the atmosphere where they freeze into ice. Super-cooled water may accumulate on frozen particles near the back-side of a storm as they are pushed forward across and above the updraft by the prevailing winds near the top of the storm. Eventually, the hailstones encounter downdraft air and fall to the ground. Hailstones grow two ways: by wet growth or dry growth. In wet growth, a tiny piece of ice is in an area where the air temperature is below freezing, but not super cold. When the tiny piece of ice collides with a super-cooled drop, the water does not freeze on the ice immediately. Instead, liquid water spreads across tumbling hailstones and slowly freezes. Since the process is slow, air bubbles can escape, resulting in a layer of clear ice. Dry growth hailstones grow when the air temperature is well below freezing and the water droplet freezes immediately as it collides with the ice particle. The air bubbles are "frozen" in place, leaving cloudy ice.

Hailstones can have layers like an onion if they travel up and down in an updraft, or they can have few or no layers if they are "balanced" in an updraft. Hailstones can begin to melt and then re-freeze together, forming large and very irregularly shaped hail.

12.1.5 Tornado

A tornado is a violently rotating column of air extending between, and in contact with, a cloud and the surface of the earth. Tornadoes are often (but not always) visible as a funnel cloud. On a local-scale, tornadoes are the most intense of all atmospheric circulations, with wind that can reach speeds of more than 300 mph. A tornado's vortex is typically a few hundred meters in diameter, and damage paths can be up to 1 mile wide and 50 miles long. Tornadoes can occur throughout the year at any time of day but are most frequent in the spring during the late afternoon. Figure 12-5 illustrates the potential impacts and damage from tornadoes of different magnitudes.

As shown in Figure 12-6, Washington has a very low to relatively low risk of tornadoes compared to states in the Midwestern and Southern U.S. Washington has experienced tornadoes on occasion. Some have produced significant damage, injury or death. Washington's tornadoes can be formed in association with large Pacific storms arriving from the west. Most of them, however, are caused by intense local thunderstorms. These storms also produce lightning, hail and heavy rain, and are more common during the warm season from April to October.

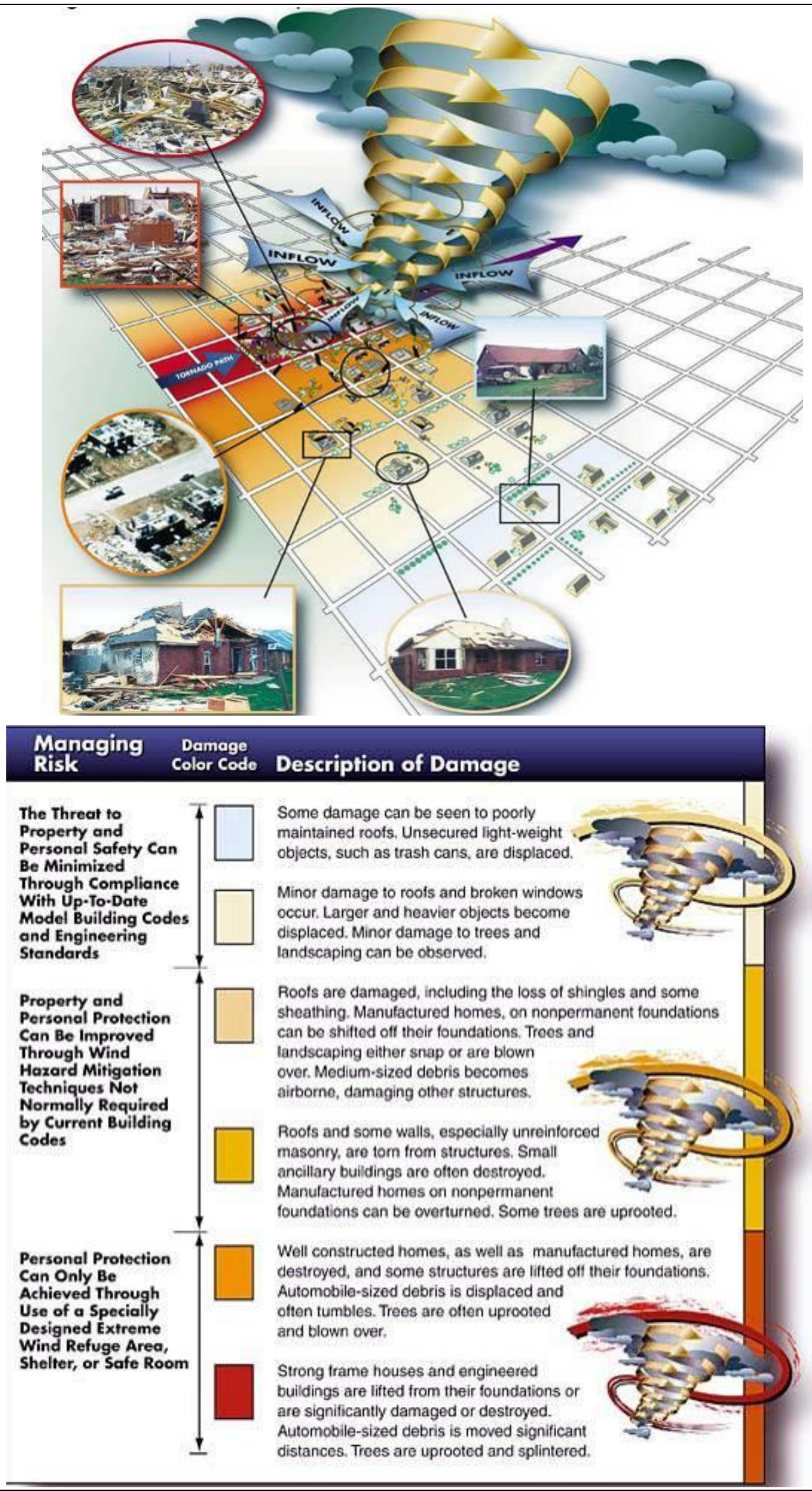

Figure 12-5. Potential Impact and Damage from a Tornado

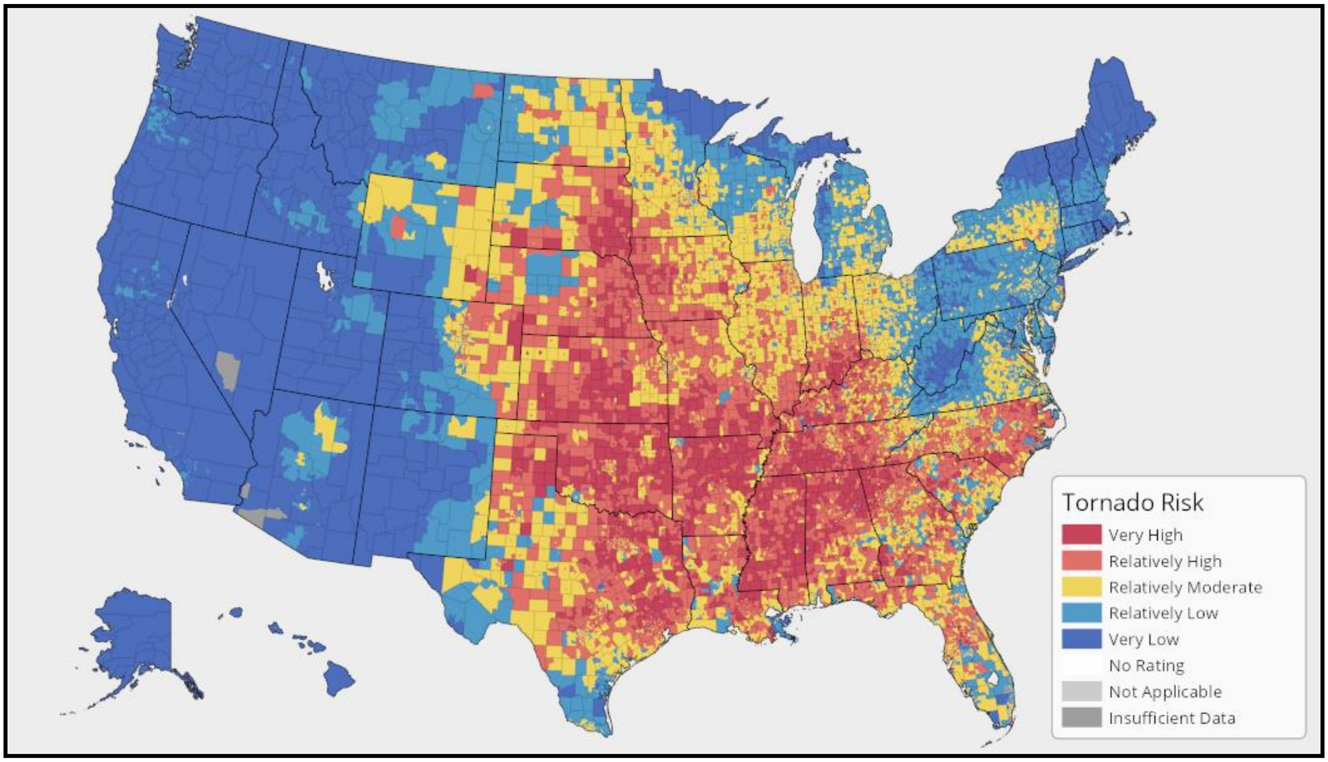

Figure 12-6. Tornado Risk Areas in the United States

12.2 HAZARD PROFILE

12.2.1 Past Events

Table 12-1 provides detailed descriptions of severe weather events in the planning area since 1996 that were reported to cause death, injuries or property damages. Table 12-2 summarizes all severe weather events in the planning area since 1950, as recorded by the National Oceanic and Atmospheric Administration (NOAA).

Table 12-1. Past Severe Weather Events Impacting Planning Area

Date	Type	Deaths or Injuries	Property Damage
4/5/1972	Tornado (F3)	306	$25,000,000
5/1/1976	Thunderstorm Wind	0	$0
5/1/1976	Hail (1.0 inches)	0	$0
10/13/1984	Tornado (F1)	0	$25,000
6/29/1989	Tornado (F1)	1	$2,500
1/27/1996	Ice Storm	0	$0
11/23/1996	Ice Storm	0	$0
Freezing rain disrupted travel in and near the western end of the Columbia River Gorge. Ice accumulation was reported at Washougal.			
12/26/1996	Ice Storm	0	$0
A severe ice storm crippled travel and communication within the Columbia Gorge and the Vancouver area. Camas and Washougal as well as towns within the Gorge sustained numerous downed trees and prolonged power outages.			
12/28/1996	Heavy Snow	0	$0

<table>
<tr><td colspan="4">Cold air to the east of the Cascade Mountains funneled through the Columbia River Gorge and produced heavy snow within the gorge and near the western end of the gorge. Skamania received 5 inches of snow and Washougal 6 inches.</td></tr>
<tr><td>1/27/1997</td><td>Ice Storm</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">Rain falling through cold air in the Columbia River Gorge produced significant accumulations of ice on roads and surfaces in the Gorge and near the western end of the gorge at Vancouver.</td></tr>
<tr><td>3/30/1997</td><td>High Wind</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">Winds gusted to 60 mph at Hockinson at 1150 AM.</td></tr>
<tr><td>5/31/1997</td><td>Tornado (F0)</td><td>0</td><td>$10,000</td></tr>
<tr><td colspan="4">A weak tornado briefly touched down in the Walnut Grove area of Vancouver, near I-205 and 4th Plain. A car was damaged, the roofing of a house was damaged, and a small shed was blown over.</td></tr>
<tr><td>6/21/1997</td><td>Lightning</td><td>0</td><td>$10,000</td></tr>
<tr><td colspan="4">Lightning struck a house in Hockinson and caused a brief fire and damaged home electronics.</td></tr>
<tr><td>9/10/1997</td><td>Lightning</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A lightning strike caused a widespread power outage that left 20000 homes without power for about 3 hours. A large school and several businesses closed for the day, and 3/4 of the traffic lights in Vancouver were out of service.</td></tr>
<tr><td>9/15/1997</td><td>Tornado (F0)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A weak tornado near Yacolt knocked down 3 trees and a telephone pole.</td></tr>
<tr><td>12/22/1997</td><td>Heavy Snow</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A weak Pacific front reached Southwest Washington with enough cold air trapped in lower elevations to drop up to two inches of snow in parts of Clark county before turning to rain.</td></tr>
<tr><td>1/10/1998</td><td>Winter Storm</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">The area of Southwest Washington and western Columbia River Gorge experienced the same storm as described in the narrative for Oregon zones 001-004 and 006-009. See that narrative for details.</td></tr>
<tr><td>1/11/1998</td><td>Ice Storm</td><td>0</td><td>$250,000</td></tr>
<tr><td colspan="4">The area of Southwest Washington and western Columbia River Gorge experienced the same storm as described in the narrative for Oregon zones 001-004 and 006-009. See that narrative for details.</td></tr>
<tr><td>10/3/1998</td><td>Hail (0.75 inches)</td><td>0</td><td>$0</td></tr>
<tr><td>11/23/1998</td><td>High Wind (50 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">The strong storm that brought high winds to Oregon also struck southwest Washington, where a gust to 58 mph was reported by a spotter around 530 pm.</td></tr>
<tr><td>12/5/1998</td><td>Heavy Snow</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">Snow accumulations of 1 to 3 inches were reported in Southwest Washington. Battle Ground reported 3 inches of new snow.</td></tr>
<tr><td>12/18/1998</td><td>Cold/Wind Chill</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">An extensive arctic airmass spread over the entire Pacific Northwest the week before Christmas. Temperatures fell sharply beginning December 18 and were coldest around the Winter Solstice December 21. High temperatures were only in the teens and 20s then. The lowest temperatures in Southwest Washington were in the Cascades, where overnight lows fell into the teens below zero. Light snow, less than one inch amounts, fell on the 19th and 21st, causing widespread traffic problems. Numerous accidents on Interstate 5 near the Oregon/Washington border during rush hour on the 21st caused a massive traffic jam. Plumbers were kept busy repairing frozen and burst water pipes.</td></tr>
<tr><td>12/24/1998</td><td>Heavy Snow</td><td>0</td><td>$0</td></tr>
</table>

<table>
<tr><td colspan="4">A Christmas Eve storm threatened to deliver a white Christmas to Southwest Washington. However, the 2 to 5 inches of snow that feel from around midnight to mid morning melted by afternoon as temperatures warmed. Battle Ground reported 4 inches of new snow, while the Vancouver area had around 3 inches.</td></tr>
<tr><td>2/5/1999</td><td>Heavy Snow</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A Pacific weather system dumped large amounts of snow over the Washington and Oregon Cascades. Up to 33 inches of snow were reported (Mt. Hood Meadows Ski Area). Oregon Dept. of Transportation measured 30 inches of snow from this storm at Santiam Pass on Hwy 20. The heavy snow briefly closed roads and made travel across the mountains very difficult.</td></tr>
<tr><td>2/6/1999</td><td>High Wind (39 knots)</td><td>0</td><td>$20,000</td></tr>
<tr><td colspan="4">One of the stronger Pacific storms of the winter season resulted in damaging winds when it moved over the coastal area and interiors of Northwest Oregon and Southwest Washington. One of the more dramatic events associated with this storm was the destruction of a Keizer, Oregon mobile home when a 200 foot douglas fir tree was toppled by winds and crushed the structure. Many thousands of residents were without power at various times as falling limbs and trees cut power lines. At higher elevations in the Cascade Mountains, very strong wind gusts were reported. Mt. Bachelor ski area reported a wind gust of 120 MPH. Mt Hood Meadows ski area reported a 103 mph wind gust. No injuries were reported. A newspaper reported very strong winds downing trees in the South Washington Cascades. Winds at the higher evelvations were inferred to be in excess of 100 mph at times. The Portland NWS Doppler Radar measured wind speeds at 110 mph at 7000 feet during the height of the storm.</td></tr>
<tr><td>8/4/1999</td><td>Lightning</td><td>0</td><td>$15,000</td></tr>
<tr><td colspan="4">Lightning from one of the many intense thunderstorms in Northwest Oregon and Southwest Washington struck a maple tree on the BS Ranch in Northeast Clark county and killed four beef cows and a bull.</td></tr>
<tr><td>1/10/2000</td><td>Heavy Snow</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">The winter storm that brought heavy snow to Northwest Oregon also dumped 2 to 3 inches of snow in Vancouver, while other Southwestern Washington totals included White Salmon 3 inches, Willapa Hills 4 to 7 inches, Bear Prairie 8 inches and Camas 3 inches.</td></tr>
<tr><td>1/16/2000</td><td>High Wind (95 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">An intense low pressure center moved over the area from the Pacific bringing very strong winds to the area. Cape Disappointment reported gusts to 109 mph, Ocean Park estimated gusts at 85 to 100 mph with many trees down, and Bay Center reported gusts to 65 mph. Inland, Vancouver had gusts to 67 mph, Hockinson 68 mph, Raymond gusts to 65 lmph and Camas 39 mph with gusts to 54 mph. Numerous downed trees and power outages were reported.</td></tr>
<tr><td>2/3/2000</td><td>High Wind (95 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">Localized strong winds 25 to 40 mph with gusts to 65 mph downed trees in the east Clark County - Brush Prairie area.</td></tr>
<tr><td>5/11/2000</td><td>Tornado (F0)</td><td>0</td><td>$10,000</td></tr>
<tr><td colspan="4">A weak tornado moved through Battleground. Three houses had minor damage as did a restaurant (blew away a sign and some metal strips of the awning). A pickup canopy resting on sawhorses was blown about 100 feet. In addition, a section of wooden fence was blown down, and 2 to 4 inch limbs were broken off of a tree. No injuries were reported.</td></tr>
<tr><td>12/13/2000</td><td>High Wind (57 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A winter storm brought strong winds to Clark County and the Southwest Washington coast. Vancouver reported gusts to 63 mph and La Center gusts to 52 mph. Ocean Park reported gusts to 60</td></tr>
</table>

mph. Damage from this storm included toppled trees, and widespread power lines down and associated power outages.			
6/27/2001	Thunderstorm Wind	5	$25,000
Portland Radar tracked a Severe Thunderstorm through Clark County into Cowlitz County. The Portland Oregonian, Vancouver Columbian and KOIN TV reported uprooted trees falling on vehicles and trailer houses, downed power lines and localized flooding of Interstate 5 and Highway 99 in the Battleground area. Clark Public Utilities reported 2600 lost power. Five were injured, two seriously; one when a tree fell across the trailer house she was in and the other was struck by a limb of a falling tree.			
10/5/2001	High Wind (45 knots)	0	$0
High winds downed power lines, knocking out power to more than 2300 users in Vancouver and northern Clark County.			
12/12/2001	High Wind (48 knots)	0	$0
A strong winter storm brought high winds to Southwest Washington resulting in gusts to 55 mph in Grays Harbor County. In Vancouver winds gusts reached 50 mph. Pacific County P.U.D. reported some power outages...the size of the outage was not reported.			
1/19/2002	Heavy Snow	0	$0
A strong winter storm brought heavy snows to the Southwest Washington area. Vancouver received 1 to 2 inches and 6+ inches was reported on Livingston Mt.			
1/24/2002	Heavy Snow	0	$0
Another winter storm brought heavy snows to the area. Brush Prairie reported 6 inches.			
1/27/2002	Heavy Snow	0	$0
Brush Prairie reported receiving 2 inches of snow.			
1/29/2002	Heavy Snow	0	$0
Kelso, Battle Ground and La Center reported 1 to 2 inches and up to 6 inches was reported at the higher elevations around Battle Ground.			
3/15/2002	Heavy Snow	0	$0
Snow blanketed Southwest Washington with 3 inches at Stevenson, 4 inches on Livingston Mountain, 3 inches at Brush Prairie, 2 inches at Salmon Creek, Camas, and Vancouver, and 1 inch at Washougal.			
12/26/2002	High Wind (57 knots)	0	$0
A Pacific storm moving across the area produced strong winds that downed trees and caused widespread power outages. Ilwaco reported gusts to 65 mph. Cathlamet reported gusts to 66 mph which ripped off metal roofs and downed trees. County wide power outages were reported in Wahkiakum County. The Columbian reported a gust of wind blew the 555 foot grain ship, "Pacific Trader" off its anchor and pushed it into a dock at Berth 8. Trees were reportedly downed in the Vancouver-Salmon Creek-Hazel Dell areas damaging two homes and disrupting traffic. No injuries were reported.			
11/17/2003	Winter Storm	0	$0
Over the three day period a series of strong Pacific storms brought strong winds to the coastal areas, heavy rain and/or snow to most of the CWA. The coastal areas were buffeted by 40 to 50 mph winds. Generous amounts of rain were reported. In 6 hours, Vancouver recorded 1.16 inches and Camas 1.02 inches. In 12 hours, Francis recorded 1.70 inches, Dixie Mt 1.00 inches, and Cougar 0.63 inches. In addition Long Beach reported 2.00 inches in 18 hours, Ocean Park 1.71 inches in 18 hours, and Camas 1.75 in 19 hours. Cold air followed in the wake of the heavy rains bringing a blanket of snow to most of the area. Some of accumulations included 8 inches at Mt Livingston, 5 inches in north Washougal, 4 inches at Camas, 2 inches in east Vancouver, and 1 inch in Longview.			

<table>
<tr><td>12/4/2003</td><td>High Wind (52 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">Strong easterly winds raised havoc in Southwest Washington. Winds reached 60 mph in Hockinson, were estimated to reach 60 mph in Battleground and 61 mph in Vancouver. Power was lost in Hockinson and Battleground. In Vancouver an 80 foot Douglas Fir tree with a diameter of 18 to 24 inches blew down. In Orchards a 30 foot Douglas Fir fell across the roof of a rental home. 6000 customers reportedly lost power. No injuries were reported.</td></tr>
<tr><td>1/6/2004</td><td>Winter Storm</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A strong winter storm packing the powerful punch of a frigid arctic airmass, heavy snow, sleet and freezing rain, along with strong east winds through and near the Columbia River Gorge snarled travel, forced the closure of most schools and businesses, and resulted in widespread power outages and properly damage in Southwest Washington. Strong high pressure built up east of the Cascade Mountains by January 5th, which forced frigid air through the Columbia River Gorge into Southwest Washington. A Pacific low pressure system brought moist Pacific air over the top of this cold dome, producing the widespread snow...sleet...and freezing rain throughout the area, and blizzard conditions in Columbia River Gorge. Snowfall totals ranged from 3 inches in Camas to 5 inches at Raymond and Longview, 7 inches in Vancouver, 8 inches in Grays River, and two feet in the South Washington Cascades. Accumulations of up to 2 inches of sleet and freezing rain followed the snowfall. Blizzard conditions in the Columbia River Gorge resulted in the closure of Interstate 84 between Troutdale, Oregon and Hood River Oregon, and Washington State Route 14 between Washougal, Washington and White Salmon, Washington during the same period, halting east-west travel through the Gorge and stranding hundreds of trucks at both ends of the Gorge. Weight from the snow and ice buildup resulted in widespread downed trees and power lines, leaving 2000 customers without power in Clark County. Clark Public Utilities estimated the storm cost between $1 and $1.5 million, while the city of Vancouver estimates up to $500,000 in damages.</td></tr>
<tr><td>1/23/2004</td><td>Heavy Snow</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A winter storm brought a blanket of snow the the area. Hockinson received one inch.</td></tr>
<tr><td>3/24/2004</td><td>Hail (0.75 inches)</td><td>0</td><td>$0</td></tr>
<tr><td>4/21/2004</td><td>Hail (0.5 inches)</td><td>0</td><td>$7,500</td></tr>
<tr><td colspan="4">About an inch of hail one half inch in diameter accumulated on Interstate Highway 5. The Washington Highway Patrol reported 14 vehicles were involved in accidents on the slippery highway, including at least one multi-car accident. At least 7 cars had damage more than $750, three of which required towing.</td></tr>
<tr><td>5/17/2004</td><td>Hail (1.0 inches)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">One inch hail in Brush Prairie was reported by both an off duty National Weather Service employee and a Trained Spotter.</td></tr>
<tr><td>5/27/2004</td><td>Tornado (F0)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A tornado reportedly touched down 2 miles northeast of La Center and uprooted a 1 1/2 foot diameter tree and tore off part of a barn roof.</td></tr>
<tr><td>9/13/2004</td><td>Tornado (F0)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A tornado ripped through the Ridgefield Wildlife Refuge, lifting and damaging a mobile home office, blowing down trees and snapping large tree limbs. A tree was blown down on top of a car.</td></tr>
<tr><td>9/13/2004</td><td>Thunderstorm Wind (50 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">Strong thunderstorms moved through Clark county generating strong winds. The Clark County Emergency Manager reported numerous trees were blown down at the Ridgefield Wildlife Refuge.</td></tr>
<tr><td>12/12/2004</td><td>High Wind (59 knots)</td><td>0</td><td>$0</td></tr>
</table>

<table>
<tr><td>1/6/2005</td><td>Winter Weather</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A Pacific weather system brought a mixture of snow...sleet..and freezing rain to Southwest Washington. There was a dusting of snow in the Vancouver and Camas areas, sleet near Brush Prairie, and freezing rain in the Cascade foothills, Vancouver, and near Kelso, with heaviest freezing rain in the Cascade foothills.</td></tr>
<tr><td>1/15/2005</td><td>Winter Storm</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A moisture-laden Pacific storm rode over cold air pouring out of the Columbia River Gorge, resulting in widespread moderate to heavy freezing rain in SW Washington. Accumulations ranged from one quarter to one half inch, with heaviest amounts near the Columbia River Gorge. The freezing rain turned to liquid rain away from the Gorge by early in the day January 16, but lasted through most of January 18 in the Gorge. The storm forced closure of bridges around the Portland/Vancouver metropolitan area. The storm also resulted in cancellation of 225 flights from Portland International Airport, 5000 power outages, and over 200 motor vehicle accidents in SW Washington and NW Oregon. Numerous trees were toppled by ice accumulation, mainly near the Gorge.</td></tr>
<tr><td>4/22/2005</td><td>Thunderstorm Wind (60 knots)</td><td>0</td><td>$0</td></tr>
<tr><td>5/20/2005</td><td>Lightning</td><td>0</td><td>$6,000</td></tr>
<tr><td colspan="4">Scattered thunderstorms produced heavy rain over the area. A storm near Ridgefield, WA produced heavy rains, sending 6 to 8 inches of water into a pump station. During that same storm, a lightning strike hit the pump station, burning out a control panel and disabling the station.</td></tr>
<tr><td>11/5/2005</td><td>High Wind (40 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A strong Pacific storm caused sustained winds of 46 mph at Cape Disappointment on the South Washington Coast. Sustained winds of 46 mph near Toutle in and reported strong winds near Kelso downed numerous foot to foot and a half diameter trees that contributed to widespread power outages in Cowlitz county.</td></tr>
<tr><td>12/18/2005</td><td>High Wind (58 knots)</td><td>0</td><td>$10,000</td></tr>
<tr><td colspan="4">A strong winter storm brought strong winds to inland portions of southwest Washington. Multiple reports were received of trees blown down in the Vancouver and Camas areas, some of which caused significant damage. In Vancouver, a tree was reported to fall through the roof of a home; in Camas, a roof was partially torn from a home, and an 80-foot tree snapped in two, damaging another roof. Nearly 40,000 customers were without power during the storm.</td></tr>
<tr><td>12/18/2005</td><td>Winter Weather</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A strong winter storm brought a mix of snow, sleet, and freezing rain to lower elevations of southwest Washington. Several reports were received of sleet and heavy freezing rain blanketing the area. Multiple damage reports were received due to ice accumulating on tree branches and power lines, especially in areas near the Columbia River Gorge.</td></tr>
<tr><td>12/24/2005</td><td>High Wind (58 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A strong Pacific low pressure system brought strong winds to the northwest Oregon and southwest Washington coastlines. Some of the strong winds reported with this system include:

50 mph gusts to 59 mph at Clatsop Spit

gusts to 59 mph at Desdemona Lighthouse

Damaging winds were also reported over inland portions of northwest Oregon and southwest</td></tr>
</table>

Washington. Trees were reported down in the Hockinson and Vancouver areas. A reported 30,000 customers were without power for a portion of the day.			
2/3/2006	Strong Wind (38 knots)	0	$100,000
A strong winter storm brought high winds to portions of southwest Washington. Following are some high winds reported with this storm: Bay Center reported frequent gusts to 50 knots Ocean Park reported frequent gusts to 63 knots Toke Point reported 39 knots with gusts to 54 knots Tongue Point reported 35 knots with gusts to 54 knots Desdemona Lighthouse reported 41 knots with gusts to 56 knots Many residents experienced power outages due to trees blown down by strong winds. An estimated 6300 residents of Cowlitz County were without power for portions of the night. Additionally, 38-year-old Ingrid Davis was killed after high winds blew down a tree which struck her car on State Route 4 near Cathlamet. The 13-year-old passenger, Alea Davis, was treated for a head injury and cuts.			
2/9/2006	Strong Wind (31 knots)	0	$200,000
A strong east wind event brought very gusty conditions to inland portions of southwest Washington. Following are some strong wind observations made during this event: Vancouver Airport reported 17 knots with gusts to 31 knots Larch Mountain RAWS reported 28 knots with gusts to 65 knots Coldwater Ridge Visitors Center reported 31 knots with gusts to 57 knots Locks RAWS reported 10 knots with gusts to 30 knots Many trees were knocked down due to high winds, and multiple power outages and areas of damage ensued. In Vancouver, a 110-foot tall tree 3 feet in diameter fell through the roof of a home, causing significant damage.			
9/14/2006	Hail (0.88 inches)	0	$0
Thunderstorms broke out under a warm, moist, unstable airmass over Washington. A few of these storms produced severe hail as well as wind gusts.			
12/14/2006	High Wind (69 knots)	0	$0
A very strong Pacific storm system plowed across the Pacific Northwest, bringing strong and damaging winds to southwest Washington. Wind speeds near 100 mph were seen on the coast and in the Willapa Hills, as well as winds speeds of 60-80 mph in Clark county and through the Columbia River Gorge. The storm brought widespread downed trees and power lines, and at the peak of the storm left nearly 500,000 homes across the region without power - some for days to come. Many roads and highways were left impassable due to downed trees.			
1/10/2007	Heavy Snow	0	$0
The new year brought a blast of cold air to the region along with and following a strong Pacific frontal system. This brought snow to every area in the county warning area, including heavy amounts of snow to areas along the coast. Schools all over the region were closed for at least one day, more in places were driving remained perilous. A minimum of 1 to 4 inches of snow fell over the entire area, with heavier amounts reported on the coast, in the Coast Range and Cascades, and in portions of the Willamette Valley.			
1/16/2007	Heavy Snow	0	$0
In the wake of a Pacific low pressure storm, cold air was entrenched over southwest Washington. As a result, post-frontal unstable shower activity resulted in additional snow accumulations over the lower			

<table>
<tr><td colspan="4">elevations. Schools in the greater Portland and Vancouver metro area were closed for a total of two-and-a-half days due to somewhat hazardous traveling conditions on smaller roads.</td></tr>
<tr><td>1/10/2008</td><td>Tornado (EF1)</td><td>0</td><td>$525,000</td></tr>
<tr><td colspan="4">In the wake of a rapidly advancing cold front, a severe thunderstorm moved through Clark county in southwest Washington and spawned a tornado. The tornado touched down near Vancouver Lake, moved east into Hazel Dell, then continued eastward to Hockinson while experiencing multiple touchdowns.</td></tr>
<tr><td>5/24/2008</td><td>Hail (0.75 inches)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">An unstable airmass with southerly flow moved over the forecast area, and many thunderstorms developed in the evening hours. Some of these storms became severe, and produced hail and lightning.</td></tr>
<tr><td>6/29/2008</td><td>Thunderstorm Wind (50 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">Under the influence of an unstable airmass and favorable south to southeasterly flow, thunderstorms broke out over eastern Oregon and over the Oregon Cascades, and advanced across the forecast area. A few of these storms became severe.</td></tr>
<tr><td>12/17/2008</td><td>Winter Storm</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A strong and very cold Pacific system brought heavy snow accumulations to southwest Washington.</td></tr>
<tr><td>12/20/2008</td><td>Winter Storm</td><td>0</td><td>$1,540,000</td></tr>
<tr><td colspan="4">The third in a series of an unusually cold storm systems brought heavy snow accumulations to southwest Washington. The heavy snowfall created a significant impact to many communities across southwest Washington.</td></tr>
<tr><td>12/24/2008</td><td>Winter Storm</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">Another cold storm system brought heavy snow accumulations to southwest Washington.</td></tr>
<tr><td>1/18/2009</td><td>High Wind (50 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">Strong east winds occurred through the Columbia River Gorge and Clark County.</td></tr>
<tr><td>11/16/2009</td><td>High Wind (50 knots)</td><td>0</td><td>$10,000</td></tr>
<tr><td colspan="4">A strong Pacific system brought strong winds to much of the Pacific Northwest.</td></tr>
<tr><td>12/17/2010</td><td>High Wind (57 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A strong low approaching the coast from the southwest brought strong southerly winds to the Pacific Northwest...especially along the south Washington coast and interior portions of southwest Washington.</td></tr>
<tr><td>2/24/2011</td><td>Heavy Snow</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A low pressure system off the Pacific Northwest Coast brought snow showers...heavy at times...to southwest Washington. An intense band of showers brought higher accumulations of snow over the Interstate 5 Corridor in Cowlitz County.</td></tr>
<tr><td>3/13/2011</td><td>High Wind (50 knots)</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">A squall line associated with a cold frontal passage moved across the Pacific Northwest Sunday afternoon bringing sudden strong winds to the area.</td></tr>
<tr><td>1/17/2012</td><td>Heavy Snow</td><td>0</td><td>$0</td></tr>
<tr><td colspan="4">With a cold air mass in place over the Pacific Northwest, two strong and very moist Pacific weather systems brought snow to the area with heavy snow in the mountains and snow levels down to the valley floor.</td></tr>
<tr><td>12/16/2012</td><td>High Wind (52 knots)</td><td>0</td><td>$100,000</td></tr>
<tr><td colspan="4">A strong low pressure system brought strong southerly winds to portions of Southwest Washington.</td></tr>
</table>

3/21/2013	Tornado (EF0)	0	$10,000
A tornado touched down in Clark county near Hockinson.			
6/19/2013	Funnel Cloud	0	$0
A cool trough of low pressure produced a funnel cloud over the Columbia River.			
1/23/2014	Strong Wind (35 knots)	0	$20,000
A strong upper level ridge resulted in gusty easty winds through the Columbia River Gorge and Vancouver Area. These winds resulted in minor damage including tipping over a semi-trailer on the Glen Jackson Bridge.			
2/6/2014	Heavy Snow	0	$0
A preceding cold arctic air mass combined with a moist Pacific storm resulted in widespread heavy snow for Southwest Washington. East winds through the Columbia River Gorge maintained colder air to the north where the precipitation fell mainly as snow.			
2/8/2014	Winter Storm	0	$0
A Weather system brought additional snow and ice to Southwest Washington March 8th. This is the third cold weather event in a series where there was a widespread snow/ice event on March 7th that followed a widespread heavy snow event on the 6th.			
2/8/2014	Ice Storm	0	$0
A Weather system brought additional snow and ice to Southwest Washington February 8th. This is the third cold weather event after a widespread snow/ice event on the 7th, and a widespread heavy snow event on the 6th.			
7/1/2014	Excessive Heat	0	$0
An upper level ridge combined with a surface thermal trough and low level offshore winds resulted in a hot day across Southwest Washington where inland temperatures peaked in the upper 90s inland and the upper 80s along the coast. The NWS Portland office had a heat advisory in effect. Many people flocked to the rivers to cool from the heat and there were unfortunately a drowning. Another man was hospitalized after rescuing a woman and two children from the Toutle River.			
10/25/2014	High Wind (61 knots)	0	$10,000
A 983mb low pressure system approached from the Southwest and moved north along the Central Oregon Coast before making landfall near Gray's Harbor, Washington. This low resulted in Gusty winds for the coast and coast range as well as damaging winds across Clark County.			
11/11/2014	High Wind (52 knots)	0	$28,000
Cold air plunged south out of the Canadian Rockies and created an east wind and down-slope wind storm across Southwest Washington. Eastern Clark County was hit the hardest with more than 60,000 customers losing power and several homes damaged by downed trees.			
12/11/2014	High Wind (52 knots)	0	$5,000
A 974 millibar surface low moved northward paralleling the Oregon coast around 80 miles offshore, and resulted in one of the strongest wind storms that Northwest Oregon had experienced in past several of years. The strongest winds occurred as high pressure filled in behind the low. Southwest Washington was less affected than Northwest Oregon, but still saw its fair share of gusty winds along the coast and the Vancouver metro area.			
3/15/2015	High Wind (50 knots)	0	$0
A surface low produced strong gusty winds across Northwest Oregon as it moved north offshore the Central and Northern Oregon coasts before making landfall in Southwest Washington. Soils were well saturated due to a prolonged period of heavy rain, and many trees were downed.			
6/26/2015	Excessive Heat	0	$0

A strong upper level ridge of high pressure resulted in hot temperatures across Southwest Washington. Afternoon temperatures peaked in the low to mid 90s which are around 20 degrees warmer than the seasonal normals. Monsoonal moisture and onshore winds resulted in fairly high humidities (40 to 50% in the afternoons) making the temperatures feel 2 to 5 degrees warmer than they were. The mid-level moisture also added to an increase of thunderstorms around the region. Clouds from these thunderstorms limited overnight radiation cooling. Nighttime temperatures were warm with minimum temperatures 10 to 15 degrees warmer than the seasonal normals.			
12/10/2015	Tornado (EF1)	0	$311,000
A tornado with winds up to 104 mph touched down southwest of Battleground around 1115 am. There were at least two touch down points along the 2 mile path. No injuries or fatalities were reported, but residences and businesses sustained property damage.			
12/21/2015	High Wind (52 knots)	0	$15,000
High winds impacted Southwest Washington as a 980 millibar low moved onshore in Pacific County. The winds resulted in widespread tree damage and power outages.			
1/3/2016	Winter Weather	0	$0
East winds through the Columbia River Gorge maintained below freezing surface temperatures for the Columbia Gorge, and areas of Clark County as a couple of precipitating events moved over the area Jan 3 and Jan 4. This resulted transportation challenges and school closures. There were a lot of car accidents and minor injuries from slips and falls on the ice.			
3/1/2016	Strong Wind (40 knots)	0	$8,000
A cold front backed by a deep surface low resulted in strong winds across Southwest Washington. The winds took down several trees and power lines.			
3/13/2016	Strong Wind (35 knots)	0	$3,000
A strong low pressure system produced strong winds across the region. The winds took down trees and power lines resulting in traffic obstructions and minor property damage.			
10/15/2016	High Wind (50 knots)	0	$3,000
A deepening low pressure system passed north along the Coast bringing strong winds to Southwest Washington.			
12/8/2016	Strong Wind (45 knots)	0	$3,000
An approaching strong frontal system brought strong winds and a mix of snow, sleet, and freezing rain down to the Valley Floor.			
12/8/2016	Winter Storm	0	$0
An approaching strong frontal system brought strong winds and a mix of snow, sleet, and freezing rain down to the Valley Floor.			
12/14/2016	Heavy Snow	0	$0
East winds ahead of an approaching low pressure system brought temperatures down below freezing across the area ahead of the approaching precipitation. This lead to a moderate snow event majorly impacting the evening commute.			
1/7/2017	Winter Storm	0	$0
A broad shortwave trough brought multiple rounds of precipitation, including a wintry mix of snow and ice for many locations across Southwest Washington. Strong easterly pressure gradients generated high winds through the Columbia River Gorge as well on January 8.			
1/10/2017	Heavy Snow	0	$30,000
A strong low pressure system moved up from the southwest. Surface temperatures as precipitation started were just above freezing, but with heavy showers, rain quickly turned over to snow during the			

early evening. Embedded thunderstorms enhanced snowfall rates around the Vancouver Metro for a crippling snowstorm Tuesday evening, with snow continuing to fall through Wednesday morning.			
1/17/2017	Ice Storm	0	$0
An approaching low pressure system brought rain across the Columbia River Gorge, while cold air was trapped at the surface and was slow to clear out. This brought a tremendous amount of freezing rain to the Columbia Gorge, closing I-84 and SR-14 to travel through the Gorge. Freezing rain was observed as far west as the Vancouver Airport, impacting the east side of the Vancouver Metro as well, mainly near the Columbia River.			
3/24/2017	Tornado (EF0)	0	$2,000
A upper-level low bringing a cold front across the area generated showers and a few thunderstorms across southwest Washington. One of these thunderstorms produced a weak tornado in Orchards, WA northeast of Vancouver.			
10/12/2017	Tornado (EF0)	0	$2,000
A low pressure system moving into Washington brought showers and thunderstorms across southwest Washington. These storms had been showing weak rotation. One of these storms produced a tornado near Vancouver.			
12/24/2017	Winter Weather	0	$0
Low pressure system moving into the Pacific Northwest pulled cold air from the Columbia Basin west of the Cascades, through the Columbia River Gorge. As this system started to bring moisture and precipitation into SW Washington, temperatures were around or below freezing, allowing for a mix of snow and ice to fall all the way to sea level around the Vancouver Metro, Lower Columbia River Valley, and in the Columbia River Gorge.			
2/20/2018	Heavy Snow	0	$0
A low pressure system slid down the coast and stayed offshore, pulling cold air from east of the Cascades into southwest Washington. This brought snow levels down to sea level, and moisture from the low pressure system meant snow down to sea level around Vancouver and along the lower Columbia River.			
6/9/2018	Thunderstorm Wind (43 knots)	0	$3,000
A cool upper-level trough moved over the Pacific Northwest, generating enough instability for thunderstorms which produced gusty winds and small hail.			
1/5/2019	Strong Wind (36 knots)	0	$250,000
A strong low pressure system moving up the coast from the south brought strong southerly winds across all of southwest Washington. The strongest winds were recorded along the coast, but winds observed in the southwest interior weren't much weaker than what was observed along the coast.			
2/8/2019	Heavy Snow	0	$0
A low pressure system dropped south along the coast from Victoria Island. The low pressure system brought arctic air south out of Canada into SW Washington. This system brought heavy snow to the Willapa Hills, Cascade Foothills, and the Columbia Gorge. It also brought snow down to the Valley floor in the Vancouver Metro area.			
4/29/2019	Strong Wind (30 knots)	0	$0
A upper-level trough generated a few stronger showers up across southwest Washington. One of these showers produced a downburst of winds, enough to bring down a private plane causing two fatalities.			
9/8/2019	Funnel Cloud	0	$0

A spotter called to report seeing a funnel cloud. Radar was used to estimate the exact location of the funnel cloud.			
9/7/2020	High Wind (52 knots)	0	$100,000,000
After a period of upper level ridging brought a return to above normal temperatures in early September, very strong easterly downslope and offshore winds off the Cascades and Coastal Ranges occurred. Winds increased rapidly during the afternoon and evening of September 7 with the passage of an unseasonably strong backdoor cold front, and persisted through much of the following day. This resulted in extremely critical fire weather conditions when the strong winds combined with extremely low relative humidity and exceptionally dry existing fuel conditions. The result was explosive growth of ongoing wildfires, and the new start and explosive spread of numerous new wildfires. Widespread wind gusts from 50-70 mph were common on ridge tops and numerous other in exposed areas, including portions of the greater Portland metro area, the Willamette Valley, and areas of the Oregon coast. Strong winds caused widespread damage to trees, and downed numerous power lines across the region, which started at least 13 additional wildfires. Large portions of the cities of Detroit, Mehama, and Gates were destroyed, and significant portions of Idanha, Mill City, and Lyons also burned. Resultant large wildfires included these named incidents - In Oregon: Beachie Creek, Chehalem Mountain/Bald Peak, Riverside, and Lionshead, and in Washington: Big Hollow. Rapidly spreading wildfires resulted in multiple fatalities, hundreds of displaced persons for many weeks, and billions of dollars in damage.			
1/13/2021	Strong Wind (34 knots)	0	$1,500
A series of strong slow moving fronts brought periods of heavy rain along with strong winds. This resulted in high surf, coastal and river flooding.			
2/11/2021	Winter Storm	0	$1,000,000
A deep upper trough drove an arctic airmass into southwest Washington. As multiple Pacific fronts moved over the area, a major elevation winter storm with heavy snow and freezing rain occurred over a multi-day period. This was a major, widespread, multi-faceted winter storm that caused major problems across the forecast area, even (and especially) in the lowlands.			
2/14/2021	Ice Storm	0	$1,000,000
A deep upper trough drove an arctic airmass into southwest Washington. As multiple Pacific fronts moved over the area, a major elevation winter storm with heavy snow and freezing rain occurred over a multi-day period. This was a major, widespread, multi-faceted winter storm that caused major problems across the forecast area, even (and especially) in the lowlands.			
6/26/2021	Excessive Heat	3	$0
A high pressure heat dome over the region led to stretch of extreme heat, shattering records from June 26 through June 29. Hot temperatures resulted in many people seeking locations to cool off in local rivers and beaches, which led to one drowning, as well as multiple people going to local hospitals for treatment of typical heat-related medical symptoms, including one reported death.			
8/11/2021	Excessive Heat	0	$0
Hot weather began to develop August 9, peaking August 11-12, but temperatures continued above normal into the weekend. Peak afternoon temperatures of 100 to 105 degrees drove people to seek relief in or near bodies of water.			
9/27/2021	Tornado (EF0)	0	$40,000
On the evening of Monday September 27, 2021 showers in the area were quite active as a cool upper trough moved into the region. One storm cell produced an EF-0 tornado in Battle Ground, WA.			
10/24/2021	Thunderstorm Wind (56 knots)	0	$10,000

A deep low pressure system off the Pacific NW coast pushed a strong front across northwest Oregon and southwest Washington, resulting in strong winds and scattered thunderstorms. One severe thunderstorm developed in the afternoon across northern Clark County. This storm produced wind damage from Woodland, WA to near Lake Merwin. Wind knocked out power to over 5000 residents in Clark County.			
11/15/2021	Strong Wind (35 knots)	0	$0
A strong cold front pushed onshore on the morning which brought high winds to the coastal areas.			
12/25/2021	Winter Weather	0	$0
A low pressure system and strong cold front moved through the Pacific Northwest on the evening of December 25, 2021 through the day on December 26th, 2021. This storm brought a significant amount of snow throughout the Pacific Northwest, including along the south Washington coast, but especially in the Cascades. Snow resulted in significant travel issues for the holiday weekend.			
4/10/2022	Winter Storm	0	$0
Unseasonably cold air was in place over the Pacific Northwest, with temperatures marginally cold enough for a low elevation snow event from the Portland metro northward. A storm system moved over northwest Oregon and southwest Washington bringing widespread snowfall to many areas north of Salem, Oregon. This system brought several inches of snow to the Willamette Valley in addition to the Coast Range and Cascades. By the late morning/early afternoon, much of the snow west of the Columbia River Gorge had transitioned to rain. This was not just your standard snowfall as it ended up being the first measurable lowland snowfall in the month of April.			

Source: http://www.ncdc.noaa.gov/stormevents/

Table 12-2. Summary of Severe Weather Event Impacts in the Planning Area

Hazard Types Includes	# of Reported Events[a]	# of Events with Deaths, Injuries[a, b]	Amount of Property Loss[a,b]
Damaging Winds			
Strong Wind	7	0	$584,000
High Wind	26	0	$201,000
Extreme Temperatures			
Excessive Heat	2	0	$0
Extreme Cold/Wind Chill	1	0	$0
Severe Winter Weather			
Ice Storm	7	0	$250,000
Heavy Snow	21	0	$30,000
Winter Storm	10	0	$1,540,000
Blizzard	0	0	$0
Winter Weather	4	0	$0
Sleet	0	0	$0
Thunderstorms and Lightning			
Lightning	4	0	$31,000
Thunderstorm Wind	6	1	$28,000
Hail	7	0	$7,500
Tornado			
Funnel Cloud	1	0	$0
Tornado	13	2	$25,897,500
Total	**153**	**30**	

a. Reported events since 1950.
b. Only events that listed injuries and/or dollar amounts are included in these estimates. Some event descriptions include property damage that was not quantified.

Source: http://www.ncdc.noaa.gov/stormevents/

12.2.2 Location

All areas in the County are potentially exposed to severe weather events.

Damaging Winds

All of Clark County is subject to high winds from thunderstorms and other severe weather events. Southwesterly winds are associated with strong storms moving onto the coast from the Pacific Ocean. Southern winds parallel to the Cascade Mountains are the strongest and most destructive winds. Strong eastern winds originate from the Columbia Gorge when high atmospheric pressure is over the Upper Columbia River Basin and low pressure is over the Pacific Ocean. The narrow point of the gorge acts as a funnel, concentrating the intensity of the winds. Strong winds are generated at the outlet of the gorge near Camas and Washougal. Windstorms tend to damage ridgelines that face into the winds (CRESA 2004).

According to FEMA, Clark County is located in Wind Zone I, where wind speeds can reach up to 130 mph. The County is also located in a special wind region along the west coast from Washington to Oregon. Figure 12-7 indicates how the frequency and strength of windstorms impacts the United States and the general location of the most wind activity. This is based on 40 years of tornado data and 100 years of hurricane data collected by FEMA.

Source: FEMA 2010

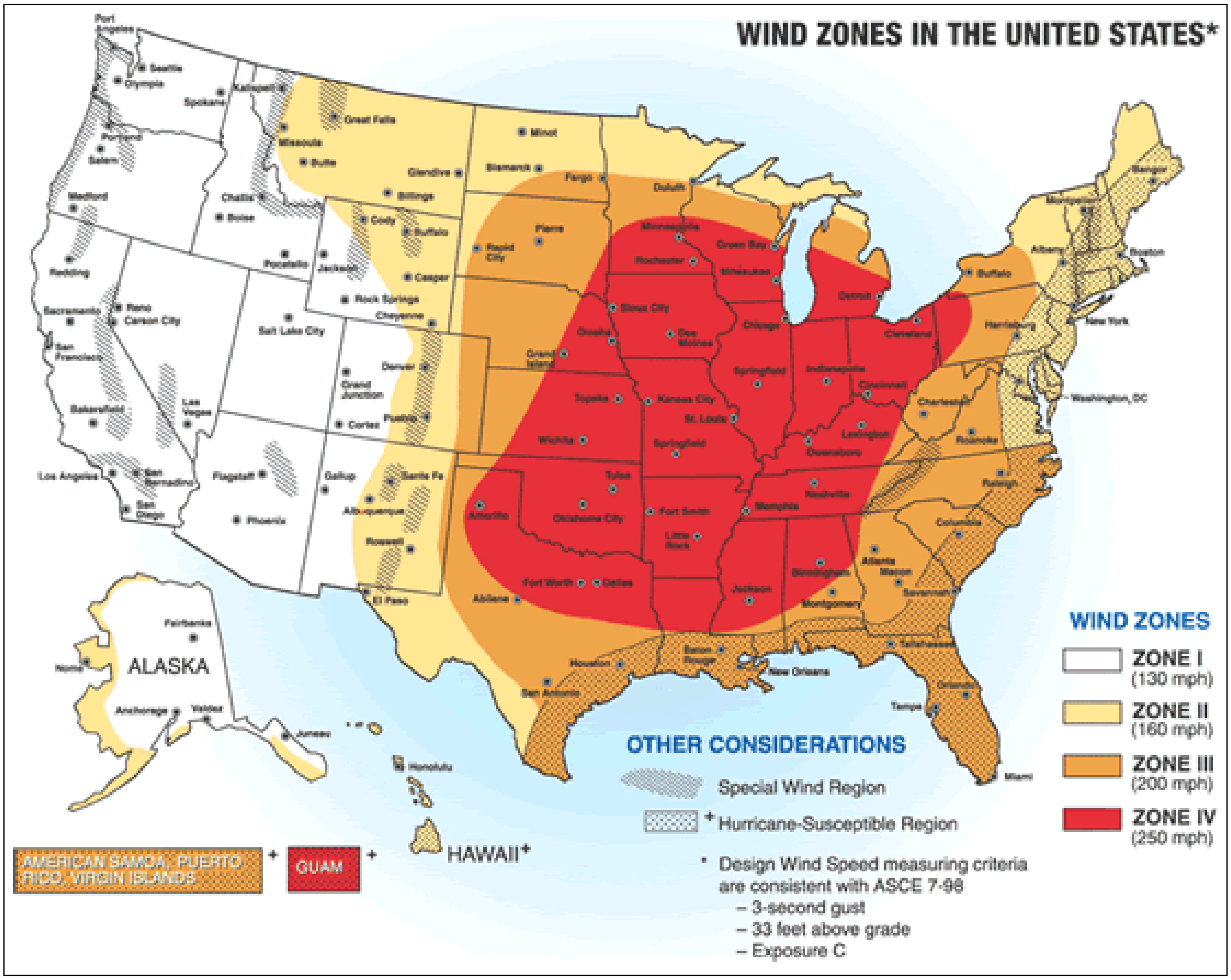

Figure 12-7. Wind Zones in the United States

Extreme Temperatures

Temperature extremes can occur throughout the planning area. The Western Regional Climate Center notes several factors that have a significant impact on the local climate including terrain (such as the Cascade Range), the Pacific Ocean, and low pressure regions over the North Pacific Ocean. These climactic controls can cause significant climate differences in relatively short distances.

In Western Washington, summers tend to be cool and dry, and winters are mild, wet, and cloudy. Specifically in areas west of the Cascade Mountains, minimum temperatures typically range from 30ºF (in lower elevations) to 20ºF (in higher elevations). Minimum temperatures as low as 0ºF to –17ºF have been recorded (WRCC 2014).

According to the Office of the Washington State Climatologist, Vancouver has the warmest annual average temperature in the state (averaged from 1981-2010) at 54.1ºF (OWSC 2015).

Severe Winter Weather

Snowstorms are a more frequent occurrence in the higher elevations of eastern Clark County, but they can occur in the lower elevations as well. In general, the Cascade Mountain Range acts as a barrier to cold air developing in the eastern part of the state, reducing the likelihood of snowstorms in Clark County. However, cooler air can enter the valley through low points or advance downriver through the Columbia Gorge. When this occurs, it can cause snowstorms in even the lower elevations of the county. Typically, the snow melts rapidly as a result of the warmer air in the valley (CRESA 2004).

Thunderstorms and Lightning

Thunderstorms affect relatively small localized areas, rather than large regions like winter storms and extreme temperature events. Thunderstorms can strike all regions of the United States, although they are most common in central and southern states. It is estimated that there are as many as 40,000 thunderstorms each day worldwide. Clark County can experience an average of 10 to 20 thunderstorm days each year (National Weather Service, 2010).

Tornadoes

Approximately 1,200 tornadoes occur in the United States each year, with the central portion of the country experiencing the most. Tornadoes can occur at any time of the year, with peak seasons at different times for different states (National Severe Storms Laboratory, 2015). The State of Washington and Clark County have a lower risk for tornados than elsewhere in the country. Tornadoes are usually localized. Severe thunderstorms can result in conditions favorable to the formation of numerous or long-lived tornadoes.

12.2.3 Frequency

Many of the severe weather events for Clark County shown in Table 12-1 are related to high winds and severe winter weather. The planning area can expect to experience exposure to some type of severe weather event at least annually. According to records, in 65 years, the county has experienced 153 severe weather events, for an average of 2 to 3 events per year.

According to the Washington State Hazard Mitigation Plan, Clark County is vulnerable to high winds. Counties considered vulnerable to high winds are those that were most affected by conditions that lead to high winds and those with a recurrence rate of 100 percent (i.e., that experienced at least one damaging high wind event per year). Clark County has a recurrence rate of 130 percent.

Clark County is also considered one of the counties most vulnerable to winter storms. This means that the county has a recurrence rate of at least 50 percent, or it experiences at least one damaging winter storm event every two years. Per the State Washington State Hazard Mitigation Plan, Clark County has a recurrence rate of 85 percent.

Six instances of extreme heat events are listed for the planning area between 1996 and 2015; however, this data likely underestimates the occurrence of such events in the planning area. Extreme heat events can occur several times per year, especially in the summer. Three extreme cold events were reported between 1996 and 2015. The actual number may be underreported, and some extreme cold events may be entered under another category, such as winter weather; the more visible impacts of a winter storm or blizzard may reduce the attention paid to extreme cold temperatures.

12.2.4 Severity

The most common problems associated with severe storms are immobility and loss of utilities. Fatalities are uncommon, but can occur. Roads may become impassable due to flooding, downed trees or a landslide. Power lines may be downed due to high winds or ice accumulation, and services such as water or phone may not be able to operate without power. Lightning can cause severe damage and injury. Physical damage to homes and facilities can be caused by wind or accumulation of snow or ice. Even a small accumulation of snow can cause havoc on transportation systems due to a lack of snow clearing equipment and experienced drivers and the hilly terrain.

Windstorms can be a frequent problem in the planning area and have been known to cause damage to utilities. The predicted wind speed given in wind warnings issued by the National Weather Service is for a one-minute average; gusts may be 25 to 30 percent higher. Lower wind speeds typical in the lower valleys are still high enough to knock down trees and power lines and cause other property damage. Mountainous sections of the County experience much higher winds under more varied conditions.

Ice storms accompanied by high winds can have especially destructive impacts, especially on trees, power lines, and utility services. While sleet and hail can create hazards for motorists when they accumulate, freezing rain can cause the most dangerous conditions within the planning area. Ice buildup can bring down trees, communication towers and wires, creating hazards for property owners, motorists and pedestrians. Rain can fall on frozen streets, cars, and other sub-freezing surfaces, creating dangerous conditions.

The severity of an extreme heat event depends on how early the event occurs in the summer and the number of consecutive days it lasts (U.S. EPA, 2006). Urban heat island effect can exacerbate the severity of an extreme heat event. While the severity of an extreme heat event may vary, impacts include increased energy consumption, elevated emissions of air pollutants and greenhouse gases, compromised human health and comfort, and impaired water quality (U.S. EPA, 2015). Extreme heat can also impact infrastructure by warping bridges, causing roads to buckle, melting runways, and more.

Lightning severity is typically investigated for both property damage and life safety (injuries and fatalities). The number of reported injuries from lightning is likely to be low. County infrastructure losses can be up to thousands of dollars each year.

Tornadoes are potentially the most dangerous of local storms, but they are not common in the planning area. If a major tornado were to strike within the populated areas of the county, damage could be widespread. Businesses could be forced to close for an extended period or permanently, fatalities could be high, many people could be homeless for an extended period, and routine services such as telephone or power could be disrupted. Buildings could be damaged or destroyed.

12.2.5 Warning Time

Meteorologists can often predict the likelihood of a severe storm or other severe weather event with several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the event. Some storms come on more quickly and have only a few hours of warning time. The Seattle and Spokane Offices of the National Weather Service (NWS) monitor weather stations and issue watches and warnings when appropriate. The Seattle Office is the closest NWS office in Washington, but the Portland, Oregon NWS office provides more accurate watches and warnings for Clark County due to its proximity. Watches and warnings are broadcast over NOAA weather radio and are forwarded to local media for retransmission using the Emergency Alert System. NWS and NOAA also issue outlooks, watches, warnings and advisory information for extreme heat.

12.3 SECONDARY HAZARDS

The most significant secondary hazards associated with severe weather are floods, falling and downed trees, landslides and downed power lines. Rapidly melting snow combined with heavy rain can overwhelm both natural and man-made drainage systems, causing overflow and property destruction. Landslides occur when the soil on slopes becomes oversaturated and fails. Excessive heat events can cause failure of motorized systems, such as ventilation systems used to control temperatures inside buildings, if these systems are operating above typical operating standards. Demand for cooling systems during these events can overload energy systems and result in controlled or unexpected power outages. Fires (both structural and wild), along with power outages, can occur as a result of lightning strikes.

12.4 EXPOSURE

12.4.1 Population

It is assumed that the entire planning area is exposed to some extent to severe weather events. Certain areas are more exposed due to geographic location and local weather patterns. People living at higher elevations with large stands of trees or power lines may be more susceptible to wind damage and lightning strikes. People in low-lying areas are at risk for possible flooding. People in densely populated urban areas without air conditioning are likely to be more exposed to extreme heat events.

12.4.2 Property

According to the Clark and Cowlitz County Assessor records used for this analysis, there are 149,741 structures within the planning area. Most of these buildings (95.4 percent) are residential. All of these buildings are considered to be exposed to the severe weather hazard.

12.4.3 Critical Facilities and Infrastructure

Critical facilities exposed to floods are at risk from severe weather with heavy rain or snowmelt. Critical facilities on higher ground may be exposed to wind damage, damage from falling trees, heavy snow and ice accumulation, tornadoes, lightning strikes and extreme temperatures. The most common problems associated with severe weather are loss of utilities. The following systems also are at risk (CRESA, 2004):

- Transportation Systems—High winds can cause significant damage to trees and power lines, disrupting ingress and egress on roads with obstructing debris. Snowstorms significantly impact the transportation system and the availability of public safety services. Of particular concern are roads providing access to isolated areas and bridges, which tend to become icy before and after other areas are clear.
- Power and communication lines—Ice and severe windstorms can create serious impacts on power and above-ground communication lines. Freezing of power and communication lines can cause them to break, disrupting both electricity and communication for households. They can also break as a result of falling trees. This can result in isolation.
- Water and Sewer lines—Severe local storms can cause water and sewer lines to freeze, which may crack pipes. This could result in a loss of potable water to households or exposed sewage causing public health hazards. However, extreme and prolonged freezing weather is required to cause underground pipes to crack, which is not likely to occur in Clark County. Above-ground pipes leading to and from individual homes are more likely vulnerabilities than large mainlines.

12.4.4 Environment

Severe local storms can have significant effects on the environment. Heavy rains cause the ground to become saturated and rivers and streams to rise. This results in the potential for flooding and landslides. Additionally, snowmelt after snowstorms can cause riverine flooding, which has the potential to damage riparian habitat (CRESA, 2004).

12.5 VULNERABILITY

12.5.1 Population

Vulnerable populations from severe weather hazards tend to be the elderly, low income or linguistically isolated populations, people with life-threatening illnesses, residents living in areas that are isolated from major roads, and residents who lack proper shelter. Power outages can be life threatening to those dependent on electricity for life support. Isolation of these populations is a significant concern. These populations face isolation and exposure during severe weather events and could suffer more secondary effects of the hazard. Population vulnerabilities to specific types of severe weather event are as follows:

- **Damaging Winds—**Debris carried by extreme winds and trees felled by gusty conditions can contribute directly to loss of life and indirectly to the failure of protective building envelopes. Utility lines brought down by thunderstorms have also been known to cause fires, which start in dry roadside vegetation. Electric power lines falling down to the pavement create the possibility of lethal electric shock.
- **Extreme Temperatures—**Individuals with physical or mobility constraints, cognitive impairments, economic constraints, or social isolation are typically at greater risk to the adverse effects of excessive heat events. The average summertime mortality for excessive heat events is dependent upon the methodology used to derive such estimates. Certain medical conditions, such as heat stroke, can be directly attributable to excessive heat, while others may be exacerbated by excessive heat, resulting in medical emergencies. Individuals who lack shelter and heating are particularly vulnerable to extreme cold and wind chill.
- **Severe Winter Weather—**Many of the deaths that result from severe winter weather are indirectly related to the actual weather event, including deaths resulting from traffic accidents on icy roads and heart attacks while shoveling snow. Icy road conditions that lead to major traffic accidents can make it difficult for emergency personnel to travel. This may pose a secondary threat to life if police, fire, and medical personnel cannot respond to calls. Homeless populations that lack adequate shelter are also vulnerable to severe winter weather events.
- **Thunderstorms—**Nationally, lighting is one of the leading causes of weather-related fatalities (CDC, 2013). Lightning strikes are far more common in other areas of the country than they are in the Pacific Northwest. The majority of injuries and deaths associated with lighting strikes occur when people are outdoors; however, almost one-third of lightning-related injuries occur indoors. Males are five times more likely than females to be struck by lighting and people between the ages of 15 and 34 account for 41 percent of all lightning strike victims (CDC, 2013).
- **Tornado—**All residents in the path of a tornado are vulnerable, especially if there is not adequate warning that tornado spawning conditions are likely.

12.5.2 Property

All property is vulnerable during severe weather events, but properties in poor condition or in particularly vulnerable locations may risk the most damage. Structures in higher elevations and on ridges may be more prone to wind damage. Those that are located under or near overhead lines or near large trees may be damaged in the event of a collapse.

Loss estimates for the severe weather hazard are not based on damage functions, because no such damage functions have been generated. Instead, estimates were developed representing 10 percent, 30 percent and 50 percent of the replacement value of planning area structures. This allows emergency managers to select a range of potential economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 12-3 lists the estimates of potential loss.

Table 12-3. Loss Potential for Severe Weather

	Total Replacement value	Estimated Loss Potential from Severe Weather		
		10% Damage	30% Damage	50% Damage
Battle Ground	$4,036,379,864	$403,637,986	$1,210,913,959	$2,018,189,932
Camas	$7,575,016,927	$757,501,693	$2,272,505,078	$3,787,508,464
La Center	$805,148,506	$80,514,851	$241,544,552	$402,574,253
Ridgefield	$2,075,091,625	$207,509,162	$622,527,487	$1,037,545,812
Vancouver	$47,993,433,972	$4,799,343,397	$14,398,030,192	$23,996,716,986
Washougal	$4,159,958,945	$415,995,894	$1,247,987,683	$2,079,979,472
Woodland	$1,777,992,519	$177,799,252	$533,397,756	$888,996,259
Yacolt	$306,406,962	$30,640,696	$91,922,089	$153,203,481
Unincorporated	$44,797,390,449	$4,479,739,045	$13,439,217,135	$22,398,695,224
Total	**$**113,526,819,769	**$**11,352,681,976	**$**34,058,045,931	**$**56,763,409,883

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

12.5.3 Critical Facilities and Infrastructure

Incapacity and loss of roads are the primary transportation failures resulting from severe weather. Snow and ice storms can significantly impact the transportation system and the availability of public safety services. Landslides caused by heavy prolonged rains can block roads. High winds can cause significant damage to trees and power lines, blocking roads with debris, incapacitating transportation, isolating population, and disrupting ingress and egress. Of particular concern are roads providing access to isolated areas and to the elderly.

Downed trees and ice can create serious impacts on power and above-ground communication lines. Freezing of power and communication lines can cause them to break, disrupting electricity and communication. Loss of electricity and phone connection would leave certain populations isolated because residents would be unable to call for assistance. Water systems may also be impacted during severe winter weather events. The most frequent water system problem related to cold weather is a break in cast iron mainlines. Breaks frequently occur during severe freeze events, as well as during extreme cooling periods in October, November and December. Another common problem during severe freeze events is the failure of commercial and residential water lines. Inadequately insulated potable water and fire sprinkler pipes can rupture and cause extensive damage to property.

Heavy snow can immobilize a region and paralyze a city, stranding commuters, stopping the flow of supplies, and disrupting emergency and medical services. Accumulations of snow can collapse buildings and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and unprotected livestock may be lost. The cost of snow removal, repairing damage, and loss of business can have large economic impacts on cities and towns.

12.5.4 Environment

The vulnerability of the environment to severe weather is the same as the exposure.

12.5.5 Economic Impact

Prolonged obstruction of major routes due to snow, debris, or floodwaters can disrupt the shipment of goods and other commerce. Large and prolonged storms can have negative economic impacts for an entire region.

12.6 FUTURE TRENDS

12.6.1 Development

All future development will be affected by severe weather. The ability to withstand impacts lies in sound land use practices and consistent enforcement of codes and regulations for new construction. The planning partners have adopted the International Building Code in response to Washington State mandates. This code is equipped to deal with the impacts of severe weather events. Land use policies identified in comprehensive plans within the planning area also address many of the secondary impacts (flood and landslide) of the severe weather hazard. To combat the effects of urban heat island effect, communities can implement design standards and urban planning principles that reduce the impacts of excessive heat events. With these tools, the planning partnership is well equipped to deal with future growth and the associated impacts of severe weather.

12.6.2 Climate Change

Climate change presents a challenge for risk management associated with severe weather. One impact of climate change is an increase in average ambient temperatures. This has several impacts including:

- A likely decrease in the frequency of winter cold spells
- An increased probability of severe weather events (see Figure 12-8)
- More intense heat waves
- Changes in the intensity, duration and frequency of storm events.

As ambient temperatures increase, more water evaporates from land and water sources. The timing, frequency, duration and type of precipitation events will be affected by these changes. In general, more precipitation will fall as rain rather than snow; however, the amount of snowfall may increase where temperatures remain below freezing (U.S. EPA, 2013). Snowfall may also change if typical storm track patterns are altered. Snowfall is already changing in the United States. The EPA reports the following trends (see Figure 12-9; U.S. EPA, 2013):

- Total snowfall has decreased in most parts of the country since widespread observations became available in 1930, with 57 percent of stations showing a decline.
- More than three-fourths of the stations across the contiguous 48 states have experienced a decrease in the proportion of precipitation falling as snow.
- The Pacific Northwest has seen a decline in both total snowfall and the proportion of precipitation falling as snow.

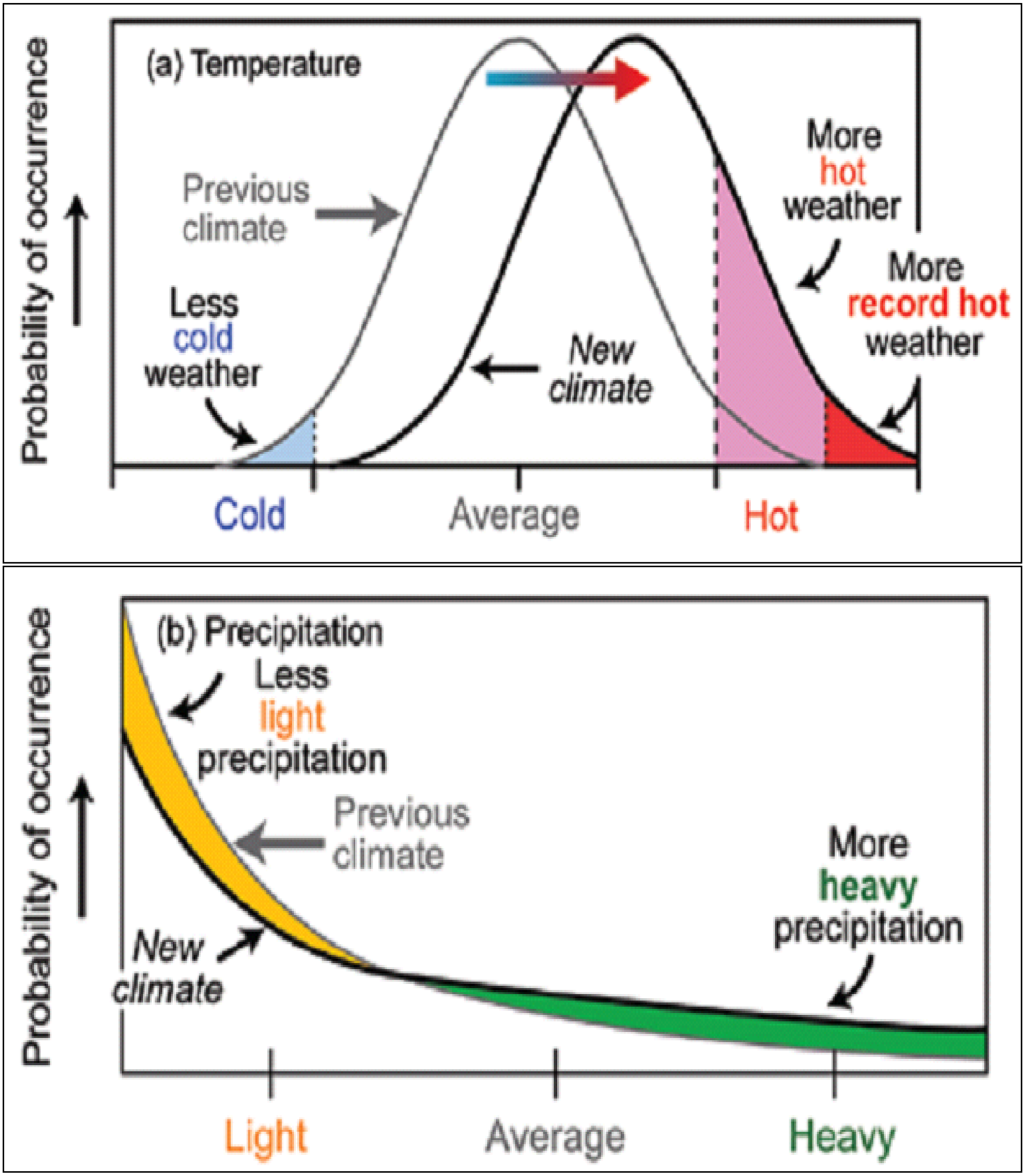

Figure 12-8. Severe Weather Probabilities in Warmer Climates

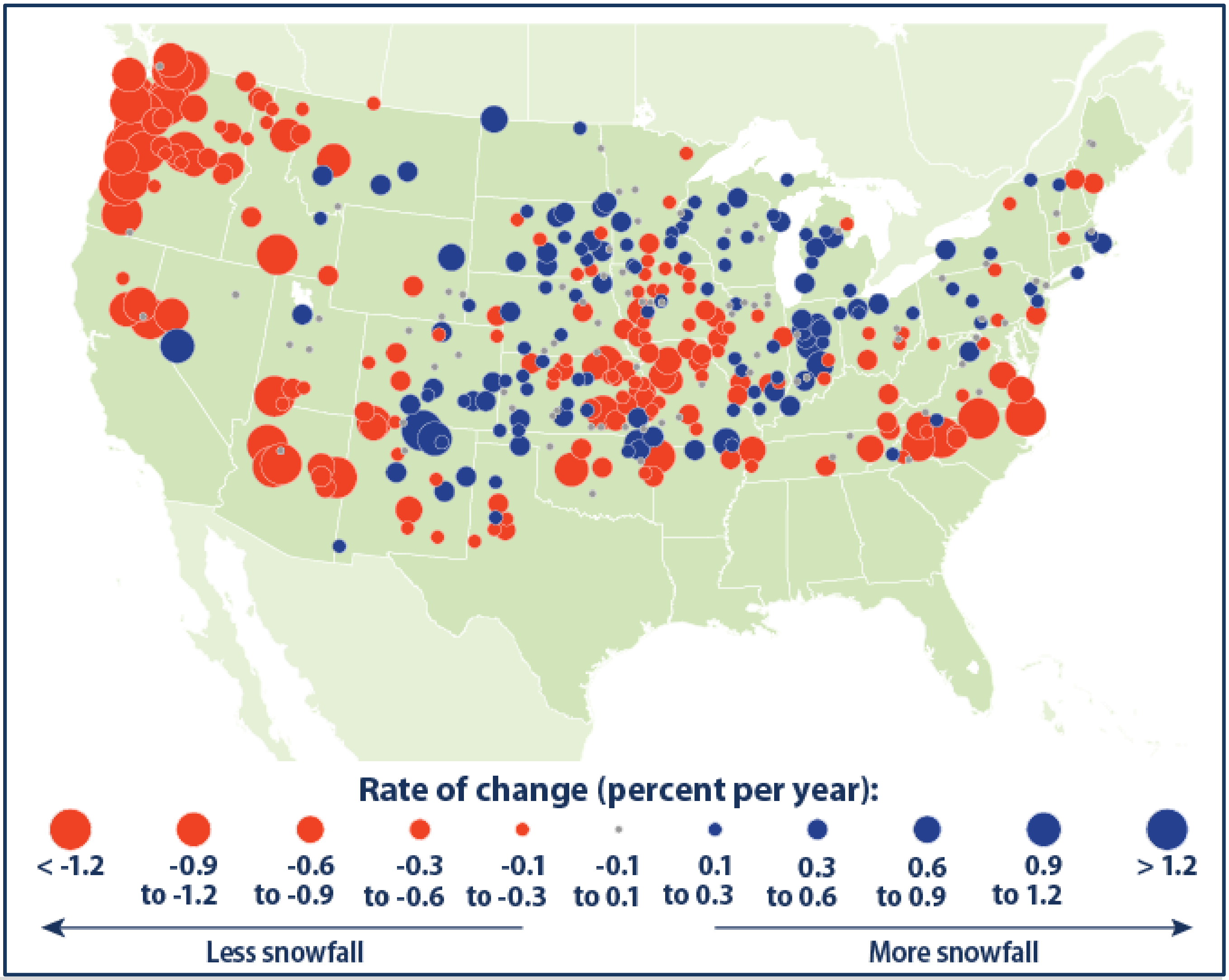

Figure 12-9. Change in Snowfall, 1930-2007

12.7 SCENARIO

Although severe local storms are infrequent, impacts can be significant, particularly when secondary hazards of flood and landslide occur in tandem. A worst-case event would involve prolonged high winds during a snowstorm accompanied by freezing temperatures, followed by warmer weather and continued rain. Such an event would have both short-term and longer-term effects. Initially, schools and roads would be closed due to snow and downed tree obstructions. Power outages would be common throughout the county. In the more rural areas, some subdivisions in unincorporated areas could experience limited ingress and egress. Later, as the weather warms and snow turns to rain, the sudden runoff could produce flooding, overtopped culverts with ponded water on roads, and landslides on steep slopes. Flooding and landslides could further obstruct roads and bridges, further isolating residents (CRESA, 2004).

This combination in November 1995 resulted in flood damage to roads and bridges, dikes and storm drainage systems, residences, businesses and farms throughout Clark County. Power lines were down throughout the county. Total damage was estimated at about $25 million. Rainfall was measured at approximately 10 inches above average for that period (CRESA, 2004).

12.8 ISSUES

Severe local storms are probably the most common widespread hazard. They affect large numbers of people in the planning area when they occur. Severe storms can quickly overwhelm city and county resources. Residents should be prepared for these types of storms: family plans should be developed, disaster kits should be put in homes, workplaces, schools and cars, and every family member should be taught how to shut off household utilities. Early dismissal from schools and businesses is an effective mitigation measure and should be encouraged.

Severe weather cannot be prevented, but measures can be taken to mitigate the effects. Critical infrastructure and utilities can be hardened to prevent damage during an event. The secondary effect of flooding can be addressed through decreasing runoff and water velocity. Important issues associated with severe weather in the planning area include the following:

- Redundancy of power supply throughout the planning area must be evaluated to better understand what areas may be vulnerable.
- The capacity for backup power generation is limited.
- The County has numerous isolated population centers.
- Public education on dealing with the impacts of severe weather needs to continue so that residents can be better informed and prepared for severe weather events.
- Debris management (downed trees, etc.) must be addressed, because debris can impact the severity of severe weather events, requires coordination efforts, and may require additional funding.
- Older building stock in the planning area is built to low code standards or none at all. These structures could be highly vulnerable to severe winter weather effects such as snow loads or high winds.
- Street tree management programs should be evaluated to help reduce impacts from tree-related damages.
- Priority snow removal routes should continue to be cleared first to ensure navigable routes through and between jurisdictions.

13. VOLCANO

13.1 GENERAL BACKGROUND

A volcano is a vent in the earth's crust through which magma, rock fragments, gases, and ash are ejected from the earth's interior. Over time, accumulation of these products on the earth's surface creates a volcanic mountain. Hazards associated with volcanoes are related to the ways in which volcanic materials and other debris flow from the volcano (CRESA 2004).

13.1.1 Cascade Range Volcanoes

Clark County is near the Cascade Range, an 800-mile-long chain of volcanoes that extends from northern California to southern British Columbia (see Figure 13-1). The volcanoes are the result of a slow slide of dense oceanic crust as it has passed below the North American continent, which releases water and melts overlying rock (USGS, 2013).

13.1.2 Stratovolcanoes and Types of Hazards

The volcanoes in the Cascade Range surrounding Clark County are all stratovolcanoes. They are typically steep-sided, symmetrical cones of large dimension, built of alternating layers of lava, volcanic ash, cinders and blocks of rock. They may rise as much as 8,000 feet above their bases. The sections below describe the hazards associated with Cascade Range volcanoes (CRESA, 2011).

Pyroclastic Flows and Surges

Pyroclastic flows are avalanches of hot (300ºC to 800°C), dry, volcanic rock fragments and gases that descend a volcano's flanks at speeds up to 200 miles per hour. They originate from the explosion related to an eruption. Pyroclastic flows and surges are a lethal hazard. They result in incineration, asphyxiation, and burial. Because of their speed they cannot be outrun. Pyroclastic flows are heavier than air and seek topographically low areas. Hot mixtures of gas and rock will flow above the ground and may go over topographical barriers such as ridges and hills.

Lava Flows

Lava flows are normally the least hazardous threat posed by volcanoes. The speed and viscosity of a lava flow are determined by the silica content of the lava. The higher the silica content, the more viscous (thick) the lava becomes. Low silica basalt lava can move 10 to 30 mph. High silica andesite and dacite tend to move more slowly and travel short distances. Cascade volcanoes are normally associated with slow moving andesite or dacite lava. However, 2,000 years ago Mount St. Helens produced a large amount of basalt.

Large lava flows may destroy property and cause forest fires but, since they are slow moving, they pose little threat to human life. The greater hazard presented by lava flows is that their extreme heat can cause snow and ice to melt very quickly, adding to flooding hazards or the lahar and debris avalanche hazards described below.

Source: USGS, 2013

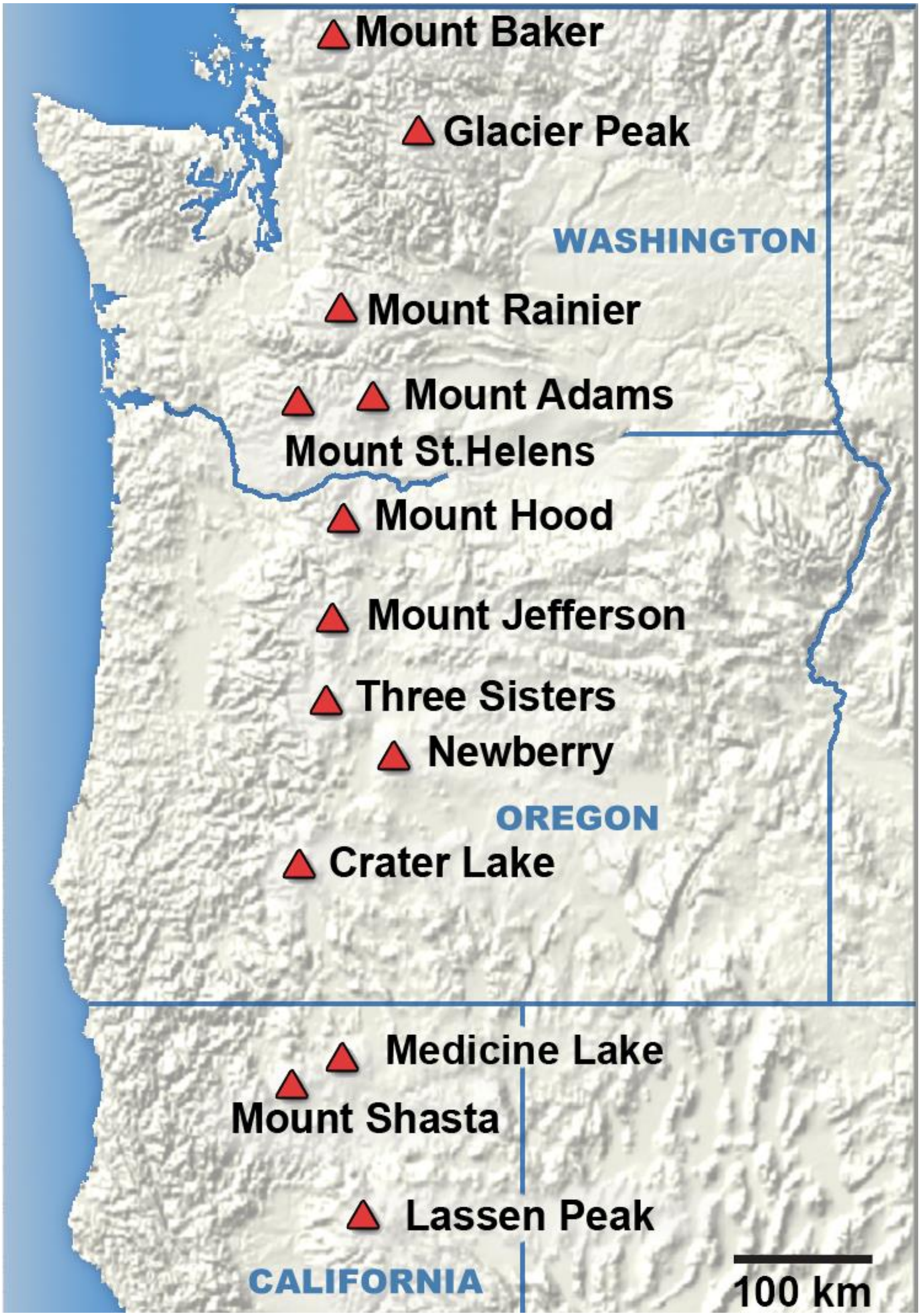

Figure 13-1. Cascade Range Volcanoes

Ash Fall

Ash and large volcanic projectiles can erupt from a volcano into the atmosphere. These materials are sometimes called tephra. The largest fragments (bombs, >64 mm) fall back to the ground fairly near the vents, as close as a few yards and as far as 6 miles. The smallest rock fragments (ash) are composed of rock, minerals, and glass that are less than 2 millimeters in diameter. Tephra plume characteristics are affected by wind speed, particle size, and precipitation.

Ash fall poses a variety of threats. Ash only 1 cm thick can impede the movement of most vehicles and disrupt transportation, communication, and utility systems. During the past 15 years, about 80 commercial jets have been damaged by inadvertently flying into ash, and several have nearly crashed. Airborne tephra will seldom kill people who are a safe distance from the vent. However, ash may cause eye and respiratory problems, particularly for those with existing medical conditions. Short-term exposure should not have any long-term health effects. Some ash fall materials may have acidic aerosol droplets that adhere to them. This may cause acid rain or corrosion of metal surfaces they fall on.

Ash may also clog ventilation systems and other machinery. When ash is mixed with rain it becomes a much greater nuisance. Wet ash is much heavier and it can cause structures to collapse. Most of the 330 deaths associated with the Mt. Pinatubo eruption were caused by roofs collapsing under the weight of rain-soaked ash. Wet ash may also cause electrical shorts. Ash fall also decreases visibility and may cause psychological stress and panic.

Lahars

Lahars are rapidly flowing mixtures of water and rock debris that originate from volcanoes. While lahars are most commonly associated with eruptions, heavy rains, debris accumulation, and even earthquakes may also trigger them. They may also be termed debris or mud flows. Lahars can travel over 50 miles downstream, reaching speeds between 20 and 40 mph. The highest recorded speed of a lahar during the 1980 Mount St. Helens eruption was 88 mph. Beyond the flanks of a volcano, lahars will normally be channeled into waterways. The threat from lahars comes from their speed and from the debris they carry. Abrasion from the heavy sediment and impacts from heavy debris can destroy forests as well as human-made structures, including bridges, dams, roads, pipelines, buildings, and farms. Lahars may also fill in channels, obstructing shipping lanes and impacting a channel’s ability to handle large volumes of water.

Debris Avalanches

Volcanoes are prone to debris and mountain rock avalanches that can approach speeds of 100 mph. Volcanoes are characterized by steep slopes of weak rock. Volcanic rock material is weakened by the acidic groundwater that seeps through rock cracks and turns rigid rock into clay. Minor eruptions, earthquakes, or releases of built up water and debris may trigger large avalanches of this material.

Volcanic Gases

All active volcanoes emit gases. These gases may include steam, carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen, and fluorine. Sometimes, these chemicals can be absorbed by ash and impact groundwater, livestock, and metal objects. Even when a volcano is not erupting, gases can escape through small surface cracks. The greatest danger to people comes when large quantities of toxic gases are emitted from several sources or when there are topographic depressions that collect gases that are heavier than air. These gases can accumulate to the point where people or animals can suffocate. Neither of these conditions exists in Cascade volcanoes, though this could change if magma were to come close to the surface. Mount St. Helens emitted thousands of tons of sulfur dioxide every day in the early 1980s. These gases were easily dispersed by the wind.

Lateral Blast

Lateral blasts are explosive events in which energy is directed horizontally instead of vertically from a volcano. They are gas-charged, hot mixtures of rock, gas and ash that are expelled at significantly high speeds. Lateral blasts vary in size, but large ones are fairly rare, with only a few historical examples worldwide. The most recent was the 1980 eruption of Mount St. Helens when almost everything within the blast zone (about 230 square miles) perished. The Mount St. Helens lateral blast is estimated to have reached a velocity of 670 mph, and there have been speculations that the velocity may have gone even higher, reaching a supersonic rate of 735+ mph for at least a few moments (USGS, 1997).

13.2 HAZARD PROFILE

13.2.1 Past Events

Cascade Range volcanoes in the U.S. have erupted more than 200 times during the past 12,000 years, for an average of nearly two eruptions per century (CRESA, 2011). Seven Cascade volcanoes have erupted since the beginning of the 18th century (USGS, 2013). At least five of these eruptions have occurred during the past 150 years (CRESA, 2011). Figure 13-2 summarize past eruptions in the Cascades.

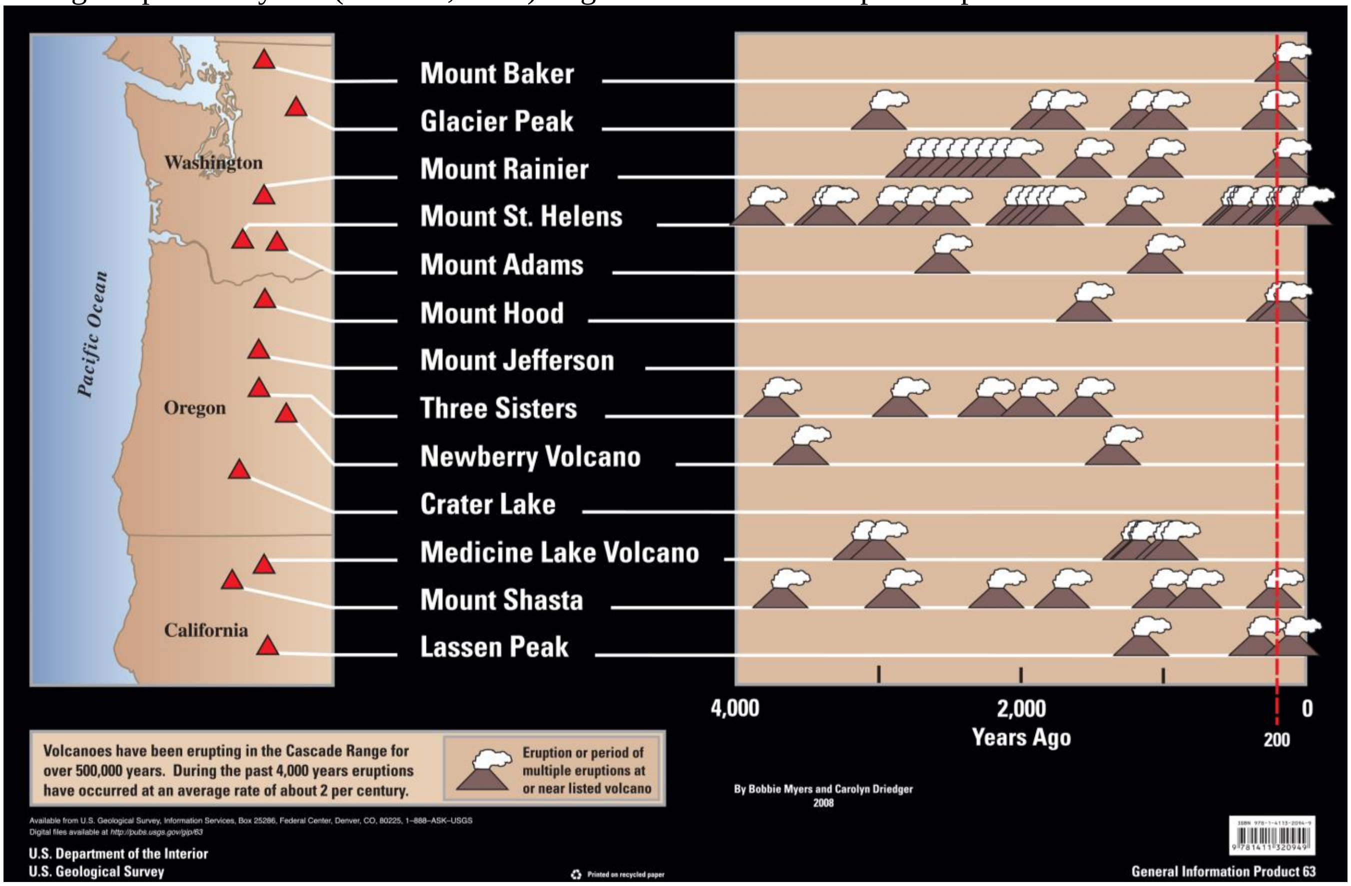

Figure 13-2. Cascade Range Eruptions in the Past 4,000 Years

The most recent major eruptions in the Cascade Range are the well-documented 1980-1986 eruptions of Mount St. Helens. The primary, major eruption on May 18, 1980 claimed 57 lives and caused nearly a billion dollars in damage and response costs. The effects were felt throughout the Northwest (CRESA, 2011). Mount St. Helens also experienced activity from 2004 to 2008, producing a series of lava spines and millions of small earthquakes (Washington Emergency Management Division, 2014).

In 1781, Mount Hood erupted, which resulted in lahar flows that reached the Columbia River (USGS, 2013). There were additional reports of eruptive activity in 1859 and 1865 from early settlers. Reports included sightings of fire, smoke, flying rock, and steaming (USGS, 2012b).

13.2.2 Location

None of the Cascade volcanoes are located in Clark County. The nearest are Mount Hood in northern Oregon and Mount Adams and Mount St. Helens in southern Washington. Expected impacts from these volcanoes are generally referred to as “distal” hazards, meaning that the hazard areas are relatively far from the volcano itself. Hazard mapping conducted by the USGS indicates that major eruptions of Mount Hood and Mount St. Helens could have direct impacts on small portions of the planning area:

- In the event of a Mount Hood eruption, a small part of the southeastern portion of the county, located along the Columbia River, may experience bank erosion and flooding caused by lahars and sediment-rich floods from the Sandy and Hood Rivers (see Figure 13-3 and Figure 13-5).
- An eruption of Mount St. Helens may directly impact a very small area of the northeastern portion of the county; however, there are no structures within that mapped hazard area (see Figure 13-4).

Ash fall from an eruption of any of the Cascade volcanoes could potentially reach the planning area depending on weather events at the time of the eruption.

13.2.3 Frequency

Mount St. Helens is currently the most active volcano in the Cascades, with four major explosive eruptions in the last 515 years as well as dozens of smaller eruptions. Still, the probability of an eruption in any given year is extremely low. Figure 13-6 shows the annual probability of an ash fall accumulation of 4 inches or more (10 cm). Clark County is in an area of varying probability for such ash fall accumulation, ranging from 0.1 percent in the eastern portion of the county to less than 0.01 percent in the western portion.

13.2.4 Severity

Although Clark County is near both Mount St. Helens and Mount Hood, the planning area does not have a large degree of exposure to direct impacts, aside from ash fall. The severity of impacts from distal hazards would likely depend on the severity of the eruption. The severity of impacts from ash fall accumulation would be related to the extent of the accumulation. Ash fall often causes damage to buildings and building systems. This can range from complete or partial roof collapse to damage to exterior materials or interior rooms and appliances. Effects are dependent on the thickness of the ash, whether it is wet or dry, the roof and building design, air-handling systems, and the amount of ash inside the building. Buildings whose mechanical systems are shut down prior to ash fall typically experience less interior damage.

In addition to the concern for structural collapse, ash is corrosive and can be electrically conductive. This can lead to metallic roof surfaces experiencing increased deterioration. The abrasive and corrosive nature of ash not only causes potential minor but painful burns to humans, it can also damage computer and electronic systems. While volcanic ash is most often associated with structural instability, it can also cause issues with agriculture, health, power supply, water supply, transportation, and wastewater (USGS, 2015a).

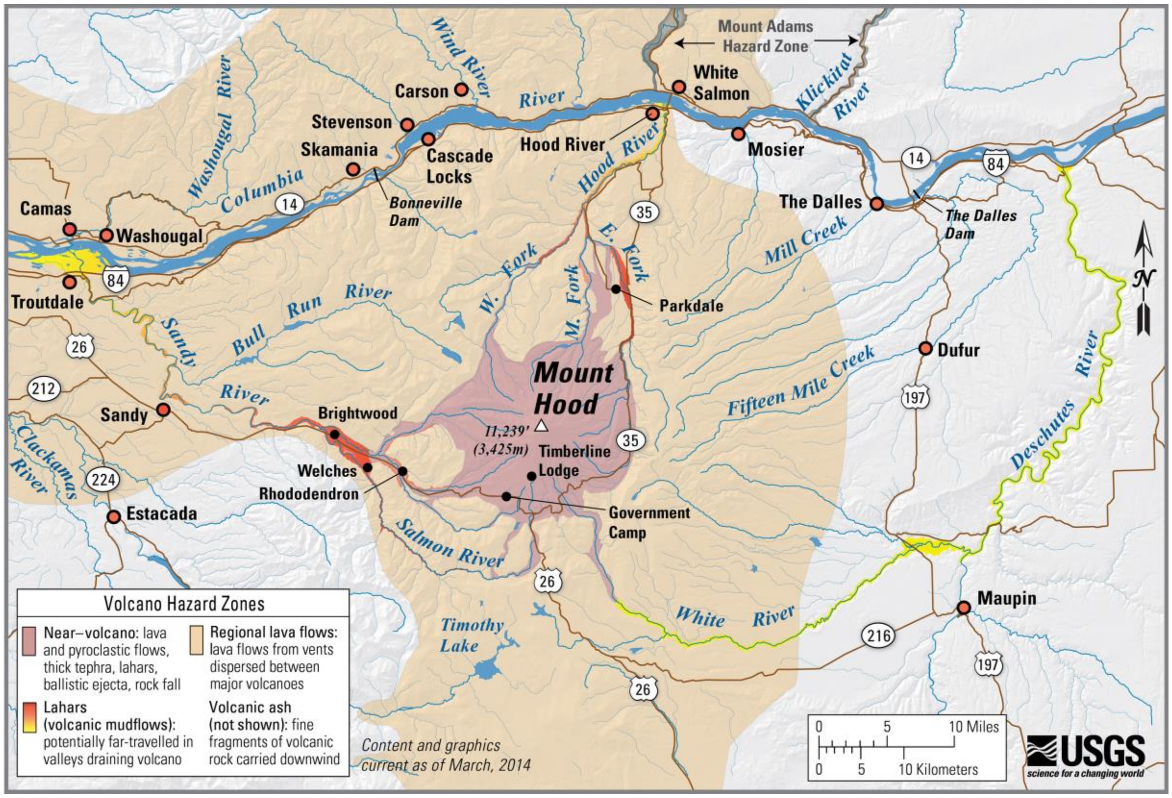

Figure 13-3. Potential Impact Area for Ground-Based Hazards during a Mount Hood Event

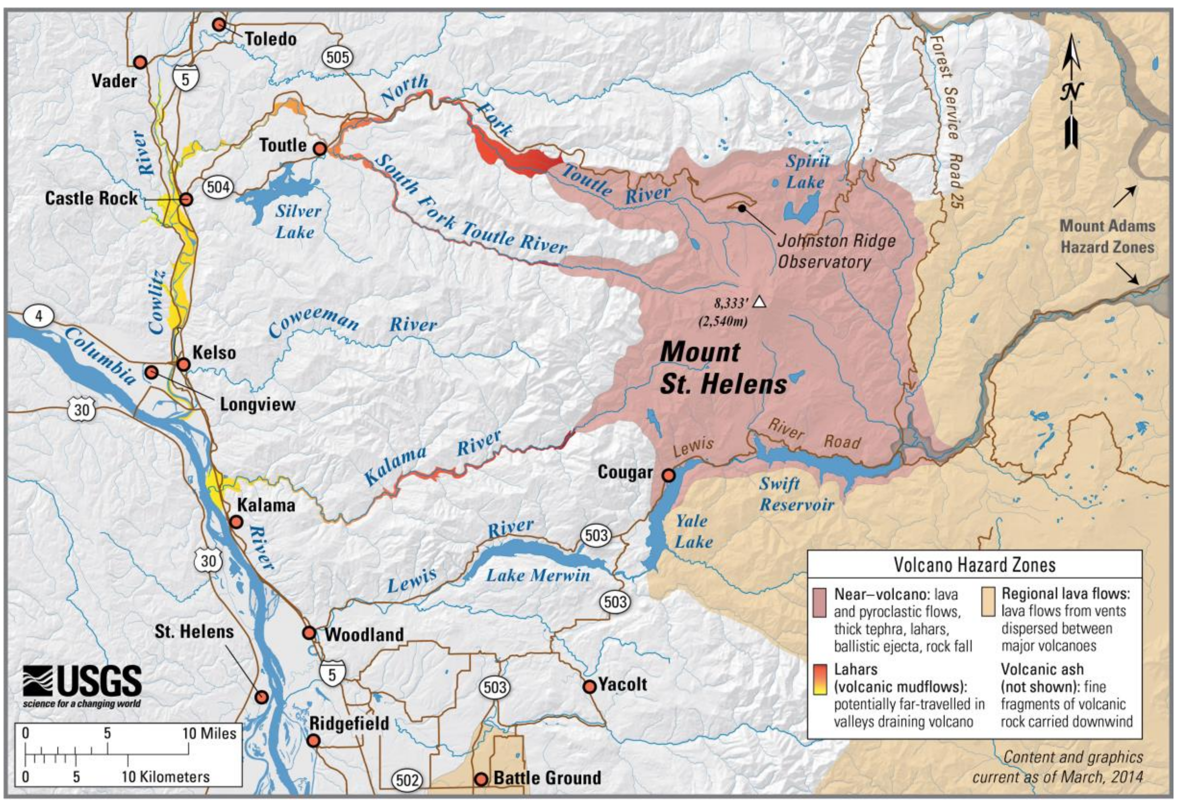

Figure 13-4. Potential Impact Area for Ground-Based Hazards during a Mount Saint Helens Event

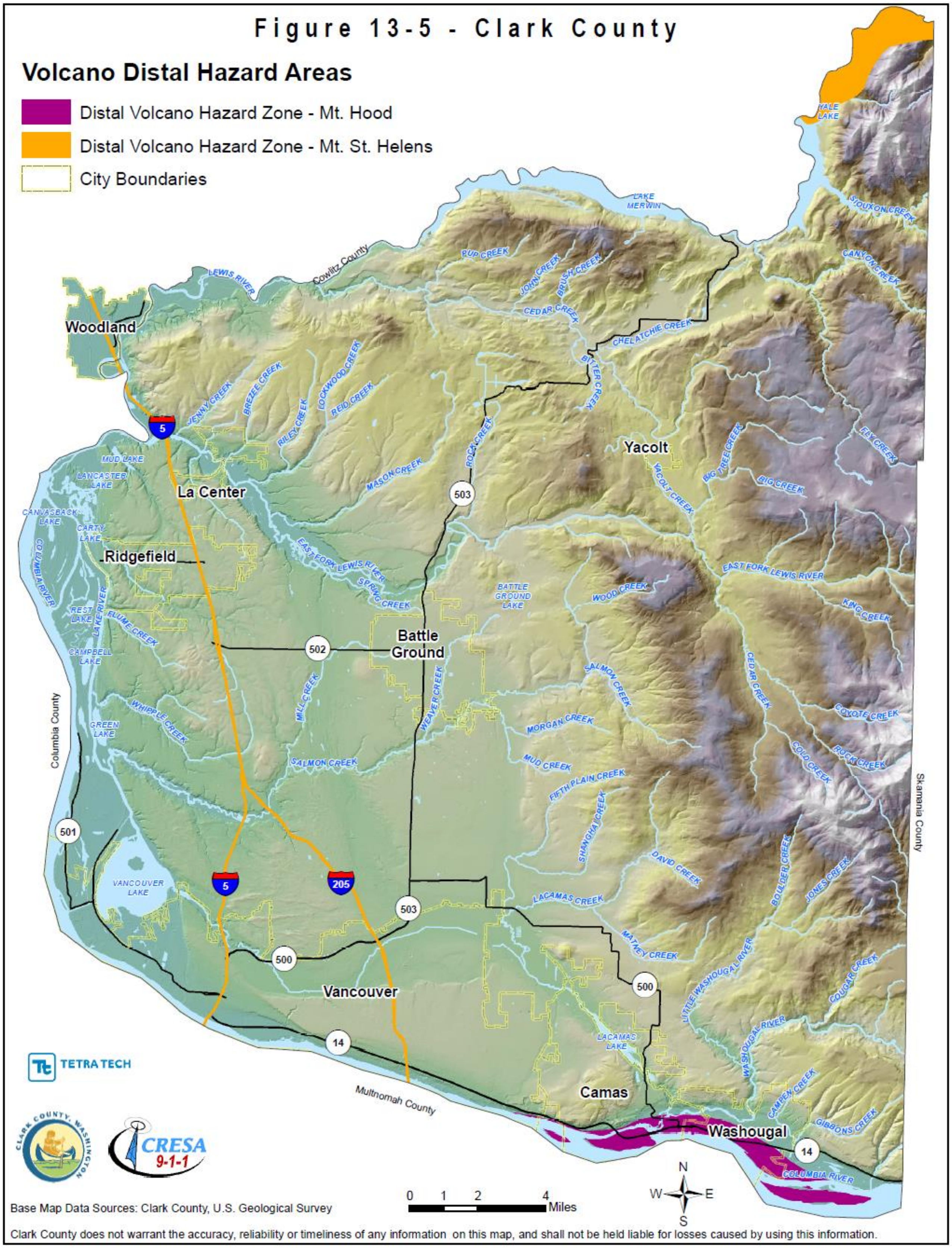

Figure 13-5. Volcano Distal Hazard Areas

Source: Hoblitt and Scott, 2011

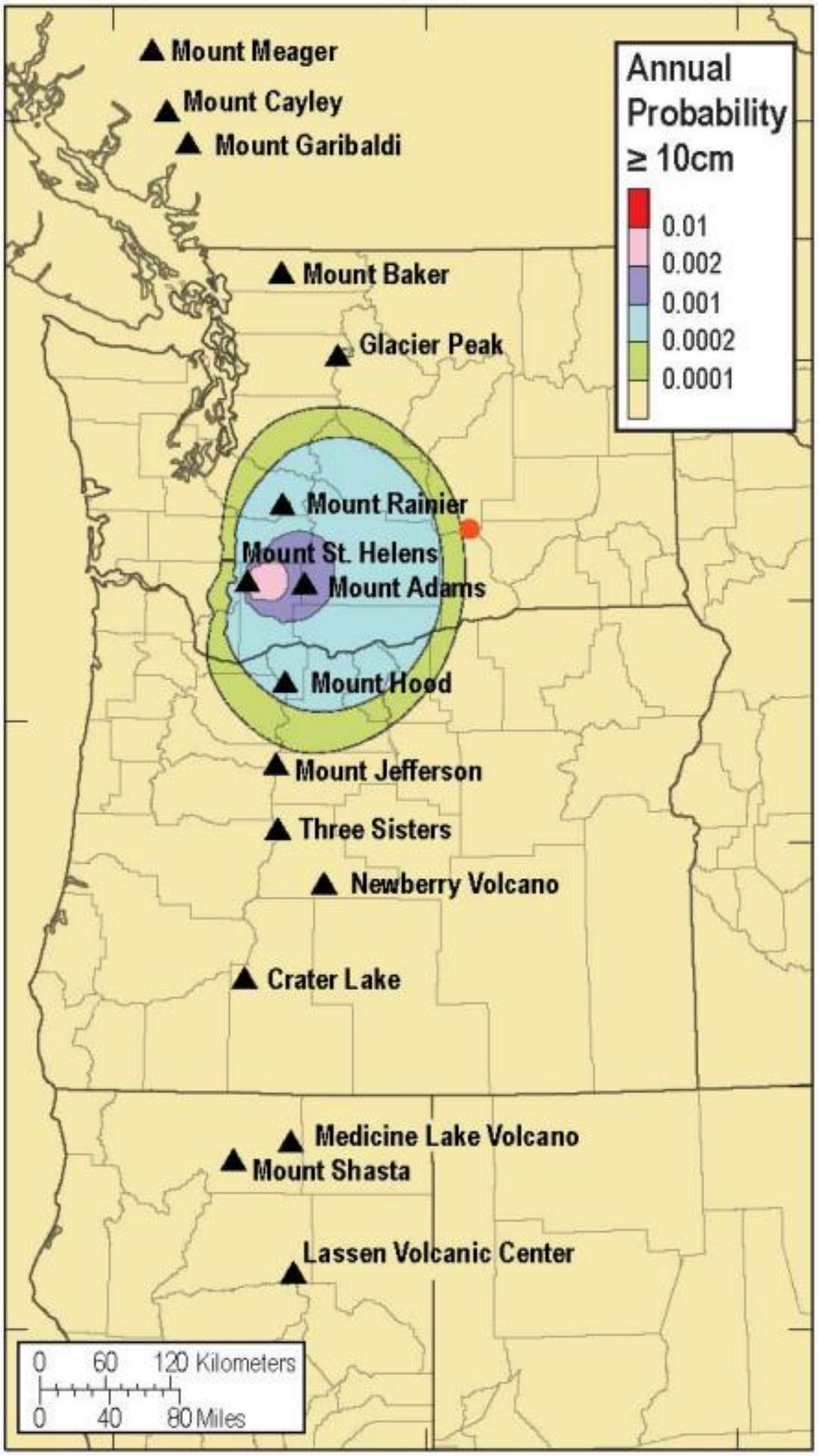

Figure 13-6. Preliminary Probabilistic Ash Fall Hazard Map

13.2.5 Warning Time

The best warning of a volcanic eruption is one that specifies when and where an eruption is likely and what type and size eruption should be expected. Such accurate predictions are sometimes possible but still rare. The most accurate warnings are those in which scientists indicate an eruption is probably only hours to days away, based on significant changes in a volcano's earthquake activity, ground deformation, and gas emissions. Experience from around the world has shown that most eruptions are preceded by such changes over a period of days to weeks. A volcano may begin to show signs of activity several months to a few years before an eruption. However, a warning that specifies months or years in advance when it might erupt are extremely rare.

Monitoring Volcanic Activity

The USGS and the Pacific Northwest Seismograph Network at the University of Washington conduct seismic monitoring of all Cascade volcanoes in Washington and Oregon. During the past decade, monitoring networks on Mount Hood and Mount St. Helen's have been expanded.

Volcanic Event Notification

Members of the public may sign up for the USGS Volcano Notification Service email subscription service on the USGS website. Notifications include several types: volcano activity notices; daily, weekly or monthly updates; status reports; volcano observatory notices for aviation; and information statements. Volcano-alert notifications are based on analysis of data from monitoring networks, direct observations, and satellite sensors. They are issued for both increasing and decreasing volcanic activity and include text about the nature of the activity and about potential or current hazards. Scientists describe a volcano's status using alert levels and color codes and issue different types of notifications to address specific information needs. These alert levels consist of two parts (USGS, 2016):

- Ranked terms to inform people on the ground about a volcano's status:
  - **Normal**—Volcano is in typical background, non-eruptive state or, after a change from a higher level, volcanic activity has ceased and volcano has returned to non-eruptive background state.
  - **Advisory**—Volcano is exhibiting signs of elevated unrest above known background level or, after a change from a higher level, volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
  - **Watch**—Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, OR, eruption is underway but poses limited hazards.
  - **Warning**—Hazardous eruption is imminent, underway, or suspected.
- Ranked colors to inform the aviation sector about airborne hazards (green, yellow, orange and red generally correspond to alert level term definitions).

This alert level ranking offers a framework that the public and civil authorities can use to gauge and coordinate a response to a developing volcano emergency.

Lahar Travel Times

According to a recent study by the Oregon Department of Geology and Mineral Industries (2016), it would take more than 3.5 hours for distal hazard impacts to reach the planning area (see Figure 13-7).

Source: USGS Simplified from Gardner et al. 2000

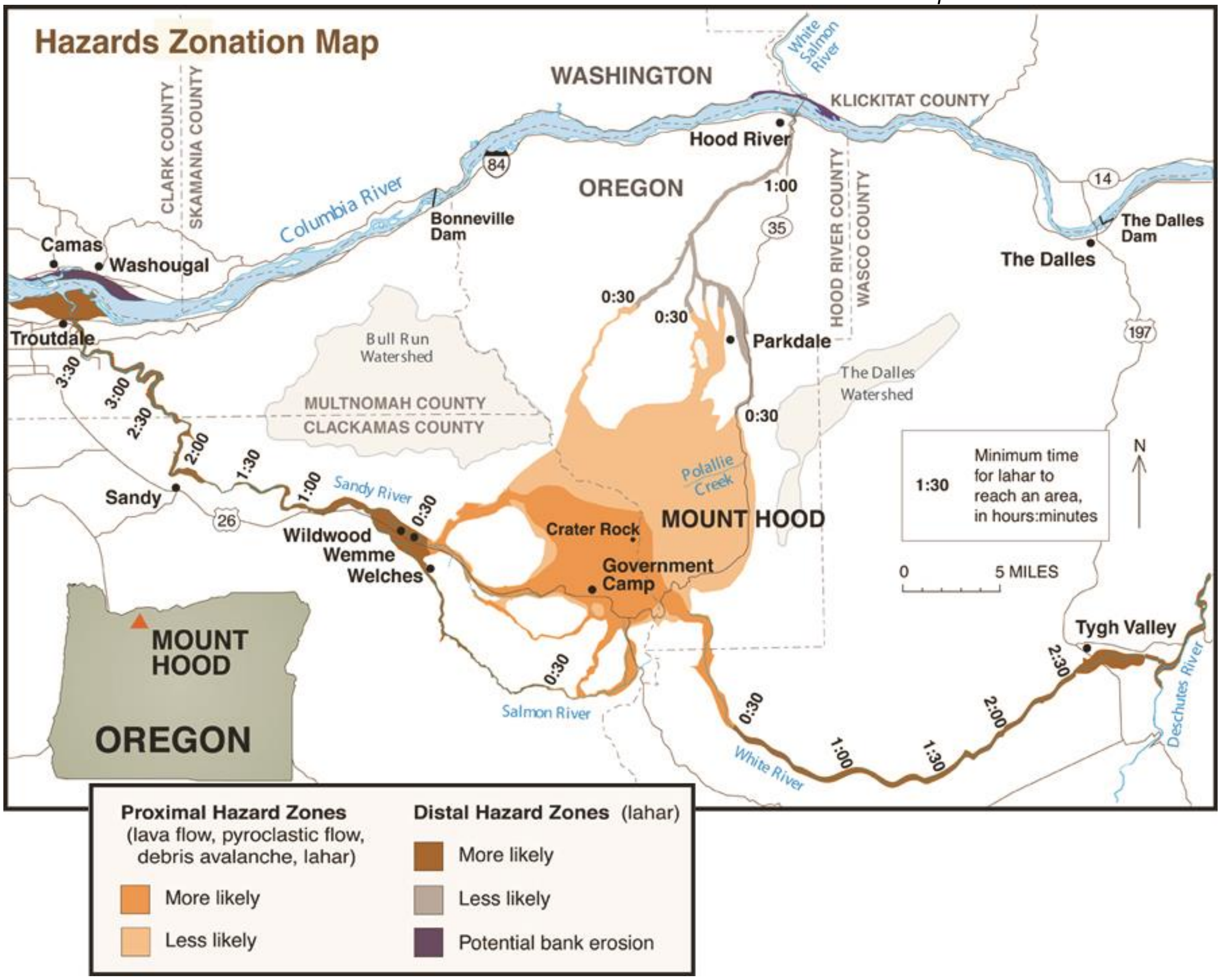

Figure 13-7. Mount Hood Hazard Zones and Lahar Travel rimes

13.3 SECONDARY HAZARDS

Ground movement often accompanies volcanic eruption. Such movement can result in subsidence, surface ruptures, earthquakes, and potentially tsunamis. Other secondary hazards can include traffic disruptions (such as if ash coats roadways and runways); utility failures (from the weight of ash or the infiltration of ash into electronic systems, particularly with communications, power, and water quality); and structural or building collapse. Areas impacted by volcanic ash and toxic gases can experience long-term secondary public health impacts associated with soil quality. Acid rain may damage water supplies, foliage, paint, machinery, and fabric.

13.4 EXPOSURE

All of the Clark County planning area would be exposed to ash fall from volcanic eruptions in the Cascade Range to some degree. The location of the event as well as the prevailing wind direction would influence the extent of this impact.

13.4.1 Population

The entire population of Clark County is exposed to the effects of ash fall. Populations along the Columbia River islands and areas along the Washington shore could be impacted by distal hazards. Population could not be examined by distal hazard zone because census block groups do not coincide with the hazard risk areas. However, population was estimated using the structure count of buildings within the distal hazard zones and applying the census value for Clark County of 2.7 persons per household. Using this approach, it is estimated that the exposed population is 3,297 (less than 1 percent of the total planning area population). Table 13-1 shows the estimated population exposure by jurisdiction.

Table 13-1. Estimated Population Residing in Distal Hazard Areas

	Population Exposed[a]	% of Total Population
Battle Ground	0	0.0%
Camas	1,291	6.1%
La Center	0	0.0%
Ridgefield	0	0.0%
Vancouver	3	0.0%
Washougal	1,979	13.0%
Woodland	0	0.0%
Yacolt	0	0.0%
Unincorporated	24	0.0%
Total	**3,297**	**0.7%**

a. Value calculated as number of buildings exposed multiplied by 2.7 people (Clark County) / 3.17 people (Woodland) per building. This multiplier is the number of persons per household per the U.S. Census Bureau, State, County and City Quick Facts 2009-2015.

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

13.4.2 Property

Distal Hazards

All of the exposure to distal hazards is in the southern portion of the planning area along the Columbia River islands and areas along the river shore. All property in the distal hazard zones would be exposed to bank erosion and flooding. It is possible that dikes and bulkheads along the north bank of the Columbia River could help to protect property from the effects of a lahar-induced flood (CRESA, 2004). The number and value of planning area structures in the distal hazard zones is summarized in Table 13-2. The type of structure is shown in Table 13-3. The breakdown of the present land use in the distal hazard areas is shown in Table 13-4.

Exposed property in the planning area is located in Camas, Washougal, Vancouver and unincorporated areas. The majority of exposed structures are residential (75 percent), although there is substantial exposure of commercial and industrial activities in the Port of Washougal, accounting for the high percentage of the estimated replacement value. Residential and industrial uses make up the majority of exposed land uses in the hazard areas.

Ash Fall

All property in the planning area would be exposed to ash fall accumulation in the event of a volcanic eruption.

Table 13-2. Exposure and Value of Structures in Distal Hazard Zone

Jurisdiction	Buildings Exposed	Value Exposed			% of Total Replacement Value
		Structure	Contents	Total	
Battle Ground	0	$0	$0	$0	0.0%
Camas	478	$479,346,070	$500,824,519	$980,170,589	12.9%
La Center	0	$0	$0	$0	0.0%
Ridgefield	0	$0	$0	$0	0.0%
Vancouver	1	$1,029,215	$1,029,215	$2,058,429	0.0%
Washougal	733	$991,165,458	$914,612,600	$1,905,778,058	45.8%
Woodland	0	$0	$0	$0	0.0%
Yacolt	0	$0	$0	$0	0.0%
Unincorporated	9	$5,911,142	$4,566,691	$10,477,833	0.0%
Total	**1,221**	**$1,477,451,884**	**$1,421,033,025**	**$2,898,484,909**	**2.6%**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 13-3. Structure Type in Distal Hazard Zone

	Number of Structures[a]							
	Residential	Commercial	Industrial	Agriculture/ Forestry	Religion	Government	Education	Total
Battle Ground	0	0	0	0	0	0	0	**0**
Camas	393	71	11	0	1	2	0	**478**
La Center	0	0	0	0	0	0	0	**0**
Ridgefield	0	0	0	0	0	0	0	**0**
Vancouver	0	1	0	0	0	0	0	**1**
Washougal	513	175	7	2	11	17	8	**733**
Woodland	0	0	0	0	0	0	0	**0**
Yacolt	0	0	0	0	0	0	0	**0**
Unincorporated County	8	0	0	1	0	0	0	**9**
Total	**914**	**247**	**18**	**3**	**12**	**19**	**8**	**1,221**

a. Structure type assigned to best fit Hazus occupancy classes based on present use classifications provided by Clark and Cowlitz County assessor's data. Where conflicting information was present in the available data, parcels were assumed to be improved.

Table 13-4. Present Land Use in Planning Area[a]

Present Use Classification[b]	Area (acres)[c, d]	% of total
Agriculture/Resource Land	362	8.6%
Commercial	793	18.8%
Education	3	0.1%
Governmental Services	13	0.3%
Industrial	943	22.3%
Religious Services	4	0.1%
Residential	1,491	35.3%
Vacant or uncategorized	618	14.6%
Total	4,227	100%

a. Present land use information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.

b. Present use classification provided by Clark and Cowlitz County assessor's data assigned to best fit occupancy classes in FEMA's Hazus model (see Section 6.3.1). Parcels for which conflicting information on current development was available were assumed to be improved. Some designated resource land may also be included in the vacant or uncategorized category.
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage includes Clark County and the incorporated areas of the City of Woodland.

13.4.3 Critical Facilities and Infrastructure

Distal Hazard Zones

All critical facilities and infrastructure in the mapped hazard areas are exposed to distal hazards, as summarized in Table 13-5. In addition the following linear features are exposed:

- Northwest pipeline
- State Route 14
- State Route 500
- 6.02 miles of Columbia River levees.

Table 13-5. Critical Facilities and Infrastructure Exposed to Distal Hazards

	Communication Facilities	Dams	Emergency Services	Energy	Government Facilities	Hazardous Materials	Health Care & Public Health	Information Technology	Schools	Transportation Systems	Water & Sanitation Systems	Total
Battle Ground	0	0	0	0	0	0	0	0	0	0	0	**0**
Camas	0	0	2	1	0	0	0	0	0	4	17	**24**
La Center	0	0	0	0	0	0	0	0	0	0	0	**0**
Ridgefield	0	0	0	0	0	0	0	0	0	0	0	**0**
Vancouver	0	0	0	0	0	0	0	0	0	0	0	**0**
Washougal	0	0	2	1	3	8	0	0	0	2	7	**23**
Woodland	0	0	0	0	0	0	0	0	0	0	0	**0**
Yacolt	0	0	0	0	0	0	0	0	0	0	0	**0**
Unincorporated	0	0	0	0	0	0	0	0	0	0	0	**0**
Total	**0**	**0**	**4**	**2**	**3**	**8**	**0**	**0**	**0**	**6**	**24**	**47**

Ash Fall

All critical facilities and infrastructure in the planning area are potentially exposed to ash fall.

13.4.4 Environment

The environment is highly exposed to the effects of a volcanic eruption. Even if ash fall from a volcanic eruption were to fall elsewhere, it could still be spread throughout the county by surrounding rivers and streams. Additionally, excess sediment in rivers and streams could impact water quality and substantially disrupt habitat.

13.5 VULNERABILITY

13.5.1 Population

Distal Hazards

Since there is generally adequate warning time before a volcanic event, the population vulnerable to distal hazards consists of those who choose not to evacuate or are unable to evacuate. The latter includes the elderly, the very young, and those with access and functional needs.

Ash Fall

The entire population of the planning area is vulnerable to the damaging effects of volcanic ash fall in the event of a volcanic eruption. The elderly, very young and those who experience ear, nose and throat problems are especially vulnerable to the ash fall hazard. Ash is harsh, acidic, gritty, and smelly. Although the gases are usually too diluted to constitute danger to a person in normal health, the combination of acidic gas and ash may cause lung problems. Extremely heavy ash can clog breathing passages and cause death. When an ash cloud combines with rain, sulfur dioxide in the cloud combines with water to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose, and throat. Hydrochloric acid rains following eruptions have also been reported. Additionally, ash fall decreases visibility and may cause psychological stress and panic.

13.5.2 Property

Distal Hazards

There are currently no generally accepted damage functions for volcanic hazards in risk assessment platforms such as Hazus-MH. All properties listed in Table 13-2 are considered vulnerable to distal hazards. The most vulnerable structures would be those that are located closest to the Columbia River hazard areas, and those that are not structurally sound. Loss estimates for distal hazards are shown in Table 13-6 representing 10, 30, and 50 percent of the exposed property value.

Ash Fall

All of the property exposed to nature in the planning area is exposed to the effects of ash fall. The most vulnerable structures are those that are not as structurally sound and may collapse under the excessive weight of ash and possible rainfall. A 1-inch deep layer of ash weighs an average of 10 pounds per square foot, causing danger of structural collapse.

Vulnerable property includes equipment and machinery left out in the open, such as combines, whose parts can become clogged by the fine dust. Infrastructure, such as drainage systems, is potentially vulnerable to the effects of ash fall, since the fine ash can clog pipes and culverts. This may be more of a problem if an eruption occurs during winter or early spring when precipitation is highest and floods are most likely.

Table 13-6. Loss Estimates for Volcano Distal Hazards

		Estimated Loss Potential from Distal Hazards		
	Exposed Value	10% Damage	30% Damage	50% Damage
Battle Ground	$0	$0	$0	$0
Camas	$980,170,589	$98,017,058.90	$294,051,176.70	$490,085,294.50
La Center	$0	$0	$0	$0
Ridgefield	$0	$0	$0	$0
Vancouver	$2,058,429	$205,842.90	$617,528.70	$1,029,214.50

	Exposed Value	Estimated Loss Potential from Distal Hazards		
		10% Damage	30% Damage	50% Damage
Washougal	$1,905,778,058	$190,577,805.80	$571,733,417.40	$952,889,029.00
Woodland	$0	$0	$0	$0
Yacolt	$0	$0	$0	$0
Unincorporated	$10,477,833	$1,047,783.30	$3,143,349.90	$5,238,916.50
Total	**$2,898,484,909**	**$289,848,491**	**$869,545,473**	**$1,449,242,455**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

To estimate the loss potential for this hazard, a qualitative approach was used, based on recommendations from FEMA guidelines on state and local mitigation planning. For this analysis, 0.1 percent of total replacement valuations was selected as the loss ratio for the ash fall hazard. The results are summarized in Table 13-7.

Table 13-7. Loss Estimates for Ash Fall

Jurisdiction	Exposed Value	Estimated Loss Potential @ 0.1% Damage
Battle Ground	$4,036,379,864	$4,036,380
Camas	$7,575,016,927	$7,575,017
La Center	$805,148,506	$805,149
Ridgefield	$2,075,091,625	$2,075,092
Vancouver	$47,993,433,972	$47,993,434
Washougal	$4,159,958,945	$4,159,959
Woodland	$1,777,992,519	$1,777,993
Yacolt	$306,406,962	$306,407
Unincorporated	$44,797,390,449	$44,797,390
Total	**$113,526,819,768**	**$113,526,820**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

13.5.3 Critical Facilities and Infrastructure

Distal Hazards

All critical facilities and infrastructure in the hazard areas are vulnerable to distal hazards. Flood protection may offer some protection for some facilities, depending on design specifications. Excess sedimentation and resulting bank erosion may significantly impact the Columbia River shipping channel.

Ash Fall

Ash fall accumulation of less than one-half inch is capable of creating temporary disruptions of transportation operations and sewage disposal and water treatment systems. Highways and roads could be closed for hours, days, or weeks afterwards. The gritty ash can cause substantial problems for internal-combustion engines and other mechanical and electrical equipment. The ash can contaminate oil systems, clog air filters, and scratch moving surfaces. Fine ash can also cause short circuits in electrical transformers, which in tum cause power blackouts.

Heavy airborne ash blots out light. Sudden heavy demand for electric light and air conditioning may cause a drain on power supplies, leading to a partial or full power failure. Ash clogs machinery of all kinds and poses a serious threat to aviation because particles can damage aircraft systems and jet engines. It drifts into roadways, railways, and runways, where it is slippery and dangerous. Its weight may cause structural collapse. Because winds and air currents easily carry it, it remains a hazard to machinery and transportation (particularly aviation) for months after the eruption

13.5.4 Environment

The increased sedimentation and bank erosion resulting from a volcanic eruption could be damaging to rivers and streams and could redirect water flow and cause changes in water courses. Ash fall would expose the local environment to lower air quality and other effects that could harm vegetation and water quality. The sulfuric acid contained in volcanic ash could be damaging to area vegetation, waters, wildlife and air quality. Secondary impacts from hazardous materials released in distal hazard areas could cause significant damage to the environment and waterways.

13.5.5 Economic Impact

Volcanic eruptions can disrupt the normal flow of commerce and daily human activity without causing severe physical harm or damage. Ash that is a few inches thick can halt traffic, cause rapid wear of machinery, clog air filters, block drains, creeks and water intakes, and impact agriculture. Removal and disposal of large volumes of deposited ash can have significant impacts on government and business. The interconnectedness of the region’s economy can be disturbed after a volcanic eruption. Roads, railroads and bridges can be damaged by lahars and mudflows. The Mount St. Helens May 1980 eruption demonstrated the negative effect on the tourism industry. Conventions, meetings, and social gatherings were canceled or postponed in cities and resorts throughout Washington and Oregon in areas not initially affected by the eruption. However, the eruption did lead to the creation of a thriving tourist industry for decades following the event.

The disruption of regional activity is further demonstrated by the 2010 eruption of Iceland’s Eyjafallajokull volcano, which led to European air travel being halted for several days. The movement of goods via major highways can also be halted due to tephra in the air. The Mount St. Helens event in May 1980 cost trade and commerce an estimated $50 million in only two days, as ships were unable to navigate the Columbia River. Clouds of ash often cause electrical storms that start fires, and damp ash can short-circuit electrical systems and disrupt radio communication. Volcanic activity can also lead to the closure of nearby recreation areas as a safety precaution long before the activity ever culminates in an eruption.

13.6 FUTURE TRENDS

13.6.1 Development

Distal Hazards

Mapped distal hazard areas in Clark County overlap significantly with special flood hazard areas, which are held to more restrictive standards for development. These areas are predominantly zoned for commercial and industrial uses. Comprehensive plans will guide future development in these areas. Table 13-8 shows the area identified as underutilized or vacant in urban growth areas in the County that intersect identified distal hazard areas.

Table 13-8. Buildable Lands in Planning Area Urban Growth Areas that Intersect Distal Hazard Areas[a]

Urban Growth Area[b]	Buildable Area[c] (acres)				
	Residential		Commercial	Industrial	Total
	Acres	Units			
Battle Ground	0		0	0	**0**
Camas	11.94		1.83	33.62	**47.39**
La Center	0		0	0	**0**
Ridgefield	0		0	0	**0**
Vancouver	1.98		0	0	**1.98**
Washougal	31.76		50.87	73.06	**155.69**
Woodland[d]	0		0	0	**0**
Yacolt	0		0	0	**0**
Total	**45.68**		**52.70**	**106.68**	**205.06**

a. Buildable lands information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Unincorporated areas outside of urban growth areas are excluded from this assessment. Development in these areas consists largely of rural lands, open space and large residential lots.
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage estimates exclude the portions of the City of Woodland in Cowlitz County and thus may be underestimated.

Ash Fall

All future development in the planning area will be susceptible to potential impacts from volcanic eruptions causing ash fall in the region. While this potential impact on the built environment is not considered to be significant, the economic impact on industries that rely on machinery and equipment, such as agriculture or civil engineering projects, could be significant. Since the extent and location of this hazard is difficult to gauge because it is dependent upon many variables, the ability to institute land use recommendations based on potential impacts of this hazard is limited. While the impacts of ash fall are sufficient to warrant risk assessment for emergency management purposes, they are not sufficient to dictate land use decisions.

13.6.2 Climate Change

Climate change is not likely to affect the risk associated with volcanoes; however, volcanic activity can affect climate change. Volcanic clouds absorb terrestrial radiation and scatter a significant amount of incoming solar radiation. By reducing the amount of solar radiation reaching the Earth's surface, large-scale volcanic eruptions can lower temperatures in the lower atmosphere and change atmospheric circulation patterns. The massive outpouring of gases and ash can influence climate patterns for years following a volcanic eruption. Additionally, while climate change is not likely to increase the frequency of eruptions, changes in precipitation amounts could increase the potential for lahars or debris avalanches in volcanic areas.

13.7 SCENARIO

Two volcanic scenarios are most likely to impact Clark County. The first would be an event similar to the 1980 eruption of Mt. Saint Helens. Such an event seems unlikely to directly impact the county, as the eruption would likely happen on the northern side of the volcano. However, depending on wind direction and velocity, ash could be an issue (CRESA, 2004).

The other possibility is a Mt. Hood event, which could trigger a mudflow along the Hood River and the Sandy River into the Columbia River below Cascade Locks. This could cause flooding in Clark County along the Columbia River (CRESA, 2004). This scenario event formed the basis of the risk assessment for this hazard.

13.8 ISSUES

The following issues have been identified for the volcano hazard:

- Researchers continue to develop methods to predict volcanic eruptions accurately. Indications that an eruption may be imminent include swarms of small earthquakes as the magma rises up through the volcano, increases in gas emissions, and physical swelling or deformation of mountain slopes. Although warning time should be sufficient to prevent loss of life, the advent of these signs and the beginning of eruptive activity may be short.
- More than 3,200 people are estimated to live in distal hazard zones in the planning area. The entire population of the planning are could be exposed to ash fall, depending on weather conditions at the time of an eruption.
- Residents may not be aware that they live in distal hazard areas.
- Distal hazard exposure is predominantly concentrated in Camas and Washougal.
- More than $2.89 billion in structure and content value is exposed to distal hazards. The exposure accounts for 2.6 percent of the total value of the planning area and 13 and 46 percent of the total value of Camas and Washougal, respectively.
- Ash fall from volcanic eruptions can cause significant damage to heating and air conditioning systems, combustion systems, electronic devices and other mechanical equipment.
- Ash fall increases in weight significantly when wet, complicating cleanup efforts.
- Ash fall can cause significant impacts on the local economy due to interruptions to the transportation system and disruptions to tourism-related industries.
- A substantial number of critical facilities and infrastructure in the planning area would be impacted by distal hazards or ash fall.
- A regional Mount Hood Coordination plan has been developed to coordinate and plan for response activities in the event of an eruption. This plan should continue to be updated.

14. WILDLAND FIRE

14.1 GENERAL BACKGROUND

The term wildland fire refers to any uncontrolled burning of grasslands, brush or woodland areas. Forest fire is a kind of wildland fire—specifically the uncontrolled burning of forestland. The wildland-urban interface/intermix area is the area that is susceptible to wildland or forest fires because wildland vegetation and urban or suburban development occur together (CRESA, 2004).

14.1.1 Factors Influencing Wildfires

Wildfires advance through the transmission of heat in the form of conduction, convection and radiation. During the day, fires generally travel uphill. Convection currents and radiation ahead of the fire preheat the fuels and air upslope, allowing the fire to expand rapidly. Radiation has an extreme impact when the fire enters a “chimney,” or a v-shaped area on a slope, such as a drainage gully. South and west facing slopes tend to be warmest and driest. Heavy dry fuels on a southwest-facing slope with chimneys on a hot day will allow for near explosive expansion of a fire. Wind can strengthen and spread a fire, though large fires can generate their own wind. The heat rising from a large fire will create a thermal column that can rise hundreds or thousands of vertical feet. These vertical columns carry burning embers that are often picked up by prevailing winds and spread. At night, the fire slows and travels downhill, following the cooling airflow (CRESA, 2004).

Fire experts attribute the generally worsening wildfire risk to increases in the presence of dry, hazardous fuel. This has been brought about by an overall decline in forest health. Forests that have been clear-cut become crowded with trees struggling against each other for nutrition, water and sunlight. This can weaken them, making them vulnerable to insects and diseases. In Washington State, trees burn hot and fast (CRESA, 2004).

Wildfires can be ignited by lightning or by human activity such as smoking, campfires, equipment use, and arson. Controlled burns are not considered hazards unless they escape control. Wildland fires are influenced by the amount and condition of fuel present, topography, and weather conditions. These factors are described in the following sections.

Fuels

Fuels for wildfires are living and dead vegetation on the ground, brush and small trees on the surface, and tree canopies above the ground. They are assessed by the following conditions:

- **Fuel loading**—Fuel loading, often expressed in tons per acre, is the amount of vegetative material available. If fuel loading doubles, the energy released also can be expected to double.
- **Burn index**—Each fuel type is given a burn index, which is an estimate of the amount of potential energy that may be released, the effort required to contain a fire in a given fuel, and the expected flame length. Different fuels have different burn qualities. Some fuels burn more easily or release more energy than others. Lighter fuels such as grasses, leaves and needles quickly

expel moisture and burn rapidly, while heavier fuels such as tree branches, logs and trunks take longer to warm and ignite.

- **Fuel continuity**—Continuity of fuels is expressed in terms of horizontal and vertical dimensions. Horizontal continuity represents the distribution of fuels over the landscape. Vertical continuity links fuels at the ground surface with tree crowns. Trees killed or defoliated by forest insects and diseases are more susceptible to wildfire. As of 2019, almost 3 percent (658,000) of Washington's 22.4 million acres of forestland showed some level of tree mortality, tree defoliation or foliar disease (Washington Department of Natural Resources, 2020).
- **Fuel moisture**—Fuel moisture is expressed as a percentage of total saturation and varies with antecedent weather. Low fuel moistures indicate the probability of severe fires. Given the same weather conditions, moisture in fuels of different diameters changes at different rates. A 1,000-hour fuel, which has a 3- to 8-inch diameter, changes more slowly than a 1- or 10-hour fuel.

Topography

Topography can have a powerful influence on wildfire behavior. The movement of air over the terrain tends to direct a fire's course. Gulches and canyons can funnel air and act as a chimney, intensifying fire behavior and inducing faster rates of spread. Saddles on ridge tops offer lower resistance to the passage of air and will draw fires. Solar heating of drier, south-facing slopes produces upslope thermal winds that can complicate behavior.

Slope is an important factor. If the percentage of uphill slope doubles, the rate of spread of wildfire will likely double. On steep slopes, fuels on the uphill side of a fire are closer physically to the source of heat. Radiation preheats and dries the fuel, thus intensifying fire behavior. Fire travels downslope much more slowly than it does upslope, and ridge tops often mark the end of wildfire's rapid spread.

Weather

Of all the factors influencing wildfire behavior, weather is the most variable. Extreme weather leads to extreme fire events, and it is often a moderation of the weather that marks the end of a wildfire's growth and the beginning of successful containment. High temperatures and low humidity can produce vigorous fire activity. The cooling and higher humidity brought by sunset can dramatically quiet fire behavior. Fronts and thunderstorms can produce winds that are capable of radical and sudden changes in speed and direction, causing similar changes in fire activity. The rate of spread of a fire varies directly with wind velocity. Winds may play a dominant role in directing the course of a fire. Strong, dry winds produce extreme fire conditions. Such winds generally reach peak velocities during the night and early morning. The effect of wind on fire behavior is a primary safety concern for firefighters. The most damaging firestorms are usually marked by high winds.

14.2 HAZARD PROFILE

14.2.1 Past Events

Fire is a normal part of most forest and range ecosystems in temperate regions of the world. Fires historically burn on a fairly regular cycle, recycling carbon and nutrients stored in the ecosystem and strongly affecting the species within the ecosystem. Annual acreage consumed by wildfires in the lower 48 states of the U.S. dropped from about 40 to 50 million acres per year in the 1930s to under 5 million acres by 1970 (Cohen, 2008).

Clark County's fire season usually runs from mid-May through October (CRESA, 2011). However, changes in climatic conditions, such as drought, snowpack and localized weather, can expand the length of the fire season. In July through early September, lightning strikes are the cause of most wildland fires in Washington State. Human-caused fires are more prevalent at the beginning and end of the fire season. Only 30 percent of fires in the state are in Western Washington (Washington Emergency Management Division, 2020). Large fires reported in Clark County since the turn of the century include the following (CRESA, 2011; Washington Emergency Management Division, 2014):

- 1902 Yacolt Fire—38 lives lost and 238,900 acres burned in Clark and Skamania Counties
- 1919 Sunset Fire—26,900 acres burned in Clark and Skamania Counties
- 1929 Dole Valley Fire—227,500 acres burned in Clark and Skamania Counties.

The Washington Department of Natural Resources' database of wildfires since 1970 on lands protected by the agency lists more than 1,050 fires in Clark County. Table 14-1 lists the 27 that were reported to have burned 10 acres or more.

Table 14-1. Wildfires in Clark County Greater than 10 Acres, 1970-2016 (January)

Incident ID	Fire Name	Cause	Start Date	Area Burned (acres)[a]
11334	N/A	Fireworks	7/22/1972	40
13989	N/A	Debris Burn	9/1/1974	11
14008	N/A	Debris Burn	9/21/1974	12
16739	N/A	Debris Burn	1/24/1977	15
18939	N/A	Debris Burn	10/3/1979	24
26505	N/A	Sparks from Vehicle	8/3/1987	15
26588	N/A	Debris Burn	10/6/1987	10
26598	N/A	Debris Burn	10/10/1987	68
26604	N/A	Debris Burn	10/11/1987	20
27916	N/A	Railroad (Hot brakes)	9/2/1988	16
29101	N/A	Railroad (Carbon)	7/5/1989	15
29146	N/A	Debris Burn	10/6/1989	10
33865	N/A	Children	8/17/1992	35
36831	N/A	Recreation	9/2/1994	14
38603	N/A	Debris Burn	5/31/1995	30
41321	N/A	Debris Burn	11/15/1997	20
46367	N/A	Debris Burn	4/15/1999	10
4710	RV	Vehicle Fire	8/15/2008	10
6062	Alworth Fire	Debris Burn	10/26/2008	12
11362	Jackson 3	Arson	10/11/2009	60
16861	Hilltop	Recreation	8/14/2010	110
29648	Steigerwald	Smoker	10/5/2012	140
40452	South Jones	Under Investigation	6/11/2015	10
41045	South Padden	Arson	7/4/2015	13
41703	Big Creek One	Under Investigation	7/17/2015	12
66527	Wiehl	Power Generator	9/7/2020	15
66624	Fruit Valley	Unknown	9/8/2020	166

a. Area may not represent the full extent of the fire across all ownerships. It may, in some cases represent only the area of Washington Department of Natural Resources managed land.

Source: Washington Department of Natural Resources Fire Statistics, 1970-2007, http://fortress.wa.gov/dnr/app1/dataweb/dmmatrix.html; Washington Department of Natural Resources Fire Statistics, 2008 – Present, http://fortress.wa.gov/dnr/app1/dataweb/dmmatrix.html

14.2.2 Location

The probability of a wildland fire in any one locality on a particular day depends on fuel conditions, topography, the time of year, the past and present weather conditions, and activities (debris burning, land clearing, camping, etc.) taking place (CRESA, 2011).

Communities at Risk

The Washington Department of Natural Resources and its federal and local partners have determined that five communities in Clark County are at a high risk of wildfire: Amboy, Hockinson, Washougal, Woodland, and Yacolt. According to the Washington State Emergency Management Division, areas of significant fire hazards are mapped based on fire behavior potential, fire protection capability, and risk to social, cultural and community resources. Risk is determined based on area fire history, type and density of vegetative fuels, extreme weather conditions, topography, number and density of structures and their distance from fuels, location of municipal watershed, and likely loss of housing or business (Washington Emergency Management Division, 2014).

Local Risk Area Designations

Clark County GIS maintains a database of areas in unincorporated Clark County with increased fire hazard as urban type development occurs in areas once considered wilderness. This data is used by the County's Department of Community Development during development review to determine minimum fire protection requirements needed to protect life, property, and natural wilderness resources from wildfire (Clark County, 2016).

Infrastructure and buildings in wildland-urban interface/intermix areas are especially susceptible to wildfires because they are close to fire fuel sources (trees and undergrowth in forests) and because their presence increases the likelihood that a wildfire will begin. Some of the triggers that can cause fire are natural, such as lightning, but fires are more likely to be caused by human activity. Humans can directly cause fires with careless campfires, sparks from ATVs, or inappropriate disposal of lit cigarettes. Downed electric lines during windstorms can also cause fires (CRESA, 2004). Clark County Code (Section 15.13.030) defines wildland-urban interface/intermix areas as areas at elevation of 500 feet or more that meet any of the following criteria (CRESA, 2004):

- Slope equal to or greater than 25 percent
- Forest type vegetation
- Outside an organized fire protection district.

If more than half of a parcel meets the criteria, the entire parcel is included in the wildland urban interface/intermix area.

The City of Vancouver maintains a dataset of wildfire risk areas similar to the County's wildland-urban interface/intermix area designation. While this definition and the resulting regulations are only applicable in unincorporated Clark County and to some extent the City of Vancouver, they provide the best available data to assess wildfire risk for planning. Figure 14-1 shows the wildfire risk areas in the County.

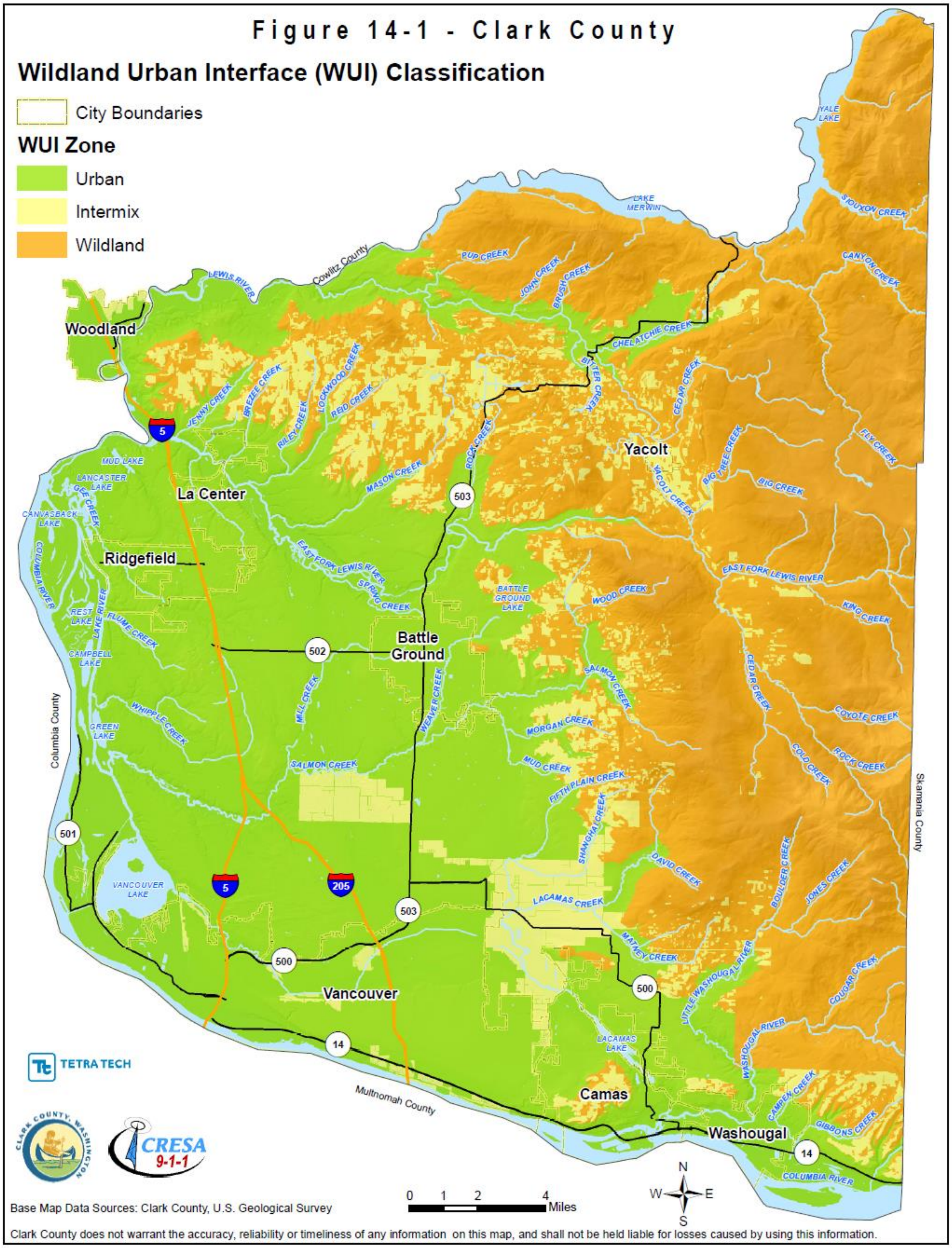

Figure 14-1. Wildland Urban Interface (WUI) Classification

Frequency

<u>Fire Regime Mapping</u>

The LANDFIRE project (a program of the U.S. Forest Service and the U.S. Department of the Interior, under the direction of the Wildland Fire Leadership Council) produces maps of historical fire regimes and vegetation and maps of current vegetation and its departure from historical conditions. The maps categorize mean fire return intervals and fire severities into five fire regimes (Hann et al., 2004):

- Fire Regime I—0 to 35 year frequency, low to mixed severity
- Fire Regime II—0 to 35 year frequency, replacement severity
- Fire Regime III—35 to 200 year frequency, low to mixed severity
- Fire Regime IV—35 to 200 year frequency, replacement severity
- Fire Regime V—200+ year frequency, any severity.

These maps support fire and landscape management planning outlined in the goals of the National Fire Plan, Federal Wildland Fire Management Policy, and the Healthy Forests Restoration Act. Figure 14-2 shows fire regimes in the planning area based on LANDFIRE models. The vast majority of Clark County falls within Fire Regime V, although all regimes are present in the county. Higher frequency regimes occur in the southwestern portion of the county, often near population centers.

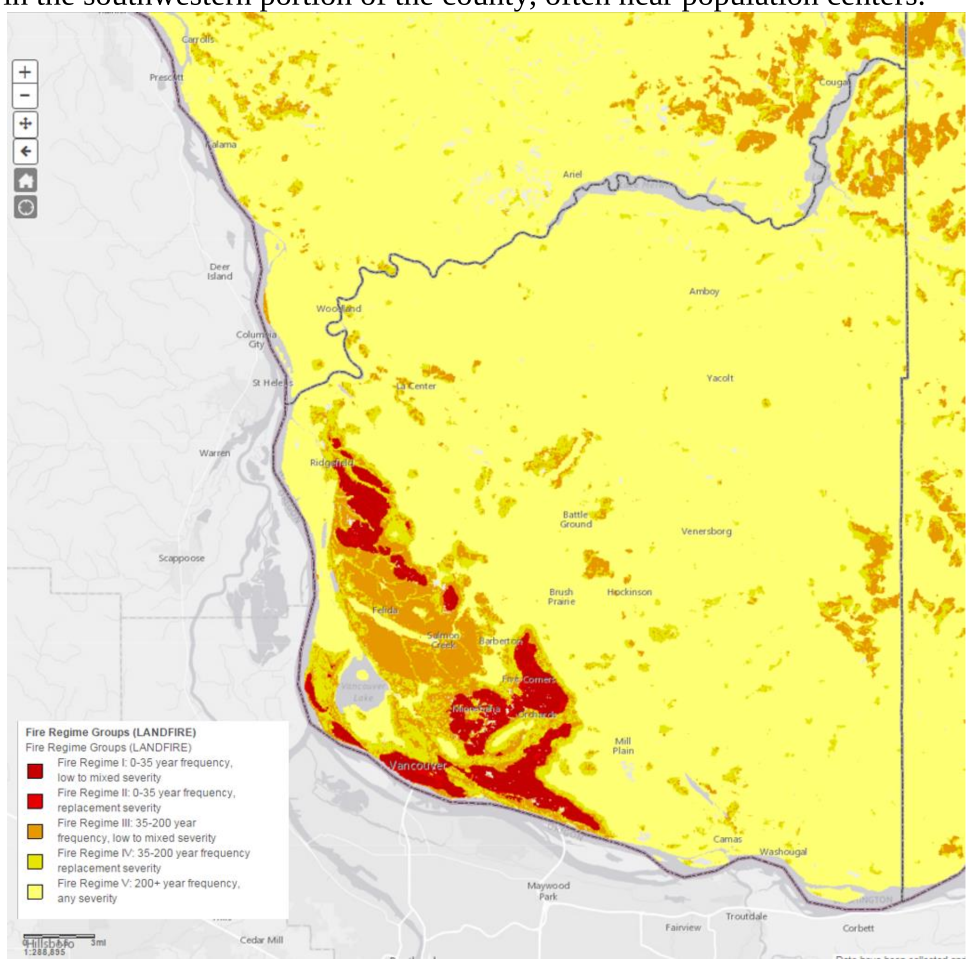

Figure 14-2. Fire Regime Groups (LANDFIRE)
Source:Washington Department of Natural Resources, Fire Prevention & Fuel Management Mapping System

The Washington Department of Natural Resources maintains an on-line Fire Prevention and Fuel Management mapping system, which provides wildfire-related information such as fire statistics, large fire burn areas and LANDFIRE fire regime groups (Washington Department of Natural Resources, 2016a).

Natural Fire Rotation

Natural fire rotation is defined as the number of years necessary for fires to burn over an area equal to that of the study area. Natural fire rotation is calculated from the historical record of fires by dividing the length of the record period in years by the percentage of total area burned during that period. It represents the average period between fires under a presumed historical fire regime. Since 1970, Clark County has seen an average of 23 wildfires per year. The vast majority of these fires burn less than 10 acres, with an overall average of 1.6 acres per incident. Fires occur annually, but fires that burn more than 10 acres occur only once every 2 years, on average.

14.2.3 Severity

Wildfires can range from isolated burns affecting a few acres to severe events that burn hundreds of thousands of acres. Large fires usually occur when groups of smaller fires merge. Property damage from wildfires can be severe and can significantly alter entire communities. The source of ignition should be discounted in evaluating the wildfire risk. If conditions are right for a major fire, any source of ignition—natural or human-caused—will bring about the same end results. Lightning on dry fuels, recreational uses, interface development or arson can all trigger fires. Mitigation efforts that limit human interaction with fuels can extend the fire cycle or change the location of ignition. However, if the fire cycle is extended and the fuel load is not mitigated, the ultimate fire will burn hotter, move faster, and generate more secondary fires. Such a fire can rapidly overwhelm response capabilities (CRESA, 2004).

14.2.4 Warning Time

Wildfires are often caused by humans, intentionally or accidentally. There is no way to predict when a human-caused wildfire might break out. Since fireworks often cause brush fires, extra diligence is warranted around the Fourth of July when the use of fireworks is highest. Dry seasons and droughts are factors that greatly increase fire likelihood. Dry lightning may trigger wildfires. Severe weather can be predicted, so special attention can be paid during weather events that may include lightning. Reliable National Weather Service lightning warnings are available on average 24 to 48 hours prior to a significant electrical storm.

If a fire does break out and spread rapidly, residents may need to evacuate within days or hours. A fire's peak burning period generally is between 1 p.m. and 6 p.m. Once a fire has started, fire alerting is reasonably rapid in most cases. The rapid spread of cellular and two-way radio communications in recent years has further contributed to a significant improvement in warning time.

The Washington Department of Natural Resources maintains an online Burn Risk Map. Residents can view current information about the wildfire danger in Washington, as well as any information on outdoor burning restrictions. This site provides information on when conditions are right for destructive wildfires (Washington Department of Natural Resources, 2016).

14.3 SECONDARY HAZARDS

Wildland fires can generate a range of secondary effects, which in some cases may cause more widespread and prolonged damage than the fire itself. Fires can cause direct economic losses in the reduction of harvestable timber and indirect economic losses in reduced tourism. Wildland fires cause the contamination of reservoirs, destroy transmission lines and contribute to flooding. Landslides can be a significant secondary hazard of wildfires. Wildfires strip slopes of vegetation, exposing them to greater amounts of rain and run-off. This in turn can weaken soils and cause failures on slopes. Major landslides can occur several years after a wildfire (CRESA, 2004). Most wildfires burn hot and for long durations that can bake soils, especially those high in clay content, thus increasing the imperviousness of the ground. This increases the runoff generated by storm events, thus increasing the chance of flooding.

14.4 EXPOSURE

14.4.1 Population

Exposed population for the wildfire risk areas (wildland-urban interface/intermix areas) was estimated using the percentage of total building value in these areas multiplied by the total population. The results are shown in Table 14-2. Approximately 3.4 percent of the total County population lives in areas identified as wildland and 6.2 percent of the total population lives in areas identified as intermix.

Table 14-2. Population Within Wildland Fire Hazard Areas

	Wildland (Relatively High)			Intermix (Relatively Moderate)		
		Population			Population	
	Buildings	Number	% of Total	Buildings	Number	% of Total
Battle Ground	9	20	0.1%	0	0	0.0%
Camas	819	1,347	6.3%	1,624	3,142	14.8%
La Center	0	0	0.0%	0	0	0.0%
Ridgefield	0	0	0.0%	0	0	0.0%
Vancouver	0	0	0.0%	1,629	4,703	2.8%
Washougal	50	206	1.4%	155	267	1.8%
Woodland	0	0	0.0%	269	213	3.6%
Yacolt	42	240	14.8%	491	1,380	85.2%
Unincorporated	5,929	13,571	6.3%	6,102	18,757	8.7%
Total	**6,849**	**15,384**	**3.4%**	**10,270**	**28,462**	**6.2%**

In addition to the populations living in wildfire risk areas, people working or recreating in resource lands, such as loggers and hikers, are exposed to the wildfire risk. Firefighting crews are exposed as they work to combat fires and to protect property. All county residents are potentially exposed to the health-related impacts of reduced air quality from wildland fires.

14.4.2 Property

Table 14-3 and Table 14-4 show the number of structures in the planning area that are located in the wildland and intermix areas and their values.

Parcels that intersect designated wildland areas and intermix areas were analyzed to assess the types of land uses that are exposed. Table 14-5 shows the area of present land uses exposed to this hazard and the percent of total exposed area for each land use. Agricultural/resource lands and vacant areas combined make up 59 percent of the total exposed acres in the wildland risk area. An additional 38 percent is residential. In the intermix risk area, more than 72 percent of exposed area is residential. It is estimated that 47 percent and 21 percent of the land area of the County is within wildland and intermix hazard areas, respectively.

Table 14-3. Exposure and Value of Structures in Wildland (Relatively High) Areas

Jurisdiction	Buildings Exposed	Value Exposed			% of Total Replacement value
		Structure	Contents	Total	
Battle Ground	9	$2,854,388	$1,427,194	$4,281,582	0.1%
Camas	819	$308,680,888	$172,296,984	$480,977,872	6.3%
La Center	0	$0	$0	$0	0.0%
Ridgefield	0	$0	$0	$0	0.0%
Vancouver	0	$0	$0	$0	0.0%
Washougal	50	$31,933,485	$24,480,983	$56,414,468	1.4%
Woodland	0	$0	$0	$0	0.0%
Yacolt	42	$24,529,095	$20,918,921	$45,448,015	14.8%
Unincorporated	5,929	$1,730,292,816	$1,102,850,918	$2,833,143,735	6.3%
Total	**6,849**	**$**2,098,290,672	**$**1,321,975,000	**$**3,420,265,672	**3.0%**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

Table 14-4. Exposure and Value of Structures in Intermix (Relatively Moderate) Areas

Jurisdiction	Buildings Exposed	Value Exposed			% of Total Replacement value
		Structure	Contents	Total	
Battle Ground	0	$0	$0	$0	0.0%
Camas	1,624	$671,729,875	$450,389,080	$1,122,118,954	14.8%
La Center	0	$0	$0	$0	0.0%
Ridgefield	0	$0	$0	$0	0.0%
Vancouver	1,629	$821,506,677	$503,178,488	$1,324,685,165	2.8%
Washougal	155	$48,728,506	$24,364,253	$73,092,759	1.8%
Woodland	269	$42,682,361	$22,120,936	$64,803,297	3.6%
Yacolt	491	$145,374,966	$115,583,981	$260,958,947	85.2%
Unincorporated	6,102	$2,308,816,716	$1,606,952,258	$3,915,768,974	8.7%
Total	**10,270**	**$**4,038,839,101	**$**2,722,588,996	**$**6,761,428,096	**6.0%**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations

Table 14-5. Present Land Use in Planning Area Parcels Intersecting Wildland Fire Hazard Areas[a]

Present Use Classification[b]	Wildland (Relatively High)		Intermix (Relatively Moderate)	
	Area (acres)[c, d]	% of total	Area (acres)[c, d]	% of total
Agriculture/Resource Land	105,300.02	48.5%	15,541.60	16.0%
Commercial	2,160.26	1.0%	1,837.64	1.9%
Education	54.24	0.0%	202.09	0.2%
Governmental Services	3,189.00	1.5%	2,014.88	2.1%
Industrial	208.02	0.1%	341.04	0.4%
Religious Services	111.11	0.1%	217.82	0.2%
Residential	83,109.03	38.3%	70,778.68	72.7%
Vacant or uncategorized	22,802.54	10.5%	6,406.44	6.6%
Total	**216,934.22**	**100%**	**97,340.19**	**100%**

a. Present land use information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.
b. Present use classification provided by Clark and Cowlitz County assessor's data assigned to best fit occupancy classes in FEMA's Hazus model (see Section 6.3.1). Parcels for which conflicting information on current development was available were assumed to be improved. Some designated resource land may also be included in the vacant or uncategorized category.
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage is likely overestimated as all parcels that intersect hazard areas were included.

14.4.3 Critical Facilities and Infrastructure

Table 14-6 and Table 14-7 identify critical facilities and infrastructure exposed to the wildfire hazard areas in the county. In addition the following linear features are exposed to the wildfire hazard:

- State Route 500
- State Route 503
- State Route 14
- A small portion of Interstate 205
- The Northwest pipeline, although the vast majority of the pipeline is located in areas designated as "urban."

Table 14-6. Critical Facilities in Wildland (Relatively High) Risk Areas

	Commu-nication Facilities	Dams	Emer-gency Services	Energy	Govern-ment Facilities	Hazardous Materials	Health Care & Public Health	Infor-mation Technol-ogy	Schools	Trans-portation Systems	Water & Sanitation Systems	Total
Battle Ground	0	0	0	0	0	0	0	0	0	0	0	**0**
Camas	0	0	0	0	0	0	0	0	0	0	2	**2**
La Center	0	0	0	0	0	0	0	0	0	0	0	**0**
Ridgefield	0	0	0	0	0	0	0		0	0	0	**0**
Vancouver	0	0	0	0	0	0	0	0	0	0	0	**0**
Washougal	0	0	0	0	0	0	0	0	0	0	1	**1**
Woodland	0	0	0	0	0	0	0	0	0	0	0	**0**
Yacolt	0	0	0	0	0	0	0	0	0	0	0	**0**
Unincorporated	0	1	6	2	0	1	1	0	0	1	40	**52**
Total	**0**	**1**	**6**	**2**	**0**	**1**	**1**	**0**	**0**	**1**	**43**	**55**

Table 14-7. Critical Facilities in Intermix (Relatively Moderate) Risk Areas

	Commu-nication Facilities	Dams	Emer-gency Services	Energy	Govern-ment Facilities	Hazardous Materials	Health Care & Public Health	Infor-mation Technol-ogy	Schools	Trans-portation Systems	Water & Sanitation Systems	Total
Battle Ground	0	0	0	0	0	0	0	0	0	0	0	**0**
Camas	1	0	0	0	0	0	5	0	2	0	3	**11**
La Center	0	0	0	0	0	0	0	0	0	0	0	**0**
Ridgefield	0	0	0	0	0	0	0	0	0	0	0	**0**
Vancouver	0	0	0	0	0	0	0	0	0	0	0	**0**
Washougal	0	0	0	0	0	0	0	0	0	0	0	**0**
Woodland	0	0	0	0	0	0	0	0	0	0	0	**0**
Yacolt	2	0	2	0	1	1	0	0	1	0	0	**7**
Unincorporated	0	0	5	1	0	2	2	0	2	1	34	**47**
Total	**3**	**0**	**7**	**1**	**1**	**3**	**7**	**0**	**5**	**1**	**37**	**65**

14.4.4 Environment

Fire is a natural and critical process in most ecosystems, dictating in part the type, structure, and spatial extent of native vegetation. However, wildfires can cause severe environmental impacts:

- Damaged Fisheries—Critical trout fisheries throughout the west and salmon and steelhead fisheries in the Pacific Northwest can suffer from increased water temperatures, sedimentation, and changes in water quality and chemistry.
- Soil Erosion—The protective covering provided by foliage and dead organic matter is removed, leaving the soil fully exposed to wind and water erosion. Accelerated soil erosion occurs, causing landslides and threatening aquatic habitats.
- Spread of Invasive Plant Species—Non-native woody plant species frequently invade burned areas. When weeds become established, they can dominate the plant cover over broad landscapes and become difficult and costly to control.
- Disease and Insect Infestations—Unless diseased or insect-infested trees are swiftly removed, infestations and disease can spread to healthy forests and private lands. Timely active management actions are needed to remove diseased or infested trees.
- Destroyed Endangered Species Habitat—Catastrophic fires can have devastating consequences for endangered species. For instance, the Biscuit Fire in Oregon destroyed up to 150,000 acres of spotted owl habitat.
- Soil Sterilization—Topsoil exposed to extreme heat can become water repellant, and soil nutrients may be lost. It can take decades or even centuries for ecosystems to recover from a fire. Some fires burn so hot that they can sterilize the soil.

Many ecosystems are adapted to historical patterns of fire. These patterns, called fire regimes, include temporal attributes (e.g., frequency and seasonality), spatial attributes (e.g., size and spatial complexity), and magnitude attributes (e.g., intensity and severity), each of which have ranges of natural variability. Ecosystem stability is threatened when any of the attributes for a given fire regime diverge from its range of natural variability.

14.5 VULNERABILITY

Structures, above-ground infrastructure, critical facilities and natural environments are all vulnerable to the wildfire hazard. There is currently no validated damage function available to support wildfire mitigation planning. Except as discussed in this section, vulnerable populations, property, infrastructure and environment are assumed to be the same as described in the section on exposure.

14.5.1 Population

All population that is exposed to wildfire risk is vulnerable to wildfire risk. The most vulnerable individuals are those who are not able to evacuate risk areas quickly, such as older populations or those with access and functional needs. Wildfires also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke.

Smoke and air pollution from wildfire can be a severe health hazard for those living near or downwind from wildfires. This is especially true for sensitive populations, including children, the elderly and those with respiratory and cardiovascular diseases. Smoke generated by wildfire consists of visible and invisible emissions that contain particulate matter (soot, tar, water vapor, and minerals), gases (carbon monoxide, carbon dioxide, nitrogen oxides), and toxics (formaldehyde, benzene). Emissions from wildfires depend on the type of fuel, the moisture content of the fuel, the efficiency (or temperature) of combustion, and the weather. Public health impacts associated with wildfire include difficulty in breathing, odor, and reduction in visibility.

Generally, few people die in wildfires because warning time is sufficient to allow for evacuation. However, many lives are disrupted. Beyond the immediate effects of disruption to life patterns, the longer-term economic effects from loss of property can be devastating (CRESA, 2004).

14.5.2 Property

All property that is exposed to the wildfire hazard is vulnerable. Home building in and near forests increases risks from forest fires. Often, structures are built and maintained with minimal awareness of the need for protection from exterior fire sources or the need to minimize interior fires from spreading to forested lands (CRESA, 2004).

Pre-1993 Construction

Properties constructed before 1993 may be more vulnerable to wildfire because they were built prior to development codes that established more stringent requirements for fire protection. A major vulnerability issue is with subdivisions platted and developed before fire codes were adopted. Water supplies may be limited within these pre-ordinance subdivisions. Many homes on wells may also have access problems, including inadequate ingress and egress and insufficient roadway width and road grade to enable evacuation or fire suppression (CRESA, 2004). There are estimated to be 5,400 parcels in intermix areas that were developed before 1993.

Post-1993 Construction

As of 1993, all new subdivisions must have adequate access, connecting bridges, turn-around areas and driveway widths to allow for fire suppression equipment. Current Clark County code requires that development and construction be designed, located and constructed to minimize the possibility of wildland fires involving structures, as well as to reduce the possibility that structural fires will ignite a wildland fire. Code incorporates the standards included in the National Fire Protection Association's *Protection of Life and Property from Wildfire* standards (NFSP-299). These standards apply to the following (CRESA, 2004):

- Setbacks from slopes
- Defensible space
- Vehicular access

- Roofing materials
- Siding materials
- Balconies and porches
- Eves and overhangs
- Access to water.

However, development after 1993 is not invulnerable to fire just because it meets current code. Any development in the intermix zone or in the wildland zone can be exposed to fire (CRESA, 2004). According to recent research, most residential areas destroyed in wildfires are not ignited by advancing flames of a large crown fire, but rather from embers falling on a non-resistant roof, radiant heat igniting a curtain or pine needles, or a forgotten gas can near a home. Without these conditions, a fire can burn quickly through a development without igniting structures. This research emphasizes the importance of fireproofing and "ring of safety" approaches advocated by such programs as FireWise. Small fuel removal efforts and building material choices around the home can save an entire subdivision from destruction (CRESA, 2004).

Loss Estimates

Loss estimations for the wildfire hazard are not based on damage functions, because no such damage functions have been generated. Instead, loss estimates were developed representing 10 percent, 30 percent and 50 percent of the replacement value of exposed structures in hazard areas. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 14-8 lists the loss estimates for the general building stock for assets in jurisdictions that have an exposure to the wildland and intermix risk areas.

Table 14-8. Loss Estimates for Wildfire

		Estimated Loss Potential from Wildfire		
	Exposed Value	10% Damage	30% Damage	50% Damage
Battle Ground	$4,281,582	$428,158	$1,284,475	$2,140,791
Camas	$1,603,096,826	$160,309,683	$480,929,048	$801,548,413
La Center	$-	$-	$-	$-
Ridgefield	$-	$-	$-	$-
Vancouver	$1,324,685,165	$132,468,517	$397,405,550	$662,342,583
Washougal	$129,507,227	$12,950,723	$38,852,168	$64,753,614
Woodland	$64,803,297	$6,480,330	$19,440,989	$32,401,649
Yacolt	$306,406,962	$30,640,696	$91,922,089	$153,203,481
Unincorporated	$6,748,912,709	$674,891,271	$2,024,673,813	$3,374,456,355
Total	**$8,574,315,360.00**	**$857,431,537.00**	**$2,572,294,609.00**	**$4,287,157,682.00**

Note: Values shown are accurate only for comparison among results in this plan. See Section 6.7 for a discussion of data limitations.

14.5.3 Critical Facilities and Infrastructure

Critical facilities of wood frame construction are especially vulnerable during wildfire events. Most roads and railroads would be without damage except in the worst scenarios. Power lines are the most at risk from wildfire because most poles are made of wood and susceptible to burning. Fires can create conditions that block or prevent access and can isolate residents and emergency service providers. Wildfire typically does not have a major direct impact on bridges, but it can create conditions in which bridges are obstructed. Many bridges in areas of high to moderate fire risk are important because they provide the only ingress and egress to large areas and in some cases to isolated neighborhoods. In the event of a wildfire, pipelines could provide a source of fuel and lead to a catastrophic explosion. Currently there are four registered Tier II hazardous material containment sites in wildfire risk zones (one in the wildland area and two in the intermix area both located in unincorporated areas of the County). During a fire event, hazardous materials storage containers could rupture due to heat and act as fuel for the fire, escalating the fire to unmanageable levels. In addition they could leak into surrounding areas, saturating soils and seeping into surface waters, and have a disastrous effect on the environment.

14.5.4 Environment

Fire hazards present a considerable risk to vegetation and wildlife habitat (CRESA, 2004). The vulnerability risks are the same as those described for exposure.

14.5.5 Economic Impact

The destruction of large tracts of forest land would have immediate economic impact on the community through lost jobs, reduced taxes, and increased public support. Collateral economic and social effect could impact the County for years (CRESA, 2011). Damage to utilities (electrical lines and substations), loss of revenue from workers unable to work, and the expense incurred fighting a fire would also result in economic impacts.

14.6 FUTURE TRENDS

14.6.1 Development

The highly urbanized portions of the planning area have little or no wildfire risk exposure. Urbanization tends to alter the natural fire regime, and can create the potential for the expansion of urbanized areas into wildland areas. The expansion of the wildland urban interface can be managed with strong land use and building codes. The planning area is well equipped with these tools and this planning process has asked each planning partner to assess its capabilities with regards to the tools. Table 14-9 shows the area identified as underutilized or vacant in urban growth areas in the County that intersect identified wildfire hazard areas. As interface areas become more developed, they will likely transition to urban risk designations. Similarly, as wildland areas are developed designations may transition to intermix.

Table 14-9. Buildable Lands in Planning Area Urban Growth Areas that Intersect Wildland Risk Areas[a]

	Buildable Area[c] (acres)				
	Residential				
Urban Growth Area[b]	Acres	Units	Commercial	Industrial	Total
Battle Ground	15.76	95	0	0	**15.76**
Camas	262.48	1,575	53.23	50.43	**366.14**
La Center	0	0	0	0	**0**
Ridgefield	0	0	0	0	**0**
Vancouver	880.36	7,043	95.73	81.60	**1,057.69**
Washougal	204.59	1,227	31.75	176.33	**412.67**
Woodland[d]	--	--	--	--	**--**
Yacolt	43.72	175	10.57	28.50	**82.79**
Total	**1,406.91**	**10,115**	**190.28**	**336.86**	**1,935.05**

a. Buildable lands information in this plan is for planning purposes only. Discrepancies may exist between these estimates and official records maintained by participating jurisdictions.

b. Unincorporated areas outside of urban growth areas are excluded from this assessment. Development in these areas consists largely of rural lands, open space and large residential lots. Changes in development can be assessed through
c. Acreage covers only mapped parcels; it excludes many rights of way and major water features.
d. Acreage estimates exclude the portions of the City of Woodland in Cowlitz County and thus may be underestimated.

14.6.2 Climate Change

Wildfire in western ecosystems is determined by climate variability, local topography, and human intervention. Climate change has the potential to affect multiple elements of the wildfire system: fire behavior, ignitions, fire management, and vegetation fuels. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. Climate change also may increase winds that spread fires. Faster fires are harder to contain, and thus are more likely to expand into residential neighborhoods.

When climate alters fuel loads and fuel moisture, forest susceptibility to wildfires changes. Forest response to increased atmospheric carbon dioxide could contribute to more tree growth and thus more fuel for fires, although the effects of carbon dioxide on mature forests are still largely unknown. Increased high-elevation wildfires could release stores of carbon and further contribute to the buildup of greenhouse gases.

Historically, drought patterns in the West are related to large-scale climate patterns in the Pacific and Atlantic oceans. El Niño years bring drier conditions to the Pacific Northwest and more fires.

14.7 SCENARIO

With increased intermix development, a wildland fire in the Clark County foothills has the potential to cause even greater damage than the 1902 Yacolt Burn. A 21st century firestorm could burn an area approaching the size of the Yacolt Burn, and because of increased development in the area, it would destroy much more property and put more lives at risk (CRESA, 2004).

A major conflagration might begin with a wet spring, adding to the fuels that are already present on the forest floor. Flashy fuels would build throughout the spring. A dry summer with insect infestation could follow the wet spring, exacerbated by dry hot Chinook winds. The Labor Day holiday brings many hikers and campers to the area. Careless campfires or a tossed lit cigarette, or a sudden lighting storm could trigger a multitude of small isolated fires. The embers from smaller fires could be carried miles by the hot, dry winds, falling deep in the forests and intermix zones. Fires that start in flat areas would move more slowly, but wind would still push them. It is not unusual for a wildfire pushed by wind to burn the ground fuel and later climb into the crown and reverse its track. This is one of many ways that fires can escape containment, typically during periods when response capabilities are overwhelmed. As small fires eventually merge, suppression resources would be redirected from protecting natural resources to saving remote subdivisions (CRESA, 2004).

Even if the existence and spread of the fire is known, it may not be possible to respond to it adequately. The worst-case scenario in Clark County would coincide with an active fire season in the entire American west, spreading resources thin. “Hot shot” teams that are exhausted or committed to fighting conflagrations elsewhere would be unavailable to assist Clark County. Many federal assets would be responding to other fires that started earlier in the season. Local fire districts would be useful in the urban intermix areas, but they have limited wildfire capabilities and would have a difficult time responding to the ignition zones. Thus an initially manageable fire could become significant before meaningful resources are dispatched (CRESA, 2004).

To further complicate the problem, heavy rains could follow, causing flooding and landslides and releasing tons of sediment into rivers, permanently changing the floodplains of the county and damaging sensitive habitat and riparian areas. Such a fire followed by rain could release millions of cubic yards of sediment into streams for years, creating new floodplains and changing existing ones. With forests removed from the watershed, discharges could easily double. Floods that previously could be expected every 50 years might occur every couple of years. With the streambeds unable to carry this increased discharge because of increased sediment, the floodplains and floodplain elevations would increase. The number of homes subject to flooding would increase substantially in a post wildland fire situation (CRESA, 2004).

14.8 ISSUES

The following are issues identified for the wildfire hazard:

- Residents should know the proper way to handle fire. Public education programs on fire safety, fire alarms and fire response are important. People should be encouraged to purchase fire insurance if not included in standard homeowner or renter policies and understand building codes.
- Since people start the vast majority of wildfires, wildfire prevention education and enforcement programs can significantly reduce the total number of wild land fires (CRESA, 2011).
- An effective early fire detection program and an emergency communications system are essential. The importance of immediately reporting any wildfire must be impressed upon local residents and persons using forest areas (CRESA, 2011).
- An effective warning system is essential to notify local inhabitants and persons in the area of the fire. An evacuation plan detailing primary and alternate escape routes is also important (CRESA, 2011).
- Fire-safe development planning should be done with local government planners to reduce the risk to local residents and businesses. Safety recommendations to implement could include the following (CRESA, 2011):
  - Sufficient fuel-free areas around structures
  - Fire-resistant roofing materials
  - Adequate two-way (ingress and egress) routes and turnarounds for emergency response units
  - Adequate water supplies with backup power generation equipment or other means to cost-effectively support firefighting efforts
  - Development of local ordinances to control human-caused fires (from debris burning, fireworks, campfires, etc.)
- Road criteria to ensure adequate escape routes for new sections of development in forest areas (CRESA, 2011).
- Road closures to be increased during peak fire periods to reduce the access to fire-prone areas (CRESA, 2011).
- Steps by the public to better protect lives, property, and the environment from wildfires (CRESA, 2011):
  - Maintaining defensible space around homes
  - Providing adequate access routes (two-way with turnaround) to homes for emergency equipment
  - Minimizing “fuel hazards” adjacent to homes
  - Using fire-resistant roofing materials
  - Maintaining adequate water supplies
  - Ensuring home addresses are visible to first responders.
- Some forest fires should be allowed to burn in limited areas as part of forest management.

- During peak wildfire season, if resources from Clark County are deployed to other areas of the State, the availability of firefighting resources could play a role in the severity of wildfire and the size of area effected.

15. PLANNING AREA RISK RANKING

A risk ranking was performed for the hazards of concern described in this plan. This risk ranking assesses the probability of each hazard's occurrence as well as its likely impact on the people, property, and economy of the planning area. The risk ranking methodology and results were reviewed, discussed and approved by the Planning Committee. When available, estimates of risk were generated with data from Hazus-MH or GIS analysis using methodologies promoted by FEMA. For hazards of concern with less robust datasets, qualitative assessments were used. As appropriate, results were adjusted based on local knowledge and other information not captured in the quantitative assessments. The results are used in establishing mitigation priorities.

15.1 PROBABILITY OF OCCURRENCE

The probability of occurrence of a hazard is indicated by a probability factor based on likelihood of annual occurrence:

- High—Hazard event is likely to occur within 25 years (Probability Factor = 3)
- Medium—Hazard event is likely to occur within 100 years (Probability Factor =2)
- Low—Hazard event is not likely to occur within 100 years (Probability Factor =1)
- No exposure—There is no probability of occurrence (Probability Factor = 0)

The assessment of hazard frequency is generally based on past hazard events in the area. Table 15-1 summarizes the probability assessment for each hazard of concern for this plan.

Table 15-1. Probability of Hazards

Hazard Event	Probability (high, medium, low)	Probability Factor
Dam Failure	Low	1
Drought	High	3
Earthquake[a]	High	3
Flood[b]	High	3
Landslide	High	3
Severe weather	High	3
Volcano	Low	1
Wildfire	Medium	2

a. 100-year probabilistic results are used for risk ranking
b. 1 percent annual chance flood event is used for risk ranking

15.2 IMPACT

Hazard impacts were assessed in three categories: impacts on people, impacts on property and impacts on the local economy. Numerical impact factors were assigned as follows:

- **People**—Values were assigned based on the percentage of the total ***population exposed*** to the hazard event. The degree of impact on individuals will vary and is not measurable, so the

calculation assumes for simplicity and consistency that all people exposed to a hazard because they live in a hazard zone will be equally impacted when a hazard event occurs. It should be noted that planners can use an element of subjectivity when assigning values for impacts on people. Impact factors were assigned as follows:
  - High—30 percent or more of the population is exposed to a hazard (Impact Factor = 3)
  - Medium—15 percent to 29 percent of the population is exposed to a hazard (Impact Factor = 2)
  - Low—14 percent or less of the population is exposed to the hazard (Impact Factor = 1)
  - No impact—None of the population is exposed to a hazard (Impact Factor = 0)
- **Property**—Values were assigned based on the percentage of the total ***property value exposed*** to the hazard event:
  - High—25 percent or more of the total replacement value is exposed to a hazard (Impact Factor = 3)
  - Medium—10 percent to 24 percent of the total replacement value is exposed to a hazard (Impact Factor = 2)
  - Low—9 percent or less of the total replacement value is exposed to the hazard (Impact Factor = 1)
  - No impact—None of the total replacement value is exposed to a hazard (Impact Factor = 0)
- **Economy**—Values were assigned based on the percentage of the total ***property value vulnerable*** to the hazard event. Values represent estimates of the loss from a major event of each hazard in comparison to the total replacement value of the property exposed to the hazard. For some hazards, such as wildfire, landslide and severe weather, vulnerability was considered to be the same as exposure due to the lack of loss estimation tools specific to those hazards. Loss estimates separate from the exposure estimates were generated for the earthquake and flood hazards using Hazus-MH.
  - High—Estimated loss from the hazard is 15 percent or more of the total replacement value (Impact Factor = 3)
  - Medium—Estimated loss from the hazard is 5 percent to 14 percent of the total replacement value (Impact Factor = 2)
  - Low—Estimated loss from the hazard is 4 percent or less of the total replacement value (Impact Factor = 1)
  - No impact—No loss is estimated from the hazard (Impact Factor = 0)

The impacts of each hazard category were assigned a weighting factor to reflect the significance of the impact. These weighting factors are consistent with those typically used for measuring the benefits of hazard mitigation actions: impact on people was given a weighting factor of 3; impact on property was given a weighting factor of 2; and impact on the economy was given a weighting factor of 1.

Table 15-2, Table 15-3 and Table 15-4 summarize the impacts for each hazard.

15.3 RISK RATING AND RANKING

The risk rating for each hazard was determined by multiplying the probability factor by the sum of the weighted impact factors for people, property and economy, as summarized in Table 15-5. Based on these ratings, a priority of high, medium or low was assigned to each hazard. The hazards ranked as being of highest concern are earthquake and severe weather. Hazards ranked as being of medium concern are flood, landslide and wildfire. The hazards ranked as being of lowest concern are volcano, drought and dam failure. Table 15-6 shows the hazard risk ranking.

Table 15-2. Impact on People from Hazards

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (3)
Dam Failure	Low (7.6%)	1	(1x3) = 3
Drought[a]	None	0	(0x3) = 0
Earthquake	High (100%)	3	(3x3) = 9
Flood	Low (1.5%)	1	(1x3) = 3
Landslide	Low (2.3%)	1	(1x3) = 3
Severe weather	High (100%)	3	(3x3) = 9
Volcano[b]	Medium (100% / 0.7%)	2	(2x3) = 6
Wildfire[c]	Medium (100% / 3.4%)	2	(2x3) = 6

a. All people in the planning area would be exposed to drought, but impacts on the health and safety of people would be minimal.
b. Impact from ash fall is high (100%), impacts from distal hazards are low (0.7%).
c. Estimated population in relatively high exposure areas is low (3.4%); however, impacts from air quality are high (100%).

Table 15-3. Impact on Property from Hazards

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (2)
Dam Failure	Medium (10.6%)	2	(2x2) = 4
Drought[a]	Low	1	(1x2) = 2
Earthquake	High (100%)	3	(3x2) = 6
Flood	Low (1.8%)	1	(1x2) = 2
Landslide	Low (1.7%)	1	(1x2) = 2
Severe weather	High (100%)	3	(3x2) = 6
Volcano[b]	Medium (100% / 2.6%)	2	(2x2) = 4
Wildfire[c]	Low (3.0%)	1	(1x2) = 2

a. All property in the planning area would be exposed to drought, but impacts on structures would be minimal.
b. Impact from ash fall is high (100%), impacts from distal hazards are low (2.6%).
c. Based on relatively high property exposure.

Table 15-4. Impact on Economy from Hazards

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (1)
Dam Failure	Low (2.5%)	1	(1x1) = 1
Drought	Low (less than 0.1%)	1	(1x1) = 1
Earthquake[a, c]	Medium (0.3%)	1	(1x1) = 1
Flood[b, c]	Medium (0.3%)	1	(1x1) = 1
Landslide	Low (less than 1%)	1	(1x1) = 1
Severe weather[c]	Medium (less than 1%)	1	(1x1) = 1
Volcano	Low (less than 1%)	1	(1x1) = 1
Wildfire	Low (less than 1%)	1	(1x1) = 1

a. Based on 100-year probabilistic results.
b. Based on 1 percent annual chance flood event.
c. Impacts were adjusted to medium due to the disruption in critical facilities and infrastructure expected from these hazards.

Table 15-5. Hazard Risk Rating

Hazard Event	Probability Factor	Sum of Weighted Impact Factors	Total (Probability x Impact)
Dam Failure	1	(3+4+1) = 8	(1x8) = 8
Drought	3	(0+2+1) = 3	(3x3) = 9
Earthquake	3	(9+6+2) = 17	(3x17) = 51
Flood	3	(3+2+2) = 7	(3x7) = 21
Landslide	3	(3+2+1) = 6	(3x6) = 18
Severe weather	3	(9+6+2) = 17	(3x17) =51
Volcano	1	(6+4+1) = 11	(1x11) = 11
Wildfire	2	(6+2+1) = 9	(2x9) = 18

Table 15-6. Hazard Risk Ranking

Hazard Ranking	Hazard Event	Category
1	Earthquake	High
1	Severe weather	High
2	Flood	Medium
2	Landslide	Medium
2	Wildfire	Medium
3	Volcano	Low
4	Drought	Low
5	Dam failure	Low

Part 3. MITIGATION PLAN

16. PURPOSE, GOALS AND OBJECTIVES

Hazard mitigation plans must identify goals for reducing long-term vulnerabilities to identified hazards (44 CFR Section 201.6(c)(3)(i)). The Planning Committee reviewed the goals from the 2017 plan and determined that they are no need to make any major changes to them. The Planning Committee reviewed goals and objectives from other relevant plans and programs such as the Washington State Hazard Mitigation Plan and the Clark County Comprehensive Plan and adapted them for the hazard mitigation plan as appropriate in 2016. Hazard mitigation specific goals and objectives were also selected. These selections were revisited throughout the planning process after the completion of the risk assessment and public engagement to ensure they accurately reflected needs within the planning area. The purpose statement, goals, objectives and actions in this plan all support each other. Goals were selected to support the purpose statement. Objectives were selected that met multiple goals. Actions were prioritized based on the action meeting multiple objectives.

16.1 PURPOSE STATEMENT

A purpose statement focuses the range of goals and, therefore, objectives and actions to be considered. This statement is not a goal because it does not describe a hazard mitigation outcome, and it is broader than a hazard-specific objective. The purpose statement for the *Clark Regional Natural Hazard Mitigation Plan* is as follows:

> Define natural hazard risk and, through collaboration and partnerships, establish strategies and actions for reducing the impacts of disasters in Clark County.

16.2 GOALS

The following are the mitigation goals for this plan:

- Reduce and prevent the loss of life and property.
- Protect public services and critical facilities from the impacts of natural disasters.
- Increase public awareness of vulnerability to natural hazards and educate on risk reduction strategies.
- Promote community resilience.
- Protect environmental resources and utilize natural systems to reduce natural hazard impacts.
- Develop and implement cost-effective mitigation strategies.

The effectiveness of a mitigation strategy is assessed by determining how well these goals are achieved.

16.3 OBJECTIVES

Each objective meets multiple goals, serving as a stand-alone measurement of the effectiveness of a mitigation action, rather than as a subset of a goal. The objectives also are used to help establish priorities. The objectives are as follows (numbering is provided as a point of reference, not as an indication of priority):

1. Inform the public on the risk exposure to natural hazards and ways to increase the public's capability to prepare, respond, recover and mitigate the impacts of these events.
2. Reduce the impacts of hazards on vulnerable populations.
3. Improve and maintain systems that provide warning and emergency communications.
4. Work cooperatively with stakeholders in planning for and reducing the impacts of natural hazards.
5. Incorporate risk reduction strategies in new and updated infrastructure and development plans to reduce the impacts of natural hazards.
6. Integrate natural hazard mitigation goals and objectives into other existing plans and programs within the planning area.
7. Provide incentives for development and land use techniques that reduce risks.
8. Strengthen and build redundancy into infrastructure, prioritizing areas that may be potentially isolated areas.
9. Retrofit, purchase, or relocate structures in high hazard areas, especially those known to be repetitively damaged.
10. Avoid, minimize or mitigate risks to critical facilities and infrastructure.
11. Support and enhance environmental protection and sustainability activities that may also accomplish mitigation objectives.
12. Use the best available data, science and technologies to implement mitigation strategies.

17. MITIGATION BEST PRACTICES

Catalogs of hazard mitigation best practices were developed that present a broad range of alternatives to be considered for use in the planning area, in compliance with 44 CFR (Section 201.6(c)(3)(ii)). One catalog was developed for each hazard of concern evaluated in this plan as well as a catalog for all hazards. The catalogs for each hazard are listed in Table 17-1 through Table 17-9. The catalogs present alternatives that are categorized in two ways:

- By what the alternative would do:
  - Manipulate a hazard
  - Reduce exposure to a hazard
  - Reduce vulnerability to a hazard
  - Increase the ability to respond to or be prepared for a hazard
- By who would have responsibility for implementation:
  - The general public - individuals
  - The private sector - businesses
  - Government.

Hazard mitigation actions recommended in this plan were selected from among the alternatives presented in the catalogs or inspired by a review of the catalogs. The catalogs provide a baseline of mitigation alternatives that are backed by a planning process, are consistent with the planning partners' goals and objectives, and are within the capabilities of the partners to implement. Some of these actions may not be feasible based on the selection criteria identified for this plan. The purpose of the catalog was to equip the planning partners with a list of what could be considered to reduce risk from natural hazards within the planning area. All actions identified in Volume 2 of this plan were selected based on the selection criteria described in Chapter 1 of Volume 2. Actions in the catalog that are not included for the partnership's action plan were not selected for one or more of the following reasons:

- The action is not feasible.
- The action is already being implemented.
- There is an apparently more cost-effective alternative.
- The action does not have public or political support.

Table 17-1. Catalog of Mitigation Best Practices—All Hazards

Public (Individual) Scale	Private (Business) Scale	Government Scale
Manipulate Hazard		
• None	• None	• None
Reduce Exposure		
• None	• None	• Relocate critical facilities out of known hazard areas • Prohibit or limit public expenditures for capital improvements in known hazard areas • Acquire safe sites for public facilities (e.g., schools, police/fire stations, etc.) • Prohibit new facilities for persons with special needs/mobility concerns in hazard areas. • Prohibit animal shelters in known hazard areas
Reduce Vulnerability		
• Apply for permits as required and follow established building codes • Perform a vulnerability check on personal property	• Establish/participate in a business-to-business mitigation mentoring program. • Perform a vulnerability check on property	• Retrofit critical facilities within known hazard areas. • Organize a managed retreat from very high-risk areas. • Promote open space uses in identified high hazard areas via techniques such as: PUD's, easements, setbacks, greenways, sensitive area tracks

Public (Individual) Scale	Private (Business) Scale	Government Scale
Increase Capability		
• Educate yourself on risk reductions methods • Educate yourself on early warning procedures • Purchase insurance for your home and valuables • Volunteer on community mitigation projects. • Develop household mitigation plan, such as creating a retrofit savings account, communication capability with outside, 2 week self-sufficiency during an event • Prepare a family post-disaster action plan • Get to know your neighbors • Participate in perishable data capture programs	• Educate your employees on the probable impacts from hazard events • Develop a Continuity of Operations Plan • Participate in perishable data capture programs	• Develop an all hazards public education campaign and resource center • Promote the purchase of insurance in known hazard areas • Establish a process to coordinate with local, state and federal agencies to maintain up-to-date hazard data, maps, and assessments. • Designate high-risk zones as special assessment districts (to fund necessary hazard mitigation projects) • Incorporate a stand-alone element for hazard mitigation into the local comprehensive (land use) plan. • Develop a post-disaster reconstruction plan to facilitate decision making following a hazard event. • Involve citizens in comprehensive planning activities that identify and mitigate hazards • Adopt a post-disaster recovery ordinance based on a plan to regulate repair activity, generally depending on property location. • Adopt the International Building Code and International Residential Code • Increase the local Building Code Effectiveness Grading Schedule classification through higher building code standards and enforcement practices. • Identify a funding mechanism for a local match to Federal funds that can fund private mitigation practices. • Identify and strengthen facilities so that they can function as public shelters • Provide hazard vulnerability checklists for homeowners to conduct their own inspections • Establish a technical assistance program for residents to access data or resources for mitigation purposes • Develop mutual aid agreements with other local governments/organizations • Warehouse critical infrastructure components such as pipe, power line, and road repair material • Develop a Continuity of Government Plan • Provide technical information and guidance during permitting and development process • Maintain existing hazard databases and establish a program for collection perishable data after hazard events • Form a citizen plan implementation steering committee to monitor progress of local mitigation actions. Include a mix of representatives from neighborhoods, local businesses, and local government.

Table 17-2. Catalog of Mitigation Best Practices —Dam Failure

Public (Individual) Scale	Private (Business) Scale	Government Scale
Manipulate Hazard		
• None	• Remove privately owned Dams • Strengthen privately owned Dams	• Remove government owned Dams • Strengthen government owned Dams
Reduce Exposure		
• Relocate out of Dam Failure Inundation areas.	Replace earthen dams with hardened structures	• Replace earthen dams with hardened structures
Reduce Vulnerability		
• Elevate your home to appropriate levels • Flood-proof your home to appropriate levels	• Flood proof facilities within Dam Failure Inundation areas • Continue/ensure regularly scheduled engineering assessments of privately owned dams	• Adopt higher regulatory floodplain standards in mapped Dam Failure/Inundation areas. • Consider low density land uses within identified Dam Failure/Inundation areas. • Continue/ensure regularly scheduled engineering assessments • Create easements in impoundment and downstream inundation areas • Study and evaluate impacts from climate change on dam operations
Increase Capability		
• Learn the evacuation routes for a dam failure event • Educate yourself on early warning procedures. • Purchase flood insurance	• Develop and update Emergency Action Plans • Educate employees on dam failure evacuation routes • Educate employees on early warning procedures.	• Create, maintain and update scenario based Dam Failure/Inundation area maps. • Enhance Emergency Operations Plan to include a dam failure component. • Institute monthly communications checks with dam operators. Maintain up to date communications list. • Inform the public on risk reduction techniques and develop a communication plan • Adopt real-estate disclosure requirements for the re-sale of property located within Dam Inundation areas. • Establish early warning systems downstream of high hazard dams. • Update evacuation routes and educate the public on those routes • Promote the purchase of flood insurance in inundation areas

Table 17-3. Catalog of Mitigation Best Practices—Drought

Public (Individual) Scale	Private (Business) Scale	Government Scale
Manipulate Hazard		
• None	• None	• Promote groundwater recharge through stormwater management • Implement cloud seeding techniques during dry season.
Reduce Exposure		
• Install stored water/captured water techniques, such as rain barrels or down spout gardens • Use permeable paving techniques whenever feasible	• Install stored water/captured water techniques, such as rain barrels or down spout gardens • Use permeable paving techniques whenever feasible.	• Identify and create ground water back up sources • Create/identify new impounded water supply points • Use permeable paving techniques whenever feasible
Reduce Vulnerability		
• Plant drought resistant landscapes • Reduce water system losses (e.g. fix drips) • Modify plumbing systems, i.e. water saving kits or grey water systems	• Plant drought resistant landscapes • Reduce private water system losses • Identify alternate water supply sources • Plant drought-resistant crop varieties • Develop and implement grey water systems	• Plant drought resistant landscapes on community owned facilities • Distribute water saving kits to community members • Implement storm water retention in regions ideally suited for groundwater recharges • Reduce water system losses through regular maintenance • Design water delivery systems to accommodate drought events
Increase Capability		
• Practice active water conservation	• Practice active water conservation techniques • Develop a water conservation plan	• Identify alternative water supplies for time of drought • Develop a drought contingency plan • Develop criteria triggers for drought related actions • Improve accuracy of water supply forecasts • Modify rate structures to influence active water conservation techniques • Consider providing incentives to property owners that utilize drought resistant landscapes in the design of their home • Develop/Implement drought education/notification systems and communication plan • Emphasize droughts relationship to other hazards in hazard awareness messaging • Increase capability to enforce water restrictions when such restrictions are in place.

Table 17-4. Catalog of Mitigation Best Practices—Earthquake

Public (Individual) Scale	Private (Business) Scale	Government Scale
Manipulate Hazard		
• None	• None	• None
Reduce Exposure		
• Locate outside of hazard area (off soft soils)	• Locate or relocate mission-critical functions outside hazard area where possible	• Locate critical facilities or functions outside hazard area where possible
Reduce Vulnerability		
• Retrofit structure (e.g. anchor house structure to foundation) • Secure household items that can cause injury or damage such as water heaters, bookcases, and other appliances • Build to higher design standards • Install window film to prevent injuries from shattered glass	• Build redundancy for critical functions/facilities • Retrofit critical buildings/areas housing mission critical functions • Perform non-structural assessments and mitigation activities (e.g. anchor bookcases to the wall) • Anchor rooftop-mounted equipment (i.e., HVAC units, satellite dishes, etc.).	• Harden infrastructure • Provide redundancy for critical functions • Encourage mitigation of private property • Perform non-structural assessments and mitigation activities (e.g. anchor bookcases to the wall) • Require bracing of generators, elevators, and other vital equipment in hospitals. • Review construction plans for all bridges to determine their susceptibility to collapse and retrofit problem bridges. • Use flexible piping when extending water, sewer, or natural gas service. • Install shutoff valves and emergency connector hoses where water mains cross fault lines. • Install window film to prevent injuries from shattered glass • Anchor rooftop-mounted equipment (i.e., HVAC units, satellite dishes, etc.). • Include retrofitting/replacement of critical system elements in Capital Improvements Plan (CIP) • Store emergency water supply sufficient for students and staff at school for at least one day

Public (Individual) Scale	Private (Business) Scale	Government Scale
Increase Capability		
• Practice "drop, cover and hold" • Participate in drills such as the Great Shakeout • Purchase earthquake insurance	• Adopt higher standard for new construction -- Consider "performance based design' when building new structures • Increase capability by having cash reserves for reconstruction • Inform your employees on the possible impacts of earthquake and how to deal with them at your work facility • Participate in drills such as the Great Shakeout	• Produce more accurate hazard maps (e.g. liquefaction and soils maps) • Initiate triggers guiding improvements such as: (< 50% substantial damage/improvements) • Further enhance seismic risk assessment to target high hazard buildings for mitigation opportunities (e.g. older structures, unreinforced masonry) • Develop a debris management plan • Participate in drills such as the Great Shakeout • Communicate earthquake secondary hazards to public (e.g. landslides, dam failure, fires, hazardous material spills) • Assess emergency response routes and determine back-up options in case of damage or disruption • Educate K-12, residents, developers and businesses on earthquake safety and building codes. • Require/encourage rapid damage assessment training for City staff • Develop and distribute guidelines or pass ordinances that require developers and building owners to locate lifelines, buildings, critical facilities, and hazardous materials out of areas subject to significant seismic hazards. • Support financial incentives, such as low interest loans or tax breaks, for home and business owners who seismically retrofit their structures. • Use Hazus to quantitatively estimate potential losses from an earthquake • Establish a school survey procedure and guidance document to inventory structural and non-structural hazards in and around school buildings • Use rapid visual screening to quickly inspect a building and identify disaster damage or potential seismic structural and non-structural weaknesses to prioritize retrofit efforts, inventory high-risk structures and critical facilities, or assess post-disaster risk to determine if buildings are safe to re-occupy • Develop a technical assistance information program for homeowners. • Create a seismic safety committee to provide policy recommendations, evaluate and recommend changes in seismic safety standards, and give an annual assessment of local and statewide implementation of seismic safety improvements • Develop an inventory of public and commercial buildings that may be particularly vulnerable to earthquake damage.

Table 17-5. Catalog of Mitigation Best Practices—Flood

Public (Individual) Scale	Private (Business) Scale	Government Scale
Manipulate Hazard		
• Clear stormwater drains and culverts	• Clear stormwater drains and culverts	• Develop and adopt a storm drain program • Dredge, construct levees, provide retention areas • Invest in structural flood control: levees, dams, channelization, revetments • Construct regional stormwater control facilities • Harden areas with significant erosion concerns • Promote/retain natural vegetation in areas with significant erosion concerns
Reduce Exposure		
• Locate outside of hazard area • Elevate utilities above base flood elevation • Institute low impact development techniques on property	• Locate business critical facilities or functions outside hazard area • Institute low impact development techniques on property	• Acquire or relocate identified repetitive loss properties • Adopt land development techniques such as density transfers or clustering • Institute low impact development techniques on property • Adopt sediment and erosion control regulations • Adopt zoning and erosion overlay districts • Prohibit any fill in floodplain areas • Encourage the use of porous pavement, vegetative buffers, and islands in large parking areas. • Use stream restoration to ensure adequate drainage and diversion of stormwater.

Public (Individual) Scale	Private (Business) Scale	Government Scale
Reduce Vulnerability		
• Retrofit structure (elevate house above base flood elevation) • Elevate items within house above base flood elevation • Build new homes above base flood elevation • Floodproof non-residential structures	• Build redundancy for critical functions/ retrofit critical buildings • Provide flood-proofing measures when new critical infrastructure must be located in floodplains	• Adopt appropriate regulatory standards such as cumulative substantial improvement/damage, freeboard, lower substantial damage threshold, compensatory storage • Develop and implement stormwater management regulations and master planning • Adopt "no-adverse impact" floodplain management policies that strive to not increase the flood risk on down-stream communities • Perform regular inspections/assessments of locally owned or maintained flood control infrastructure • Replace undersized culverts • Provide permanent protection for pump stations at risk of flooding • Identify/mitigate drainage issues resulting in ponding • Enhance road drainage programs or elevate/relocate roads subject to frequent flooding • Ensure permitting process is consistent with the adopted floodplain management ordinance • Develop an erosion protection program for high hazard areas • Construct open foundation systems on buildings to minimize scour • Construct deep foundations in erosion hazard areas • Establish a green infrastructure program • Use subdivision design standards to require elevation data collection during platting and to have buildable space on lots above the base flood elevation • Require tie downs of propane tanks • Require a drainage study with new development • Design a "natural runoff" or "zero discharge" policy for stormwater in subdivision design • Require and maintaining FEMA elevation certificates for all new and improved buildings located in floodplains • Extend the freeboard requirement past the mapped floodplain to include an equivalent land elevation • Include requirements in the local floodplain ordinance for homeowners to sign non-conversion agreements for areas below base flood elevation. • Offer incentives for building above the required freeboard minimum (code plus). • Inspect bridges and identify if any repairs or retrofits are needed to prevent scour • Floodproof critical facilities and infrastructure located in flood hazard areas • Require all critical facilities to meet requirements of Executive Order 11988 and be built 1 foot above the 500-year flood elevation

Public (Individual) Scale	Private (Business) Scale	Government Scale
Increase Capability		
• Comply with National Flood Insurance Program • Purchase flood insurance	• Increase capability by having cash reserves for reconstruction • Support and implement hazard disclosure for the sale/re-sale of property in identified risk zones • Solicit 'cost-sharing" through partnerships with public sector stake holders on projects with multiple benefits	• Produce more accurate flood hazard maps or identify areas for further study • Join Community Rating System (CRS) program or maintain/improve class • Provide training for staff and decision-makers in floodplain management (e.g. maintain certified floodplain managers on staff) • Create a building and elevation inventory of structures in the floodplain • Develop a Flood Task Force • Pre-stage flood response equipment before events • Integrate floodplain management policies into other planning mechanisms within the planning area • Develop framework/continue efforts for cooperation between agencies/districts in flood mitigation activities (e.g. sand and sand bag deployment) • Retain good standing in National Flood Insurance Program • Participate in information sharing with other agencies (e.g. U.S. Army Corps of Engineers, NWS) • Identify and mitigate sources of nuisance flooding • Review and update floodplain damage prevention ordinances • Identify debris collection sites • Require/encourage rapid damage assessment training for staff • Map locations of storm drains, catch basins and dry wells so that they may be located and cleared • Identify and map erosion hazard areas • Develop a tracking program for erosion hazards and their impacts on the community • Pass and enforce an ordinance that regulates dumping in streams and ditches • Develop a stormwater committee • Form a regional watershed council • Incorporate digital floodplain and topographic data into GIS systems, in conjunction with Hazus, to assess risk • Conduct NFIP community workshops to provide information and incentives for property owners to acquire flood insurance. • Increase drainage or absorption capacities with detention and retention basins, relief drains, spillways, drain widening/dredging or rerouting, logjam and debris removal, extra culverts, bridge modification, dike setbacks, flood gates and pumps, or channel redirection

Table 17-6. Catalog of Mitigation Alternatives—Landslide

Public (Individual) Scale	Private (Business) Scale	Government Scale
Manipulate Hazard		
• Stabilize slope (de-water, armor toe) • Reduce weight on top of slope • Minimize vegetation removal and the addition • Install rip rap boulders of geotextile fabric • Using bioengineered bank stabilization techniques. • Use a rock splash pad to direct run off and minimize the potential for erosion	• Stabilize slope (de-water, armor toe) • Reduce weight on top of slope • Minimize vegetation removal and the addition of impervious surfaces • Using bioengineered bank stabilization techniques. • Use a rock splash pad to direct run off and minimize the potential fort erosion	• Monitor/review accumulated effects from piecemeal development on steep slopes • Implement post-fire vegetation management plans • Coordinate with resource management agencies to identify potential issues from resource extraction activities • Using bioengineered bank stabilization techniques.
Reduce Exposure		
• Locate structures outside of hazard area (off unstable land and away from slide-run out area)	• Locate structures outside of hazard area (off unstable land and away from slide runout area)	• Acquire properties located in high risk landslide areas • Adopt land use policies that prohibit the placement of habitable structures in high risk landslide areas • Adopt land use policies that limit accumulated effects in landslide risk areas
Reduce Vulnerability		
• Retrofit homes on steep slopes	• Retrofit at-risk facilities.	• Adopt higher regulatory standards for new development within unstable slope areas • Armor/retrofit critical infrastructure from the impact of landslides • Post signage in landslide hazard areas • Prohibit removal of natural vegetation from slopes • Assess vegetation in wildfire-prone areas to prevent landslides after fires (e.g., encourage plants with strong root systems).
Increase Capability		
• Sign up for warning systems • Learn the warning signs that indicate a landslide may occur • Educate yourself on risk reduction techniques for landslide hazards	• Sign up for warning system and develop evacuation plan • Increase capability by having cash reserves for reconstruction • Educate your employees on the potential exposure to landslide hazards and your emergency response protocol	• Produce landslide hazard risk maps • Enact tools to help manage development in hazard areas: better land controls, tax incentives, information, limit new impervious/pervious surfaces • Collect and compile landslide event history database • Develop plan/strategy for communicating risk to property owners/communities recently affected by wildfires • Increase regulatory authority for post-fire mitigation enforcement • Establish and communicate post-event repair responsibilities (e.g. roads that are impacted) • Conduct geological/engineering studies of potential slide areas • Notify property owners in high-risk areas • Develop a brochure describing risk and potential mitigation techniques

Table 17-7. Catalog of Mitigation Best Practices—Severe Weather

Public (Individual) Scale	Private (Business) Scale	Government Scale
Manipulate Hazard		
• Increase tree plantings around buildings to shade parking lots and along public rights-of-way	• Increase tree plantings around buildings to shade parking lots and along public rights-of-way.	• Increase tree plantings around buildings to shade parking lots and along public rights-of-way.
Reduce Exposure		
• None	• None	• None
Reduce Vulnerability		
• Insulate house • Provide redundant heat and power • Plant appropriate trees near home and power lines ("Right tree, right place" National Arbor Day Foundation Program) • Incorporate passive ventilation in the site design. • Secure loose items (i.e., patio furniture)	• Relocate critical infrastructure, such as power lines, underground • Install tree wire • Install lightning protection devices and methods, such as lightning rods and grounding, on communications infrastructure and other critical facilities • Install and maintain surge protection on critical electronic equipment. • Avoid placing flag poles or antennas near buildings	• Trim trees back from power lines • Designate snow routes and strengthen critical road sections and bridges • Continue/expand participation in Storm Ready programs • Continue to support/maintain/improve notification and warning systems • Support/continue/formalize shelter agreements • Ensure critical facilities have back-up power generation capabilities • Install lightning protection devices on critical facilities and communications equipment • Inspect/ensure facilities can withstand high winds • Encourage construction of guard rails where appropriate • Ensure critical facilities/shelters can easily transition to generator produced power • Stockpile response/preparedness supplies • Install and maintain surge protection on critical electronic equipment • Review building codes and structural policies to ensure they are adequate to protect older structures from wind damage • Use natural environmental features as wind buffers in site design • Incorporate inspection and management of hazardous trees into the drainage system maintenance process. • Preemptively test power line holes to determine if they are rotting • Use designed-failure mode for power line design to allow lines to fall or fail in small sections rather than as a complete system to enable faster restoration • Avoid placing flag poles or antennas near buildings • Convert traffic lights to mast arms

Public (Individual) Scale	Private (Business) Scale	Government Scale
Increase Capability		
• Trim or remove trees that could affect power lines • Obtain a NOAA weather radio • Obtain an emergency generator • Identify locations of emergency shelters • Participate in amateur radio groups • Sign up for reverse 911 systems/other notification options • Post address so as to be visible to first responders • Teach school children about the dangers of lightning and how to take safety precautions.	• Trim or remove trees that could affect power lines • Create redundancy in critical systems • Equip facilities with a NOAA weather radio • Equip vital facilities with emergency power sources	• Support/continue programs such as "Tree Watch" that proactively manage problem areas by use of selective removal of hazardous trees, tree replacement, etc. • Establish and enforce building codes that require all roofs to withstand snow loads and wind speeds • Improve communication alternatives/redundancy • Modify landscape and other ordinances to encourage appropriate planting near overhead power, cable, and phone lines • Provide NOAA weather radios to the public • Encourage coordination with amateur radio groups • Identify/ear mark funding opportunities for generator purchases • Develop evacuation/ emergency road plans and prioritize roads for response efforts • Encourage residents to sign-up for reverse 911 services or other notification services • Encourage/require residents to post addresses where they are visible to first responders • Include safety strategies for severe weather in driver education classes and materials. • Organize outreach to vulnerable populations, including establishing and promoting accessible heating centers in the community

Table 17-8. Catalog of Mitigation Best Practices—Volcano

Public (Individual) Scale	Private (Business) Scale	Government Scale
Manipulate Hazard		
• None	• None	• None
Reduce Exposure		
• Identify equipment/resources that may be negatively impacted by ash fall and develop plan to move indoors/protect	• Identify equipment/resources that may be negatively impacted by ash fall and develop plan to move indoors/protect	• Identify equipment/resources that may be negatively impacted by ash fall and develop plan to move indoors/protect
Reduce Vulnerability		
• None	• Build redundancy for critical facilities and functions	• Retrofit older building stock to be able to support accumulated ash fall loads
Increase Capability		
• Sign up for early warning systems and notifications	• Educate employees on impacts and emergency plans	• Support detailed wind/ash fall studies • Develop post-event cleanup plan

Table 17-9. Catalog of Mitigation Best Practices—Wildfire

Public (Individual) Scale	Private (Business) Scale	Government Scale
Manipulate Hazard		
• Clear potential fuels on property: dry, overgrown underbrush, diseased trees	• Clear potential fuels on property: dry underbrush, diseased trees	• Clear fuels (dry underbrush, diseased trees) on land that can trigger and maintain wildfires • Implement "Best Management Practices" on public lands • Partner with local communities to create fire breaks
Reduce Exposure		
• Create and maintain defensible space around structures • Reduce exposure --Locate outside of hazard area • Mow regularly • Stay clear of hazard areas during a wildfire event	• Create and maintain defensible space around structures and infrastructure • Reduce exposure -- Locate outside of hazard area	• Create and maintain defensible space around structures and infrastructure • Enhance building code to include use of fire resistant materials in high hazard areas • Reduce exposure -- Locate outside of hazard area
Reduce Vulnerability		
• Create and maintain defensible space around structures, provide water on site. • Use fire-retardant building materials • Create defensible spaces around your home	• Create and maintain defensible space around structures and infrastructure, provide water on site • Use fire-retardant building materials	• Create and maintain defensible space around structures and infrastructure • Use fire-retardant building materials • Develop/implement higher regulatory standards in wildfire hazard areas • Develop/support biomass reclamation initiatives • Increase regulatory requirements/code enforcement for fire risk reduction or incentivize higher standards • Develop fire smart building code regulations • Implement road side vegetation management best practices • Conduct pre-construction building inspections that include fire prevention requirements and provide emphasis on a fire resistant structure • Develop programs to identify/install wildland fire water supply systems such as cisterns, ponds and dry hydrants • Involve fire protection agencies in determining guidelines and standards and in development and site plan review procedures • Enclose the foundations of homes and other buildings in wildfire-prone areas, rather than leaving them open and potentially exposing undersides to blown embers or other materials. • Prohibit wooden shingles/wood shake roofs on any new development in areas prone to wildfires. • Routinely inspect the functionality of fire hydrants • Use prescribed burning to reduce fuel loads that threaten public safety and property.

Public (Individual) Scale	Private (Business) Scale	Government Scale
Increase Capability		
• Employ "Firewise" techniques to safeguard your home • Identify alternative water supplies for fire fighting • Install/replace roofing material with non-combustible roofing materials • Ensure that all fuel-burning equipment should be vented to the outside • Install carbon monoxide monitors and alarms.	• Support "Firewise" community initiatives • Create /establish stored water supplies to be utilized for fire fighting	• Seek alternative water supplies in urban wildland interface areas • Become a "Firewise" community • Utilize academia to study impacts/solutions to wildfire risk • Create/implement/update wildfire protection plans • Develop evacuation/ emergency road plans and prioritize roads for response efforts • Provide public outreach to increase understanding of forest management practices • Enhance/provide redundant communication infrastructure • Require/encourage rapid damage assessment training • Pre-plan responses to wildland urban interface areas • Use zoning and/or a special wildfire overlay district to designate high-risk areas and specify the conditions for the use and development of specific areas • Develop a vegetation management plan • Work with insurance companies, utility providers, and others to include wildfire safety information in materials provided to area residents

18. MITIGATION ACTIONS AND IMPLEMENTATION

18.1 STATUS OF PREVIOUS PLAN INITIATIVES

Table 1-8 summarized the initiative that were recommended in the previous version of the hazard mitigation plan and their implementation status at the time this update was prepared.

Table 18-1 Previous Hazard Mitigation Plan Initiatives

Action Item	Completed	Carry Over to Plan Update	Removed; No Longer Feasible
Establish a county-wide repository of perishable data from hazard events and develop a standard form for capturing information.		X	
***Comment**: GIS Partners from multiple jurisdictions have met to discuss this issue, but more work is required.*			
Develop a county-wide recovery/resiliency plan.		X	
***Comment**: Clark County participated in a regional recovery framework development process with the other 4 counties of the Portland-Vancouver Metro Region and completed a regional framework. Funding had been identified to develop local level framework with a consulting team that would tie into the regional framework, but COVID-19 required a change of priorities. We still intend to move the project forward when new funding can be identified and partners have available bandwidth.*			
Participate in the plan implementation hazard mitigation working group by sharing lessons learned and mitigation success stories and actively participating in progress reporting		X	
***Comment**: The workgroup was ongoing before COVID-19 response. The workgroup will be rebooted following the approval of this plan.*			
Support and guide the technology for regional hazard warning systems	X		
***Comment**: CRESA maintains a new hazard warning system which is used by CRESA Emergency Management and the municipalities within Clark County. CRESA also works with neighboring counties to share standard operating practices and develop regional use standards.*			
Ensure that a link to the hazard mitigation plan website hosted by CRESA is posted conspicuously on each planning partner website		X	
***Comment**: CRESA is in the process of having a new website developed. Once the new website is active, links will need to be updated.*			
Support regional collaboration and consistency in hazard mitigation implementation and programs		X	
***Comment**: This is ongoing through both local and regional workgroups*			

Where appropriate, support retro-fitting, relocating or acquisition from willing property owners of structures located in hazard-prone areas to protect structures from future damage, with repetitive and severe repetitive loss as a priority. Seek opportunities to leverage partnerships within the planning area in these pursuits		X	
Comment*: This is an on-going task.*			
Utilize information contained within the Clark Regional Natural Hazard Mitigation Plan to support updates to other emergency management plans in effect within the planning area		X	
Comment*: This is an on-going task.*			
Utilize information contained within the Clark Regional Natural Hazard Mitigation Plan to support updates to other plans in effect within the planning area		X	
Comment*: This is an on-going task.*			
Develop the capacity for a regional post-disaster volunteer coordination program		X	
Comment*: The Clark County Community Organizations Active in Disaster (COAD) began discussions around re-developing a program. At this time, there is no developed program.*			
Explore opportunities with all community stakeholders to implement, identify and fund mitigation actions		X	
Comment*: This is an on-going task*			
Continue regional partnerships to improve and enhance mitigation efforts in the larger region		X	
Comment*: This is an on-going task*			
Establish guidelines to increase communication and coordination of mitigation actions across agencies whenever feasible		X	
Comment*: This is an on-going task*			
Continue to work with planning partners and other stakeholders to clearly articulate and define emergency management roles and responsibilities within the County, including the implementation of identified mitigation actions.		X	
Comment*: This is an on-going task.*			

18.2 SELECTED COUNTY-WIDE MITIGATION ACTIONS

The Steering Committee determined that some actions could be implemented to provide hazard mitigation benefits county-wide. Table 18-2 lists the recommended county-wide actions and their implementation details. Table 18-3 lists the implementation and grant pursuit priorities for the recommended actions. Explanations for categorizations in these tables are in the sections that follow.

18.2.1 Timeline

Timelines for actions are defined as:

- Short-term: action can be completed in 1 to 5 years
- Long-term: action can be completed in 5 years or greater
- Ongoing: action is a continual program.

18.2.2 Benefit/Cost Review

The action plan must be prioritized according to a benefit/cost analysis of the proposed actions and their associated costs (44 CFR, Section 201.6(c)(3)(iii)). The benefits of proposed actions were weighed against estimated costs as part of the action prioritization process. The benefit/cost analysis was not of the detailed variety required by FEMA for action grant eligibility under relevant grant programs. A less formal approach was used because some actions may not be implemented for up to 10 years, and associated costs and benefits could change dramatically in that time. Therefore, a review of the apparent benefits versus the apparent cost of each action was performed. Parameters were established for assigning subjective ratings (high, medium, and low) to the costs and benefits of these actions.

Benefit ratings were defined as follows:

- ➢ High: Action will have an immediate impact on the reduction of risk exposure to life and property.
- ➢ Medium: Action will have a long-term impact on the reduction of risk exposure to life and property, or action will provide an immediate reduction in the risk exposure to property.
- ➢ Low: Long-term benefits of the action are difficult to quantify in the short term.

Cost ratings were defined as follows:

- ➢ High: Would require an increase in revenue via an alternative source (i.e., bonds, grants, fee increases) to implement. Existing funding levels are not adequate to cover the costs of the proposed action.
- ➢ Medium: Could budget for under existing work-plan, but would require a reapportionment of the budget or a budget amendment, or the cost of the action would have to be spread over multiple years.
- ➢ Low: Possible to fund under existing budget. Action is or can be part of an existing ongoing program.

Using this approach, actions with positive benefit versus cost ratios (such as high over high, high over medium, medium over low, etc.) are considered cost-beneficial. For many of the strategies identified in this action plan, the partners may seek financial assistance under the Hazard Mitigation Grant Program or Pre-Disaster Mitigation Assistance programs, both of which require detailed benefit/cost analyses. These analyses will be performed on actions at the time of application using the FEMA benefit-cost model. For actions not seeking financial assistance from grant programs that require detailed analysis, the partners reserve the right to define “benefits” according to parameters that meet the goals and objectives of this plan.

18.2.3 Prioritization

Two prioritization categories were established for this planning process: implementation and grant pursuit.

Implementation priorities were established using the following considerations:

- High Priority—An action that meets multiple objectives, has benefits that exceed cost, has funding secured or is an ongoing action and meets eligibility requirements for a grant program. High priority actions can be completed in the short term (1 to 5 years). The key factors for high priority actions are that they have funding secured and can be completed in the short term.
- Medium Priority—An action that meets multiple objectives, that has benefits that exceed costs, and for which funding has not yet been secured, but is eligible for funding. Action can be completed in the short term, once funding is secured. Medium priority actions will become high priority actions once funding is secured. The key factors for medium priority actions are that they

are eligible for funding, but do not yet have funding secured, and they can be completed within the short term.
- Low Priority—An action that will mitigate the risk of a hazard, that has benefits that do not exceed the costs or are difficult to quantify, for which funding has not been secured, that is not eligible for grant funding, and for which the time line for completion is long term (1 to 10 years). Low priority actions may be eligible for grant funding from other programs that have not yet been identified. Low priority actions are generally "blue-sky" or "wish-list." actions. Financing is unknown, and they can be completed over a long term.

Grant pursuit priories were established using the following considerations:
- High Priority—An action that has been identified as meeting grant eligibility requirements, assessed to have high benefits, is listed as high or medium priority, and where local funding options are unavailable or where dedicated funds could be utilized for actions that are not eligible for grant funding.
- Medium Priority—An action that has been identified as meeting grant eligibility requirements, assessed to have medium or low benefits, is listed as medium or low priority, and where local funding options are unavailable.
- Low Priority—An action that has not been identified as meeting grant eligibility requirements, or has low benefits.

Table 18-2. County-Wide Action Plan Matrix

Applies to new or existing assets	Hazards Mitigated	Objectives Met	Lead Agency	Estimated Cost	Sources of Funding[a]	Timeline
CW-1—Establish a county-wide repository of perishable data from hazard events and develop a standard form for capturing information.						
New and existing	All hazards	4, 12	CRESA	Low	Staff time	Short-term
CW-2—Develop a county-wide recovery/resiliency plan.						
New and existing	All hazards	2, 4, 6	CRESA	High	Local, possible grant funding (UASI)	Short-term
CW-3—Participate in the plan implementation hazard mitigation working group by sharing lessons learned and mitigation success stories and actively participating in progress reporting						
New and existing	All hazards	1, 4, 6, 12	Planning Partners/ facilitated by CRESA	Low	Staff time	Ongoing
CW-4—Ensure that a link to the hazard mitigation plan website hosted by CRESA is posted conspicuously on each planning partner website						
N/A	All hazards	1, 4	Planning Partners	Low	Staff time	Short-term
CW-5—Support regional collaboration and consistency in hazard mitigation implementation and programs						
New and existing	All hazards	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	Clark County/CRESA	Low	Staff time	Ongoing
CW-6—Where appropriate, support retro-fitting, relocating or acquisition from willing property owners of structures located in hazard-prone areas to protect structures from future damage, with repetitive and severe repetitive loss as a priority. Seek opportunities to leverage partnerships within the planning area in these pursuits						
Existing	All hazards	4, 5, 7, 9, 10	Planning Partners	High	HMGP, PDM, FMA, CDBG-DR	Ongoing
CW-7—Utilize information contained within the Clark Regional Natural Hazard Mitigation Plan to support updates to other emergency management plans in effect within the planning area						
New and existing	All hazards	2, 4	CRESA	Low	Staff time	Ongoing
CW-8—Utilize information contained within the Clark Regional Natural Hazard Mitigation Plan to support updates to other plans in effect within the planning area						
New and existing	All hazards	2, 4, 5	Planning Partners	Low	Staff time	Ongoing
CW-9—Develop the capacity for a regional post-disaster volunteer coordination program						
N/A	All hazards	1, 2, 3, 4	CRESA	Medium	Staff time, Local funds	Long-term
CW-10—Explore opportunities with all community stakeholders to implement, identify and fund mitigation actions						
New and existing	All hazards	1, 2, 4,12	CRESA	Medium	Staff time, Local funds	Ongoing
CW-11—Continue regional partnerships to improve and enhance mitigation efforts in the larger region						
New and existing	All hazards	1, 4	CRESA	Low	Staff-time	Ongoing
CW-12—Establish guidelines to increase communication and coordination of mitigation actions across agencies whenever feasible						
New and existing	All hazards	4	CRESA	Low	Staff time	Short-term
CW-13— Continue to work with planning partners and other stakeholders to clearly articulate and define emergency management roles and responsibilities within the County, including the implementation of identified mitigation actions.						
New and existing	All hazards	1, 4, 6	CRESA	Low	Staff time	Ongoing

a. HMGP = Hazard Mitigation Grant Program; FMA = Flood Mitigation Assistance = PDM = Pre-Disaster Mitigation Assistance; CDBG-DR = Community Development Block Grants Disaster Recovery; UASI = Urban Area Security Initiative

Table 18-3. Mitigation Strategy Priority Schedule

Action #	# of Objectives Met	Benefits	Costs	Do Benefits Equal or Exceed Costs?	Is Action Grant-Eligible?	Can Action Be Funded Under Existing Programs/ Budgets?	Implementation Priority[a]	Grant Priority[a]
CW-1	2	Medium	Low	Yes	No	Yes	High	Low
CW-2	3	Medium	High	No	Yes	Maybe	Medium	Medium
CW-3	4	Low	Low	Yes	No	Yes	High	Low
CW-4	2	Low	Low	Yes	No	Yes	High	Low
CW-5	12	Medium	Low	Yes	No	Yes	High	Low
CW-6	5	High	High	Yes	Yes	Maybe	Medium	High
CW-7	2	Medium	Low	Yes	No	Yes	High	Low
CW-8	3	Medium	Low	Yes	No	Yes	High	Low
CW-9	4	Medium	Medium	Yes	No	Maybe	Medium	Low
CW-10	4	Medium	Medium	Yes	No	Yes	High	Low
CW-11	2	Medium	Low	Yes	No	Yes	High	Low
CW-12	1	Low	Low	Yes	No	Yes	Low	Low
CW-13	4	Medium	Low	Yes	No	Yes	High	Low

18.3 PLAN ADOPTION

A hazard mitigation plan must document that it has been formally adopted by the governing body of the jurisdiction requesting federal approval of the plan (44 CFR Section 201.6(c)(5)). For multi-jurisdictional plans, each jurisdiction requesting approval must document that is has been formally adopted. This plan will be submitted for a pre-adoption review prior to adoption to Washington State Emergency Management Division and FEMA's Community Rating System contractor, the Insurance Services Office. Once pre-adoption approval has been provided, all planning partners will formally adopt the plan. All partners understand that DMA compliance and its benefits cannot be achieved until the plan is adopted. Copies of the resolutions adopting this plan for all planning partners can be found in Appendix F of this volume.

18.4 PLAN IMPLEMENTATION AND MAINTENANCE STRATEGY

A hazard mitigation plan must present a plan maintenance process that includes the following (44 CFR Section 201.6(c)(4)):

- A section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan over a 5-year cycle.
- A process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms, such as comprehensive or capital improvement plans, when appropriate.
- A discussion on how the community will continue public participation in the plan maintenance process.

18.4.1 Plan Implementation

The effectiveness of the hazard mitigation plan depends on its implementation and the incorporation of its action items into partner jurisdictions' existing plans, policies and programs. Together, the action items in the plan provide a framework for activities that the partnership can implement over the next 5 years. The Planning Team has established goals and objectives and have prioritized mitigation actions that will be implemented through existing plans, policies, and programs.

The plan will be evaluated by how successfully the implementation of identified actions have moved the planning partnership toward reaching the goals and objectives identified in this plan. This will be assessed at the next update by a review of the changes in risk that occurred over the performance period and by the degree to which mitigation goals and objectives were incorporated into existing plans, policies and programs.

CRESA will have lead responsibility for coordinating and tracking the plan implementation and maintenance strategy. Plan implementation and evaluation will be a shared responsibility among all planning partnership members and agencies identified as lead agencies in the mitigation action plans (see planning partner annexes in Volume 2 of this plan).

Integration with Other Planning Initiatives

The information on hazard, risk, vulnerability and mitigation contained in this plan update is based on the best science and technology currently available. This information can be invaluable in making decisions required through other planning efforts, such as critical areas designation, growth management planning, and capital facilities planning. All partners will use information from this updated plan as the best available science and data on natural hazards impacting Clark County. Each planning partner has identified existing linkages between the hazard mitigation plan and opportunities for linkage that can be pursued over the performance period of this plan (see planning partner annexes in Volume 2). Many of these opportunities for linkage are included as actions in planning partner annexes. As the identified plans and programs are updated and revised, the information contained in this plan will be used to inform their development. Those plans and programs where linkages already exist will incorporate the newly compiled information available in this plan at the next point of update. Examples of these planning processes and programs to be coordinated with the recommendations of the hazard mitigation plan include the following:

- Critical areas regulations
- Comprehensive plans
- Capital improvement plans and programs
- Shoreline management programs
- Stormwater management programs
- Emergency management plans and programs
- Strategic plans
- Facility acquisition plans.

As information becomes available from other planning mechanisms that can enhance this plan, that information will be incorporated via the update process.

Hazard Mitigation Plan Working Group

The hazard mitigation Planning Team was a total volunteer body that oversaw the development of the plan and made recommendations on key elements of the plan, including the implementation and maintenance strategy. It was the Planning Team’s position that an oversight committee with representation similar to that of the Planning Team should have an active role in the plan implementation and maintenance. Therefore, it is recommended that a hazard mitigation working group remain a viable body involved in key elements of the plan implementation and maintenance strategy. This working group should strive to include representation from stakeholders in the planning area as well as planning partners. The hazard mitigation working group will work toward fulfilling the following three responsibilities:

- Coordinating project implementation through the discussion of potential opportunities for partnership and regional coordination and the sharing of success stories and lessons learned;
- Reviewing the annual progress report; and
- Providing input and recommendations on possible enhancements to be considered at the next plan update.

Future plan updates will be overseen by a working group similar to the one that participated in this plan development process, so keeping an interim group in tact will provide a head start on future updates.

Implementation Coordination

It is anticipated that upon completion of this plan, there will be interest among the planning partnership in pursuing grant funding under FEMA hazard mitigation grant programs and other relevant programs. In order to keep planning partners informed of these opportunities, the CRESA staff person charged with coordinating the implementation of this plan will strive to:

- Coordinate with planning partners and stakeholders through scheduling hazard mitigation plan working group meetings on a quarterly basis; and
- Monitor grant funding opportunities identified in this plan and notify planning partners when such funding opportunities become available.

Planning partners will be responsible for developing proposals in pursuit of any available grants. CRESA staff will simply provide notices of funding availability to the planning partnership.

Annual Progress Report

The planning partnership will evaluate the progress on the action plan during a 12-month performance period. This review will include items such as the following:

- Summary of any hazard events that occurred during the performance period and the impact these events had on the planning area;
- Review of mitigation success stories;
- Review of continuing public involvement;
- Brief discussion about why targeted strategies were not completed;
- Reevaluation of the action plan to determine if the timeline for identified projects needs to be amended (such as changing a long-term project to a short-term project because of new funding);
- Recommendations for new projects;
- Changes in or potential for new funding options (grant opportunities);
- Impacts of changes in other planning programs or initiatives that involve hazard mitigation; and
- Identification of training needs within the partnership, such as benefit-cost analysis or E-grants.

The planning team has created a template for preparing a progress report (see Appendix G). The hazard mitigation working group and all planning partners will provide feedback to the CRESA support staff on items included in the template. CRESA staff will compile the information into a formal annual report on the progress of the plan, which will be presented to the hazard mitigation plan working group for their review and comment. This report should be used as follows:

- Posted on the CRESA website dedicated to the hazard mitigation plan;
- Provided to the local media through a press release;

- Presented to the governing bodies of planning partners to inform them of the progress of mitigation initiatives implemented during the reporting period; and
- Provided as part of the CRS annual re-certification package for those planning partners participating in CRS.

It is recommended that the annual progress report be finalized before October 1 of each year.

Plan Update

Clark County and its planning partners intend to update the hazard mitigation plan on a 5-year cycle from the date of final plan approval. This cycle may be accelerated to less than 5 years based on the following triggers:

- A federal disaster declaration that impacts the planning area;
- A hazard event that causes loss of life; or
- A comprehensive update of the Clark County Comprehensive Plan.

It will not be the intent of future updates to develop a complete new hazard mitigation plan for the planning area. The update will, at a minimum, include the following elements:

- The update process will be convened through a planning team.
- The goals and objectives will be reviewed to evaluate the effectiveness of the plan.
- The hazard risk assessment will be reviewed and, if necessary, updated using best available information and technologies.
- The action plan will be reviewed and revised to account for any actions completed, dropped, or changed and to account for changes in the risk assessment or new policies identified under other planning mechanisms.
- The draft update will be sent to appropriate agencies and organizations for comment.
- The public will be given an opportunity to comment on the update prior to adoption.
- The governing body of each planning partner will adopt the updated plan.

18.4.2 Opportunities for Continued Public Access and Participation

The public will continue to be apprised of the plan’s progress through the hazard mitigation plan working group, the hazard mitigation plan website and through the provision of copies of the annual progress reports to the media. The website will not only house the final plan, it will become the one-stop shop for information regarding the plan and plan implementation. The website will continue to provide contact information where members of the public wishing to ask questions or provide comments on the plan may do so. Upon initiation of future update processes, a new public involvement strategy will be initiated based on guidance from a new planning team. This strategy will be based on the needs and capabilities of the planning partnership at the time of the update.

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Clark Regional Natural Hazard Mitigation Plan: Volume 1—Planning Area-Wide Elements

Appendix A. Acronyms and Definitions

A. ACRONYMS AND DEFINITIONS

ACRONYMS

ADA—Americans with Disabilities Act
CDBG-DR—Community Development Block Grant Disaster Resilience
CFR—Code of Federal Regulations
CIP—Capital Improvement Plan or Program
CRESA—Clark Regional Emergency Services Agency
CRS—Community Rating System
CWA—Clean Water Act
DEWS—Drought Emergency Warning System
DFIRM—Digital Flood Insurance Rate Map
DHS—Department of Homeland Security
DMA—Disaster Mitigation Act
DR—Major Disaster Declaration
DSEIS—Draft Supplemental Environmental Impact Statement
DSO—Dam Safety Office
EM—Emergency Declaration
EPA—U.S. Environmental Protection Agency
ESA—Endangered Species Act
ESD—Washington State Employment Security Department
EWP—Emergency Watershed Protection Program
FCAAP—Flood Control Assistance Account Program
FEMA—Federal Emergency Management Agency
FERC—Federal Energy Regulatory Commission
FIRM—Flood Insurance Rate Map
FMA—Flood Mitigation Assistance
GIS—Geographic Information System
Hazus-MH—Hazards, United States-Multi Hazard
HMGP—Hazard Mitigation Grant Program
HMP—Hazard Mitigation Plan
HUD—United States Department of Housing and Urban Development
HVAC—Heating, Ventilation and Air Conditioning System
LiDAR—Light Detection and Ranging
ML—Local Magnitude Scale
MMI— Modified Mercalli Intensity Scale
MRSC—Municipal Research Services Center
NASA—National Aeronautics and Space Administration
NEHRP—National Earthquake Hazards Reduction Program

NFIP—National Flood Insurance Program
NIDIS—National Integrated Drought Information System
NIMS—National Incident Management System
NOAA—National Oceanic and Atmospheric Administration
NRCS—National Resource Conservation Services
NWS—National Weather Service
PDM—Pre-Disaster Mitigation Grant Program
PGA—Peak Ground Acceleration
PP&L—Pacific Power and Light
RCW—Revised Code of Washington
SEPA—State Environmental Policy Act
SNOTEL—Snow Telemetry
SR—State Route
UASI—Urban Area Security Initiative
UGA—Urban Growth Area
USDA—United States Department of Agriculture
USGS—U.S. Geological Survey
WAC—Washington Administrative Code
WSU-Vancouver—Washington State University-Vancouver

DEFINITIONS

100-Year Flood: The term “100-year flood” can be misleading. The 100-year flood does not necessarily occur once every 100 years. Rather, it is the flood that has a 1 percent chance of being equaled or exceeded in any given year. Thus, the 100-year flood could occur more than once in a relatively short period of time. The Federal Emergency Management Agency (FEMA) defines it as the 1 percent annual chance flood, which is now the standard definition used by most federal and state agencies and by the National Flood Insurance Program.

Acre-Foot: An acre-foot is the amount of water it takes to cover 1 acre to a depth of 1 foot. This measure is used to describe the quantity of storage in a water reservoir. An acre-foot is a unit of volume. One acre foot equals 7,758 barrels; 325,829 gallons; or 43,560 cubic feet. An average household of four will use approximately 1 acre-foot of water per year.

Asset: An asset is any man-made or natural feature that has value, including, but not limited to, people; buildings; infrastructure, such as bridges, roads, sewers, and water systems; lifelines, such as electricity and communication resources; and environmental, cultural, or recreational features such as parks, wetlands, and landmarks.

Base Flood: The flood having a 1% chance of being equaled or exceeded in any given year, also known as the “100-year” or “1% chance” flood. The base flood is a statistical concept used to ensure that all properties subject to the National Flood Insurance Program are protected to the same degree against flooding.

Basin: A basin is the area within which all surface water—whether from rainfall, snowmelt, springs, or other sources—flows to a single water body or watercourse. The boundary of a river basin is defined by natural topography, such as hills, mountains, and ridges. Basins are also referred to as “watersheds” and “drainage basins.”

Benefit: A benefit is a net project outcome and is usually defined in monetary terms. Benefits may include direct and indirect effects. For the purposes of benefit-cost analysis of proposed mitigation measures, benefits are limited to specific, measurable, risk reduction factors, including reduction in expected property losses (buildings, contents, and functions) and protection of human life.

Benefit/Cost Analysis: A benefit/cost analysis is a systematic, quantitative method of comparing projected benefits to projected costs of a project or policy. It is used as a measure of cost effectiveness.

Building: A building is defined as a structure that is walled and roofed, principally aboveground, and permanently fixed to a site. The term includes manufactured homes on permanent foundations on which the wheels and axles carry no weight.

Capability Assessment: A capability assessment provides a description and analysis of a community's current capacity to address threats associated with hazards. The assessment includes two components: an inventory of an agency's mission, programs, and policies, and an analysis of its capacity to carry them out. A capability assessment is an integral part of the planning process in which a community's actions to reduce losses are identified, reviewed, and analyzed, and the framework for implementation is identified. The following capabilities were reviewed under this assessment:

- Legal and regulatory capability
- Administrative and technical capability
- Fiscal capability

Community Rating System (CRS): The CRS is a voluntary program under the NFIP that rewards participating communities (provides incentives) for exceeding the minimum requirements of the NFIP and completing activities that reduce flood hazard risk by providing flood insurance premium discounts.

Critical Area: An area defined by state or local regulations as deserving special protection because of unique natural features or its value as habitat for a wide range of species of flora and fauna. A sensitive/critical area is usually subject to more restrictive development regulations.

Critical Facility: Facilities and infrastructure that are critical to the health and welfare of the population. These become especially important after any hazard event occurs. For the purposes of this plan, critical facilities include:

- Structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic and/or water reactive materials;
- Hospitals, nursing homes, and housing likely to contain occupants who may not be sufficiently mobile to avoid death or injury during a hazard event.
- Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for disaster response before, during, and after hazard events, and
- Public and private utilities, facilities and infrastructure that are vital to maintaining or restoring normal services to areas damaged by hazard events.
- Government facilities.

Cubic Feet per Second: Common unit of measurement for river discharge or flow. One cubic foot is about 7.5 gallons of liquid.

Dam: Any artificial barrier or controlling mechanism that can or does impound 10 acre-feet or more of water.

Dam Failure: Dam failure refers to a partial or complete breach in a dam (or levee) that impacts its integrity. Dam failures occur for a number of reasons, such as flash flooding, inadequate spillway size, mechanical failure of valves or other equipment, freezing and thawing cycles, earthquakes, and intentional destruction.

Debris Avalanche: Volcanoes are prone to debris and mountain rock avalanches that can approach speeds of 100 mph.

Debris Flow: Dense mixtures of water-saturated debris that move down-valley; looking and behaving much like flowing concrete. They form when loose masses of unconsolidated material are saturated, become unstable, and move down slope. The source of water varies but includes rainfall, melting snow or ice, and glacial outburst floods.

Debris Slide: Debris slides consist of unconsolidated rock or soil that has moved rapidly down slope. They occur on slopes greater than 65 percent.

Disaster Mitigation Act of 2000 (DMA); The DMA is Public Law 106-390 and is the latest federal legislation enacted to encourage and promote proactive, pre-disaster planning as a condition of receiving financial assistance under the Robert T. Stafford Act. The DMA emphasizes planning for disasters before they occur. Under the DMA, a pre-disaster hazard mitigation program and new requirements for the national post-disaster hazard mitigation grant program were established.

Drainage Basin: A basin is the area within which all surface water- whether from rainfall, snowmelt, springs or other sources- flows to a single water body or watercourse. The boundary of a river basin is defined by natural topography, such as hills, mountains and ridges. Drainage basins are also referred to as **watersheds** or **basins**.

Drought: Drought is a period of time without substantial rainfall or snowfall from one year to the next. Drought can also be defined as the cumulative impacts of several dry years or a deficiency of precipitation over an extended period of time, which in turn results in water shortages for some activity, group, or environmental function. A hydrological drought is caused by deficiencies in surface and subsurface water supplies. A socioeconomic drought impacts the health, well-being, and quality of life or starts to have an adverse impact on a region. Drought is a normal, recurrent feature of climate and occurs almost everywhere.

Earthquake: An earthquake is defined as a sudden slip on a fault, volcanic or magmatic activity, and sudden stress changes in the earth that result in ground shaking and radiated seismic energy. Earthquakes can last from a few seconds to over 5 minutes, and have been known to occur as a series of tremors over a period of several days. The actual movement of the ground in an earthquake is seldom the direct cause of injury or death. Casualties may result from falling objects and debris as shocks shake, damage, or demolish buildings and other structures.

Exposure: Exposure is defined as the number and dollar value of assets considered to be at risk during the occurrence of a specific hazard.

Extent: The extent is the size of an area affected by a hazard.

Extreme Heat Event/Heat Wave: Summertime weather that is substantially hotter and/or more humid than average for a location at that time of year. Typically a heat wave lasts two or more days.

Fire Behavior: Fire behavior refers to the physical characteristics of a fire and is a function of the interaction between the fuel characteristics (such as type of vegetation and structures that could burn), topography, and weather. Variables that affect fire behavior include the rate of spread, intensity, fuel consumption, and fire type (such as underbrush versus crown fire).

Fire Frequency: Fire frequency is the broad measure of the rate of fire occurrence in a particular area. An estimate of the areas most likely to burn is based on past fire history or fire rotation in the area, fuel conditions, weather, ignition sources (such as human or lightning), fire suppression response, and other factors.

Flash Flood: A flash flood occurs with little or no warning when water levels rise at an extremely fast rate

Flood Insurance Rate Map (FIRM): FIRMs are the official maps on which the Federal Emergency Management Agency (FEMA) has delineated the Special Flood Hazard Area.

Flood Insurance Study: A report published by the Federal Insurance and Mitigation Administration for a community in conjunction with the community's Flood Insurance rate Map. The study contains such background data as the base flood discharges and water surface elevations that were used to prepare the

FIRM. In most cases, a community FIRM with detailed mapping will have a corresponding flood insurance study.

Floodplain: Any land area susceptible to being inundated by flood waters from any source. A flood insurance rate map identifies most, but not necessarily all, of a community's floodplain as the Special Flood Hazard Area.

Floodway: Floodways are areas within a floodplain that are reserved for the purpose of conveying flood discharge without increasing the base flood elevation more than 1 foot. Generally speaking, no development is allowed in floodways, as any structures located there would block the flow of floodwaters.

Floodway Fringe: Floodway fringe areas are located in the floodplain but outside of the floodway. Some development is generally allowed in these areas, with a variety of restrictions. On maps that have identified and delineated a floodway, this would be the area beyond the floodway boundary that can be subject to different regulations.

Fog: Fog refers to a cloud (or condensed water droplets) near the ground. Fog forms when air close to the ground can no longer hold all the moisture it contains. Fog occurs either when air is cooled to its dew point or the amount of moisture in the air increases. Heavy fog is particularly hazardous because it can restrict surface visibility. Severe fog incidents can close roads, cause vehicle accidents, cause airport delays, and impair the effectiveness of emergency response. Financial losses associated with transportation delays caused by fog have not been calculated in the United States but are known to be substantial.

Freeboard: Freeboard is the margin of safety added to the base flood elevation.

Frequency: For the purposes of this plan, frequency refers to how often a hazard of specific magnitude, duration, and/or extent is expected to occur on average. Statistically, a hazard with a 100-year frequency is expected to occur about once every 100 years on average and has a 1 percent chance of occurring any given year. Frequency reliability varies depending on the type of hazard considered.

Fujita Scale of Tornado Intensity: Tornado wind speeds are sometimes estimated on the basis of wind speed and damage sustained using the Fujita Scale. The scale rates the intensity or severity of tornado events using numeric values from F0 to F5 based on tornado wind speed and damage. An F0 tornado (wind speed less than 73 miles per hour (mph)) indicates minimal damage (such as broken tree limbs), and an F5 tornado (wind speeds of 261 to 318 mph) indicates severe damage.

Goal: A goal is a general guideline that explains what is to be achieved. Goals are usually broad-based, long-term, policy-type statements and represent global visions. Goals help define the benefits that a plan is trying to achieve. The success of a hazard mitigation plan is measured by the degree to which its goals have been met (that is, by the actual benefits in terms of actual hazard mitigation).

Geographic Information System (GIS): GIS is a computer software application that relates data regarding physical and other features on the earth to a database for mapping and analysis.

Hazard: A hazard is a source of potential danger or adverse condition that could harm people and/or cause property damage.

Hazard Mitigation Grant Program: Authorized under Section 202 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, the Hazard Mitigation Grant Program is administered by FEMA and provides grants to states, tribes, and local governments to implement hazard mitigation actions after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to disasters and to enable mitigation activities to be implemented as a community recovers from a disaster

Hazards U.S. Multi-Hazard (Hazus-MH) Loss Estimation Program: Hazus-MH is a GIS-based program used to support the development of risk assessments as required under the DMA. The Hazus-MH software program assesses risk in a quantitative manner to estimate damage and losses associated with natural hazards. Hazus-MH is FEMA's nationally applicable, standardized methodology and software program and contains modules for estimating potential losses from earthquakes, floods, and wind hazards. Hazus-MH has also been used to assess vulnerability (exposure) for other hazards.

Hydraulics: Hydraulics is the branch of science or engineering that addresses fluids (especially water) in motion in rivers or canals, works and machinery for conducting or raising water, the use of water as a prime mover, and other fluid-related areas.

Hydrology: Hydrology is the analysis of waters of the earth. For example, a flood discharge estimate is developed by conducting a hydrologic study.

Intensity: For the purposes of this plan, intensity refers to the measure of the effects of a hazard.

Inventory: The assets identified in a study region comprise an inventory. Inventories include assets that could be lost when a disaster occurs and community resources are at risk. Assets include people, buildings, transportation, and other valued community resources.

Landslide: Landslides can be described as the sliding movement of masses of loosened rock and soil down a hillside or slope. Fundamentally, slope failures occur when the strength of the soils forming the slope exceeds the pressure, such as weight or saturation, acting upon them.

LiDAR: A remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light.

Lightning: Lightning is an electrical discharge resulting from the buildup of positive and negative charges within a thunderstorm. When the buildup becomes strong enough, lightning appears as a "bolt," usually within or between clouds and the ground. A bolt of lightning instantaneously reaches temperatures approaching 50,000ºF. The rapid heating and cooling of air near lightning causes thunder. Lightning is a major threat during thunderstorms. In the United States, 75 to 100 Americans are struck and killed by lightning each year (see http://www.fema.gov/hazard/thunderstorms/thunder.shtm).

Liquefaction: Liquefaction is the complete failure of soils, occurring when soils lose shear strength and flow horizontally. It is most likely to occur in fine grain sands and silts, which behave like viscous fluids when liquefaction occurs. This situation is extremely hazardous to development on the soils that liquefy, and generally results in extreme property damage and threats to life and safety.

Local Government: Any county, municipality, city, town, township, public authority, school district, special district, intrastate district, council of governments (regardless of whether the council of governments is incorporated as a nonprofit corporation under State law), regional or interstate government entity, or agency or instrumentality of a local government; any Indian tribe or authorized tribal organization, or Alaska Native village or organization; and any rural community, unincorporated town or village, or other public entity.

Magnitude: Magnitude is the measure of the strength of an earthquake, and is typically measured by the Richter scale. As an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

Mass movement: A collective term for landslides, mudflows, debris flows, sinkholes and lahars.

Mitigation: A preventive action that can be taken in advance of an event that will reduce or eliminate the risk to life or property.

Mitigation Actions: Mitigation actions are specific actions to achieve goals and objectives that minimize the effects from a disaster and reduce the loss of life and property.

Objective: For the purposes of this plan, an objective is defined as a short-term aim that, when combined with other objectives, forms a strategy or course of action to meet a goal. Unlike goals, objectives are specific and measurable.

Peak Ground Acceleration: Peak Ground Acceleration (PGA) is a measure of the highest amplitude of ground shaking that accompanies an earthquake, based on a percentage of the force of gravity.

Preparedness: Preparedness refers to actions that strengthen the capability of government, residents, and communities to respond to disasters.

Prevention: Prevention refers to building capabilities necessary to avoid, prevent or stop a threatened or actual act of terrorism.

Presidential Disaster Declaration: These declarations are typically made for events that cause more damage than state and local governments and resources can handle without federal government assistance. Generally, no specific dollar loss threshold has been established for such declarations. A Presidential Disaster Declaration puts into motion long-term federal recovery programs, some of which are matched by state programs, designed to help disaster victims, businesses, and public entities.

Probability of Occurrence: The probability of occurrence is a statistical measure or estimate of the likelihood that a hazard will occur. This probability is generally based on past hazard events in the area and a forecast of events that could occur in the future. A probability factor based on yearly values of occurrence is used to estimate probability of occurrence.

Repetitive Loss Property: Any NFIP-insured property that, since 1978 and regardless of any changes of ownership during that period, has experienced:

- Four or more paid flood losses in excess of $1000.00; or
- Two paid flood losses in excess of $1000.00 within any 10-year period since 1978 or
- Three or more paid losses that equal or exceed the current value of the insured property.

Recovery: A phase of emergency management where activities are intended to restore essential services and repair damages caused by the event.

Response: A phase of emergency management that is comprised of activities that are immediate actions to save lives, protect property and the environment and meet basic human needs.

Return Period (or Mean Return Period): This term refers to the average period of time in years between occurrences of a particular hazard (equal to the inverse of the annual frequency of occurrence).

Riverine: Of or produced by a river. Riverine floodplains have readily identifiable channels. Floodway maps can only be prepared for riverine floodplains.

Risk: Risk is the estimated impact that a hazard would have on people, services, facilities, and structures in a community. Risk measures the likelihood of a hazard occurring and resulting in an adverse condition that causes injury or damage. Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage above a particular threshold due to occurrence of a specific type of hazard. Risk also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.

Risk Assessment: Risk assessment is the process of measuring potential loss of life, personal injury, economic injury, and property damage resulting from hazards. This process assesses the vulnerability of people, buildings, and infrastructure to hazards and focuses on (1) hazard identification; (2) impacts of hazards on physical, social, and economic assets; (3) vulnerability identification; and (4) estimates of the cost of damage or costs that could be avoided through mitigation.

Risk Ranking: This ranking serves two purposes, first to describe the probability that a hazard will occur, and second to describe the impact a hazard will have on people, property, and the economy. Risk estimates for the City are based on the methodology that the City used to prepare the risk assessment for this plan. The following equation shows the risk ranking calculation:

Risk Ranking = Probability + Impact (people + property + economy)

Robert T. Stafford Act: The Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 100-107, was signed into law on November 23, 1988. This law amended the Disaster Relief Act of

1974, Public Law 93-288. The Stafford Act is the statutory authority for most federal disaster response activities, especially as they pertain to FEMA and its programs.

Sinkhole: A collapse depression in the ground with no visible outlet. Its drainage is subterranean. It is commonly vertical-sided or funnel-shaped.

Special Flood Hazard Area: The base floodplain delineated on a Flood Insurance Rate Map. The special flood hazard area is mapped as a Zone A in riverine situations and zone V in coastal situations. The special flood hazard area may or may not encompass all of a community’s flood problems

Stakeholder: Business leaders, civic groups, academia, non-profit organizations, major employers, managers of critical facilities, farmers, developers, special purpose districts, and others whose actions could impact hazard mitigation.

Stream Bank Erosion: Stream bank erosion is common along rivers, streams and drains where banks have been eroded, sloughed or undercut. However, it is important to remember that a stream is a dynamic and constantly changing system. It is natural for a stream to want to meander, so not all eroding banks are “bad” and in need of repair. Generally, stream bank erosion becomes a problem where development has limited the meandering nature of streams, where streams have been channelized, or where stream bank structures (like bridges, culverts, etc.) are located in places where they can actually cause damage to downstream areas. Stabilizing these areas can help protect watercourses from continued sedimentation, damage to adjacent land uses, control unwanted meander, and improvement of habitat for fish and wildlife.

Steep Slope: Different communities and agencies define it differently, depending on what it is being applied to, but generally a steep slope is a slope in which the percent slope equals or exceeds 25%. For this study, steep slope is defined as slopes greater than 33%.

Sustainable Hazard Mitigation: This concept includes the sound management of natural resources, local economic and social resiliency, and the recognition that hazards and mitigation must be understood in the largest possible social and economic context.

Thunderstorm: A thunderstorm is a storm with lightning and thunder produced by cumulonimbus clouds. Thunderstorms usually produce gusty winds, heavy rains, and sometimes hail. Thunderstorms are usually short in duration (seldom more than 2 hours). Heavy rains associated with thunderstorms can lead to flash flooding during the wet or dry seasons.

Tornado: A tornado is a violently rotating column of air extending between and in contact with a cloud and the surface of the earth. Tornadoes are often (but not always) visible as funnel clouds. On a local scale, tornadoes are the most intense of all atmospheric circulations, and winds can reach destructive speeds of more than 300 mph. A tornado’s vortex is typically a few hundred meters in diameter, and damage paths can be up to 1 mile wide and 50 miles long.

Vulnerability: Vulnerability describes how exposed or susceptible an asset is to damage. Vulnerability depends on an asset’s construction, contents, and the economic value of its functions. Like indirect damage, the vulnerability of one element of the community is often related to the vulnerability of another. For example, many businesses depend on uninterrupted electrical power. Flooding of an electric substation would affect not only the substation itself but businesses as well. Often, indirect effects can be much more widespread and damaging than direct effects.

Watershed: A watershed is an area that drains downgradient from areas of higher land to areas of lower land to the lowest point, a common drainage basin.

Wildfire: These terms refer to any uncontrolled fire occurring on undeveloped land that requires fire suppression. The potential for wildfire is influenced by three factors: the presence of fuel, topography, and air mass. Fuel can include living and dead vegetation on the ground, along the surface as brush and small trees, and in the air such as tree canopies. Topography includes both slope and elevation. Air mass includes temperature, relative humidity, wind speed and direction, cloud cover, precipitation amount, duration, and the stability of the atmosphere at the time of the fire. Wildfires can be ignited by lightning and, most frequently, by human activity including smoking, campfires, equipment use, and arson.

Windstorm: Windstorms are generally short-duration events involving straight-line winds or gusts exceeding 50 mph. These gusts can produce winds of sufficient strength to cause property damage. Windstorms are especially dangerous in areas with significant tree stands, exposed property, poorly constructed buildings, mobile homes (manufactured housing units), major infrastructure, and aboveground utility lines. A windstorm can topple trees and power lines; cause damage to residential, commercial, critical facilities; and leave tons of debris in its wake.

Zoning Ordinance: The zoning ordinance designates allowable land use and intensities for a local jurisdiction. Zoning ordinances consist of two components: a zoning text and a zoning map

Appendix B. Concepts and Methods Used for Hazard Mapping

B. Concepts and Methods Used for Hazard Mapping

EARTHQUAKE

Shake Maps

A shake map is designed as a rapid response tool to portray the extent and variation of ground shaking throughout the affected region immediately following significant earthquakes. Ground motion and intensity maps are derived from peak ground motion amplitudes recorded on seismic sensors (accelerometers), with interpolation based on both estimated amplitudes where data are lacking, and site amplification corrections. Color-coded instrumental intensity maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity.

Cascadia Subductions Zone Scenario

- Magnitude: 9.0
- Epicenter: N45.7329 W125.125
- Depth: 0km

Portland Hills Scenario

- Magnitude: 6.5
- Epicenter: N45.5544 W122.798
- Depth: 0km

Probabilistic Peak Ground Acceleration

Probabilistic Peak Ground Acceleration data generated by Hazus-MH 2.2. In Hazus' probabilistic analysis procedure, the ground shaking demand is characterized by spectral contour maps developed by the United States Geological Survey (USGS) as part of a 2008 update of the National Seismic Hazard Maps. USGS probabilistic seismic hazard maps are revised about every six years to reflect newly published or thoroughly reviewed earthquake science and to keep pace with regular updates of the building code. Hazus includes maps for eight probabilistic hazard levels: ranging from ground shaking with a 39% probability of being exceeded in 50 years (100 year return period) to the ground shaking with a 2% probability of being exceeded in 50 years (2500 year return period).

Soil Classification

Soil classification data provided by Washington State Department of Natural Resources, Geology and Earth Resources Division. The dataset identifies site classes for approximately 33,000 polygons derived from the geologic map of Washington. The methodology chosen for developing the site class map required the construction of a database of shear wave velocity measurements. This database was created by compiling shear wave velocity data from published and unpublished sources, and through the collection of a large number of shear wave velocity measurements from seismic refraction surveys conducted for this project. All of these sources of data were then analyzed using the chosen methodologies to produce the statewide site class maps. The polygons were classified with site classes based on criteria described in Palmer, S. P.; Magsino, S. L.; Bilderback, E. L.; Poelstra, J. L.; Folger, D. S.; and Niggemann, R. A., 2004, Liquefaction susceptibility and site class maps of Washington State, by county: Washington Division of Geology and Earth Resources Open-file Report 2004-20, 78 sheets, with 45 p. text.

Liquefaction Susceptibility

Liquefaction data provided by the Washington State Department of Natural Resources, Division of Geology and Earth Resources. Data is based solely on surficial geology published at a scale of 1:100,000. A liquefaction susceptibility map provides an estimate of the likelihood that soil will liquefy as a result of earthquake shaking. This type of map depicts the relative susceptibility in a range that varies from very low to high. Areas underlain by bedrock or peat are mapped separately as these earth materials are not liquefiable, although peat deposits may be subject to permanent ground deformation caused by earthquake shaking.

Liquefaction is a phenomenon in which strong earthquake shaking causes a soil to rapidly lose its strength and behave like quicksand. Liquefaction typically occurs in artificial fills and in areas of loose sandy soils that are saturated with water, such as low-lying coastal areas, lakeshores, and river valleys. When soil strength is lost during liquefaction, the consequences can be catastrophic. Movement of liquefied soils can rupture pipelines, move bridge abutments and road and railway alignments, and pull apart the foundations and walls of buildings.

FLOOD

Flood hazard areas as depicted on FEMA Digital Flood Insurance Rate Maps (DFIRM)

LANDSLIDE

The landslide areas presented in this map are a combination of Clark County and Washington State Department of Natural Resources datasets. Clark County Landslide Areas data acquired from Clark County GIS Services. This dataset contains unstable slopes and landslide polygon coverage of historical, potential or active landslide areas.

Washington Department of Natural Resources Landslide Areas data provided by the Washington State Department of Natural Resources, Division of Geology and Earth Resources. This dataset contains 1:24,000 & 1:100,000-scale polygons defining the extent of mapped landslides in the state of Washington. This dataset is compiled chiefly from pre-existing landslide databases created in different divisions of the Washington State Department of Natural Resources to meet a variety of purposes.

VOLCANO

Distal Volcano Hazard Zones are Columbia River islands and areas along the Washington shore that could be affected by bank erosion and flooding induced by lahars and sediment-rich floods from Sandy and Hood Rivers during and immediately following eruptions. Volcano data provided by the Cascade Volcano Observatory.

WILDFIRE

The wildfire areas presented in this map are a combination of Clark County, City of Vancouver and Washington State Department of Natural Resources datasets. Clark County Wildfire data acquired from Clark County GIS Services. This dataset contains classifications of the Wildland Urban Interface. Intermix areas are generally defined as where elevations exceed five hundred feet, where slopes exceed twenty-five percent, forest type vegetation exists, or is outside of an organized fire protection district.

Clark Regional Natural Hazard Mitigation Plan: Volume 1—Planning Area-Wide Elements

Appendix C. Plan Adoption Resolutions from Planning Partners

C. Plan Adoption Resolutions from Planning Partners

To be completed as adoption resolutions are received.

Appendix D. Progress Report Template

D. PROGRESS REPORT TEMPLATE

Clark County
Hazard Mitigation Plan Update
Annual Progress Report

Reporting Period: *(Insert reporting period)*
Background: Clark County and participating cities and special purpose districts in the county developed a hazard mitigation plan to reduce risk from natural hazards by identifying resources, information, and strategies for risk reduction. The federal Disaster Mitigation Act of 2000 requires state and local governments to develop hazard mitigation plans as a condition for federal disaster grant assistance. To prepare the plan, the participating partners organized resources, assessed risks from natural hazards within the county, developed planning goals and objectives, reviewed mitigation alternatives, and developed an action plan to address probable impacts from natural hazards. By completing this process, these jurisdictions maintained compliance with the Disaster Mitigation Act, achieving eligibility for mitigation grant funding opportunities afforded under the Robert T. Stafford Act. The plan can be viewed on-line at:

INSERT LINK

Summary Overview of the Plan's Progress: The performance period for the Hazard Mitigation Plan became effective on ____, 2023, with the final approval of the plan by FEMA. The initial performance period for this plan will be 5 years, with an anticipated update to the plan to occur before ______, 2022. As of this reporting period, the performance period for this plan is considered to be __% complete. The Hazard Mitigation Plan has targeted __ hazard mitigation actions to be pursued during the 5-year performance period. As of the reporting period, the following overall progress can be reported:

- __ out of __ actions (__%) reported ongoing action toward completion.
- __ out of __ actions (__%) were reported as being complete.
- __ out of __ actions (___%) reported no action taken.

Purpose: The purpose of this report is to provide an annual update on the implementation of the action plan identified in the *Clark Regional Natural Hazard Mitigation Plan*. The objective is to ensure that there is a continuing and responsive planning process that will keep the Hazard Mitigation Plan dynamic and responsive to the needs and capabilities of the partner jurisdictions. This report discusses the following:

- Natural hazard events that have occurred within the last year
- Changes in risk exposure within the planning area (all of Clark County and the incorporated area of the City of Woodland)
- Mitigation success stories
- Review of continuing public involvement

- Review of the action plan
- Changes in capabilities that could impact plan implementation
- Recommendations for changes/enhancement
- Relevant training needs identified within the planning partnership.

The Hazard Mitigation Work Group: The Hazard Mitigation Plan Work Group, made up of planning partners and stakeholders within the planning area, reviewed and approved this progress report at its meeting held on _____, 202_. It was determined through the plan's development process that a working group would remain in service to oversee maintenance of the plan. At a minimum, the work group will provide technical review and oversight on the development of the annual progress report. It is anticipated that there will be turnover in the membership annually, which will be documented in the progress reports. For this reporting period, the work group membership is as indicated in Table 1.

Table 1. Hazard Mitigation Work Group

Name	Title	Jurisdiction/Agency

Natural Hazard Events within the Planning Area: During the reporting period, there were __ natural hazard events in the planning area that had a measurable impact on people or property. A summary of these events is as follows:

- ____________________________
- ____________________________

Changes in Risk Exposure in the Planning Area: *(Insert brief overview of any natural hazard event in the planning area that changed the probability of occurrence or ranking of risk for the hazards addressed in the hazard mitigation plan)*

Mitigation Success Stories: *(Insert brief overview of mitigation accomplishments during the reporting period)*

Continued Public Involvement: *(Insert brief overview of any continued public involvement related to hazard mitigation during the reporting period)*

Review of the Action Plan: Table 2 reviews the action plan, reporting the status of each action. Reviewers of this report should refer to the Hazard Mitigation Plan for more detailed descriptions of each action and the prioritization process.

Address the following in the "status" column of the following table:

- *Was any element of the action carried out during the reporting period?*
- *If no action was taken, why?*
- *Is the timeline for implementation for the action still appropriate?*

- *If the action was completed, does it need to be changed or removed from the action plan?*
- *Do any newly identified actions need to be added as a result in a change of capabilities or the next step in a completed action?*

Table 2. Action Plan Matrix

Action Taken? (Yes or No)	Time Line	Priority	Status	Status (X, O,✓)
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				
Action #__—____________________[description]				

Completion status legend:
✓= Project Completed
O = Action ongoing toward completion
X = No progress at this time

Changes That May Impact Implementation of the Plan: *(Insert brief overview of any significant changes in the planning area that would have a profound impact on the implementation of the plan. Specify any changes in technical, regulatory and financial capabilities identified during the plan's development)*

Need for Training: *(Insert brief overview of any training needs identified within the planning partnership)*

Recommendations for Changes or Enhancements: Based on the review of this report by the Hazard Mitigation Work Group, the following recommendations will be noted for future updates or revisions to the plan:

- ______________________________
- ______________________________
- ______________________________
- ______________________________

Public review notice: *The contents of this report are considered to be public knowledge and have been prepared for total public disclosure. Copies of the report have been provided to the governing boards of all planning partners and to local media outlets and the report is posted on the Clark Regional Natural Hazard Mitigation Plan website. Any questions or comments regarding the contents of this report should be directed to:*
Insert Contact Info Here

Clark Regional Natural Hazard Mitigation Plan: Volume 1—Planning Area-Wide Elements

Appendix E. FEMA Review Crosswalk

E. FEMA Plan Review Crosswalk

To be completed.