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MASON COUNTY 2023 HAZARD MITIGATION PLAN

RISK ASSESSMENT FINDINGS

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MASON COUNTY MULTI-JURISDICTION

2023 HAZARD MITIGATION PLAN UPDATE

VOLUME 1: RISK ASSESSMENT FINDINGS

DRAFT

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CHAPTER 4.
RISK ASSESSMENT METHODOLOGY

4.1 OVERVIEW

The DMA requires measuring potential losses to critical facilities and property resulting from natural hazards. A hazard is an act or phenomenon that has the potential to produce harm or other undesirable consequences to a person or thing. Natural hazards can exist with or without the presence of people and land development. However, hazards can be exacerbated by societal behavior and practice, such as building in a floodplain, along a sea cliff, or on an earthquake fault. Natural disasters are inevitable, but the impacts of natural hazards can, at a minimum, be mitigated or, in some instances, prevented entirely.

The goal of the risk assessment is to determine which hazards present the greatest risk and what areas are the most vulnerable to hazards. Mason County and its planning partners are exposed to many hazards. The risk assessment and vulnerability analysis help identify where mitigation measures could reduce loss of life or damage to property in the planning region. Each hazard-specific risk assessment provides risk-based information to assist Mason County and its planning partners in determining priorities for implementing mitigation measures.

The risk assessment approach used for this plan entailed using geographic information system (GIS), Hazus hazard-modeling software, and hazard-impact data to develop vulnerability models for people, structures and critical facilities, and evaluating those vulnerabilities in relation to hazard profiles that model where hazards exist. This approach is dependent on the detail and accuracy of the data used. In all instances, this assessment used Best Available Science and data to ensure the highest level of accuracy possible.

The risk assessment is broken down into three phases, as follows:

> The first phase, hazard identification, involves the identification of the geographic extent of a hazard, its intensity, and its probability of occurrence (discussed below). This level of assessment typically involves producing a map. The outputs from this phase can be used for land use planning, management, and development of regulatory authority; public awareness and education; identifying areas which require further study; and identifying properties or structures appropriate for mitigation efforts, such as acquisition or relocation.
>
> The second phase, the vulnerability assessment, combines the information from the hazard identification with an inventory of the existing (or planned) property and population exposed to the hazard. It then attempts to predict how different types of property and population groups will be impacted or affected by the hazard of concern. This step assists in justifying changes to building codes or regulatory authority, property acquisition programs, such as those available through various granting opportunities; developing or modifying policies concerning critical or essential facilities, and public awareness and education.

The third phase, the risk analysis, involves estimating the damage, injuries, and costs likely to be incurred in the geographic area of concern over a period of time. Risk has two measurable components:

1. The magnitude of the harm that may result, defined through the vulnerability assessment; and
2. The likelihood or probability of harm occurring.

Utilizing those three phases of assessment, information was developed which identifies the hazards that affect the planning area, the likely location of natural hazard impact, the severity of the impact, previous occurrences, and the probability of future hazard events. That data, once complete, is utilized to complete the Risk Ranking process described in Chapter 12, which applies all of the data captured in the Calculated Priority Risk Index (CPRI).

The following is provided as the foundation for the standardized risk terminology:

- Hazard: Natural (or human caused) source or cause of harm or damage, demonstrated as actual (deterministic/historical events) or potential (probabilistic) events.
- Risk: The potential for an unwanted outcome resulting from a hazard event, as determined by its likelihood and associated consequences. For this plan, where possible, risk includes potential future losses based on probability, severity, and vulnerability, expressed in dollar losses when possible. In some instances, dollar losses are based on actual demonstrated impact, such as through the use of the Hazus model. In other cases, losses are demonstrated through exposure analysis due to the inability to determine the extent to which a structure is impacted.
- Location: The area of potential or demonstrated impact within the area in which the analysis is being conducted. In some instances, the area of impact is within a geographically defined area, such as a floodplain. In other instances, such as for severe weather, there is no established geographic boundary associated with the hazard, as it can impact the entire area.
- Severity/Magnitude: The extent or magnitude upon which a hazard is ranked, demonstrated in various means, e.g., Richter Scale.
- Vulnerability: The degree of damage, e.g., building damage or the number of people injured.
- Probability of Occurrence and Return Intervals: These terms are used as a synonym for likelihood, or the estimation of the potential of an incident to occur.

4.2 METHODOLOGY

The risk assessment for this hazard mitigation plan evaluates the risk of natural hazards prevalent in Mason County and meets requirements of the DMA (44 CFR Section 201.6(c)(2)). The methodology used to complete the risk assessment is described below.

4.2.1 Hazard Identification and Profiles

For this plan, the planning partners and stakeholders considered the full range of natural hazards that could impact the planning area and then listed hazards 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 natural hazards and the perceived vulnerability of the planning area's assets to them was also used.

The Planning Team again reviewed the Tsunami hazard for consideration in this update, but elected to not do so. This decision was reached, in part, on the fact that there are currently no scenarios available on which to run analysis to determine vulnerability. However, with the inclusion of Tsunami in the newly-released Hazus model, it was suggested that this hazard be again reviewed during the next update cycle. It is hoped that developers will create a scenario on which potential impact can be determined. In the interim, review of FEMA's Risk Map data indicates that based on a M9.0 Cascadia Earthquake Scenario, FEMA and Washington State DNR estimate that a tsunami would arrive at Mason County approximately three (3) hours after the triggering incident, creating a 5-6-foot wave height, impacting Lynch Cove.

The Volcano hazard was also discussed, but the County had little historic impact from previous occurrences, and therefore the hazard was also tabled during this update, but will again be reviewed for inclusion in future updates.

The planning team further reviewed the hazards considered during the 2004, 2010, and 2018 plan update. Based on the review, the planning team confirmed the following natural hazards that this plan addresses as the hazards of concern, which are the same hazards addressed during the last update:

- Climate Change (Qualitative assessment now incorporated into impacted hazards rather than a stand-alone hazard)
- Drought
- Earthquake
- Flood
- Landslide
- Severe Weather
- Wildfire

The hazard profiles describe the risks associated with identified hazards of concern. Each chapter describes the hazard, the planning area's vulnerabilities, and, when possible, probable event scenarios. The following steps were used to define the risk of each hazard:

Identify and profile the following information for each hazard:

- General overview and description of hazard;
- Identification of previous occurrences;
- Geographic areas most affected by the hazard;
- Event frequency estimates;

- Severity estimates;
- Warning time likely to be available for response;
- Risk and vulnerability assessment, which includes identification of impact on people, property, economy, and the environment.

4.2.2 Risk Assessment Process and Tools

The hazard profiles and risk assessments contained in the hazard chapters describe the risks associated with each identified hazard of concern. Each chapter describes the hazard, the planning area's vulnerabilities, and probable event scenarios.

Once the profiles identified above were completed, the following steps were used to define the risk of each hazard:

- Determine exposure to each hazard—Exposure was determined by overlaying hazard maps with an inventory of structures, facilities, and systems to determine which of them would be exposed to each hazard.
- 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. Tools such as GIS and Hazus were used in this assessment.
- Where specific quantitative assessments could not be completed, vulnerability was measured in general, qualitative term, summarizing the potential impact based on past occurrences, spatial extent, and subjective damage and casualty potential. Those items were categorized utilizing the criteria established in the CPRI index.
- The final step in the process was to determine the cumulative results of vulnerability based on the risk assessment and Calculated Priority Risk Index (discussed below) scoring, assigning a final qualitative assessment based on the following classifications:
  - Extremely Low—The occurrence and potential cost of damage to life and property is very minimal to nonexistent.
  - Low—Minimal potential impact. The occurrence and potential cost of damage to life and property is minimal.
  - Medium—Moderate potential impact. This ranking carries a moderate threat level to the general population and/or built environment. Here the potential damage is more isolated and less costly than a more widespread disaster.
  - High—Widespread potential impact. This ranking carries a high threat to the general population and/or built environment. The potential for damage is widespread. Hazards in this category may have occurred in the past.
  - Extremely High—Very widespread with catastrophic impact.

4.2.3 Hazus and GIS Applications

Earthquake and Flood Modeling Overview

Hazus 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 facility, transportation and utility lifeline, and multiple models to estimate potential losses from natural disasters. The program maps and displays hazard data and the results of damage and economic loss estimates for buildings and infrastructure. Its advantages include the following:

- 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.

Building Inventory

The critical facilities list was again reviewed and updated for this 2023 edition of the HMP. Each planning partner was provided the opportunity to review the previous data, and update the information. For some partners, this included a significant increase in the number of structures analyzed, while for others, the number of structures did not change, or changed only minimally. In most instances, these were not newly constructed facilities, but rather facilities purchased from other entities or service providers, such as water purveyors, or existing buildings remodeled, such as the County's courthouse.

Hazus Application for this Plan

During the development of the 2018 plan, FEMA's RiskMap Program was developing new NFIP Flood Maps and other risk data for the County. That data remains the most current, and was utilized as appropriate for this update.

The following methods were used to assess specific hazards for this plan:

- **Flood**— Analysis was based on current FEMA regulatory 100- and 500-year flood hazard data based on the 2017 Flood Study. The updated critical facilities data was utilized at the exposure level for identify structures at risk.

- **Earthquake**— Earthquake shake maps and probabilistic data prepared by the U.S. Geological Survey (USGS) were used for the analysis of this hazard. A modified version of the National Earthquake Hazard Reduction Program (NEHRP) soils inventory was used.

GIS Application for this Plan

Drought, Dam, Landslide, Severe Weather, and Wildfire - For drought, dam, landslide, severe weather, and wildfire, historical data is not adequate to model future losses as no specific damage functions have been developed. However, GIS is able to map hazard areas and calculate exposure if geographic information is available with respect to the location of the hazard and inventory data. Areas and inventory susceptible to some of the hazards of concern were mapped and exposure was evaluated. For other hazards, a qualitative analysis was conducted using the best available data and professional judgment. Locally relevant information was gathered from a variety of sources. Frequency and severity indicators include past events and the expert opinions of geologists, tribal staff, emergency management personnel and others. The primary data source was Mason County GIS data, augmented with state and federal data sets, including FEMA's RiskMap data. Additional data sources for specific hazards were as follows:

- **Drought**—The risk assessment methodologies used for this plan focus on damage to structures. Because drought does not impact structures, the risk assessment for drought was limited to a qualitative assessment.
- **Dam Failure**—Inundation data was unavailable for the high- or medium-hazard dams in the County (2018, 2023). Therefore, available dam data was used only to identify the location and hazard classification of dams located within the planning area.
- **Landslide**—Historic landslide hazard data was used to assess exposure to landslides using Washington DNR Landslide Susceptibility data. Landslide exposure is illustrated based on the number of structures which intersect a slope greater than or equal to 40 percent (or =/>21.8 degree).
- **Severe Weather**—Severe weather data was downloaded from the Natural Resources Conservation Service and the National Climatic Data Center, as well as other sources as cited.
- **Wildfire**—Information on wildfire analysis was captured from various sources, including Washington DNR Wildfire History data, Wildfire Protection data, US Forest Service data, LAND FIRE data, and Wildland Urban Interface Zone data, among other sources.

4.2.4 Calculated Priority Risk Index Scoring Criteria

Vulnerabilities are described in terms of critical facilities, structures, population, economic values, and functionality of government which can be affected by the hazard event. Hazard impact areas describe the geographic extent a hazard can impact a jurisdiction and are uniquely defined on a hazard-by-hazard basis. Mapping of the hazards, where spatial differences exist, allows for hazard analysis by geographic location. Some hazards can have varying levels of risk based on location. Other hazards cover larger geographic areas and affect the area uniformly. Therefore, a system must be established which addresses all elements (people, property, economy, continuity of government) in order to rate each hazard consistently. The use of the Calculated Priority Risk Index allows such application, based on established criteria of application to determine the risk factor. For identification purposes, the six criteria on which the CPRI is based are probability, magnitude, geographic extent and location, warning time/speed of onset, and duration of the event. Those elements are further defined as follows:

Probability

Probability of a hazard event occurring in the future was assessed based on hazard frequency over a 100- year period (where available). Hazard frequency was based on the number of times the hazard event occurred divided by the period of record. If the hazard lacked a definitive historical record, the probability was assessed qualitatively based on regional history and other contributing factors. Probability of occurrence was assigned a 40% weighting factor, and was broken down as follows:

Rating	Likelihood	Frequency of Occurrence
1	Unlikely	Less than 1% probability in the next 100 years.
2	Possible	Between 1% and 10% probability in the next year, or at least one chance in the next 100 years.
3	Likely	Between 10% and 100% probability in next year, or at least one chance in the next 10 years.
4	Highly Likely	Greater than 1 event per year (frequency greater than 1).

Magnitude

The magnitude of potential hazard events was evaluated for each hazard. Magnitude is a measure of the strength of a hazard event, usually determined using specific technical measures. Magnitude was calculated for each hazard where property damage data was available, and was assigned a 25% weighting factor. (Magnitude calculation was determined using the following mathematical equation: *(Property Damage / Number of Incidents) / $ of Building Stock Exposure = Magnitude.)* Magnitude was broken down as follows:

Rating	Magnitude	Percentage of People and Property Affected
1	Negligible	Less than 5% Very minor impact to people, property, economy, and continuity of government at 90%.
2	Limited	6% to 24% Injuries or illnesses minor in nature, with only slight property damage and minimal loss associated with economic impact; continuity of government only slightly impacted, with 80% functionality.
3	Critical	25% to 49% Injuries result in some permanent disability; 25-49% of population impacted; moderate property damage ; moderate impact to economy, with loss of revenue and facility impact; government at 50% operational capacity with service disruption more than one week, but less than a month.
4	Catastrophic	More than 50% Injuries and illness resulting in permanent disability and death to more than 50% of the population; severe property damage greater than 50%; economy significantly impacted as a result of loss of buildings, content, inventory;

Rating	Magnitude	Percentage of People and Property Affected
		government significantly impacted; limited services provided, with disruption anticipated to last beyond one month.

Extent and Location

The measure of the percentage of the people and property within the planning area impacted by the event, and the extent (degree) to which they are impacted. Extent and location was assigned a weighting factor of 20%, and broken down as follows:

Rating	Magnitude	Percentage of People and Property Affected
1	Negligible	Less than 10% Few if any injuries or illness. Minor quality of life lost with little or no property damage. Brief interruption of essential facilities and services for less than four hours.
2	Limited	10% to 24% Minor injuries and illness. Minor, short term property damage that does not threaten structural stability. Shutdown of essential facilities and services for 4 to 24 hours.
3	Critical	25% to 49% Serious injury and illness. Major or long-term property damage, that threatens structural stability. Shutdown of essential facilities and services for 24 to 72 hours.
4	Catastrophic	More than 50% Multiple deaths Property destroyed or damaged beyond repair Complete shutdown of essential facilities and services for 3 days or more.

Warning Time/Speed of Onset

The rate at which a hazard occurs, or the time provided in advance of a situation occurring (e.g., notice of a cold front approaching or a potential hurricane, etc.) provides the time necessary to prepare for such an event. Sudden-impact hazards with no advanced warning are of greater concern. Warning Time/Speed of onset was assigned a 10% weighting factor, and broken down as follows:

Rating	Probable amount of warning time
1	More than 24 hours warning time.
2	12-24 hours warning time.
3	5-12 hours warning time.
4	Minimal or no warning time.

Duration

The time span associated with an event was also considered, the concept being the longer an event occurs, the greater the threat or potential for injuries and damages. Duration was assigned a weighting factor of 5%, and was broken down as follows:

Rating	Duration of Event
1	6-24 hours
2	More than 24 hours
3	Less than 1 week
4	More than 1 week

Chapter 12 summarizes all of the analysis conducted by way of completion of the Calculated Priority Risk Index (CPRI) for hazard ranking.

4.3 PROBABILITY OF OCCURRENCE AND RETURN INTERVALS

Natural hazard events with relatively long return periods, such as a 100-year flood or a 500- or 1,000-year earthquake, are often thought to be very unlikely. In reality, the probability that such events occur over the next 30 or 50 years is relatively high, having significant probabilities of occurring during the lifetime of a building:

- Hazard events with return periods of 100 years have probabilities of occurring in the next 30 or 50 years of about 26 percent and about 40 percent, respectively.
- Hazard events with return periods of 500 years have about a 6 percent and about a 10 percent chance of occurring over the next 30 or 50 years, respectively.
- Hazard events with return periods of 1,000 years have about a 3 percent chance and about a 5 percent chance of occurring over the next 30 or 50 years, respectively.

For life safety considerations, even natural hazard events with return periods of more than 1,000 years are often deemed significant if the consequences of the event happening are very severe (extremely high damage and/or substantial loss of life). For example, the seismic design requirements for new construction are based on the level of ground shaking with a return period of 2,475 years (2 percent probability in 50 years). Providing life safety for this level of ground shaking is deemed necessary for seismic design of new buildings to minimize life safety risk. Of course, a hazard event with a relatively long return period may occur tomorrow, next year, or within a few years. Return periods of 100 years, 500 years, or 1,000 years mean that such events have a 1 percent, a 0.2 percent or a 0.1 percent chance of occurring in any given year.

4.4 COMMUNITY VARIATIONS TO THE RISK ASSESSMENT

Each planning partner within their respective annex describes where or how their risk varies from what is described in the hazard profiles and risk ranking. Variations are documented in the risk assessment section in their annex to the plan, if appropriate. In some instances, declared disaster events may not have impacted a specific jurisdiction or entity. Similarly, there may have been incidents of significance which did not rise to a level of a disaster declaration, but were nonetheless significant to the jurisdiction or entity. As such, those differences are noted where applicable.

4.5 LIMITATIONS

The models and information presented in this document does not replace or supersede any official document or product generated to meet the requirements of any state, federal, or local program, which may be much more detailed and encompassing beyond the scope of this project. The datasets presented in this document are the product of modeling and reprojection of existing data. As such, it carries an inherent degree of error and uncertainty. Users are strongly encouraged to read and fully comprehend the full reports of the data presented prior to data use. No warranty is made as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data, or for purposes not intended by the Originator. No life safety measures should be based on this document.

This document is intended for planning purposes only and does not include any scientific analysis completed as a result of the document, as such far exceeds the intent of this document. This document and its contents have been prepared and are intended solely for Mason County and its planning partners' information and use with respect to hazard mitigation planning, incorporating other relevant data into other planning mechanisms as appropriate. While this process utilized best available science and scientific data, the planning team, consultant, nor any of the planning partners conducted any scientific analysis within this document, and none should be construed. In some instances, national data sets are the only source available, and are for the purpose of comparing relative risk. Data included is not intended to replace studies completed by engineers, geologists, hydrologists, or other subject matter experts. It is the responsibility of the user to be familiar with the value, assumptions, and limitations of this document. Reviewers must evaluate these data according to the scale and requirements specific to their needs. Our process only reproduced existing data in different ways to meet the guidelines and requirements of 33 CFR 201.6. All data layers utilized are identified within the various sections of this document should reviewers wish greater clarification and information.

Loss estimates, exposure assessments, and hazard-specific vulnerability evaluations rely on the best available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from the following:

- 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.

These factors can affect loss estimates by a factor of two or more. Therefore, potential exposure and loss estimates are approximate. The results do not predict precise results and should be used only to understand relative risk. Over the long term, Mason County and its planning partners will collect additional data to assist in estimating potential losses associated with other hazards.

Some assumptions were made by the planning partnership in an effort to capture as much data as necessary to supplant any significant data gaps. One example of this is the valuation for structures within the assessed data, most commonly as it relates to the general building stock. For structures for which data was not provided, the missing information was determined using averages of similar types of structures, determining square footage and applying a multiplier. This process is identified in the Hazus User's Guide.

Some hazards, such as earthquake, are pre-loaded with scientifically determined scenarios which are used during the modeling process. This does not allow for manipulation of the data as with other hazards, such as flood. In the case of earthquake, greater reliance existed on the use of the Hazus default data, which is known to be less accurate, most often causing higher loss values. Therefore, while loss estimates are provided, they should be viewed with this flaw in mind. A much more in-depth scientific analysis is necessary to rely on this type of data with a high degree of accuracy. Readers should view this document as a baseline or starting point, and information should be further studied and analyzed by scientists and other subject matter experts in specific hazard fields.

CHAPTER 5.
DROUGHT

5.1 GENERAL BACKGROUND

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 a couple of 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.

> **DEFINITIONS**
> **Drought**—The cumulative impacts of several dry years on water users and agricultural producers. It can include deficiencies in surface and subsurface water supplies and cause impacts to health, well-being, and quality of life.
> **Hydrological Drought**—Deficiencies in surface and subsurface water supplies.
> **Socioeconomic Drought**—Drought impacts on health, well-being, and quality of life.

Drought is a prolonged period of dryness severe enough to reduce soil moisture, water, and snow levels below the minimum necessary for sustaining plant, animal, and economic systems. Droughts are a natural part of the climate cycle. For this plan, the County has elected to use Washington’s statutory definition of drought (RCW Chapter 43.83B.400), which is based on both of the following conditions occurring:

- The water supply for the area is below 75 percent of normal.
- Water uses and users in the area will likely incur undue hardships because of the water shortage.

5.2 HAZARD PROFILE

5.2.1 Extent and Location

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 National Drought Mitigation Center uses three categories to describe likely drought impacts:

- Agricultural—Drought threatens crops that rely on natural precipitation, while also increasing the potential for infestation.
- Water supply—Drought threatens supplies of water for irrigated crops, for communities and for fish and salmon and other species of wildlife.
- Fire hazard—Drought increases the threat of wildfires from dry conditions in forest and rangelands.

In Washington, where hydroelectric power plants generate nearly three-quarters of the electricity produced, drought also threatens the supply of electricity. Unlike most disasters, droughts normally occur slowly but last a long time. Drought conditions occur every few years in Washington.

On average, the nationwide annual impacts of drought are greater than the impacts of any other natural hazard. They occur primarily in the agriculture, transportation, recreation and tourism, forestry, and energy sectors. Social and environmental impacts are also significant, although it is difficult to put a precise cost on these impacts.

Drought affects groundwater sources, but generally not as quickly as surface water supplies, although groundwater supplies generally take longer to recover. Reduced precipitation during a drought means that groundwater supplies are not replenished at a normal rate. This can lead to a reduction in groundwater levels and problems such as reduced pumping capacity or wells going dry. Shallow wells are more susceptible than deep wells. About 16,000 drinking water systems in Washington get water from the ground; these systems serve about 5.2 million people. Reduced replenishment of groundwater affects streams. Much of the flow in streams comes from groundwater, especially during the summer when there is less precipitation and after snowmelt ends. Reduced groundwater levels mean that even less water will enter streams when steam flows are lowest. Reduced water levels in wells also means that the wells are subject to saltwater intrusion.

Much of the area depends on well water, which currently supplies a large portion of Mason County residents with their drinking water. Drought conditions within the planning area increase pressure on local aquifers, with increased pumping potentially resulting in saltwater intrusion into freshwater aquifers. This, in turn, could cause restrictions on economic growth and development.

A drought directly or indirectly impacts all people in affected areas. A drought can result in farmers not being able to plant crops or the failure of planted crops. This results 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 also 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. With much of Washington's energy coming from hydroelectric plants, a drought means less inexpensive electricity coming from dams and probably higher electric bills. All people would pay more for water if utilities increase their rates. This has become an issue within Washington State as a whole previously, when a lack of snow pack has decreased hydroelectric generating capacity, and raised the electric prices, impacting residents.

5.2.2 Previous Occurrences

The County has never been declared in a federal disaster declaration related to drought. As of this 2023 update, the County's water supply was above average (see Figure 5-1).[1] However, in the past century, Washington has experienced a number of drought episodes, including several that lasted for more than a single season. Table 5-1 identifies drought occurrences within the State of Washington. Figure 5-1 identifies precipitation outlooks in Mason County as of this 2023 update. Figure 5-2 identifies drought instances during the period 2015 through 2022 in Mason County.

[1] NOAA Drought.gov. Accessed 27 Jan 2023. Available online at: Mason County Conditions | Drought.gov

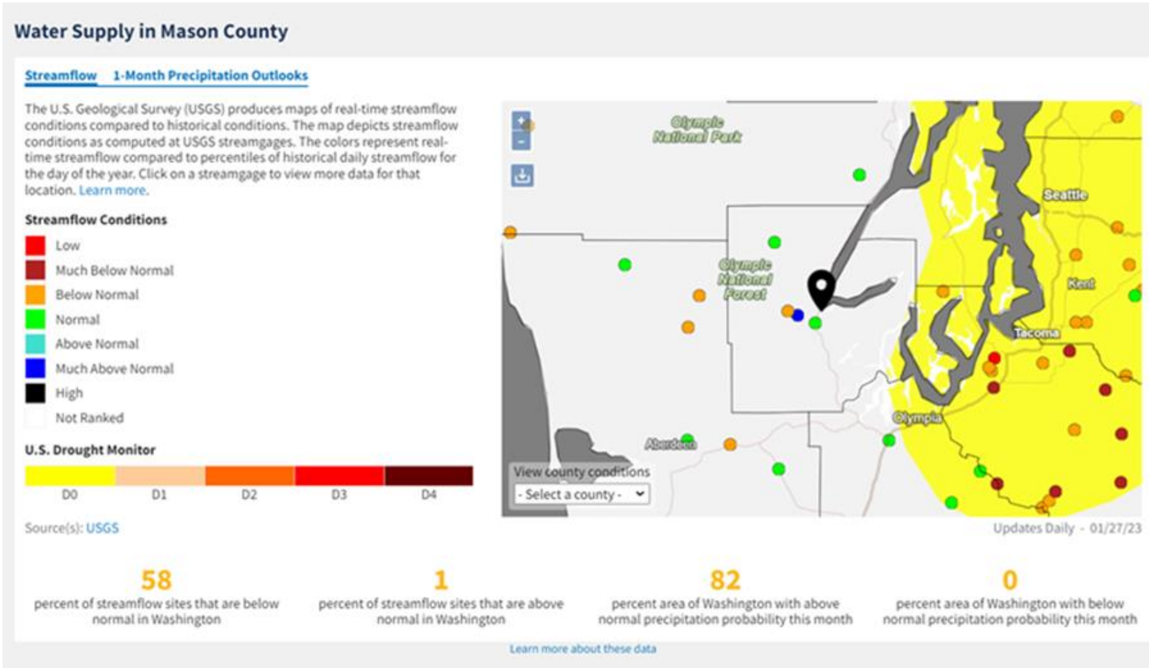

Figure 5-1 Water Supply in Mason County January 2023

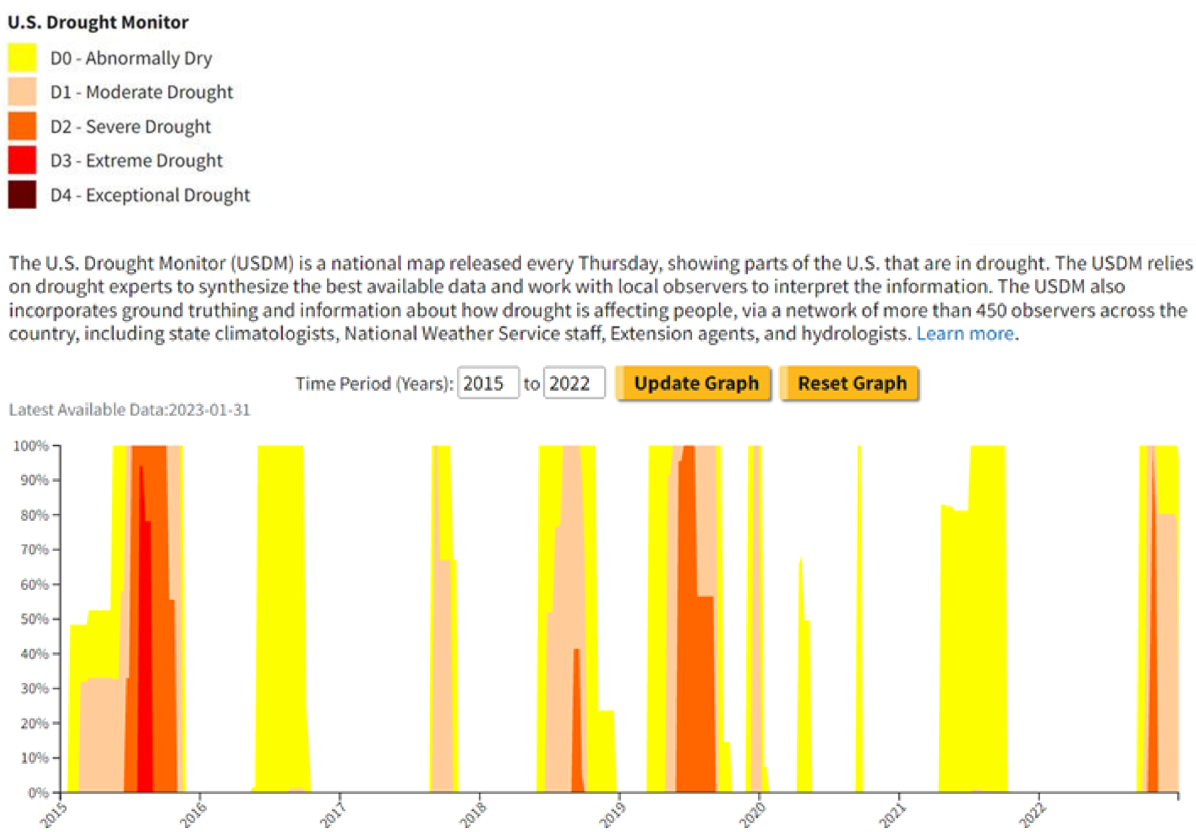

Figure 5-2 Historical Drought Conditions in Mason County 2015-2022

Table 5-1 Drought Occurrences	
July-August 1902	No measurable rainfall in Western Washington
August 1919	Drought and hot weather occurred in Western Washington
July – August 1921	Drought in all agricultural sections.
June-August 1922	The statewide precipitation averaged 0.10 inches.
March – August 1924	Lack of soil moisture retarded germination of spring wheat.
July 1925	Drought occurred in Washington
July 21-August 25, 1926	Little or no rainfall was reported.
June 1928-March 1929	Most stations averaged less than 20 percent of normal rainfall for August and September and less than 60 percent for nine months.
July – August 1930	Drought affected the entire state. Most weather stations averaged 10 percent or less of normal precipitation.
April 1934-March 1937	The longest drought in the region's history – the driest periods were April-August 1934, September-December 1935, and July-January 1936-1937.
May – September 1938	Driest growing season in Western Washington.
1952	Every month was below normal precipitation except June. The hardest hit areas were Puget Sound and the central Cascades.
January – May 1964	Drought covered the southwestern part of the state. Precipitation was less than 40 percent of normal.
Spring 1966	Drought throughout Washington
June – August 1967	Drought throughout Washington
January – August 1973	Dry in the Cascades.
October 1976 – September 1977	Worst drought in Pacific Northwest history. Below normal precipitation in Olympia, Seattle, and Yakima. Crop yields were below normal and ski resorts closed for much of the 1976-77 season.
2001	Governor declared statewide Stage 2 drought in response to severe dry spell.
June – September 2003	Federal disaster number 1499 assigned to 15 counties. The original disaster was for flooding but several jurisdictions were included because of previous drought conditions.
March 10, 2005 Governor Declared Drought	Precipitation levels was below or much below the average from November through February, with extremely warm fall and winter months, adversely affecting the state's mountain snow pack. A warm mid-January removed much of the remaining snow pack, with March projections at 66 percent of normal, indicating that Washington might be facing a drought as bad as, or worse, than the 1977 drought. Late March rains filled reservoirs to about 95 percent. State legislature approved $12 million supplemental budget that provided funds to buy water, improve wells, and implement other emergency water supply projects. Wildfires numbers was about 75 percent of previous five years, but acreage burned was three times greater.

Table 5-1 Drought Occurrences	
2015	2015 was the year of the "snowpack drought." Washington State had normal or near-normal precipitation over the 2014-2015 winter season. However, October through March the average statewide temperature was 40.5 degrees Fahrenheit, 4.7 degrees above the 20th century long-term average and ranking as the warmest October through March on record. Washington experienced record low snowpack because mountain precipitation that normally fell as snow instead fell as rain. The snowpack deficit then was compounded as precipitation began to lag behind normal levels in early spring and into the summer. With record spring and summer temperatures, and little to no precipitation over many parts of the state, the snowpack drought morphed into a traditional precipitation drought, causing injury to crops and aquatic species. Many rivers and streams experienced record low flows.
2019	On May 20, 2019, Governor Jay Inslee issued an emergency drought declaration in 24 watersheds statewide. According to the Washington State Department of Ecology, very dry conditions over several months and a diminished snowpack impacted streamflow, which were identified to be well below normal conditions across most of the state.[2] Watersheds west of the Cascades crest, which are more rain dependent than rivers on the east side, flowed at much below normal levels. Some rivers set record daily lows for historic May flows. Statewide, at the time the declaration was ordered, only four (4) percent of rivers were flowing at levels above normal. While stream flows were strong in the southeast corner of the state, 27 out of 62 watersheds were declared for drought as of May 20, 2019.
2020	Several months in a row of below-average precipitation brought drought to the Pacific Northwest in spring 2020, with only the northwestern corner of Washington, around Seattle, free of any kind of drought or abnormal dryness. As the region's dry summer approached, the winter and spring precipitation deficits pose a threat to livestock operators, farmers, and fish, and heighten the risk of wildfires. In this event, while precipitation falling as snow was initially at normal levels, the higher-than-average temperatures caused rapid snow melt, with runoff coming earlier in the year causing high rates of soil moisture evaporation.
2021	The spring of 2021 was the second driest on record, and then an unprecedented late-June heatwave smashed temperature records across the state. In response, Washington State Department of Ecology issued an emergency drought declaration in July 2021 covering 96 percent of the state. Only Seattle, Everett, and Tacoma – cities with ample water storage – escaped the designation.
2022	Historically low water levels in several areas closed most recreational fishing on most streams of the Olympic Peninsula.

[2] Source: https://waterwatch.usgs.gov/?m=real&r=wa

5.2.3 Severity

Droughts impact individuals (farm owners, tenants, and farm laborers), the agricultural industry, and other agriculture-related sectors. Lack of snow pack has forced ski resorts into bankruptcy. There is increased danger of forest and wildland fires. Millions of board feet of timber have been lost. Loss of forests and trees increases erosion, causing serious damage to aquatic life, irrigation, and power development by heavy silting of streams, reservoirs, and rivers.

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 duration of the drought and the larger the area impacted, the more severe the potential impacts. Droughts are not usually associated with direct impacts on people or property, but they can have significant impacts on agriculture, wildlife, and fishing, which can impact people indirectly. When measuring the severity of droughts, analysts typically look at economic impacts.

The National Oceanic and Atmospheric Administration (NOAA) has developed several indices to measure drought impacts and severity to map their extent and locations.

- 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.
- The ***Palmer Z Index*** measures short-term drought on a monthly scale. Figure 5-3 shows this index for August 2022.
- 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. This index responds more slowly to changing conditions than the Palmer Drought Index.
- While the Palmer indices consider precipitation, evapotranspiration and runoff, the ***Standardized Precipitation Index*** considers only precipitation. In this index, a value 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 24 months.
- 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 this index can respond fairly rapidly.

These indices change very frequently. The data contained in this profile frequently changes, and is meant to provide only a brief overview. Reviewers wishing additional or more current data should check NOAA's website at Historical Palmer Drought Indices | National Centers for Environmental Information (NCEI) (noaa.gov)

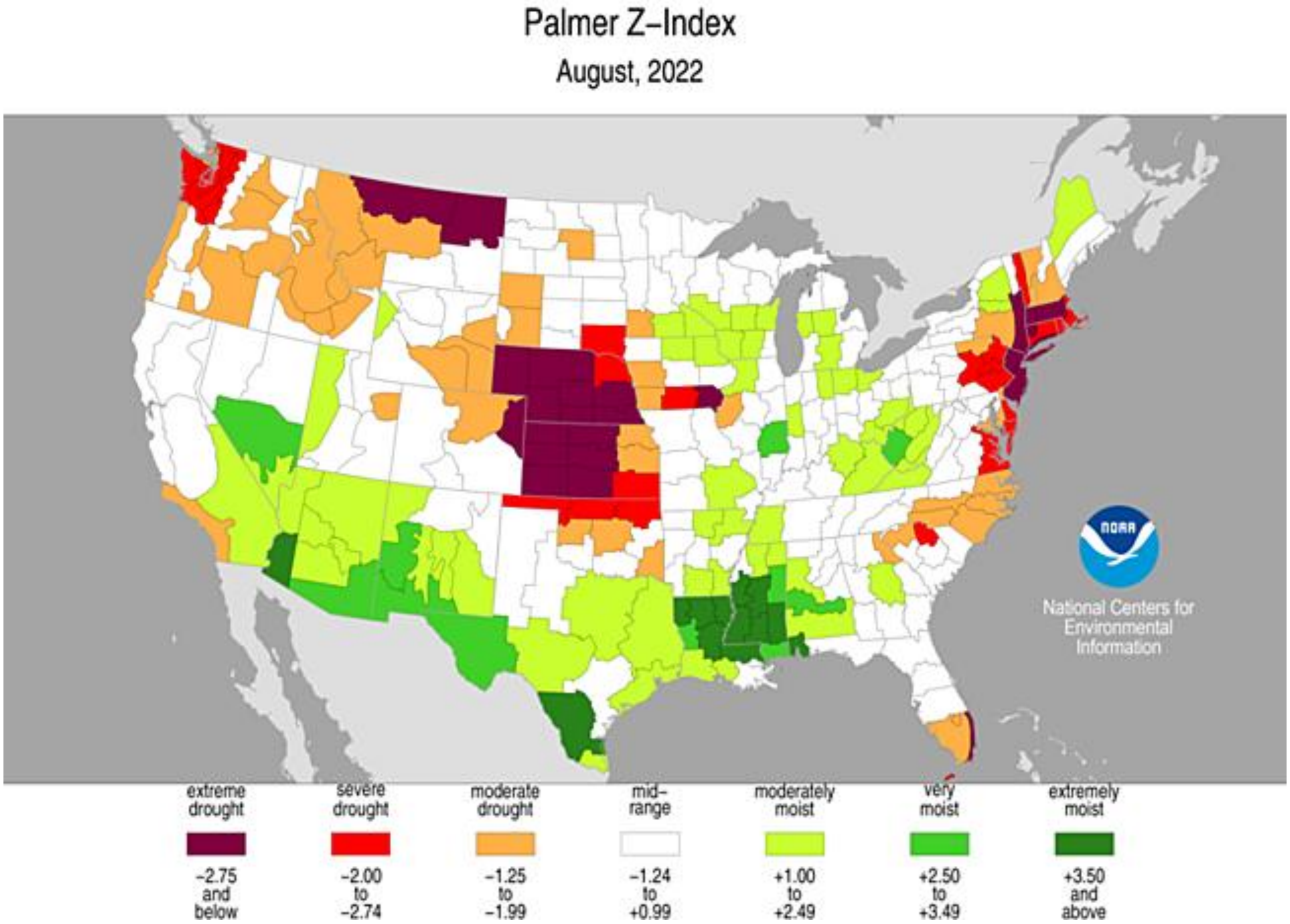

Figure 5-3 Palmer Z Index Short-Term Drought Conditions (August 2022)

5.2.4 Frequency

Empirical studies conducted over the past century have shown that meteorological drought is never the result of a single cause. It is the result of many causes, often synergistic in nature; these include global weather patterns that produce persistent, upper-level high-pressure systems along the West Coast with warm, dry air resulting in less precipitation.

In temperate regions, including Washington, long-range forecasts of drought have limited reliability. In the tropics, empirical relationships have been demonstrated between precipitation and El Niño events, but few such relationships have been demonstrated above 30º north latitude. Meteorologists do not believe that reliable forecasts are attainable at this time a season or more in advance for temperate regions.

A great deal of research has been conducted in recent years on the role of interacting systems in explaining regional and even global patterns of climatic variability. These patterns tend to recur periodically with enough frequency and with similar characteristics over a sufficient length of time that they offer opportunities to improve the ability for long-range climate prediction. However, too many variables exist in determining the frequency with which a drought will occur.

Reliable forecasts of drought are not attainable for temperate regions of the world more than a season in advance. However, based on a 100-year history with drought, the state as a whole can expect severe or extreme drought at least 5 percent of the time in the future, with most of eastern Washington experiencing severe or extreme drought about 10 to 15 percent of the time." (EMD, 2012). With changing climatic conditions, the State's 2018 Hazard Mitigation Plan indicates that the "state may likely experience one or two major drought events," impacting 75 percent of the State area, and approximately 21 percent of the State's population, which resides in areas with medium or high drought exposure. Based on the State's 2018 HMP, Mason County has a low exposure rate (WA EMD HMP, 2018).

5.3 VULNERABILITY ASSESSMENT

5.3.1 Overview

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 associated with 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.

All people, property and environments in the planning area could be exposed to some degree to the impacts of moderate to extreme drought. Areas densely wooded, especially areas in parks throughout the County which host campers, increase the exposure to forest fires. Additional exposure comes in the form of economic impact should a prolonged drought occur that would impact fishing, recreation, agriculture, and timber harvesting—primary sources of income in the planning area. Prolonged drought would also decrease capacity within the watersheds, thereby reducing fish runs and, potentially, spawning areas.

Warning Time

A drought is not a sudden-onset hazard. Droughts are climatic patterns that occur over long periods, providing for some advance notice. In many instances, annual situations of low water levels are identified months in advance (e.g., snow pack at lower levels are identified during winter months), allowing for advanced planning for water conservation.

Meteorological drought is the result of many causes, including global weather patterns that produce persistent, upper-level high-pressure systems along the West Coast resulting in less precipitation. Only general warning can take place, due to the numerous variables that scientists have not pieced together well enough to make accurate and precise predictions. It is often difficult to recognize a drought before being in the middle of it. Droughts do not occur spontaneously, they evolve over time as certain conditions are met.

Scientists do not know how to predict drought more than a month in advance for most locations. Predicting drought depends on the ability to forecast precipitation and temperature. Weather anomalies may last from several months to several decades. How long they last depend 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. In temperate regions such as Washington, long-range forecasts of drought have limited reliability. Meteorologists do not believe that reliable forecasts are attainable at this time a season or more in advance for temperate regions.

5.3.2 Impact on Life, Health, and Safety

Wildfires are often associated with drought. A prolonged lack of precipitation dries out vegetation, which becomes increasingly susceptible to ignition as the duration of the drought extends. This increases the risk to the health and safety of the residents within the planning area, especially those in wildland-urban interface areas. Smoke and particles embedded within the smoke are of significant concern for the elderly and very young, especially those with breathing problems.

The County and its jurisdictions have the ability to minimize impacts on residents and water consumers within the planning area should several consecutive dry years occur.

5.3.3 Impact on Property

No structures will be directly affected by drought conditions, though some 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 to property owners. However, these impacts are not considered critical in planning for impacts from the drought hazard.

5.3.4 Impact on Critical Facilities and Infrastructure

Critical facilities will continue to be operational during a drought unless impacted by fire. Critical facility elements such as landscaping may not be maintained due to limited resources, but the risk to the planning area's critical facilities inventory 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.

5.3.5 Impact on Economy

Economic impact from a drought is associated with different aspects, including potential loss of agri- and aqua-cultural production. The County's economy relies heavily on aquaculture. Also ranking high with respect to agricultural dependency is Christmas trees and short rotation woody crops, ranking fourth statewide. Combined, the impact from a drought situation on the County's agri- and aqua-cultural markets for economic sustainability could be high. One of Mason County's largest employers, Taylor Shellfish, Inc., is also one of the largest producers of aquaculture shellfish. Drought situations such that have previously occurred statewide which impacted the fishing industry could have a negative impact on both Christmas tree production – another of the County's leading economic industries, and the shellfish industry.

Additional economic impact stems from the potential loss of critical infrastructure due to fire damage and impacts on industries that depend on water for their business, such as fishing industries, water-based recreational activities, and public facilities and recreational areas.

Problems of domestic and municipal water supplies have historically been corrected by building another reservoir, a larger pipeline, new well, or some other facility. With drought conditions increasing pressure on aquifers and increased pumping, which can result in saltwater intrusion into fresh water aquifers, resultant reductions or restrictions on economic growth and development could occur. Given potential political issues, a drought situation, if prolonged, could restrict building within specific areas due to lack of supporting infrastructure, thereby impacting the tax base and economy of the region by limiting growth. In addition, impact to or the lack of hydroelectric generating capacity associated with drought conditions as a result of reduced precipitation levels could raise electric prices throughout the region.

5.3.6 Impact on Environment

Environmental losses from drought are associated with aquatic life, plants, animals, wildlife habitat, air and water quality, forest fires, landscape quality, biodiversity, and soil erosion. Some effects are short-term and conditions quickly return to normal after the drought. Other effects linger or even become permanent. Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes, and vegetation, but many species will eventually recover from this effect. Degraded landscape quality, including soil erosion, may lead to a more permanent loss of biological productivity. Life-cycles for fish spawning in the area would have environmental impacts years into the future.

Public awareness and concern for environmental quality has led to greater attention to these effects. Drought conditions within the planning area could increase the demand for water supplies. Water shortages would have an adverse impact on the environment, relied upon by the planning partnership, causing social and political conflicts. If such conditions persisted for several years, the economy of Mason County could experience setbacks, especially in water dependent industries.

5.3.7 Impact from Climate Change

The impact from climate change on drought will be significant. With historic records demonstrating increased temperature rise, the results will only further exacerbate drought stations. Ocean acidification has also been noted. Drought also plays a significant role in 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 will further change the use of water available for fish spawning due to increased temperatures. It will also impact availability for agricultural growers for their crops; with decreased precipitation in the form of snow, water levels will fall, creating water shortages for use by consumers as drinking water, irrigation and watering of livestock, and firefighters to control and fight fires.

5.4 FUTURE DEVELOPMENT TRENDS

Mason County and the City of Shelton have a relatively high amount of land available for future construction. With the anticipated increase in population, the rezoning of land from agricultural to residential would have the propensity to increase water demands, as well as increase demands on other infrastructure, and increase the potential for wildfires. The City of Shelton and Mason County have established comprehensive plans that include policies directing land use and dealing with issues of water supply and the protection of water resources, as well as fire regulations. These plans provide the capability at the local municipal level to protect future development from the impacts of drought. All planning partners reviewed their general plans under the capability assessments performed for this effort. Deficiencies identified by these reviews can be identified as mitigation actions to increase the capability to deal with future trends in development.

The planning area continues to move forward in developing policies directing land use and dealing with zoning, density and permitting for any new development. This will provide the capability to protect future development from the impacts of drought.

5.5 ISSUES

An extreme drought could impact the region with little warning. Combinations of low precipitation and unusually high temperatures could occur over several consecutive years, especially in response to climate change. Intensified by such conditions, extreme wildfires could break out throughout the area, increasing the need for water. Surrounding communities, also in drought conditions, could increase their demand for water, causing social and political conflicts. Low water tables could increase issues of life, safety, and health, while also impacting the economy both for loss of potential agricultural income, but also with respect to decreased ability to construct new housing due to lack of ability to provide water. If such conditions persisted for several years, the economy of the region could experience setbacks, especially in water dependent industries.

The planning team has identified the following drought-related issues:

- The need for alternative water sources should a prolonged drought occur;
- Use of groundwater recharge to stabilize the groundwater supply;
- The probability of increased drought frequencies and durations due to climate change;
- The promotion of active water conservation even during non-drought periods;
- The potential impact on businesses in the area;
- The potential impact on the livelihood of those employed in industries that could be impacted by drought, such as agriculture, fishing, forestry, and tourism.

5.6 RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from Drought throughout the area is highly likely. The area has previously experienced drought conditions. As of this 2023 update, the State has experienced some of its driest summers on record, as well as setting high-temperature records. With anticipated increase in temperatures as a result of climate change expected to continue, drought situations will only intensify. With the planning area's dependence on aqua- and agri-culture, there is a significant potential economic loss in the region. In addition, higher temperatures anticipated with climate change would increase vulnerability of the population due to excessive heat, while also potentially impacting power supplies at the hydro-dams in the area. With a higher number of aged population than that of the remaining state, as well as older residential structures that may not have air conditioning or air purification systems in place, this would increase the potential vulnerability. Based on the potential impact, the Planning Team determined the CPRI score to be 2.6, with overall vulnerability determined to be a medium level.

CHAPTER 6.
EARTHQUAKE

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. Its epicenter is the point on the earth's surface directly above the hypocenter of an earthquake. The location of an earthquake is described by the geographic position of its epicenter and by its focal depth. Earthquakes many times occur along a fault, which is a fracture in the earth's crust.

> **DEFINITIONS**
>
> **Earthquake**—The shaking of the ground caused by an abrupt shift of rock along a fracture in the earth or a contact zone between tectonic plates.
>
> **Epicenter**—The point on the earth's surface directly above the hypocenter of an earthquake. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth.
>
> **Fault**—A fracture in the earth's crust along which two blocks of the crust have slipped with respect to each other.
>
> **Focal Depth**—The depth from the earth's surface to the hypocenter.
>
> **Hypocenter**—The region underground where an earthquake's energy originates
>
> **Liquefaction**— Loosely packed, water-logged sediments losing their strength in response to strong shaking, causing major damage during earthquakes.

6.1 GENERAL BACKGROUND

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.

Geologists classify faults by their relative hazards. Active faults, which represent the highest hazard, are those that have ruptured to the ground surface during the Holocene period (about the last 11,000 years). Potentially active faults are those that displaced layers of rock from the Quaternary period (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.

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.

It is generally agreed that three source zones exist for Pacific Northwest quakes: a shallow (crustal) zone; the Cascadia Subduction Zone; and a deep, intraplate "Benioff" zone. These are shown in Figure 6-1. More than 90 percent of Pacific Northwest earthquakes occur along the boundary between the Juan de Fuca plate and the North American plate.

An earthquake will generally produce the strongest ground motions near the epicenter (the point on the ground above where the earthquake initiated) with the intensity of ground motions diminishing with increasing distance from the epicenter. The intensity of ground shaking at a given site depends on four main factors:

- Earthquake magnitude
- Earthquake epicenter
- Earthquake depth
- Soil or rock conditions at the site, which may amplify or de-amplify earthquake ground motions.

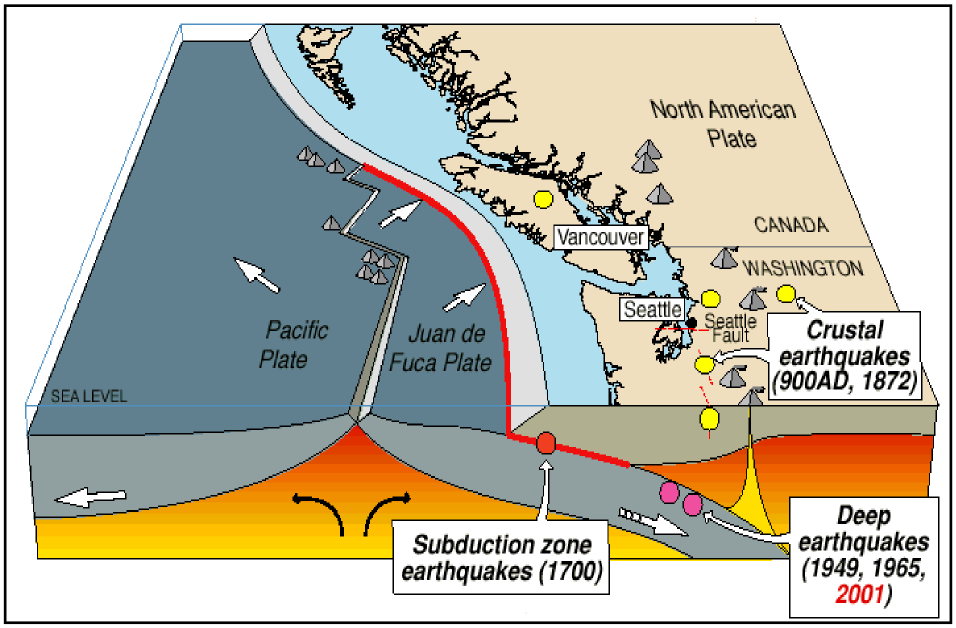

Figure 6-1 Earthquake Types in the Pacific Northwest

For any given earthquake, there will be contours of varying intensity of ground shaking with distance from the epicenter. The intensity will generally decrease with distance from the epicenter, and often in an irregular pattern, not simply in concentric circles. The irregularity is caused by soil conditions, the complexity of earthquake fault rupture patterns, and directionality in the dispersion of earthquake energy.

6.1.1 Earthquake Classifications

Earthquakes are typically classified in one of two ways: By the amount of energy released, measured as **magnitude** (size or power based on the Richter Scale); or by the impact on people and structures, measured as **intensity** (based on the Mercalli Scale). 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. Magnitude is represented by a single, instrumentally determined value for each earthquake event. Intensity indicates how the earthquake is felt at various distances from the earthquake epicenter.

Magnitude

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

There are many measures of the severity or intensity of earthquake ground motions. The Modified Mercalli Intensity scale (MMI) (Table 6-1) was widely used beginning in the early 1900s. MMI is a descriptive, qualitative scale that relates severity of ground motions to the types of damage experienced. MMI values range from I to XII (USGS, 1989).

Table 6-1
Modified Mercalli Intensity (MMI) Scale Descriptions

MMI VALUE	DESCRIPTION
I	Not felt except by a very few under especially favorable conditions
II	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it is an earthquake. Standing cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like a heavy truck striking building. Standing cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

Table 6-1
Modified Mercalli Intensity (MMI) Scale Descriptions

MMI VALUE	DESCRIPTION
VII	Damage negligible in buildings of good design and construction; slight in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
X	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

More accurate, quantitative measures of the intensity of ground shaking have largely replaced the MMI and are used in this mitigation plan. These scales use terms that can be physically measured with seismometers, such as the acceleration, velocity, or displacement (movement) of the ground. The intensity may also be measured as a function of the frequency of earthquake waves propagating through the earth. In the same way that sound waves contain a mix of low-, moderate- and high-frequency sound waves, earthquake waves contain ground motions of various frequencies. The behavior of buildings and other structures depends substantially on the vibration frequencies of the building or structure versus the frequency of earthquake waves. Earthquake ground motions also include both horizontal and vertical components.

Ground Motion

Earthquake hazard assessment is also based on expected ground motion. This involves determining the probability that certain ground motion accelerations will be exceeded over a time period of interest. A common physical measure of the intensity of earthquake ground shaking, and the one used in this mitigation plan, is peak ground acceleration (PGA). PGA is a measure of the intensity of shaking relative to the acceleration of gravity (g). For example, an acceleration of 1.0 g PGA is an extremely strong ground motion, which does occur near the epicenter of large earthquakes. With a vertical acceleration of 1.0 g, objects are thrown into the air. With a horizontal acceleration of 1.0 g, objects accelerate sideways at the same rate as if they had been dropped from the ceiling. A PGA equal to 10% g means that the ground acceleration is 10 percent that of gravity, and so on.

Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures. The following generalized observations provide qualitative statements about the likely extent of damage for earthquakes with various levels of ground shaking (PGA) at a given site:

- Ground motions of only 1% g or 2% g are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.
- Ground motions below about 10% g usually cause only slight damage.
- Ground motions between about 10% g and 30% g may cause minor to moderate damage in well-designed buildings, with higher levels of damage in more vulnerable buildings. At this level of ground shaking, some poorly built buildings may be subject to collapse.
- Ground motions above about 30% g may cause significant damage in well-designed buildings and very high levels of damage (including collapse) in poorly designed buildings.
- Ground motions above about 50% g may cause significant damage in most buildings, even those designed to resist seismic forces.

PGA is 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). The amount of earthquake damage and the size of the geographic area affected generally increase with earthquake magnitude:

- Earthquakes below M5 are not likely to cause significant damage, even near the epicenter.
- Earthquakes between about M5 and M6 are likely to cause moderate damage near the epicenter.
- Earthquakes of about M6.5 or greater (e.g., the 2001 Nisqually earthquake in Washington) can cause major damage, with damage usually concentrated fairly near the epicenter.
- Larger earthquakes of M7+ cause damage over increasingly wider geographic areas with the potential for very high levels of damage near the epicenter.
- Great earthquakes with M8+ can cause major damage over wide geographic areas.
- An M9 mega-quake on the Cascadia Subduction Zone could affect the entire Pacific Northwest from British Columbia, through Washington and Oregon, and as far south as Northern California, with the highest levels of damage nearest the coast.

Table 6-2 lists damage potential and perceived shaking by PGA factors, compared to the Mercalli scale.

Table 6-2
Comparison Of Mercalli Scale and Peak Ground Acceleration

Modified Mercalli Scale	Perceived Shaking	Potential Structure Damage: Resistant Buildings	Potential Structure Damage: Vulnerable Buildings	Estimated PGA[a] (%g)
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

6.1.2 Effect of Soil Types

Liquefaction is 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, unconsolidated sedimentary soils. The National Earthquake Hazard Reduction Program (NEHRP) creates maps based on soil characteristics to help identify locations subject to liquefaction. Table 6-3 summarizes NEHRP soil classifications. NEHRP Soils B and C typically can sustain ground shaking without much effect, dependent on the earthquake magnitude. Areas that are commonly most affected by ground shaking and susceptible to liquefaction have NEHRP Soils D, E and F.

Table 6-3
NEHRP Soil Classification System

NEHRP Soil Type	Description	Mean Shear Velocity to 30 Meters (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)	

Table 6-4
Acres of NEHRP Soil Classification by Type Countywide

NEHRP Soil Type	Description	Mean Shear Velocity to 30 Meters (m/s)	# of Acres w/n Mason County	# of Acres w/in Shelton	# of Acres w/in Allyn	# of Acres w/in Belfair
A	Hard Rock	1,500	0	0	0	0
B	Firm to Hard Rock	760-1,500	220,707.8	0.0	0.0	0.0
C	Dense Soil/Soft Rock	360-760	259,940.8	1,659.1	869.9	1,513.8
D	Stiff Soil	180-360	108,100.7	1,813.2	216.8	746.3
E	Soft Clays	< 180	34,397.0	236.8	216.8	32.8
F	Special Study Soils (liquefiable soils, sensitive clays, organic soils, soft clays >36 m thick)		0.0	0.0	0.0	0.0

6.1.3 Fault Classification

The U.S. Geologic Survey defines four fault classes based on evidence of tectonic movement associated with large-magnitude earthquakes during the Quaternary period, which is the period from about 1.6 million years ago to the present:

- Class A—Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether the fault is exposed by mapping or inferred from liquefaction or other deformational features.
- Class B—Geologic evidence demonstrates the existence of Quaternary deformation, but either (1) the fault might not extend deep enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A.
- Class C—Geologic evidence is insufficient to demonstrate (1) the existence of tectonic faulting, or (2) Quaternary slip or deformation associated with the feature.
- Class D—Geologic evidence demonstrates that the feature is not a tectonic fault or feature; this category includes features such as joints, landslides, erosional or fluvial scarps, or other landforms resembling fault scarps but of demonstrable non-tectonic origin.

6.2 HAZARD PROFILE

Seismic-related hazards in Mason County include ground motion from shallow (less than 20 miles deep) or deep faults; liquefaction and differential settling of soil in areas with saturated sand, silt, or gravel; and tsunamis that result from seismic activities. Earthquakes also can cause damage by triggering landslides or bluff failure. The Puget Sound region is entirely within Seismic Risk Zone 3, requiring that buildings be designed to withstand major earthquakes measuring 7.5 in magnitude. It is anticipated, however, that earthquakes caused from subduction plate stress can reach a magnitude greater than 8.0.

High-magnitude earthquakes are possible in Mason County when the Juan de Fuca slips beneath the North American plates. Deep zone or Benioff zone quakes have occurred within the San De Fuca plate (1949, 1965, and 2001) and can be expected in the future.

6.2.1 Extent and Location

Washington State as a whole is one of the most seismically active states in United States. There are a number of faults running near or through Mason County (see Figure 6-2), including the Saddle Mountain East Fault, Frigid Creek Fault, and Canyon Creek Fault, which are located north and west of Hoodsport near the Olympic National Forest (USGS, 2015a). The Saddle Mountain fault was first recognized in the early 1970’s. Drowned trees and trench excavations demonstrate that the fault produced a MW 6.5-7.0 earthquake 1,000-1,300 years ago, likely occurring with the MW 7.5 Seattle fault earthquake 1,100 years ago.

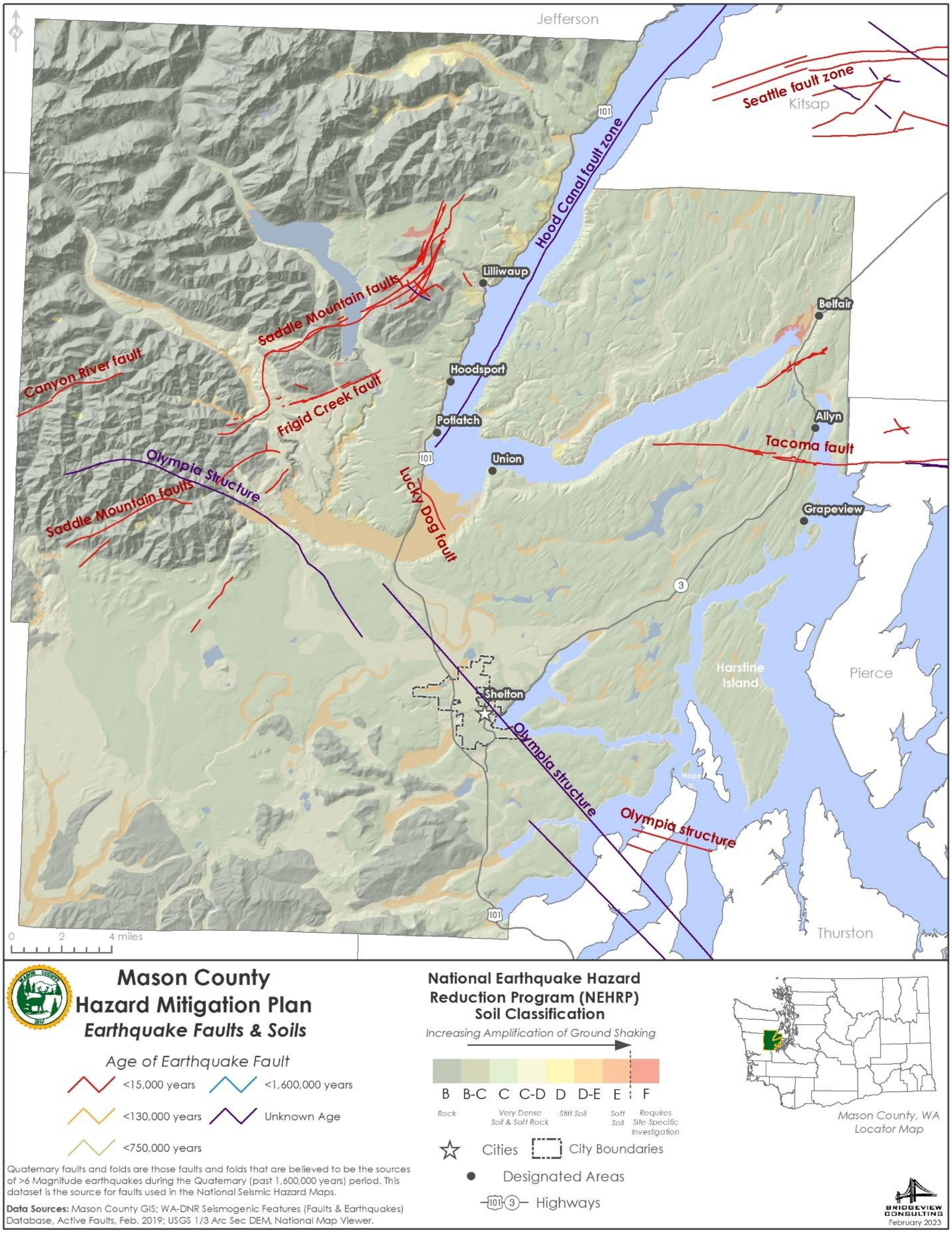

Figure 6-2 Mason County Faults

Hazard Mapping

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

- 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. While the impacts from each of these components can build upon each other during an earthquake event, the mapping looks at each component individually. The mapping used in this assessment is described below.

Shake Maps

A shake map is a representation of ground shaking produced by an earthquake (Peak Ground Acceleration). 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 recorded on seismic sensors, with interpolation where data are lacking and site-specific corrections. Color-coded 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. Hazard maps for the 100-year and 500-year probabilistic earthquakes are shown on Figure 6-3 and 6-4, and are carried over from the 2018 plan.
- 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. Three scenarios were carried forward from the 2018 plan:
  - Canyon River (Price Lake) Scenario (see Figure 6-5)
  - Nisqually Fault Scenario (see Figure 6-6)
  - Cascadia Subduction Zone Earthquake (see Figure 6-7).

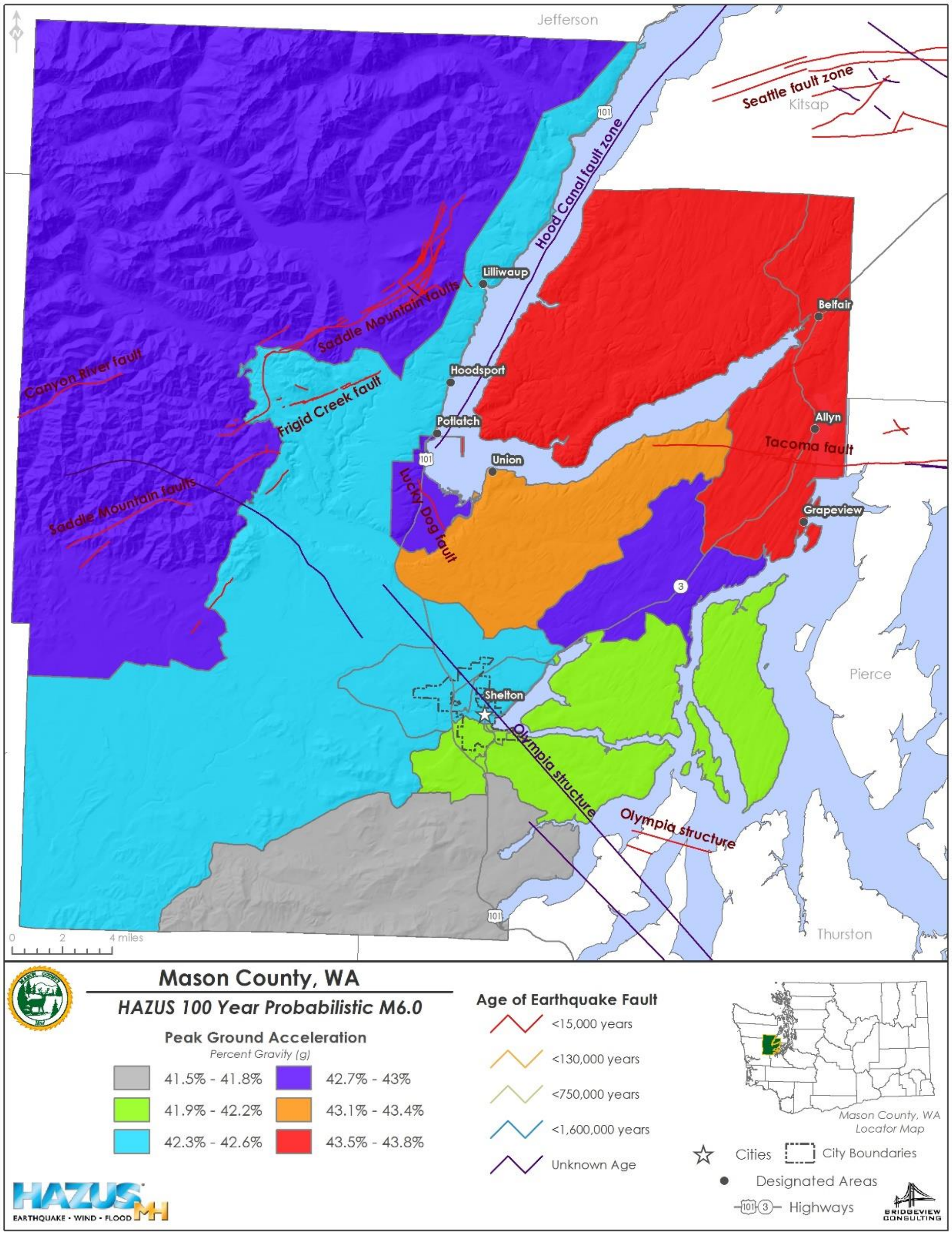

Figure 6-3 100-Year Probabilistic Earthquake Event

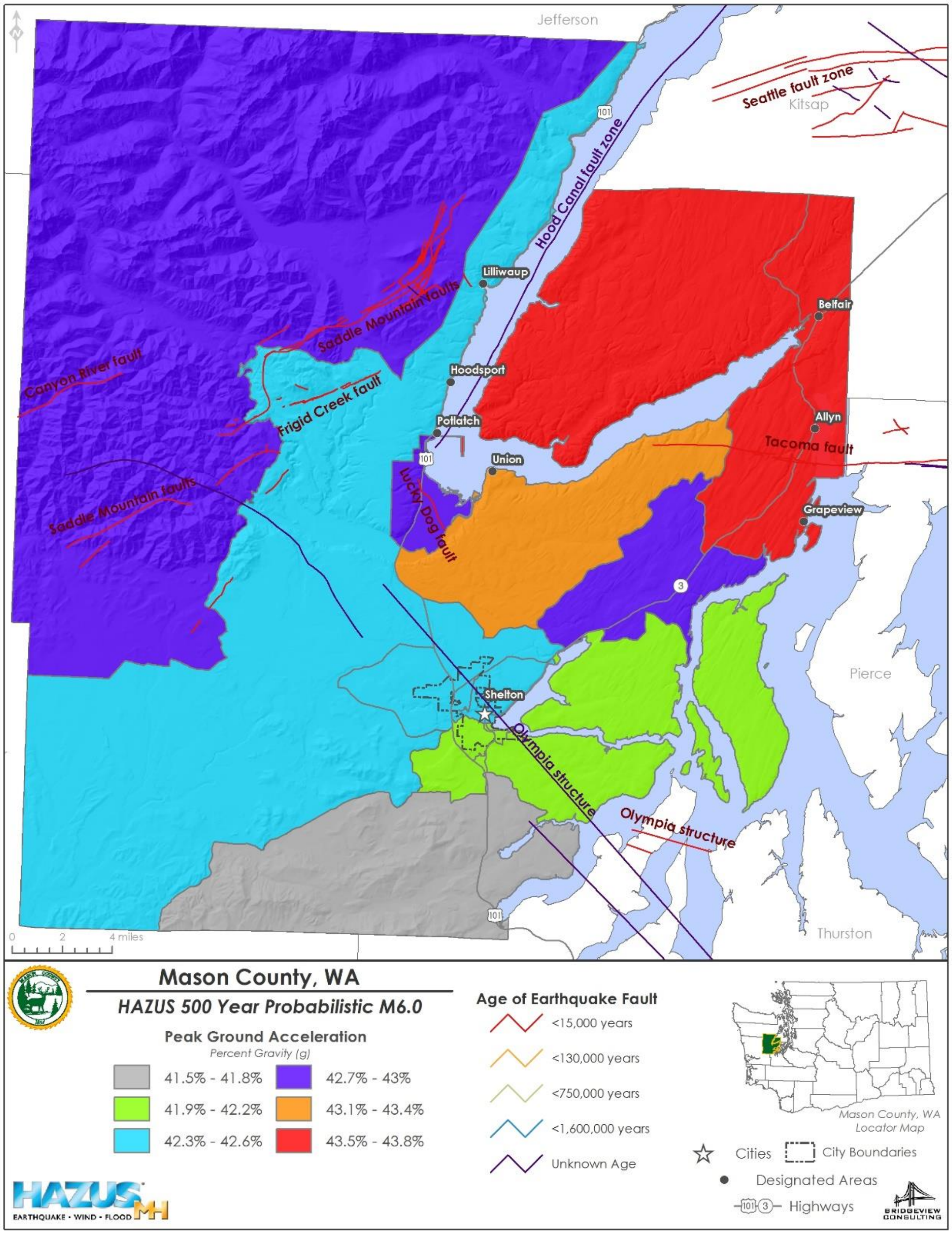

Figure 6-4 500-Year Probabilistic Earthquake Event

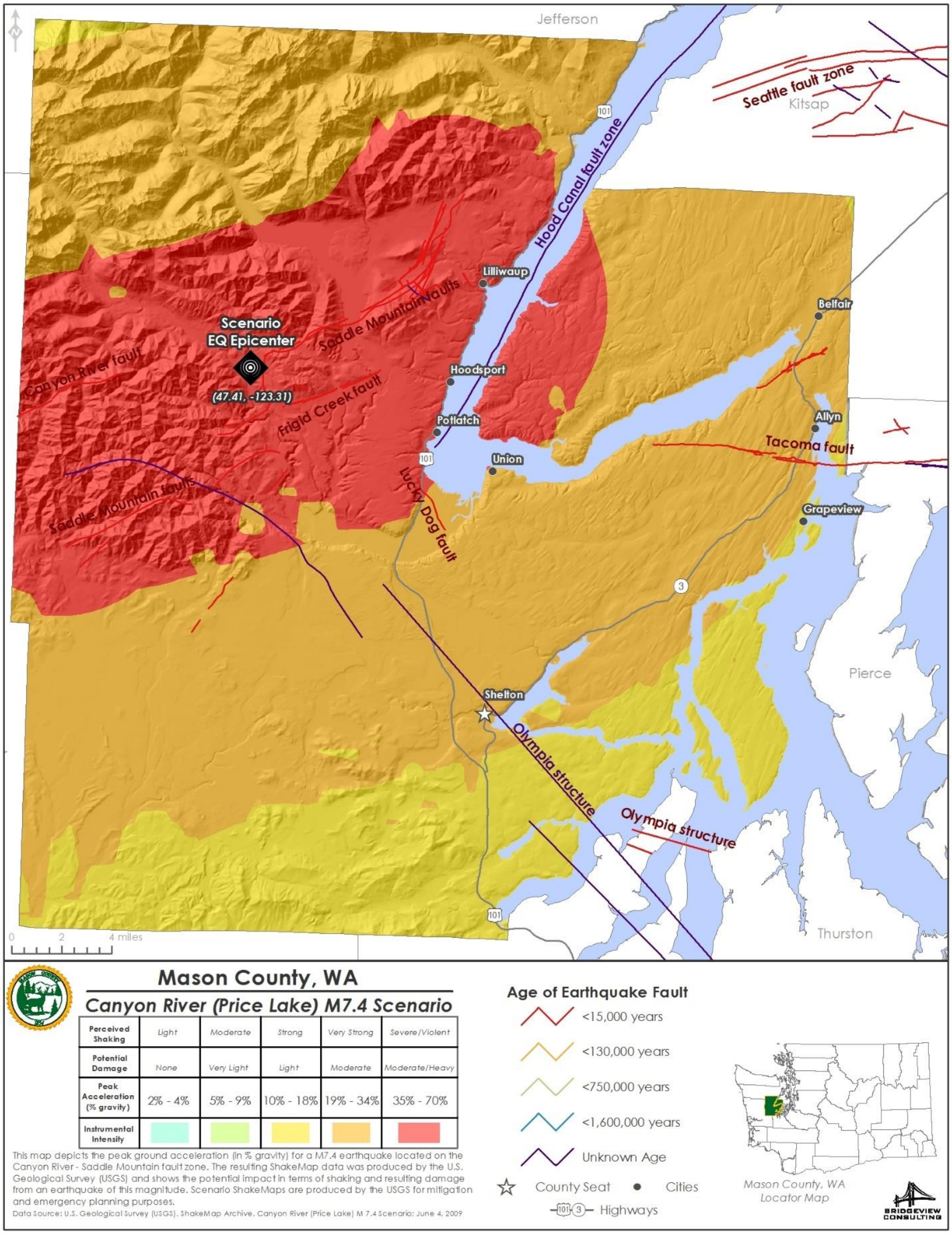

Figure 6-5 Canyon River (Price Lake) Scenario

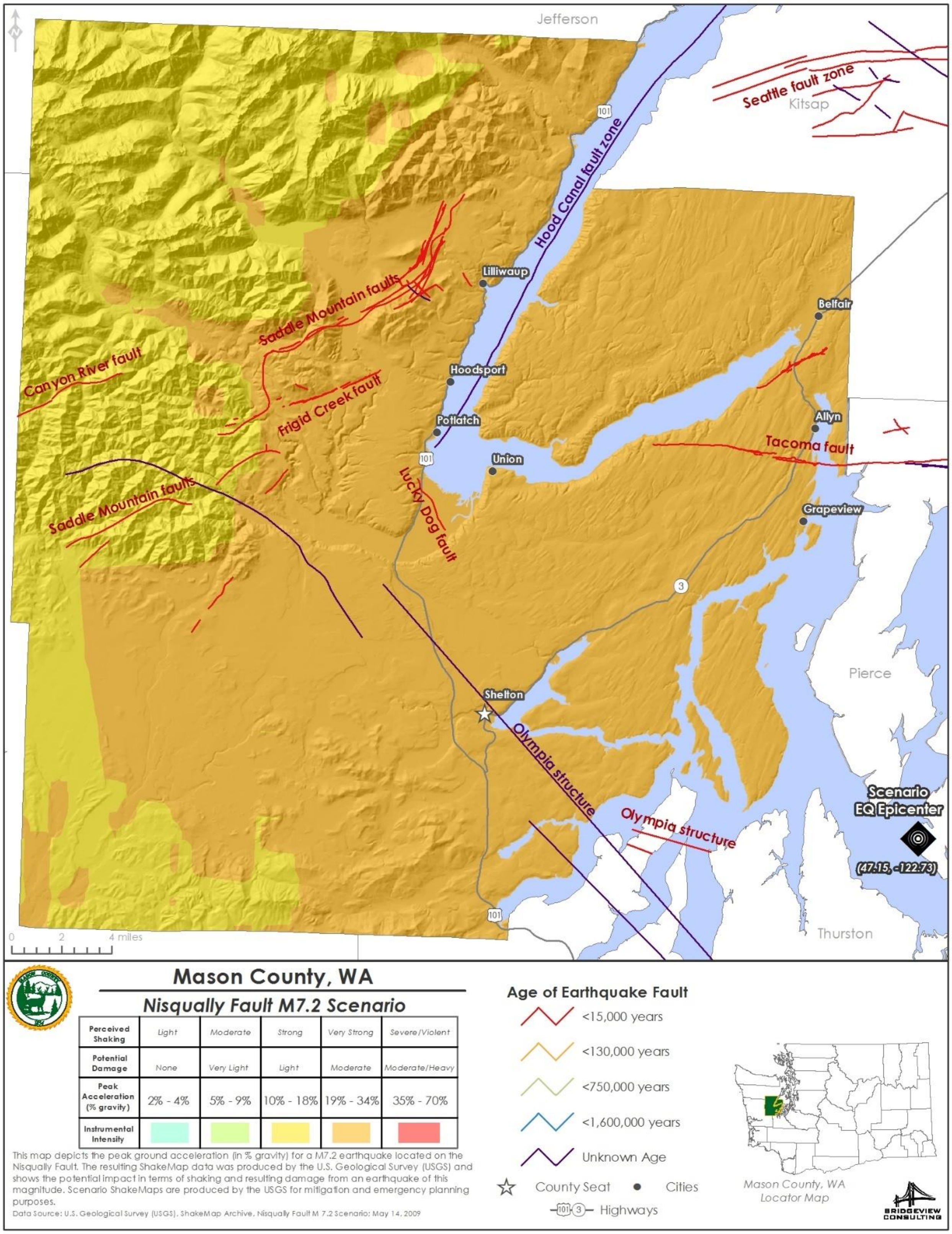

Figure 6-6 Nisqually Fault Scenario

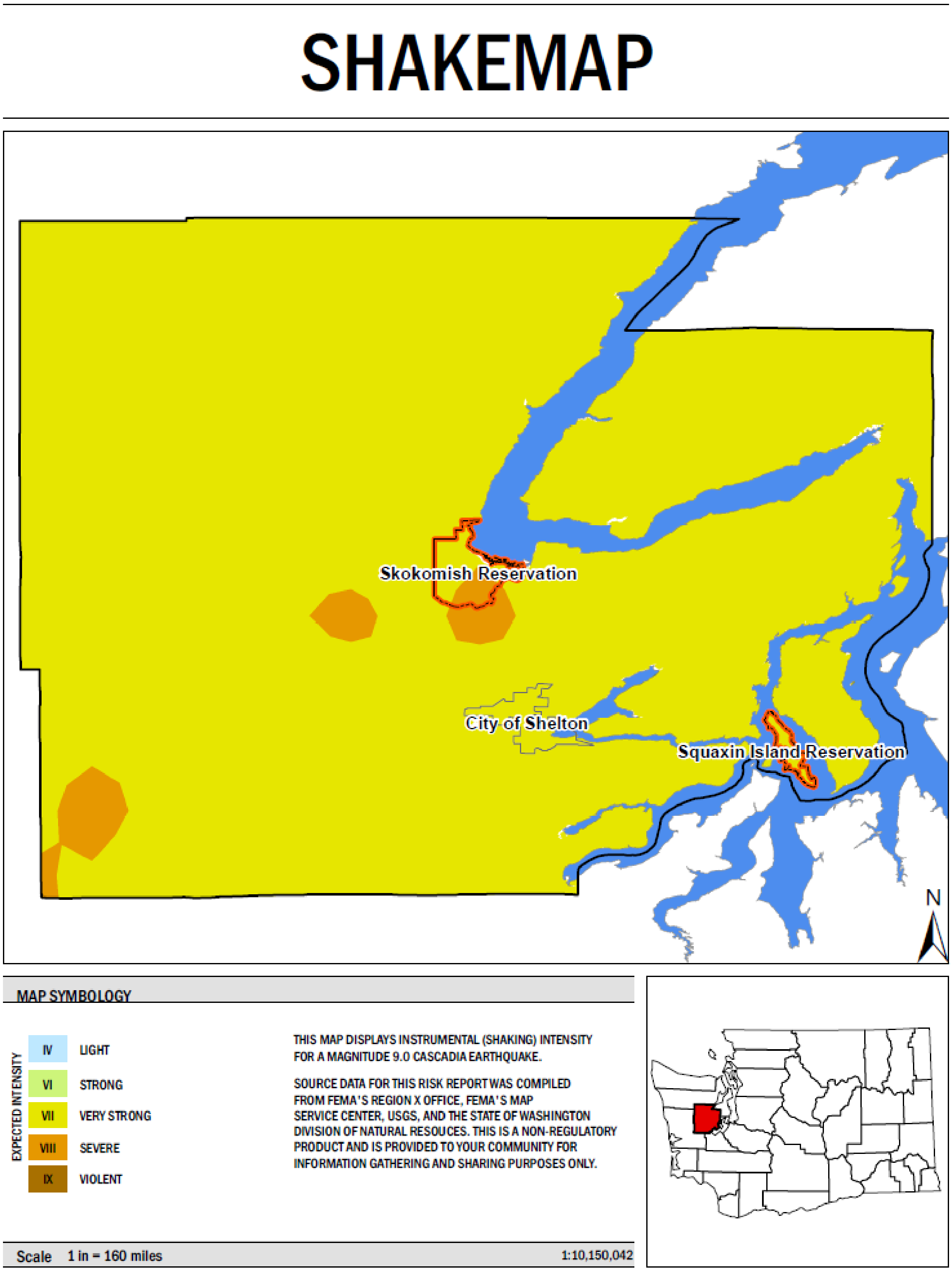

Figure 6-7 Cascadia M9.0 Fault Scenario (Source: FEMA Risk Map, 2017)

NEHRP Soil Maps

NEHRP soil types define the 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 that are most commonly affected by ground shaking have NEHRP Soils D, E, and F. Figure 6-8 shows NEHRP soil classifications in Mason County.

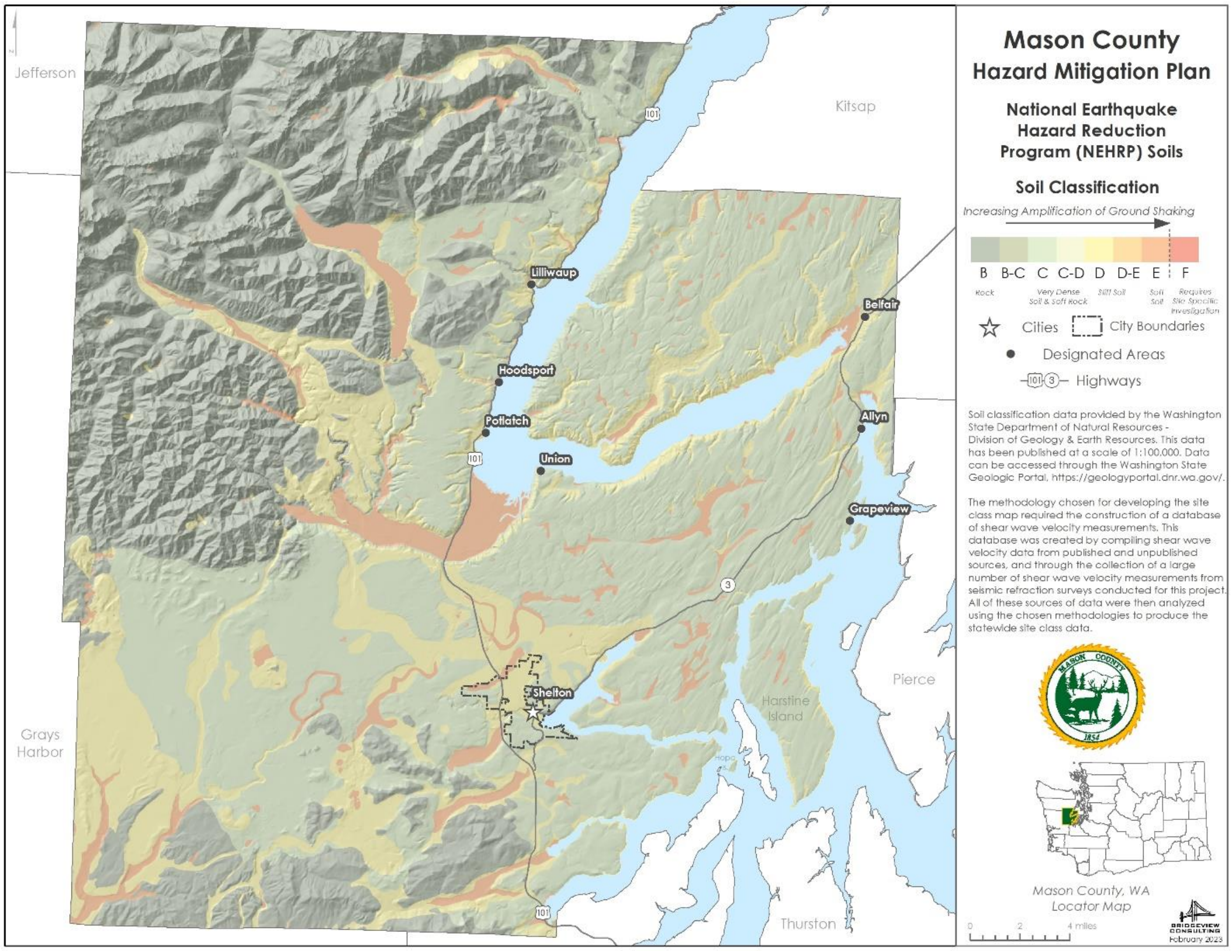

Figure 6-8 NEHRP Soils

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 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 and creating sand boils. Figure 6-9 shows liquefaction susceptibility throughout the County. Table 6-5 identifies the acres of the various susceptible liquefiable soil types countywide. Potential structure losses associated with the various liquefaction zones in Mason County are identified in Table 6-6.

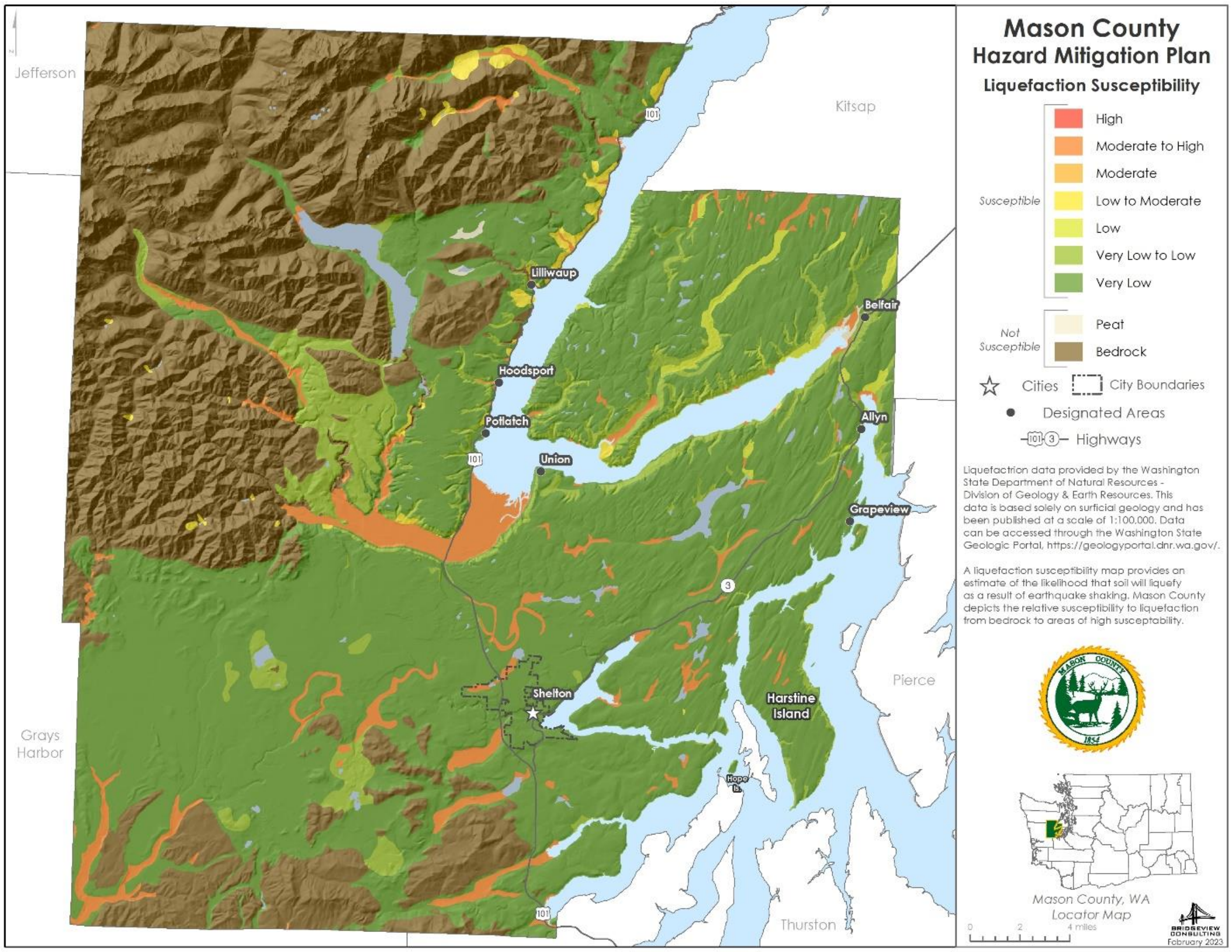

Figure 6-9 Liquefaction Susceptibility Zones

Table 6-5
Liquefiable Soils By Acres

Liquefaction Susceptibility Type/Zone		# of Acres w/n Mason County	# of Acres within Unincorporated Mason County	# of Acres w/n Shelton	# of Acres w/n Allyn	# of Acres w/n Belfair
Susceptible	High	0.0	0.0	0.0	0.0	0.0
	Moderate to High	25,547.2	25,301.8	215.6	34.3	0.0
	Moderate	0.0	0.0	0.0	0.0	0.0
	Low to Moderate	4,910.2	4,910.2	0.0	0.0	0.0
	Low	3,651.1	3,405.2	0.0	118.9	127.0
	Very Low to Low	36,906.2	36,189.0	0.0	97.9	619.3
	Very Low	322,574.0	316,687.9	3,441.2	869.9	1,513.8
Not Susceptible	Peat	786.0	753.1	0.0	0.0	32.8
	Bedrock	220,707.8	220,707.8,	0.0	0.0	0.0

Table 6-6
Potential Critical Facility Impact From Liquefaction Zones

Liquefaction Susceptibility Zones	Government Function	Communications	Medical	Hazardous Materials	Protective Services	Power	Shelter	Other (Landfill)	Water	Wastewater	Total
High	0	0	0	0	0	0	0	0	0	0	**0**
Moderate to High	0	0	0	0	2	1	0	0	17	0	**20**
Moderate	0	0	0	0	0	0	0	0	0	0	**0**
Low to Moderate	0	0	0	0	0	0	0	0	3	0	**3**
Low	0	0	0	0	2	0	0	0	1	1	**4**
Very Low to Low	1	0	0	0	2	1	0	0	9	3	**16**
Very Low	19	1	1	4	41	16	2	5	138	20	**247**
Not Susceptible to Liquefaction											
Bedrock	0	1	0	0	0	0	0	0	1	0	**2**
Peat	0	0	0	0	0	0	0	0	0	0	**0**

6.2.2 Previous Occurrences

Mason County is subject to Modified Mercalli Intensity VII or IX from several sources: the Canyon River-Price Lake fault zone (Walsh and Logan, 2007; Barnett and others, 2012), which generated earthquakes about 1,000, 1,800, and 3,500 years ago; the Seattle and Tacoma faults, which generated large earthquakes about 1,000 years ago (Nelson and others, 2003; Sherrod and others, 2004); and the Cascadia subduction zone, which generated large magnitude earthquakes as recently as a few hundred years ago. Abundant physical evidence for an earthquake in AD 1700 on the Cascadia subduction zone includes evidence for abrupt tectonic subsidence. This event was probably about an M9 and is the largest earthquake in the Pacific Northwest in the historic or paleoseismic record. The evidence for this earthquake is documented in Atwater and others (2005) and Goldfinger and others (2012). This fault has an average recurrence interval of approximately 500 years for earthquakes of about M9, making it the most active fault that can affect Mason County. Significant losses would also result from repeat of a Benioff Zone earthquake such as the Nisqually earthquake. These earthquakes can be larger than the M6.8 Nisqually earthquake, and the project team modeled an M7.2 scenario in about the same place (FEMA Risk Report, 2017).

Based on geologic evidence along the Washington coast, the Cascadia Subduction Zone has ruptured and created tsunamis at least seven times in the past 3,500 years and has a considerable range in recurrence intervals, from as little as 140 years between events to more than 1,000 years. The last Cascadia Subduction Zone-related earthquake is believed to have occurred on January 26, 1700, and researchers predict a 10 to 14 percent chance that another could occur in the next 50 years. Table 6-6 lists past seismic events that have affected the areas in and around Mason County.[3] Those which directly impacted Mason County are highlighted. No major earthquakes have occurred in the County since completion of the 2018 plan. The County has received two disaster declarations as a result of earthquake damage – the Nisqually Earthquake, which occurred on February 28, 2001, and the May 11, 1965 earthquake.

Table 6-6
Historical Earthquakes Impacting The Planning Area

Year	Magnitude	Epicenter	Type
2/28/2001 (DR 1361)	6.8	Olympia (Nisqually)	Benioff
6/10/2001	5.0	Matlock	Benioff
7/3/1999	5.8	8.0 km N of Satsop	Benioff
6/23/1997	4.7	Bremerton	Shallow Crustal
5/3/1996	5.5	Duvall	Shallow Crustal
1/29/1995	5.1	Seattle-Tacoma	Shallow Crustal

[3] PNSN, 2017

Table 6-6
Historical Earthquakes Impacting The Planning Area

Year	Magnitude	Epicenter	Type
2/14/1981	5.5	Mt. St. Helens (Ash)	Crustal
9/9/76	4.5	Union	Benioff Zone (28 miles deep)
5/11/1965 (DR 196)	6.6	18.3 KM N of Tacoma	Benioff
4/29/1965	6.5	12 miles North of Tacoma	Benioff
1/13/1949	7.0	12.3 KM ENE of Olympia	Benioff
6/23/1946	7.3	Strait of Georgia	Benioff
2/14/1946	6.3	Puget Sound	Benioff
4/1945	5.7	Northbend (8 miles south/southeast)	Unknown
1939	5.8	Puget Sound – Near Vashon Island	Unknown
1932	5.3	Central Cascades	Unknown
1/23/1920	5.5	Puget Sound	Unknown
12/6/1918	7.0	Vancouver Island	Unknown
8/18/1915	5.6	North Cascades	Unknown
1/11/1909	6.0	Puget Sound	Unknown
4/30/1882	5.8	Olympia area	Unknown
12/15/1872	6.8	Pacific Coast	Unknown

6.2.3 Severity

Earthquakes can last from a few seconds to over five minutes; they may also occur as a series of tremors over several days. The actual movement of the ground in an earthquake is seldom the direct cause of injury or death. Casualties generally result from falling objects and debris, because the shocks shake, damage or demolish buildings and other structures. Disruption of communications, electrical power supplies and gas, sewer and water lines should be expected. Earthquakes may trigger fires, dam failures, landslides, or releases of hazardous material, compounding their disastrous effects.

Small, local faults produce lower magnitude quakes, but ground shaking can be strong, and damage can be significant in areas close to the fault. In contrast, large regional faults can generate earthquakes of great magnitudes but, because of their distance and depth, they may result in only moderate shaking in an area.

USGS ground motion maps based on current information about fault zones show the PGA that has a certain probability (2 or 10 percent) of being exceeded in a 50-year period. The PGA is measured in %g. Figure 6-10 shows the PGA with a 2 percent exceedance chance in 50 years in Washington.

Effects of a major earthquake in the Puget Sound basin area could be catastrophic, providing the worst-case disaster short of drought-induced wild fire sweeping through a suburban area. Hundreds of residents could be killed, and a multitude of others left homeless.

Although recorded damage sustained to date in Mason County has been relatively minor and has been restricted to some incidence of cracked foundations, walls and chimneys, and damage to private wells, depending on the time of day and time of year, a catastrophic earthquake could cause hundreds of injuries, deaths, and hundreds of thousands of dollars in property damage.

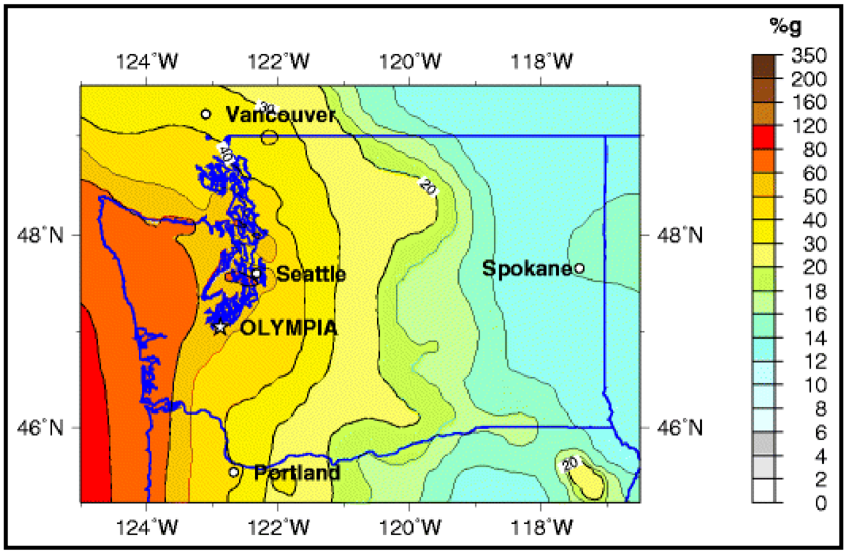

Figure 6-10 PGA with 2-Percent Probability of Exceedance in 50 Years, Northwest Region

6.2.4 Frequency

Scientists are currently developing methods to more accurately determine when an earthquake will occur. Recent advancements in determining the probability of an earthquake in a given period use a log-normal, Brownian Passage Time, or other probability distribution in which the probability of an event depends on the time since the last event. Such time-dependent models produce results broadly consistent with the elastic rebound theory of earthquakes. The USGS and others are beginning to develop such products as new geologic and seismic information regarding the dates of previous events along faults becomes more and more available (USGS, 2015a).

Scientists currently estimate that a Magnitude-9 earthquake in the Cascadia Subduction Zone occurs about once every 500 years. The last one was in 1700. Paleoseismic investigations have identified 41 Cascadia Subduction Zone interface earthquakes over the past 10,000 years, which corresponds to one earthquake about every 250 years. About half were M9.0 or greater earthquakes that represented full rupture of the fault zone from Northern California to British Columbia. The other half were M8+ earthquakes that ruptured only the southern portion of the subduction zone.

The 300+ years since the last major Cascadia Subduction Zone earthquake is longer than the average of about 250 years for M8 or greater and shorter than some of the intervals between M9.0 earthquakes.

Scientists currently estimate the frequency of deep earthquakes similar to the 1965 Magnitude-6.5 Seattle-Tacoma event and the 2001 Magnitude-6.8 Nisqually event as about once every 35 years. The USGS estimates an 84-percent chance of a Magnitude-6.5 or greater deep earthquake over the next 50 years.

Scientists estimate the approximate recurrence rate of a Magnitude-6.5 or greater earthquake anywhere on a shallow fault in the Puget Sound basin to be once in about 350 years. There have been four earthquakes of less than Magnitude 5 in the past 20 years.

Earthquakes on the Seattle Faults have a 2-percent probability of occurrence in 50 years. A Benioff zone earthquake has an 85 percent probability of occurrence in 50 years, making it the most likely of the three types.

6.3 VULNERABILITY ASSESSMENT

6.3.1 Overview

Several faults within the planning region have the potential to cause direct impact. The area also is vulnerable to impact from an event outside the County, although the intensity of ground motions diminishes with increasing distance from the epicenter. As a result, the entire population of the planning area is exposed to both direct and indirect impacts from earthquakes. The degree of direct impact (and exposure) is dependent on factors including the soil type on which homes are constructed, the proximity to fault location, the type of materials used to construct residences and facilities, etc. Indirect impacts are associated with elements such as the inability to evacuate the area as a result of earthquakes occurring in other regions of the state as well as impact on commodity flow for goods and services into the area, many of which are serviced only by one roadway in or out. Impact from other parts of the state could require shipment of supplies via a barge. Evacuation points of potential concern include:

- Landslides associated with an earthquake occurring along Highway 101 and
- Impact on State Route 3, which connects to Highway 101.

Warning Time

There is currently no reliable way to predict the day or month that an earthquake will occur at any given location. Research has developed warning systems that use the low energy waves that precede major earthquakes. These potential warning systems give approximately 40 seconds notice that a major earthquake is about to occur. 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. Mason County is a licensed operator for the USGS ShakeAlert® project. MyShake delivers ShakeAlert-powered alerts across California, Oregon, and Washington for magnitude 4.5 or greater quakes to users in the areas of light to severe shaking.

6.3.2 Impact on Life, Health, and Safety

The entire population of the planning area is potentially exposed to direct and indirect impacts from earthquakes. Two of the most vulnerable populations to a disaster incident such as this are the young and the elderly. Mason County has a fairly high population of retirees and individuals with disabilities, both higher than the state averages. The need for increased rescue efforts and/or to provide assistance to such a large population base could tax the first-responder resources in the area during an event. Although many injuries may not be life-threatening, people will require medical attention and, in many cases, hospitalization. Potential life-threatening injuries and fatalities are expected; these are likely to be at an increased level if an earthquake happens during the afternoon or early evening.

The degree of exposure is dependent on many factors, including the soil type their homes are constructed on, quality of construction, their proximity to fault location, etc. Whether impacted directly or indirectly, 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.

The number of people without power or water will be high, especially given the number of wells on which the County relies to supply water to individuals who most likely do not have generators to run pumps on the wells. This need will increase the number of individuals seeking shelter assistance.

For the 2023 update, due to structure and time constraints, and the relatively limited growth within the area (both population and structure), the Planning Team determined that the Hazus model runs for the various scenarios and probabilistic events developed in 2018 would be utilized for this update. As such, based on the 2018 Hazus outputs, analysis for the 100-year probabilistic earthquake indicates that 21 people will seek temporary shelters, while 31 households will be displaced due to the earthquake. Analysis for the 500-year probabilistic earthquake indicates that 207 people will seek temporary shelters, while 302 households will be displaced due to the earthquake. For the Cascadia M9.0 scenario, the model indicates that 155 households will be displaced, with 113 individuals seeking temporary shelter. It should be noted that the 100- and 500-year probabilistic events utilized Hazus 4.0. For the Cascadia event, Hazus 3.2 was utilized, which is presumed to be less accurate than Hazus 4.0. It is important to remember that these are planning numbers only based on impact to structures. In many instances, people will shelter with family and friends after such an event, and therefore the numbers may be significantly off.

6.3.3 Impact on Property

There are over 33,680 buildings in the planning area, with an estimated total replacement value over $4.0 billion. Most of the buildings are residential, and most of the building stock is of considerable age and not supported by building codes which increase resilience to seismic events. Portions of these buildings are constructed out of unreinforced masonry; many have chimneys that may be in need of repair, and many, because of the age of the building stock, may contain some level of asbestos in building components such as the boiler room, ceiling tiles, carpeting, or glue. Since all structures in the planning area are susceptible to earthquake impacts to varying degrees (including liquefaction and landslides), these figures represent total numbers region-wide for property exposure to seismic events.

Property losses were estimated through the analysis for the 100- and 500-year probabilistic events, as well as the Cascadia, Canyon River, and Nisqually earthquake scenarios events (utilizing the 2017 structure data, USGS/Washington State Department of Natural Resources scenario catalog data, and FEMA GIS datasets). A summary of the total potential building-related losses are identified below, and in Table 6-7. These figures represent structure loss only. It should be noted that in some instances, such as with pump houses, no separate content value is associated with the structures, as the structure value is inclusive of the mechanisms affixed to the ground within those structures.

TABLE 6-7 BUILDING STRUCTURE VALUES IMPACTED BY EARTHQUAKE SCENARIOS					
Community	**Total Estimated Building Value**	**Total Number of Buildings**	**Canyon River M7.4 Earthquake**	**Nisqually M7.2 Earthquake**	**Cascadia M9.0 Earthquake**
Unincorporated Mason County	$3.3B	25,632	$221.2M	$9.8M	$464.4M
Allyn	$158.5M	1,007	$3.0M	$175.0K	$9.6M
Belfair	$68.9M	456	$2.0M	$88.4K	$7.6M
City of Shelton	$422.7M	3,279	$11.4M	$460.3K	$74.0M
Skokomish Indian Reservation*	$36.5M	381	$5.7M	$121.7K	$7.0M
Total	$4.0B	30,755	$243.3M	$10.6M	$562.6M
*The Skokomish Tribe was not a participant in the planning process as they were developing their own plan simultaneous with the County's effort. Data incorporated in this assessment was derived from FEMA's Risk Map data. *Direct Economic and Social Losses utilize demographic and building square footage data to determine losses. In some instances, square footage of structures was estimated due to the lack of data. This deficiency is identified as a strategy for future plan updates.					

When reviewing analysis from the 100-year probabilistic event, Hazus estimates that 2,825 buildings will be at least moderately damaged. This is over 9.00 % of the buildings in the region. There are an estimated 34 buildings that will be damaged beyond repair.

When reviewing analysis from the 500-year probabilistic event, Hazus estimates that about 10,939 buildings will be at least moderately damaged. This is over 33.00 % of the buildings in the region. There are an estimated 1,278 buildings that will be damaged beyond repair.

For the Cascadia M9.0 event, Hazus estimates that about 8,268 buildings will be at least moderately damaged. This is over 25 % of the buildings in the region. There are an estimated 385 buildings that will be damaged beyond repair. Figure 6-11 illustrates FEMA's output based on the 2017 RiskMap project.

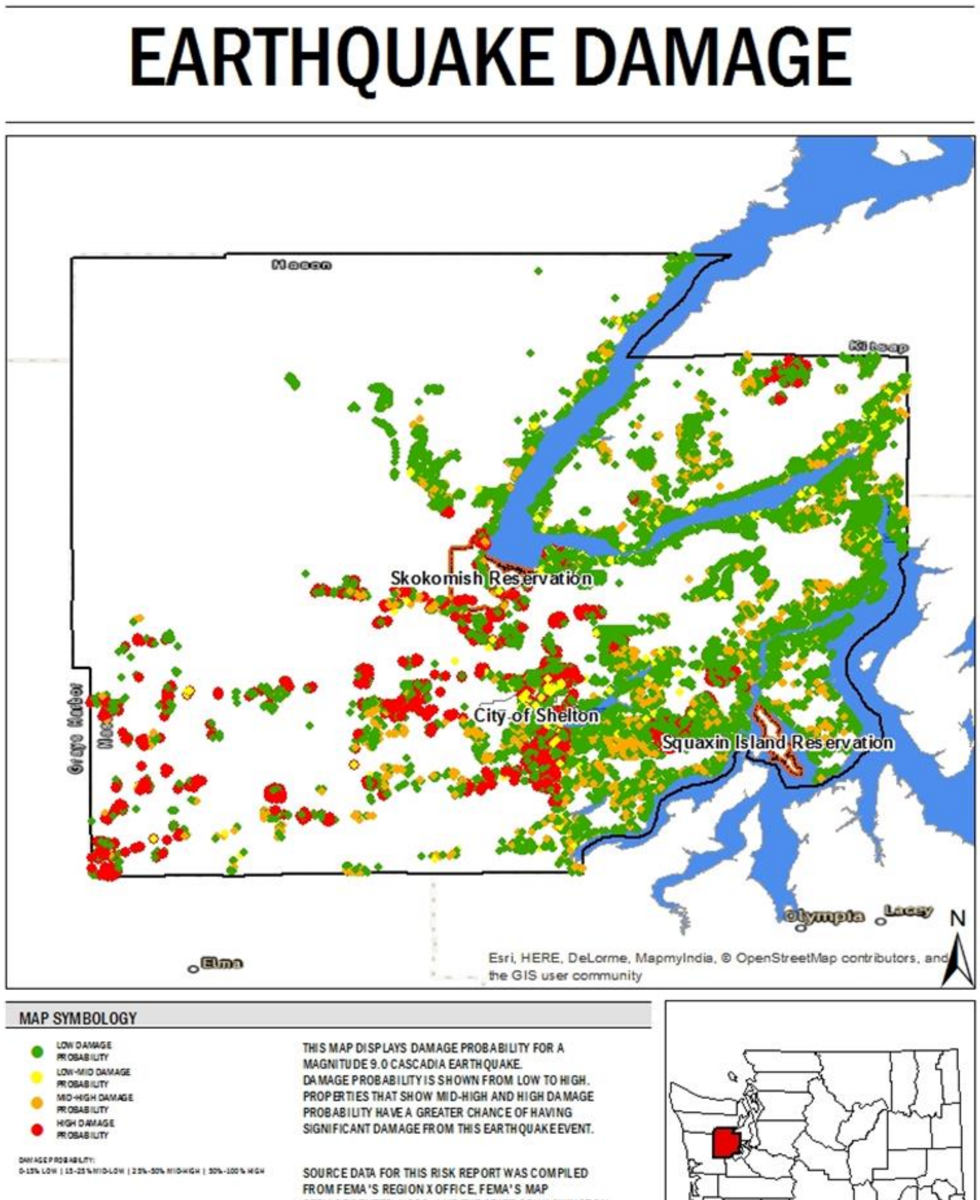

Figure 6-11 Mason County Earthquake Damage Based on M9.0 Cascadia Event (FEMA 2017)

Building Age

Structures that are in compliance with the Uniform Building Code (UBC) of 1970 or later are generally less vulnerable to seismic damage because 1970 was when the UBC started including seismic construction standards based on regional location. This stipulated that all structures be constructed to at least seismic risk Zone 2 standards.

The State of Washington adopted the UBC as its state building code in 1972, so it is assumed that buildings in the planning area built after 1972 were built in conformance with UBC seismic standards and have less vulnerability. Issues such as code enforcement and code compliance could impact this assumption. Construction material is also important when determining the potential risk to a structure. However, for planning purposes, establishing this line of demarcation can be an effective tool for estimating vulnerability. In 1994, seismic risk Zone 3 standards of the UBC went into effect in Washington, requiring all new construction to be capable of withstanding the effects of 0.3 g. More recent housing stock is in compliance with Zone 3 standards. In July 2004, the state again upgraded the building code to follow International Building Code Standards. While the "zones" are still referenced, they are, in large part, no longer used in the capacity they once were as there can be different zones within political subdivisions, making it difficult to apply. For instance, within Washington, there are both Seismic Zones 2B and 3. Table 6-7 further discusses the timelines of the various building code standards. Chapter 3, Section 3.6.3 discusses the age of the existing building stock in place as of this 2023 update.

Table 6-8
Timeline of Building Code Standards

Time Period	Code Significance for Identified Time Period
Pre-1974	No standardized earthquake requirements in building codes. Washington State law did not require the issuance of any building permits, or require actual building officials
1975-2003	UBC seismic construction standards were adopted in Washington.
1994-2003	Seismic Risk Zone 3 was established within the Uniform Building Code in 1994, requiring higher standards.
2004-Present	Washington State upgrades its building codes to follow the International Building Code Standard. As upgrades occur, the State continues to adopt said standards.

6.3.4 Impact on Critical Facilities and Infrastructure

All critical facilities in Mason County are exposed to the earthquake hazard. Additionally, hazardous materials releases can occur during an earthquake from fixed facilities or transportation-related incidents. Transportation corridors can be disrupted during an earthquake, leading to the release of materials to the surrounding environment. Facilities holding hazardous materials are of particular concern because of possible isolation of residences surrounding them. During an earthquake, structures storing these materials could rupture and leak into the surrounding area or an adjacent waterway, having a disastrous effect on the environment. As a portion of the county is a coastal community, this is of particular concern as spills into water bodies, including the coastline or significant rivers in the area, could have devastating impact. Additionally, the potential for landslide-induced roadway closure is of significant concern. Closure of major arterials could require increased evacuation periods in some instances by several hours.

Level of Damage

The Hazus model classifies the vulnerability of 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 selected occupancy types in the planning area except hazmat facilities and “other infrastructure” facilities, for which there are no established damage functions. The analysis (based on 2017 structure data) was performed for the 100- and 500-year probabilistic events. Those results are summarized in Table 6-9 and Table 6-10.

Table 6-9
Expected Building Damage By Occupancy From100-Year Probabilistic Earthquake

Category	No Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage
Agriculture	65	16	8	2	0
Commercial	698	180	122	32	4
Government Functions	28	7	4	1	0
Industrial	237	65	48	13	1
Other Residential	3,121	1,518	1,368	311	21
Single Family	19,545	4,549	835	28	8
Schools	30	7	5	1	0

Table 6-10
Expected Building Damage By Occupancy From 500-Year Probabilistic Earthquake

Category	No Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage
Agriculture	26	23	23	13	7
Commercial Functions	220	218	310	186	102
Government	9	8	12	8	4
Industrial	68	72	112	72	40
Other Residential	296	758	2,044	2,219	1,023
Single Family	10,779	9,488	4,245	361	82
Schools	11	10	12	7	4

Debris

The 2018 Hazus analysis also estimated the amount of earthquake-caused debris in the planning area for the various earthquake events as summarized in Table 6-11.

Table 6-11. Estimated Earthquake Caused Debris

Event	Amount of Debris to be Removed
100-Year Earthquake (M6)	28 million tons or 1,200 truckloads*
500- Year Probabilistic Earthquake (M6)	230 million tons or 9,200 truckloads*

Note: Values in this table are accurate only for purposes of comparison among results presented in this plan. Data limitations exist as defined. Analysis for the 100- and 500-year probabilistic events utilized Hazus 4.0; the Cascadia Shake Map was not updated to a useable format in Hazus 4.0 at the time the analysis was conducted, and therefore is not included in this table.

*Truck loads are determined for 25 tons/truck.

6.3.5 Impact on Economy

Economic losses due to earthquake damage include damage to buildings, including the cost of structural and non-structural damage, damage to contents, and loss of inventory, loss of wages and loss of income. Loss of tax base both from revenue and lack of improved land values will increase the economic loss to the County and its planning partners. In addition, loss of goods and services may hamper recovery efforts, and even preclude residents from rebuilding within the area. No specific loss data is available with respect to loss of inventory, wages, or loss of income; however, economic loss with respect to building impact is the same as identified above.

6.3.6 Impact on Environment

Earthquake-induced landslides can significantly impact 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.

6.3.7 Impact from 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. Sea level rise is not anticipated to impact the earthquake hazard, as the normal tidal flows mimic a similar increase.

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 these impacts.

6.4 FUTURE DEVELOPMENT TRENDS

Mason County continues to utilize the International Building Code, which requires structures to be built at a level which supports soil types and earthquake hazards (ground shaking). As existing buildings are renovated, provisions are in place which require reconstruction at higher standards.

6.5 ISSUES

While the area has a high probability of an earthquake event occurring within its boundaries, an earthquake does not necessarily have to occur in the planning area to have a significant impact as such an event would disrupt transportation to and from the region as a whole and impact commodity flow. As such, any seismic activity of 6.0 or greater on faults in or near the planning area would have significant impact. Potential warning systems could give approximately 40 seconds notice that a major earthquake is about to occur. This would provide limited time for preparation. Earthquakes of this magnitude or higher would lead to massive structural failure of property on NEHRP C, D, E, and F soils. Levees and revetments built on these poor soils would likely fail, representing a loss of critical infrastructure. These events could cause secondary hazards, including landslides and mudslides that would further damage structures. River valley hydraulic-fill sediment areas are also vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction would occur in water-saturated sands, silts, or gravelly soils.

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. Earthquakes at sea can generate destructive tsunamis. Important issues associated with an earthquake include, but are not limited to the following:

- More information is needed on the exposure and performance of construction within the planning area. Much information on the age, type of construction, or updated work on facilities is not readily available in a useable format for a risk assessment of this type.
- It is presently unknown to what standards portions of the planning area's building stock were constructed or renovated.
- Based on the modeling of critical facility performance for FEMA's 2017 RiskMap Report, a high number of facilities in the planning area are expected to have complete or extensive damage from scenario events. These facilities should be considered for structural retrofits.
- Geotechnical standards should continue to take into account the probable impacts from earthquakes in the design and construction of new or enhanced facilities.
- Dam failure warning, evacuation plans and procedures should be updated (and maintained) to reflect dam risk potential associated with earthquake activity in the

region, with said information being distributed to the County and its planning partners to allow for appropriate planning to occur.

- Earthquakes could trigger other natural hazard events such as a tsunami, which would have far-reaching impacts.

6.6 RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from an Earthquake throughout the area is highly likely. A Cascadia-type event, such as that utilized as one of the scenarios modeled for this update, has a high probability of occurring within the region, while also generating the largest amount of damage. The losses related to earthquake scenarios are largely due to the proximity to the faults. In addition, the Unincorporated Areas of Mason County have large percentage of buildings located in the moderate-high liquefaction zone. Due to the age of many buildings throughout the planning area, there are large amounts of pre-code structures. With the absence of building codes at time of construction, the structures would undoubtedly be impacted and perform poorly when compared to structures built after code implementation. Based on the potential impact, the Planning Team determined the CPRI score to be 3.6, with overall vulnerability determined to be a high level.

CHAPTER 7.
FLOOD

Floods are one of the most common natural hazards in the U.S. They can develop slowly over a period of days or develop quickly, with disastrous effects that can be local (impacting a neighborhood or community) or regional (affecting entire river basins, coastlines and multiple counties or states) (FEMA, 2010). Most communities in the U.S. have experienced some kind of flooding, after spring rains, heavy thunderstorms, coastal storms, or winter snow thaws. Floods are one of the most frequent and costly natural hazards in terms of human hardship and economic loss, particularly to communities that lie within flood-prone areas or floodplains of a major water source.

DEFINITIONS

Flood—The inundation of normally dry land resulting from the rising and overflowing of a body of water.

Floodplain—The land area along the sides of a river that becomes inundated with water during a flood.

100-Year Floodplain—The area flooded by a flood that has a 1-percent chance of being equaled or exceeded each year. This is a statistical average only; a 100-year flood can occur more than once in a short period of time. The 1-percent annual chance flood is the standard used by most federal and state agencies.

Floodway—The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

7.1 GENERAL BACKGROUND

Flooding is a general and temporary condition of partial or complete inundation on normally dry land from the following:

- Riverine flooding, including overflow from a river channel, flash floods, alluvial fan floods, dam-break floods, and ice jam floods;
- Local drainage or high groundwater levels;
- Fluctuating lake levels;
- Coastal flooding;
- Coastal erosion;
- Unusual and rapid accumulation or runoff of surface waters from any source;
- Mudflows (or mudslides);
- Collapse or subsidence of land along the shore of a lake or similar body of water that result in a flood, caused by erosion, waves or currents of water exceeding anticipated levels (Floodsmart.gov, 2012);
- Sea level rise;
- Climate Change.

7.1.1 Flooding Types

Many floods fall into one of three categories: riverine, coastal, or shallow (urban flooding) (FEMA, 2005). Other types of floods include alluvial fan floods, dam failure floods, and floods associated with local drainage or high groundwater. For this hazard mitigation plan and as deemed appropriate by the County, riverine/stormwater flooding are the main flood types of concern for the planning area.

Riverine

Riverine floods are the most common flood type. They occur along a channel, and include overbank and flash flooding. Channels are defined ground features that carry water through and out of a watershed. They may be called rivers, creeks, streams, or ditches. When a channel receives too much water, the excess water flows over its banks and inundates low-lying areas.

Flash Floods

A flash flood is a rapid, extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam). The time may vary in different areas. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising floodwaters (NWS, 2009).

Coastal Flooding

Coastal flooding is the flooding of normally dry, low-lying coastal land, primarily caused by severe weather events along the coast, estuaries, and adjoining rivers. These flood events are some of the more frequent, costly, and deadly hazards that can impact coastal communities. Factors causing coastal flooding include:

- Storm surges, which are rises in water level above the regular astronomical tide caused by a severe storm's wind, waves, and low atmospheric pressure. Storm surges are extremely dangerous, because they are capable of flooding large coastal areas.
- Large waves, whether driven by local winds or swell from distant storms, raise average coastal water levels and individual waves roll up over land.
- High tide levels are caused by normal variations in the astronomical tide cycle.
- Other larger scale regional and ocean scale variations are caused by seasonal heating and cooling and ocean dynamics.

Coastal floods are extremely dangerous, and the combination of tides, storm surge, and waves can cause severe damage. Coastal flooding is different from river flooding, which is generally caused by severe precipitation. Depending on the storm event, in the upper reaches of some tidal rivers, flooding from storm surge may be followed by river flooding from rain in the upland watershed. This increases the flood severity. Within the National Flood Insurance Flood Maps (discussed below), coastal flood zones identify special flood hazard areas (SFHA) which are subject to waves with heights of between 1.5 and 3 feet during a 1-percent annual chance storm (100-year event). Figure 7-1 illustrates the various SFHA zones.

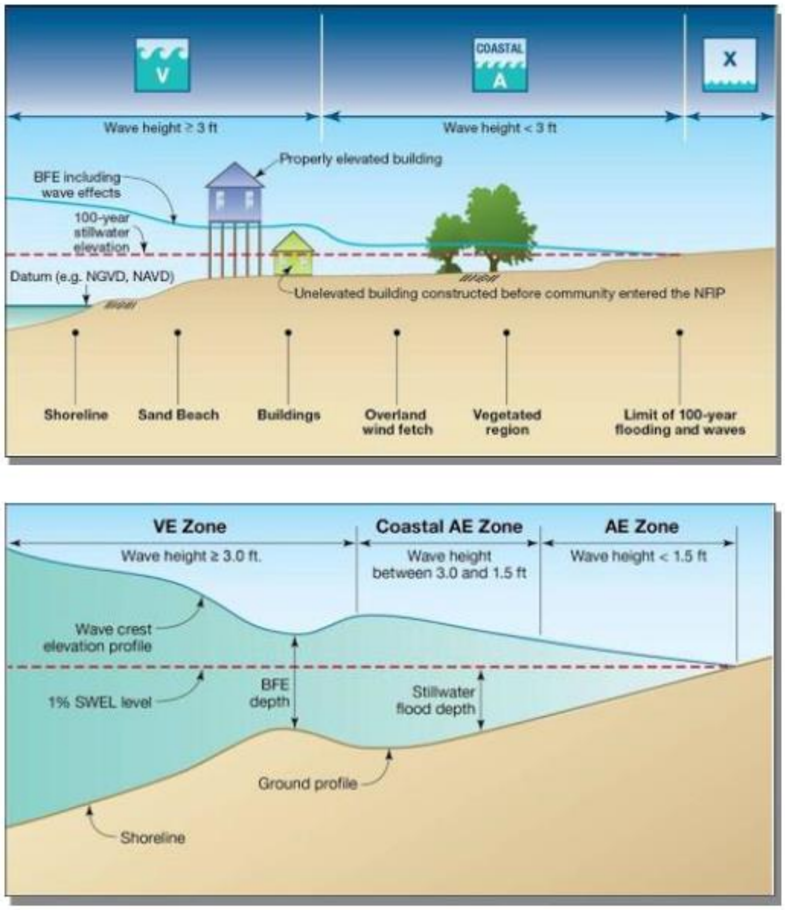

Figure 7-1 Schematic of Coastal Flood Zones within the National Flood Insurance Program

7.1.2 Dam Failure

Dam failures in the United States typically occur in one of four ways (Association of State Dam Safety Officials, 2012):

- 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 due to piping and seepage, 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. The most likely disaster-related causes of dam failure in Mason County are earthquakes.

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.

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.

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 provides reasonable 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. The DSO regulates dams with the sole purpose of reasonably securing public safety; environmental and natural resource issues are addressed by other state agencies. The DSO neither advocates nor opposes the construction and operation of dams.

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, 1997).

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. There are over 3,000 dams that 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 staff 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 engineer approved by the FERC must inspect and evaluate projects with dams higher than 32.8 feet, or with a total storage capacity of more than 2,000 acre-feet.

FERC staff monitors and evaluates seismic research and applies it in investigating and performing structural analyses of hydroelectric projects. FERC staff also evaluates the effects of potential and actual large floods on the safety of dams. During and following floods, FERC staff 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.

The 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.

Hazard Ratings

The DSO classifies dams and reservoirs in a hazard rating system based solely on the potential consequences to downstream life and property that would result from a failure of the dam and sudden release of water. The following codes are used as an index of the potential consequences in the downstream valley if the dam were to fail and release the reservoir water:

- 1A = Greater than 300 lives at risk (High hazard);
- 1B = From 31 to 300 lives at risk (High hazard);
- 1C = From 7 to 30 lives at risk (High hazard);
- 2 = From 1 to 6 lives at risk (Significant hazard);
- 3 = No lives at risk (Low hazard).

The Corps of Engineers developed the hazard classification system for dam failures shown in Table 7-1. The Washington and Corps of Engineers hazard rating systems are both based only on the potential consequences of a dam failure; neither system takes into account the probability of such failures.

Table 7-1
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

As of 2023, Mason County has 23 dams within its boundaries identified by the Washington State Department of Ecology Dam Safety Program. That is an increase in one dam since completion of the last pan, the North Ranch Storage Lagoon, a Class 2 dam, owned by Bio-Recycling Corp. The 23 dams within the county are illustrated in Figure 7-2.[4] The entire list is available for review at the Washington State Department of Ecology's website at Inventory of Dams Report for Selected Washington Counties and Selected Dam Hazard Categories.

Based on review of the data, Mason County has eight (8) high hazard dams (one being the spillway head for Cushman Dam) within its boundary. One of those high-hazard dams is owned by the County, the Mason County Belfair Wastewater Treatment Plant Water Storage facility. The County also owns

[4] https://fortress.wa.gov/ecy/publications/documents/94016.pdf

one Hazard Class 2 dam – the North Bay Water Reclamation Pond, and one Hazard Class 3 dam – the Haven Lake Dam on the Tahuya River.

The dams are utilized for many different purposes, and in most cases serve several functions. Of the 23 dams in the county:

- 17 are utilized for recreational purposes
- two for hydro-electric generation
- three for flood control purposes
- two for fish and wildlife protection, and
- three for water quality purposes.

The surface area measured for the dams encompasses the reservoirs at their normal operating levels. Combined, there are in excess of 5,175 acres of surface area protected by the dams, with the Cushman Dam No. 1 being the largest, at 4,010 acres. In addition to the normal surface area, there is an additional 240 square miles of downstream drainage area, which is the combined area of the tributary watershed and the reservoir surface that can contribute runoff to the dam and reservoir.

Inundation

The owner of a dam is responsible for developing an inundation map, which is used in determining exposure to a potential dam failure or breech during development of dam response plans. As of this 2023 update, limited data is available for public use for many of the dams in Mason County.

Mason County does have two FERC regulated hydro dams within its boundaries which are owned by the City of Tacoma, both of which are high-hazard dams (Cushman 1 and 2). In addition, it also has the Cushman Dam spillway, which is also considered a high-hazard dam. Inundation maps are not available for those dams.

Two dams owned by Mason County - the Belfair Water Reclamation Facility Dam (Hazard Class 2E) and the North Bay/Case Inlet Water Reclamation Facility Dam (Hazard Class 2E) maintain Emergency Action Plans (EAP). Review of the EAPs indicate that there are approximately 16 parcels at risk (depth unknown) for the Belfair Facility. Review of the North Bay/Case Inlet EAP indicates there is no inundation impact should the dam fail.

For the remaining dams, it is not possible to estimate the population living within the inundation zone beyond the information designated in the dam classification analysis. Based on the dam classification category identified above (e.g., high, significant or low hazard), were failure of all dams to occur, the potential lives at risk is in excess of 1,600 individuals. This number would be dependent on the level of failure or breach. This number also does not take into account the actual number of structures in place, nor the number of individuals living in or making use of those structures.

Without the ability to perform an inundation study, it is not possible to estimate property losses from a dam failure which could ultimately affect the planning area. In some instances, however, dam inundation areas may coincide with flood hazard areas. Further review of the flood profile may provide a general concept of structures at risk, although, based on the size of the dams, damage would vary. As development occurs downstream of dams, it is necessary to review the dams' emergency action plans and inundation maps to determine whether the dams require reclassification based on the established standards. The County and its planning partners will continue to work with dam owners in the area to gain information for high-hazard dams.

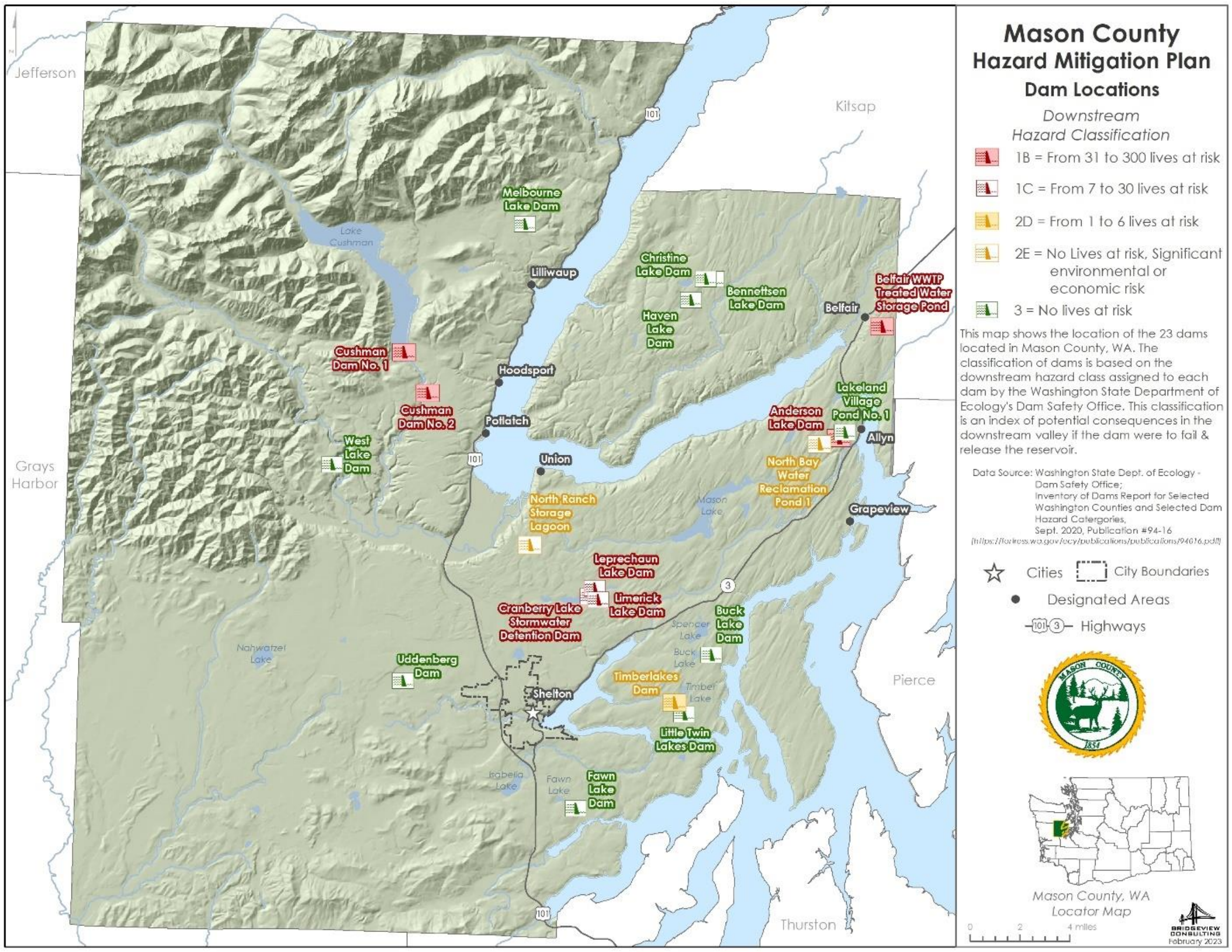

Figure 7-2 Select Mason County Dams and Hazard Classification

7.1.3 Measuring Floods and Floodplains

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.

In the case of riverine or flash flooding, once a river reaches flood stage, the flood extent or severity categories used by the NWS include minor flooding, moderate flooding, and major flooding. Each category has a definition based on property damage and public threat (NWS, 2011):

- Minor Flooding—Minimal or no property damage, but possibly some public threat or inconvenience.
- Moderate Flooding—Some inundation of structures and roads near streams. Some evacuations of people and/or transfer of property to higher elevations are necessary.
- Major Flooding—Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations.

7.1.4 Flood Insurance Rate Maps

According to FEMA, flood hazard areas are defined as areas that are shown to be inundated by a flood of a given magnitude on a map (see Figure 7-3). These areas are determined using statistical analyses of records of river flow, storm tides, and rainfall; information obtained through consultation with the community; floodplain topographic surveys; and hydrologic and hydraulic analyses. Three primary areas make up the flood hazard area: the floodplains, floodways, and floodway fringes. Figure 7-4 depicts the relationship among the various designations, collectively referred to as the special flood hazard area.

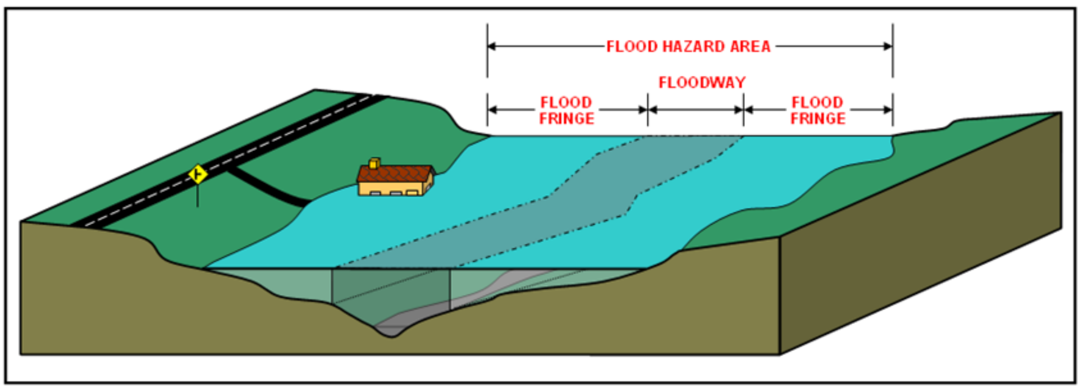

Figure 7-3 Flood Hazard Area Referred to as a Floodplain

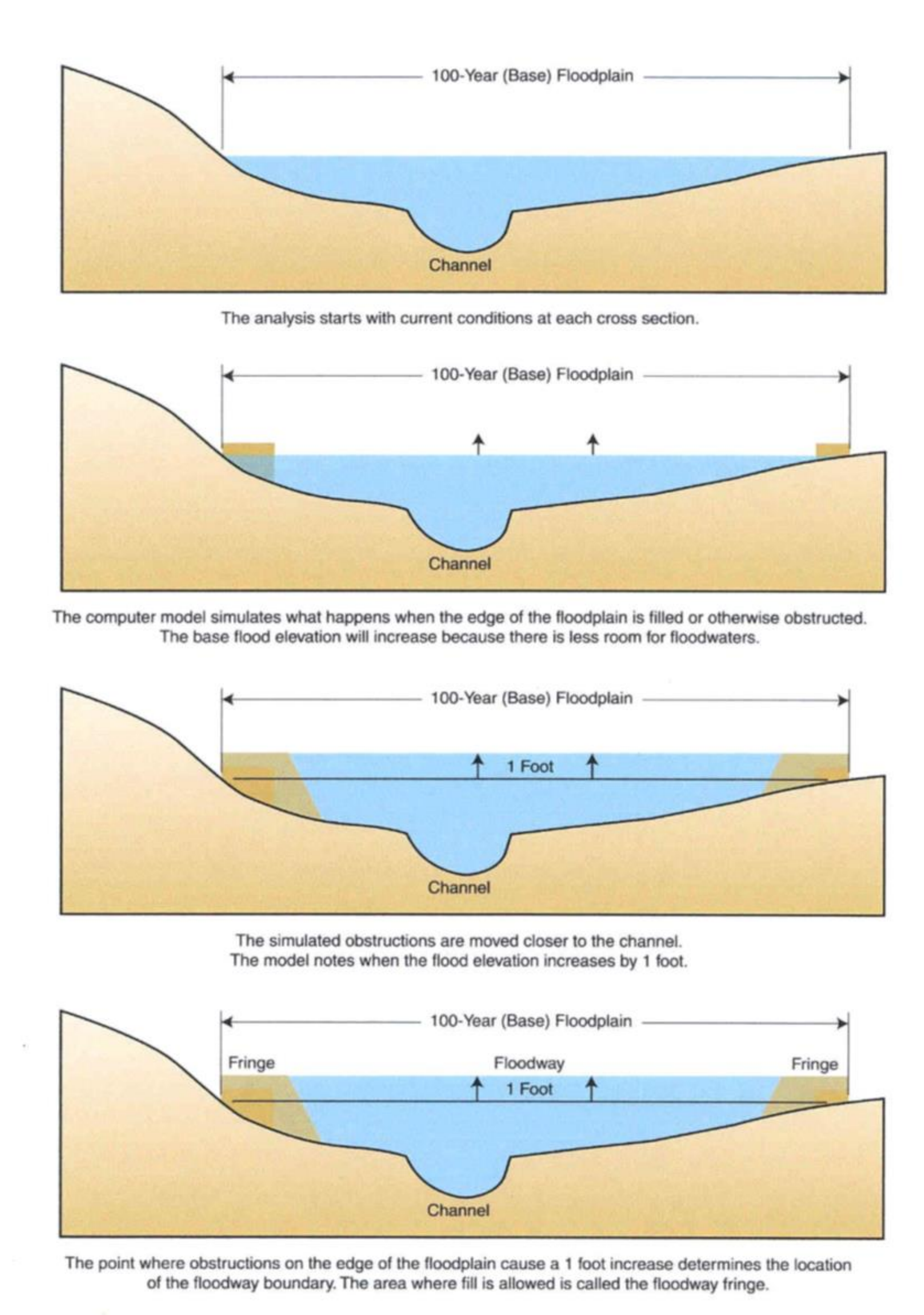

Figure 7-4 Special Flood Hazard Area

Flood hazard areas are delineated on FEMA's Flood Insurance Rate Maps (FIRM), which are official maps of a community on which the Federal Insurance and Mitigation Administration has indicated both the special flood hazard areas and the risk premium zones applicable to the community. These maps identify the special flood hazard areas; the location of a specific property in relation to the special flood hazard area; the base (100-year) flood elevation at a specific site; the magnitude of a flood hazard in a specific area; and undeveloped coastal barriers where flood insurance is not available. The maps also locate regulatory floodways and floodplain boundaries—the 100-year and 500-year floodplain boundaries (FEMA, 2003; FEMA, 2005; FEMA, 2008).

The frequency and severity of flooding are measured using a discharge probability, which is a statistical tool used to define the probability that a certain river discharge (flow) level will be equaled or exceeded within a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels.

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.

A structure located within a 1 percent (100-year) floodplain has a 26 percent chance of suffering flood damage during the term of a 30-year mortgage. The 100-year flood is a regulatory standard used by federal agencies and most states to administer floodplain management programs. The 1 percent (100-year) annual chance flood is used by the NFIP as the basis for insurance requirements nationwide. FIRMs also depict 500-year flood designations, which is a boundary of the flood that has a 0.2-percent chance of being equaled or exceeded in any given year. It is important to recognize, however, that flood events and flood risk are not limited to the NFIP delineated flood hazard areas.

7.1.5 National Flood Insurance Program (NFIP)

The NFIP is a federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for state and community floodplain management regulations that reduce future flood damage. The U.S. Congress established the NFIP with the passage of the National Flood Insurance Act of 1968 (FEMA's 2002 *National Flood Insurance Program (NFIP): Program Description*). There are three components to the NFIP: flood insurance, floodplain management and flood hazard mapping. Nearly 20,000 communities across the U.S. and its territories participate in the NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage. In exchange, the NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in these communities. Community participation in the NFIP is voluntary.

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 100- and 500-year 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 for many communities they represent the minimum area of oversight under their floodplain management program.

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

- New buildings and those undergoing substantial improvements must, at a minimum, be elevated to protect against damage by the 100-year 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 threatened salmonid species.

NFIP Status and Severe Loss/Repetitive Loss Properties

Mason County is a member in good standing in the NFIP, and does incorporate regulatory authority within its land use planning. Table 7-2 presents the NFIP policy status as of January 31, 2017. Table 7-3 illustrates the number of policies in force in 2022 (last full year of reporting).

Comparison of the 2017 data to that of 2023 shows a reduced number of policies for both the County and the City of Shelton. For the County, coverage fell by 53 policies from 421 to 368, a loss of approximately 14 percent. Insurance in force rose slightly, which would demonstrate the increased cost in real estate values, particularly since the premiums in force fell. The City of Shelton lost approximately 55 percent of their policies in force, falling from 22 in 2017 to 10 in 2022.

Table 7-2
NFIP Insurance Policies in Force in 2017

Community Name	Policies In-Force	Insurance In-Force	Premiums In-Force
Mason County	421	100,439,800	412,997
Shelton, City of	22	4,157,000	37,590
Skokomish Indian Tribe	5	1,387,800	11,076

Source: FEMA NFIP Policy Information (2017)

Table 7-3
NFIP Insurance Policies in Force in 2022

Community Name	Policies In-Force	Insurance In-Force	Premiums In-Force
Mason County	368	$108,073,600	$273,853
Shelton, City of	10	$3,194,000	$12,876
Skokomish Indian Tribe	7	$4,102,600	$26,698

Source: FEMA NFIP Policy Information (November 2022) (Most current data available as of update.)

Repetitive Flood Claims

Residential or non-residential (commercial) properties that have received one or more NFIP insurance payments are identified as repetitive flood properties under the NFIP. Such properties are eligible for funding to help mitigate the impacts of flooding through various FEMA programs, subject to meeting certain criteria and based on the State's Hazard Mitigation Plan maintaining a Repetitive Loss Strategy. Washington State's 2018 Hazard Mitigation Plan does contain such a strategy. Specifically, the Repetitive Loss Strategy must identify the specific actions the State has taken to reduce the number of repetitive loss properties, which must include severe repetitive loss properties, and specify how the State intends to reduce the number of such repetitive loss properties. In addition, the hazard mitigation plan must describe the State's strategy to ensure that local jurisdictions with severe repetitive loss properties take actions to reduce the number of these properties, including the development of local hazard mitigation plans.

Repetitive flood claims provide funding to reduce or eliminate the long-term risk of flood damage to structures insured under the NFIP that have had one or more claim payments for flood damages.

Severe Repetitive Loss Program

The severe repetitive loss program is authorized by Section 1361A of the National Flood Insurance Act (42 U.S.C. 4102a), with the goal of reducing flood damages to residential properties that have experienced *severe* repetitive losses under flood insurance coverage and that will result in the greatest savings to the NFIP in the shortest period of time. A severe repetitive loss property is a residential property that is covered under an NFIP flood insurance policy and:

- a) That has at least four NFIP claim payments (including building and contents) over $5,000 each, and the cumulative amount of such claims payments exceeds $20,000; or
- b) For which at least two separate claims payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building.

For both (a) and (b) above, at least two of the referenced claims must have occurred within any 10-year period, and must be greater than 10 days apart.

The Community Rating System

The Community Rating System (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.

Flood claim, repetitive loss, and severe repetitive loss property data is indicated in Table 7-4[5], which also identifies the CRS Community Status in the County. At present, the planning partnership does not feel the level of effort to become a CRS community is warranted, nor within the capacity of the present staffing levels to facility such an endeavor.

[5] Data reflected is from 2016. Updated data was requested multiple times from multiple sources at the State during this update process, but no data was provided. The data is not publicly available. As such, information presented serves as the best available information as of this update.

Table 7-4 (Table pending update of data from FEMA/State)
Community Status and Claims

Community Name	CRS Community	Flood Claims	Total Losses Paid	Repetitive Loss Properties*	Severe Repetitive Loss (SRL) Properties *	(SRL) Losses Paid
City of Shelton	N	8	$133K	3	2	$185K
Unincorporated Areas of County	N	192	$3.7M	27	1	$82K
Squaxin Island Tribe	N	--	--	--	--	--
Skokomish Indian Tribe	N	1	<$1K	1		
TOTAL	**--**	**201**	**$3.8M**	**30**	**3**	**$267K**

Note: Repetitive Loss (12/2016) and Severe Repetitive Loss Data (2/2016) from State and FEMA sources (variations exist, but worst-case scenario presented); Population data obtained from 2015 US Census Bureau. Unincorporated County population statistics were calculated by subtracting the populations of the City of Shelton, the Squaxin Island Reservation, and the Skokomish Indian Reservation from Mason County (FEMA Risk Report). *= Residential Structures.

7.2 HAZARD PROFILE

7.2.1 Extent and Location

Flooding is the most common hazard occurring in Mason County, and is mostly due to riverine and urban flooding. Riverine flooding is seen on all main rivers and tributaries in the rural portions of the county. Urban flooding generally occurs within the boundaries of the City of Shelton, and the Belfair and Allyn urban growth areas. In addition, the County is also subject to coastal flooding.

FEMA Flood Maps

FEMA performed a new flood study for Mason County that resulted in the creation of new flood maps in March 2017, and adopted by the County thereafter. The project updated flood modeling along the Mason County coastline, as well as multiple riverine and lake analyses throughout the county. In addition to FIRMs, FEMA also developed the flood risk assessment products used in their Risk Report, which supports much of the flood data utilized throughout this HMP update.

Mason County's 100- and 500-year flood areas are illustrated in Figure 7-5. It should be noted that only a very small area, or 0.3863 square miles of land fall within the 500-year flood hazard area based on FEMA's FIRMs.

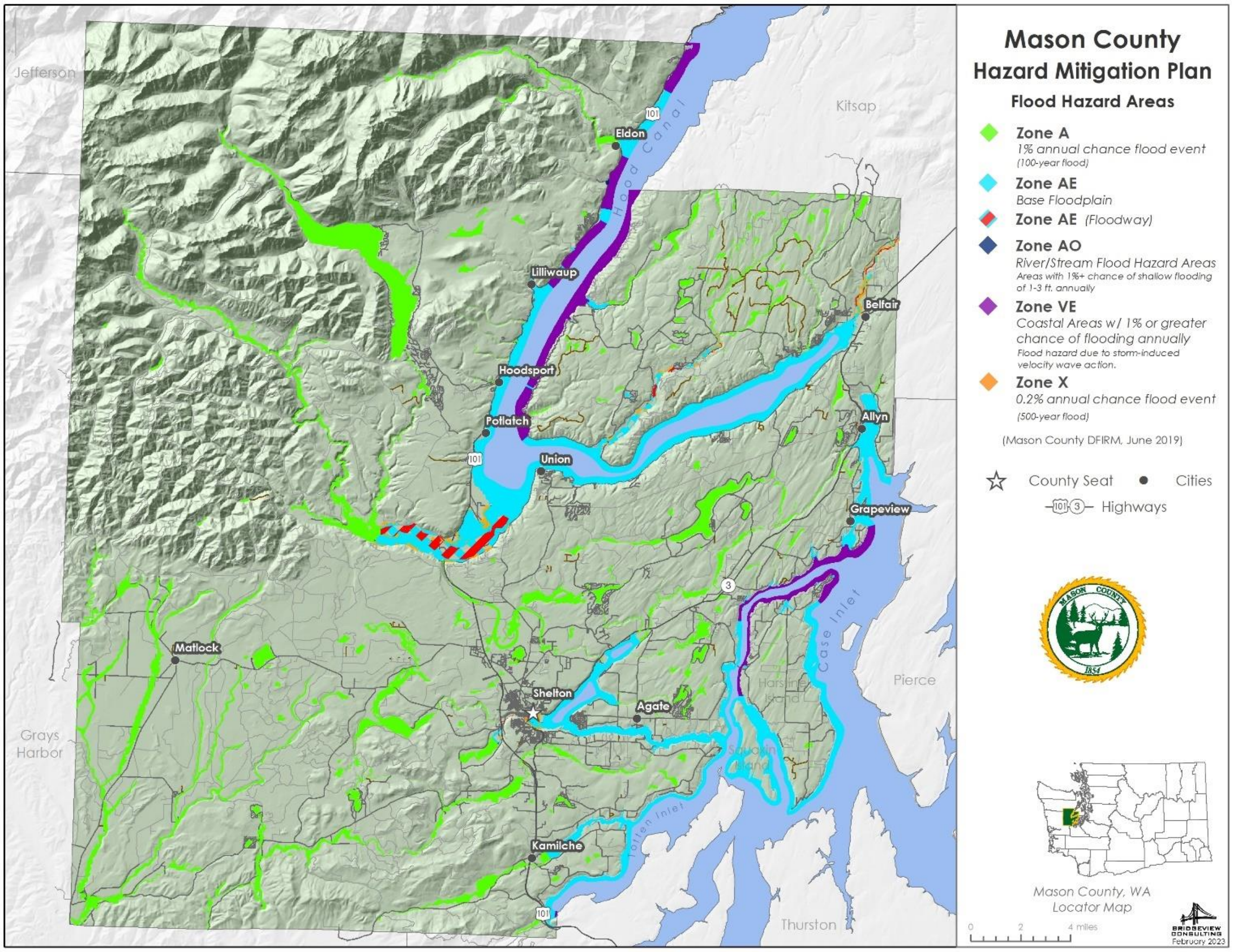

Figure 7-5 Mason County 100-and 500-Year Flood Hazard Areas

As a result of the FIRMS, FEMA developed depth grids for the 1-percent-annual-chance flood for the coastal and riverine areas, as well as 2-percent and 0.2-percent-annual-chance flood depth grids for Union River, Tahuya River, Coffee Creek, and Goldsborough Creek. FEMA also generated the depth grids from the flood model, which show the level of flooding in feet. The project team used the depth grids in the risk assessment to determine which properties are affected by flooding. The 1-percent-annual-chance depth grid for the City of Shelton area is shown Figure 7-6. Detailed information containing all data in the report is available for download from FEMA's website, or available for viewing from the County's Floodplain Manager.

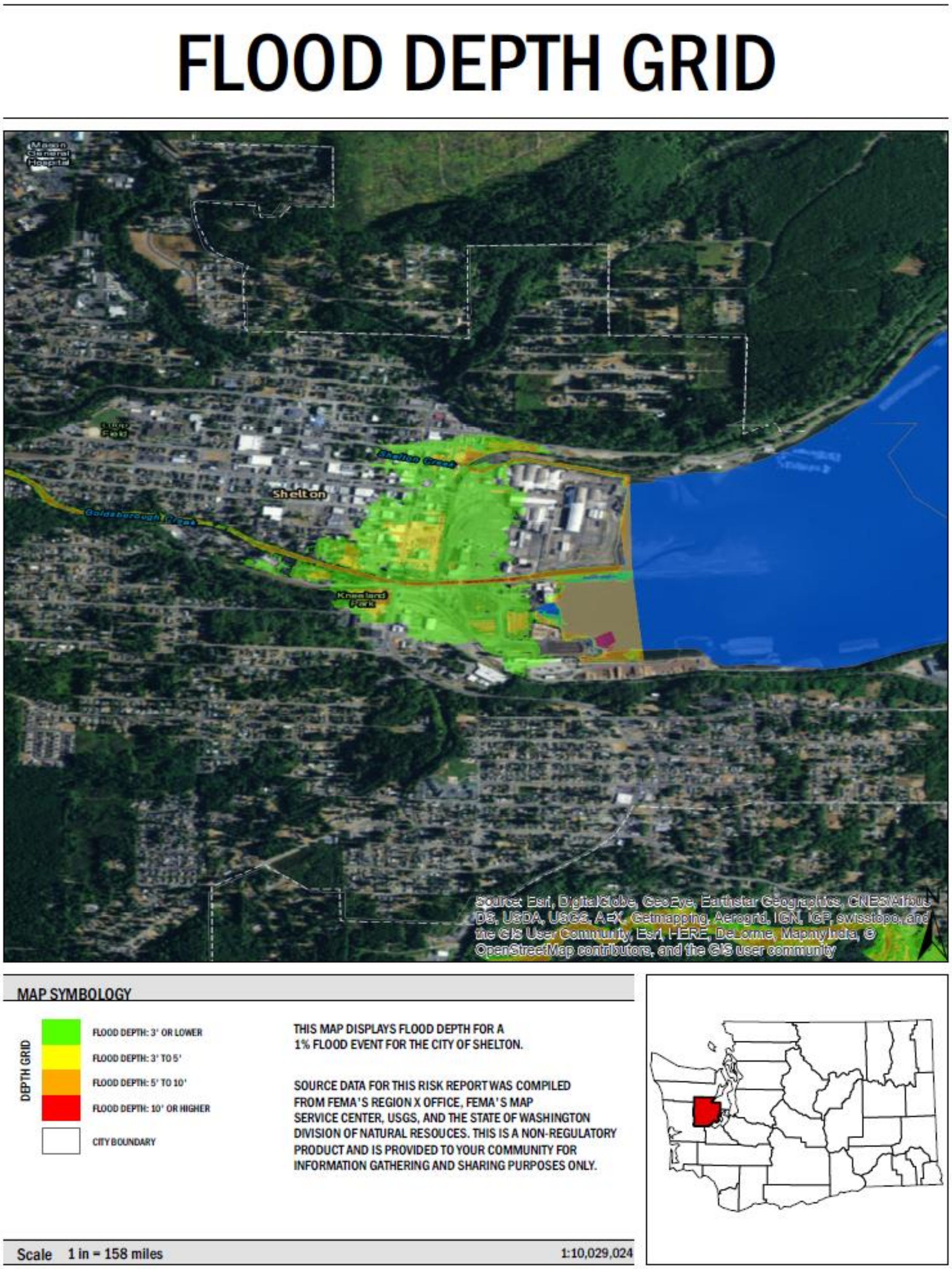

Figure 7-6 100-Year Flood Hazard Depth Grid for the City of Shelton (FEMA 2017 Risk Report)

Principal Flooding Sources

Most flooding in Mason County is due to river and urban flooding. Riverine flooding is seen on all main rivers and tributaries in the rural portions of the county. Urban flooding generally occurs within the boundaries of the Shelton, Belfair, and Allyn urban growth areas.

Principal flooding sources in Mason County are influenced by several rivers, including the Satsop, Tahuya, Union, and Skokomish Rivers. Flooding in the first three rivers can effectively cut off pockets of residents due to mudslides and water over the roadways. The primary flood concern in Mason County is the Skokomish River. While previous flooding on the Skokomish River regularly caused closure of U. S. Highway 101, the main north-south route through Mason County, since completion of the last plan, that flooding was alleviated by improvements done to the Purdy Creek Bridge by WSDOT, and the removal of the Nally Farm dike. However, flooding does continue to close the Skokomish Valley Road and Bourgault Road several times annually.

The Skokomish River Basin, located on the Great Bend of Hood Canal, is a natural fjord-like arm of the Puget Sound and water of national significance identified by the U.S. Environmental Protection Agency (EPA).

The Skokomish River is the largest source of freshwater to Hood Canal and of critical importance to the overall health of Hood Canal, draining approximately 240 square miles of forested terrain into Hood Canal. According to a 2015 study conducted by the US Army Corps of Engineers (USACE), the ecosystem in the Skokomish River Basin, which includes the Skokomish Indian Reservation, has been significantly degraded, with high sediment load, reduced flows, and encroachment on the floodplain by human-made structures causing continued degradation of natural ecosystem structures, functions, and processes throughout the basin. Channel capacity of the mainstem and South Fork Skokomish Rivers, as well as Vance Creek have been significantly reduced due to sediment accumulation. The mainstem has lost about 10,000 cfs of flow capacity since 1941 (USACE, 2015, p. 77). Aggradation is suspected to have been occurring since 1912 as a result of flooding evidence experienced at that time. During storms, gravel eroded from landslides deposits and is transported to lower channels as bedload. As floodwaters recede, the streams and rivers do not have enough stream energy to transport the bedload, causing accumulation in channels, increasing the level of floodwaters over the banks due to lower stream capacity. Over the course of time, this has, and will continue to increase flooding both in frequency and size in the area. But one example is the December 2007 storm event, which impacted several small creeks along US Highway 101 between Hoodsport and Lilliwaup that previously had not had a significant documented history of flooding. These creeks include Finch, Clark, Miller, and Sund Creeks (see Figure 7-7 below).

Areas of the Tahuya Peninsula have been severely impacted by flooding from both the Tahuya and Union Rivers, in addition to the majority of the smaller creeks. Incidents such as the December 2007 severe storm event impacted several small creeks along US Highway 101 between Hoodsport and Lilliwaup. The December 2007 storm event resulted in large quantities of alluvial material being deposited in the lower stream reaches. These streams now exhibit significant aggradation, which has elevated the streambeds and consequently will likely continue to cause flooding. Finch Creek experienced severe bank erosion. At least six property owners required bank armoring in order to protect homes and septic systems. Several homes in the Holiday Beach area (Miller Creek) also experienced flooding.

Tidal changes from Hood Canal combined with increased runoff from the Olympics have also exacerbated the frequency of flooding in Mason County. The December 2022 King Tide event caused significant flooding issues within the County as a whole, with reports of damage and flooding from several areas of the county.

One of the hardest hit areas fell within North Mason Fire Authority (see cover photo). The King Tides did extensive damage to numerous homes along the North Shore and South Shore of the Hood Canal. Rain caused water tributaries to back up and flood numerous residences along both shores. In addition, the high tides over-topped numerous beachfront bulkheads, flooding and eroding yards as well as homes. The Fire Authority estimated the number of homes impacted to be in excess of 50, with the estimate of homes significantly impacted by flood damage to be in excess of 20. Two families on the Southshore were trapped in their homes due to the rising flood waters and required Fire Authority rescue/evacuation. The Union River also swelled, making vehicle passage on Highway 300 impossible. Several cars attempted to travel through the flood waters but were unable to maneuver through the floodwaters. Two vehicle owners required Fire Authority assistance for evacuation from their cars.

Figure 7-7 Finch, Clark, Miller and Sund Creeks

7.2.2 Previous Occurrences

Major floods in the planning area have resulted from intense rainstorms customarily between October and April. In addition to events discussed above, Table 7-5 highlights some of the historical flood events occurring in the area. It should be noted that due to the disaster typing which occurs at the FEMA level, there are other types of events which also include flooding, but due to the typing, those are not referenced within this chapter. Specific examples of this include Severe Weather events which include flooding as a hazard of impact. Viewers should also review the Severe Weather hazard profile for additional information.

Table 7-5
Flood Events Impacting Planning Area 1956-2016

Disaster Number	Declaration Date	Disaster Type	Incident Type	Title	Incident Begin Date	Incident End Date	PA Dollars Obligated or Losses (State)
4539	4/23/2020	DR	Flood	Severe Storm, Flooding, Landslides, and Mudslides	1/20/2020	2/10/2020	$10.6M statewide
Several days of heavy rain in January 20, 2020 resulted in widespread flooding of roadways, homes, and property. On April 23, 2020, a Federal disaster aid was made available to the State of Washington to supplement state, tribal, and local recovery efforts in the Mason County and other areas affected by the flooding.							
4253	2/2/2016	DR	Flood	Severe Winter Storm, Straight-Line Winds, Flooding, Landslides, and Tornado	12/1/2015	12/14/2015	$3,166,346
Several days of heavy rain in December 2015 resulted in widespread flooding of roadways, homes, and property. On February 2, 2016, Federal disaster aid was made available to the State of Washington to supplement state, tribal, and local recovery efforts in the Mason County and other areas affected by the flooding.							
1817	1/30/2009	DR	Flood	Severe Winter Storm, Landslides, Mudslides, & Flooding	1/6/2009	1/16/2009	
January 2009- Washington State was hit with severe winter storms that brought heavy rains and warmer temperatures, resulting in snow melting causing flooding, land- and mudslides. ~12 county roads were impacted by flooding; three homes were destroyed; two had major damage; three had minor damage; and 12 more were affected. Costs for damages due to flooding were estimated at $750,000. Mason County received $65,000 of HMGP funds to update their HMP.							
1172	4/2/1997	DR	Flood	Heavy Rains, Snow Melt, Flooding, Land Slides	3/18/1997	3/28/1997	$50,889,413
A week of torrential rain in late March 1997 created flooding and landslides in multiple places in Washington State. In Mason County, multiple roads were closed and five homes were posted for evacuation.							
883	11/26/1990	DR	Flood	Severe Storms & Flooding	11/9/1990	12/20/1990	$2.9 million
Two individuals died as a result of this incident statewide. Over the Thanksgiving weekend, between 8 and 15 inches of rain fell. County road damage, including replacement costs for a bridge over Mission Creek, totaled $260,000. Several homes were extensively damaged in the Skokomish Valley and two homes were uninhabitable. Twenty-five people were evacuated from the Skokomish Valley. Highways and roads were closed. Residents lost power. On November 26, 1990, Federal disaster aid was made available. Mason County received $754,238 of HMGP funds for the East Bourgault Road area property acquisition project.							
612	12/31/1979	DR	Flood	Storms, High Tides, Mudslides & Flooding	12/31/1979	12/31/1979	
Heavy rains and snowmelt caused floods, mudslides, and road washouts. Twenty-eight Skokomish Valley residents were evacuated. Damage to county roads was estimated at $375,000 to $515,000 and damage to other property was estimated at $160,000.							

Table 7-5 Flood Events Impacting Planning Area 1956-2016							
492	12/13/1975	DR	Flood	Severe Storms & Flooding	12/13/1975	12/13/1975	
Damage to county roads totaled ~ $185,000. Flooding in Skokomish Valley damaged a number of levees. Numerous residences had water damage. Several persons were evacuated from their homes by boat. The total estimate of damage to private and farm land was $300,000.							
414	1/25/1974	DR	Flood	Severe Storms, Snowmelt & Flooding	1/25/1974	1/25/1974	Unknown
Impacts included roadway closures resulting from flooding and landslides in the area.							
185	12/29/1964	DR	Flood	Heavy Rains & Flooding	12/29/1964	12/29/1964	
In December 1964, snow and heavy rains caused slides and run-off knocking two houses 12 feet off of their foundations, covering half of Hwy 21 above Alderbrook. One house was unoccupied. The other residents were not injured. Slides and running water closed the Purdy Cut-Off Road. Snow accumulation amounted to 20 inches in Union and Hoodsport areas, 19 inches at Lilliwaup, 16 inches at Dayton, 20 inches in the Matlock area, and 36 inches at the upper end of Lake Cushman. Shelton, Kamilche, and Mary M. Knight schools were closed for 1 day. Falling branches and the weight of the snow caused numerous power outages. Numerous reports were received of roofs of barns, sheds, carports, and garages collapsing under the weight of the snow. Snow (4 ½ feet deep) closed logging operations at Camps Grisdale and Govey. Dairymen in the Skokomish Valley couldn't operate milking machines or water cattle due to power outages. At the height of the storm only 150 of the 1600 PUD customers had electricity. Cost of the storm damage was estimated between $25,000 and $30,000.							

7.2.3 Severity

The severity of a flood depends not only on the amount of water that accumulates in a period of time, but also on the land's ability to manage this water. One element is the size of rivers and streams in an area; but an equally important factor is the land's absorbency. When it rains, soil acts as a sponge. When the land is saturated or frozen, infiltration into the ground slows and any more water that accumulates must flow as runoff (Harris, 2001).

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. Figure 7-8 and Figure 7-9 illustrates the December 3, 2007 Severe Storm event (DR-1734), when U.S. Highway 101 was inundated due to approximately four feet of floodwaters crossing the roadway.

These types of incidents indicate that more areas are becoming prone to flooding. As of 2017, there are approximately 58.67 square miles of land within the 100-year and 0.3863 sq. miles of land within the 500-year flood hazard areas based on the identified flood hazard area within the 2017 FIRMs. In 2010, during the last HMP update process, there were approximately 23 square miles of land within the flood hazard area.

One of the County's identified action items in the 2010 plan was to work with the USGS and other agencies to install river gauges or other technology on rivers other than the Skokomish. The County is aware of a number of repetitive flood loss properties within the Tahuya River watershed, but without accurate frequency determinations it is extremely difficult to develop cost-effective mitigation solutions. The County itself has installed additional gauges on the Skokomish since completion of the 2018 plan. This 2010 project was brought forward to the 2018 plan update, and will remain as a strategy in this 2023 update.

7.2.4 Frequency

Mason County experiences some level of flooding on an annual basis. What customarily constituted the "normal" flood season of October through April in Western Washington does not necessarily apply to the Skokomish River, which has received Flood Warnings issued by the National Weather Service during the month of July.

Large floods that have caused property damage have occurred 10 times during the time period 1956 through 2022, with the first recorded flood occurring in 1964. Frequency for this calculation was based on the period covering 1956 to 2022, and the number of events averaged based on years and number of floods. It should be noted that this does not reflect the recurrence interval, as that calculation is specific on varying factors, such as the incident type, discharge rate, etc., and that type of analysis was not included in this process. Based on this method of assessment, the return interval is 6.5 years, or a 15 percent chance of some level of a flood event occurring every year.

Figure 7-8 December 3, 2007 Incident Highway 101 North of Shelton

Figure 7-9 Belfair-Tahuya Bridge on the Tahuya River December 2007 (DR 1734)

7.3 VULNERABILITY ASSESSMENT

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For this planning purpose, the flood hazard areas identified include the 1-percent (100-year) floodplain and the coastal floodplain. The following text evaluates and estimates the potential impact of flooding in Mason County.

7.3.1 Overview

All types of flooding can cause widespread damage throughout rural and urban areas, including but not limited to: water-related damage to the interior and exterior of buildings; destruction of electrical and other expensive and difficult-to-replace equipment; injury and loss of life; proliferation of disease vectors; disruption of utilities, including water, sewer, electricity, communications networks and facilities; loss of agricultural crops and livestock; placement of stress on emergency response and healthcare facilities and personnel; loss of productivity; and displacement of persons from homes and places of employment.

Methodology

The 1 percent (100-year) annual chance Riverine flood and the 1 percent (100-year) Coastal events were examined to evaluate Mason County's risk and vulnerability to the flood hazard. These events are generally those considered by planners and evaluated under federal programs such as the NFIP.

As indicated, the County's FIRMs were developed and later adopted during the 2017 HMP planning cycle. During this 2023 update, WA DOE, as the responsible state agency charged with the RiskMap flood analysis, was queried if other updated data for flood determination was available. The Planning Team was advised that the 2017 data remains the most current and determined to be the best available science for use in this update. During the HMP update, the planning team developed a new list of critical facilities, which was utilized to supplement the 2017 critical facilities list throughout the various processes to identify exposure to the flood-prone areas.

Warning Time

Due to the sequential pattern of meteorological conditions needed to cause serious flooding, it is unusual for a flood to occur without some 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.

7.3.2 Impact on Life, Health, and Safety

The impact of flooding on life, health and safety is dependent upon several factors including the severity of the event and whether or not adequate warning time is provided to residents. Exposure represents the population living in or near floodplain areas that could be impacted should a flood event occur. Additionally, exposure should not be limited to only those who reside in a defined hazard zone, but everyone who may be affected by the effects of a hazard event (e.g., people are at risk while traveling in flooded areas, or their access to emergency services is compromised during an event). The degree of that impact will vary and is not measurable.

Of significant concern within the planning area is the number of tourists who can be impacted during periods of flooding. Tourism is a fairly large economy within the planning area (the Olympic National Forest, water sports, large recreational camping locations, Little Creek Casino), with many tourists traveling through the area to other areas of the state. Tourism also fluctuates based on season.

To estimate the population exposed to the 1 percent and 0.2 percent annual chance (100- and 500-year) flood events, the DFIRM floodplain boundaries were intersected with residential parcels (based off of Mason County 2017 Assessor data) whose centers intersect the floodplain. Total population was estimated by multiplying the number of residential structures by the average Mason County household size of 2 persons per household. Table 7-6 identifies the estimated population located within these flood zones by municipality or census designated place.

Table 7-6
Population Exposed within Flood Hazard Areas

Jurisdiction	Population in the 1% annual chance event (100- Year) Flood Boundary	Population in the 0.2% annual chance (500-Year) Flood Boundary
Unincorporated Mason County	1,818	742
Shelton, City of	486	512
Allyn	0	0
Belfair	22	0
Total	2,326	1,254

**Based on 2017 Assessor's data for residential structures within the 100-year and 500-year floodplains and an estimate of 2 persons per residential structure*

Of the population exposed, the most vulnerable include the economically disadvantaged and the population over the age of 65. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on the net economic impact on their family. The population over the age of 65 is also more vulnerable because they are more likely to seek or need medical attention which may not be available due to isolation during a flood event and they may have more difficulty evacuating.

The number of injuries and casualties resulting from flooding is generally limited based on advance weather forecasting, blockades, and warnings. Therefore, injuries and deaths generally are not anticipated if proper warning and precautions are in place. Ongoing mitigation efforts should help to avoid the most likely cause of injury, which results from persons trying to cross flooded roadways or channels during a flood.

7.3.3 Impact on Property

Table 7-7 identifies the number of acres within the 100- and 500-year flood hazard areas. Table 7-8 summarizes the total number of structures and losses by coastal and riverine hazards, and number of structures within the SFHAs which would be inundated by the 1-percent-annual-chance flood. Figure 7-10 illustrates the general building stock at risk as determined during FEMA's 2017 flood study.

Table 7-7
Acres in 100 and 500 Year Flood Hazard Areas for Jurisdiction's Boundary

Flood Zone	Mason County, WA	Unincorporated Mason Co.	City of Shelton	Town of Allyn	Town of Belfair
100 Year Flood Zone - *(Includes Zones A, AE, AH, AO, VE)*	37,458	*37,161.0*	*186.9*	*85.5*	*24.4*
500-Year Flood Zone	247	*223.6*	*22.0*	*0.0*	*1.2*

Table 7-8 Structures At Risk										
Community	**Total Estimated Building (Bldg) Value**	**Total Number Of Bldgs.**	**Bldg. Dollar Loss For A 1% Annual Chance Coastal Flood Event**	**Loss Ratio (Dollar Losses/ Total Bldg. Value)**	**Bldg. Dollar Loss For A 1% Annual Chance Riverine Flood Event**	**Loss Ratio (Dollar Losses/ Total Bldg. Value)**	**Number Of Bldgs. Within The VE Zone**	**Number Of Bldgs. within the AE or A Zones**	**Number of Bldgs. within the SFHA**	**Per-Cent Of Bldgs. in the SFHA**
City of Shelton	$422.6M	3,279	-	-	$1.4M	<1%	0	93	93	2.8%
Skokomish Indian Reservation	$36.4M	381	$69.7k	<1%	<$3.1k	<1%	0	31	31	8.1%
Unincorporated Mason County	$3.5B	$27,118	$13.2M	<1%	$22.0M	<1%	135	1986	2121	7.8%
Total	**$4.0B**	**30,778**	**$13.3M**	**<1%**	**$23.5M**	**<1%**	**135**	**2110**	**2245**	**7.3%**

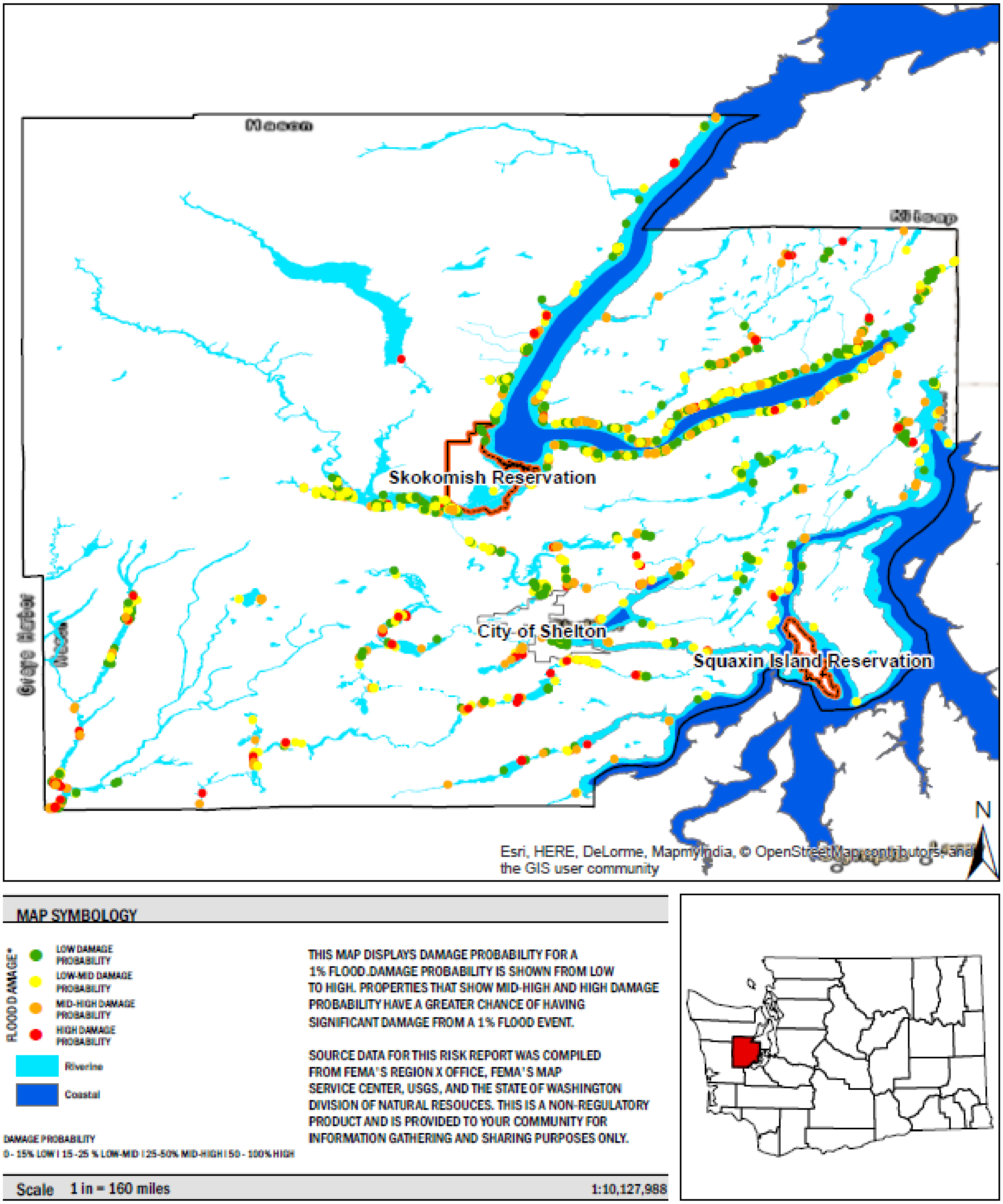

Figure 7-10 FEMA Coastal and Riverine Flood Damage in Mason County (2017 Risk Map)

7.3.4 Impact on Critical Facilities and Infrastructure

In addition to considering general building stock at risk, the risk of flood to critical facilities and utilities was evaluated. Exposure analysis was utilized based on FEMA's 2017 flood maps and the 2023 critical facilities identified for this update.

Table 7-9 and Table 7-10 identify the critical facilities and infrastructure located in the FEMA 100-year flood hazard area. No critical facilities are identified within the 500-year flood zone; however, there are a total of 15 structures in very close proximity (within 100-500 feet) of the 500-year flood zone. Figure 7-11 illustrates all critical facilities and proximity to the 100- and 500-year flood zones.

Table 7-9
Critical Facilities in the 100-Year Floodplain

Jurisdiction	Medical and Health Services	Government Function	Protective	Hazardous Materials	Shelter	**Total**
Unincorporated	0	0	2	0	0	**2**
Shelton, City	0	0	1	0	1	**2**
Total	**0**	**0**	**3**	**0**	**1**	**4**

Table 7-10
Critical Infrastructure in the 100-Year Floodplain

Jurisdiction	Water Supply	Wastewater	Power	Communications	Other	**Total**
Unincorporated	22	1	0	0	0	**23**
Shelton, City	1	0	1	0	0	**2**
Total	**23**	**1**	**1**	**0**	**0**	**25**

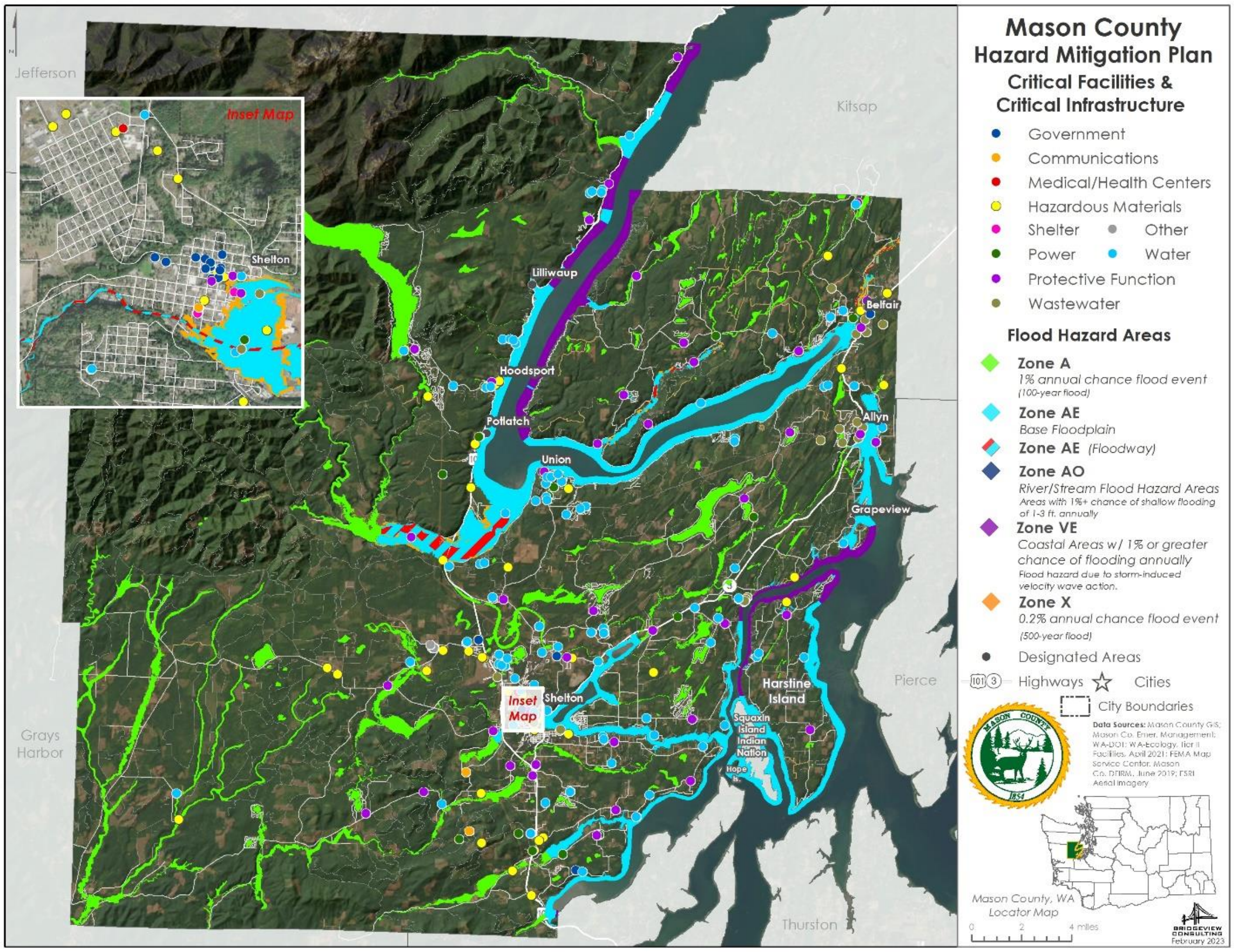

Figure 7-11 Critical Facily Proximity to 100- and 500-Year Flood Hazard Areas

In cases where short-term functionality is impacted by a hazard, other facilities of neighboring municipalities may need to increase support response functions during a disaster event. Mitigation planning should consider means to reduce impact on critical facilities and ensure sufficient emergency and school services remain when a significant event occurs.

7.3.5 Impact on Economy

Impact on the economy related to a flood event in Mason County would include loss of property, associated tax revenue (real estate), as well as potential loss of businesses and the associated revenues generated from those businesses, both in taxes and on individual income loss of spending. Depending on the duration between onset of the event and recovery, businesses within the area may not be able to sustain the economic loss of their business being disrupted for an extended period of time. Historical data has demonstrated that those businesses impacted by a disaster are less likely to reopen after an event.

7.3.6 Impact on 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.

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 all stages of a flood event. 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. In 2014, the US Army Corp of Engineers developed an Integrated Feasibility Report and Environmental Impact Statement specifically for the Skokomish River Basin. Review of the report identifies the fact that high sediment load, reduced flows, and encroachment on the floodplain by human-made structures have, and continue to degrade the natural ecosystem structures, functions, and processes throughout the basin. That degradation has caused a significant decline in populations of four anadromous fish species under the Endangered Species Act (ESA) (e.g., Chinook salmon, chum salmon, steelhead, and bull trout) that use the river as their primary habitat. The impaired ecosystem has also adversely affected critical riverine, wetland, and estuarine habitats used by other wildlife species such as bears, bald eagles, and river otters to name a few.

Floodplains can support ecosystems that are rich in quantity and diversity of plant and animal species. A floodplain can contain 100 or even 1000 times as many species as a river. Wetting of the floodplain soil releases an immediate surge of nutrients: those left over from the last flood, and those that result from the rapid decomposition of organic matter that has accumulated since then. Microscopic organisms thrive and larger species enter a rapid breeding cycle. Opportunistic feeders (particularly birds) move in to take advantage. The production of nutrients peaks and falls away quickly; however, the surge of new growth endures for some time. This makes floodplains particularly valuable for agriculture. Species growing in floodplains are markedly different from those that grow outside floodplains. For instance, riparian trees (trees that grow in floodplains) tend to be very tolerant of root disturbance and very quick-growing compared to non-riparian trees.

7.3.7 Impact from Climate Change

Global climate change is expected to result in warmer and wetter winters and are projected to increase flooding frequency in most Western Washington river basins. Future floods are expected to exceed the capacity and protective abilities of many 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 in many areas 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, increased sedimentation will occur, 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. Mason County has already experienced such influences such as with the 2007 flooding, and with the 2023 King Tide events. Sediment movement is influencing the banks of the waterways, increasing flooding events in areas where typical flooding has not occurred.

As hydrology changes, what is currently considered a 100-year 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 wastewater treatment facilities and storm drains. For Mason County, this also includes the availability of additional stream flow gauges along the various waterways.

Dams

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.

Throughout the west, communities downstream of dams are already experiencing increases in stream flows from earlier releases from dams.

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.

Sea Level Rise

Sea level and temperature are interrelated (U.S. EPA, 2016). Warmer temperatures result in the melting of glaciers and ice sheets. This melting means that less water is stored on land and, thus, there is a greater volume of water in the oceans. Water also expands as it warms, and the heat content of the world's oceans has been increasing over the last several decades. The impacts of sea level rise could include increased coastal community flooding, coastal erosion and landslides, seawater well intrusion, acidification of waters, and lost wetlands and estuaries.

7.4 FUTURE DEVELOPMENT TRENDS

Mason County and its planning partners are subject to the provisions of the Washington State Growth Management Act (GMA), which regulates identified critical areas. Mason County critical areas regulations include frequently flooded areas, defined as the FEMA 100-year mapped floodplain. The GMA establishes review and evaluation programs that monitor commercial, residential, and industrial development and the densities at which this development has occurred under each jurisdiction's GMA comprehensive plan and development regulations. An evaluation is required at least every five years of the sufficiency of remaining land within urban growth areas to accommodate projected residential, commercial, and industrial growth at development densities observed since the adoption of GMA plans. This buildable lands report compares planned versus actual urban densities in order to determine whether original plan assumptions were accurate. In addition, the County also is required to develop shoreline management practices, which also support mitigation efforts with respect to reduced flooding and building more resilient communities. Section 3 of this plan discusses the County's land use designations, including identification of critical areas. Since completion of the 2018 HMP, the County has updated its Shoreline plan, and is currently in the process of updating its Comprehensive Land Use Plan.

The floodplain portions of the planning area are regulated under the GMA and the NFIP. Development will occur in the floodplain; however, it will be regulated such that the degree of risk will be reduced through building standards and performance measures. As NFIP map updates have occurred, those updates will continue to be utilized to further expand, modify, and enhance planning efforts occurring within the County.

7.5 ISSUES

A large portion of the planning area has the potential to flood, generally in response to a succession of winter rainstorms. Storm patterns of warm, moist air are normal events, usually occurring between October and April can cause severe flooding in the planning area, although flooding can occur at any time. The issue of high tides, particularly in light of anticipated sea level rise, will continue to be of issue. Such issues would be of even greater concern if the high tide occurs in conjunction with a wind-driven event.

A worst-case scenario for a flood event within the County would be a series of storms that result in high accumulations of runoff surface water within a relatively short time period. This could overwhelm response capabilities within Mason County. Major roads could be blocked as has previously occurred, preventing critical access for residents and critical functions in portions of the planning region. High in-channel flows could cause watercourses to scour, possibly washing out roads or impacting bridges, creating more isolation problems, and further exacerbating erosion along the coastline. In the case of multi-basin flooding, repairs could not be made quickly enough to restore critical facilities and infrastructure. While human activities influence the impact of flooding events, human activities can also interface effectively with a floodplain as long as steps are taken to mitigate the activities' adverse impacts on floodplain functions.

The following flood-related issues are relevant to the planning area:

- While flooding on the Skokomish River is well documented, there are limited river gauges available.
- Additional rivers in the County, such as the Tahuya River in North Mason, also regularly experience flooding. There are currently no USGS river gauges outside the Skokomish watershed, which significantly impacts the County's ability to monitor and develop effective mitigations actions. The county has installed several gauges additional gauges on the Skokomish River in an attempt to capture data, but additional gauges are needed on the additional rivers.
- The risk associated with the flood hazard overlaps the risk associated with other hazards such as severe storm events, high tides, earthquake, and landslide. This provides an opportunity to seek mitigation goals with multiple objectives to reduce the risk of multiple hazards.
- Climate change will impact flood conditions throughout the County. The County lacks the resources to complete any type of climate change impact study.
- More information is needed on flood risk with respect to structure type, year built, elevation, etc., to support the concept of risk-based analysis of capital projects.
- There needs to be a sustained effort to gather historical damage data, such as high-water marks on structures and damage reports, to measure the cost-effectiveness of future mitigation projects.
- Ongoing flood hazard mitigation will require funding from multiple sources.
- There needs to be a coordinated hazard mitigation effort between the County, the City of Shelton, the Skokomish and Squaxin Island Tribes, and the Washington Department of Transportation as it relates to flooding and flood induced issues and the potential for areas to experience isolation as a result of limited ingress and egress to certain areas of the County during storm/flooding events.
- Floodplain residents need to continue to be educated about flood preparedness and the resources available during and after floods.

- The promotion of flood insurance as a means of protecting property from the economic impacts of frequent flood events should continue. Since completion of the last plan, the County and the City of Shelton have experienced a reduction in the number of policies in force.
- Existing floodplain-compatible uses such as agricultural and open space need to be maintained.

7.6 RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from Flood throughout the area is highly likely. The area experiences some level of flood almost annually. While structural damage may vary due to flood depths and existing floodplain management regulations, there is a fairly high rate of property ownership that does not have flood insurance. Based on the potential impact, the Planning Team determined the CPRI score to be 3.25, with overall vulnerability determined to be a high level.

CHAPTER 8. LANDSLIDE

A landslide is defined as the sliding movement of masses of loosened rock and soil down a hillside or slope. Such failures occur when the strength of the soils forming the slope is exceeded by the pressure acting upon them, such as weight or saturation. Earthquakes provide many times more energy than needed to initiate soil liquefaction, enhancing not only the probability of a landslide, but also its magnitude. Washington State climate, topography, and geology create a perfect setting for landslides, which occur in the state every year.

In Western Washington, most landslides are triggered during fall and winter after storms dump large amounts of rain or snow (Washington Department of Natural Resources, 2015). Landslides can be shallow or deep. Shallow landslides typically occur in winter in Western Washington and summer in Eastern Washington, but are possible at any time. They often form as slumps along roadways or fast-moving debris flows down valleys or concave topography. They are commonly called "mudslides" by the news media. Deep-seated landslides are often slow moving, but can cover large areas and devastate infrastructure and housing developments.

> **DEFINITIONS**
>
> **Landslide**—The movement of masses of loosened rock and soil down a hillside or slope. Such failures occur when the strength of the soils forming the slope is exceeded by the pressure, such as weight or saturation, acting upon them.
>
> **Mass Movement—**A collective term for landslides, debris flows, falls and sinkholes.
>
> **Mudslide (or Mudflow or Debris Flow)—**A river of rock, earth, organic matter and other materials saturated with water.

A mudslide or debris flow is a fast-moving fluid mass of rock fragments, soil, water, and organic material with more than half of the particles being larger than sand size. Generally, these types of movement occur on steep slopes or in gullies and can travel long distances. Typically, debris flows result from unusually high rainfall, or rain-on-snow events.

A rock fall is the fall of newly detached segments of bedrock of any size from a cliff or steep slope. The rock descends by free fall, bouncing, or rolling. Movements are very rapid to extremely rapid, and may not be preceded by minor movements.

8.1 GENERAL BACKGROUND

A landslide, or a mass of rock, earth or debris moving down a slope, 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.

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 or "slurry." A debris flow or mudflow can move rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. The slurry 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. Locally, they can be some of the most destructive events in nature.

All 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 occurrence of a landslide is dependent on a combination of site-specific conditions and influencing factors. Most commonly, the factors that contribute to landslides fall into four broad categories:

- Climatic or hydrologic (rainfall or precipitation);
- Geomorphic (slope form and conditions, e.g., slope, shape, height, steepness, vegetation, and underlying geology);
- Geologic/geotechnical/hydrogeological (groundwater);
- Human activity.

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, and removing or changing the type of vegetation covering slopes are all contributing factors. 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:

- Areas identified as having slopes greater than 33 percent;
- A history of landslide activity or movement during the last 10,000 years;
- Stream or wave activity, which has caused erosion, undercut a bank, or cut into a bank to cause the surrounding land to be unstable;
- The presence of an alluvial fan, indicating vulnerability to the flow of debris or sediments;
- The presence of impermeable soils, such as silt or clay, which are mixed with granular soils such as sand and gravel.

Flows and slides are commonly categorized by the form of initial ground failure. Common types of slides are shown on Figure 8-1 through Figure 8-4 (Washington State Department of Ecology, 2014). The most common is the shallow colluvial slide, occurring particularly in response to intense, short-duration storms, where antecedent conditions are prevalent (Baum, et. al, 2000). The largest and most destructive are deep-seated slides, although they are less common.

Deep-seated landslides are much larger than shallow landslides and can occur at any time of the year. Soil degradation can happen over years, decades, and centuries with little to no warning to people above ground. The most notable and deadliest deep-seated landslide event in the United States was SR 530 (also known as the Oso Landslide) that took the lives of 43 people in Oso, Washington, in 2014.

Slides and earth flows can pose serious hazard to property in hillside terrain. They tend to move slowly and thus rarely threaten life directly. When they move—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.

Erosion is the process by which material is removed from a region of the earth's surface. It can occur by weathering and transport of solids (sediment, soil, rock, and other particles) in the natural environment. This also leads to the deposition of these materials elsewhere, which can increase the impacts from flood events. Erosion usually occurs as a result of transport of solids by wind, water or ice, and by down-slope creep of soil and other material under the force of gravity, similar to landslides. It can also be caused by animals burrowing, reducing soil stability.

Although erosion is a natural process, as with landslides, human land use policies have an effect on erosion, especially industrial agriculture, deforestation, and urban sprawl. Land that is used for industrial agriculture generally experiences a significantly greater rate of erosion than land with natural vegetation or land used for sustainable agricultural. This is particularly true if tillage is used in farm practices, which reduces vegetation cover on the surface of the soil and disturbs both soil structure and plant roots that would otherwise hold the soil in place.

Improved land use practices can limit erosion, using techniques such as terracing or terrace-building, no or limited tilling, limited logging or replanting after logging, and the planting of vegetation to limit erosion through ground cover.

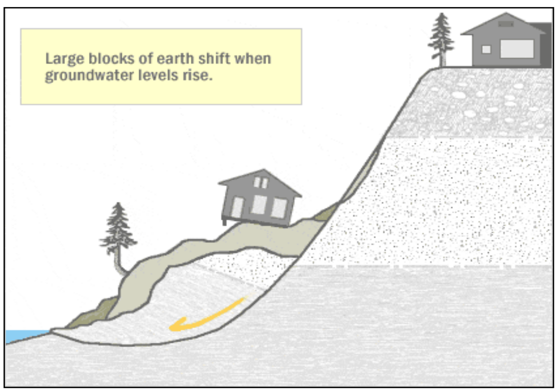

Figure 8-1 Deep Seated Slide

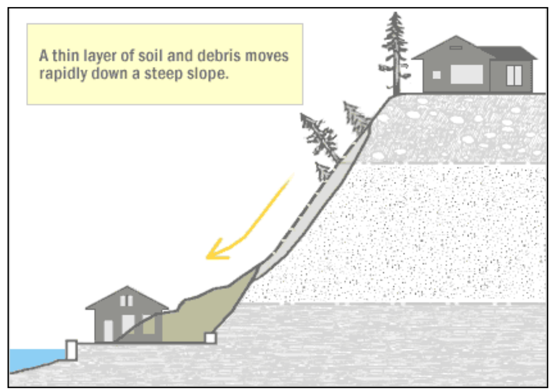

Figure 8-2 Shallow Colluvial Slide

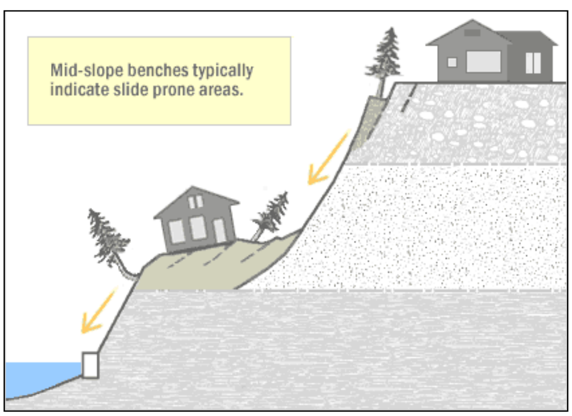

Figure 8-3 Bench Slide

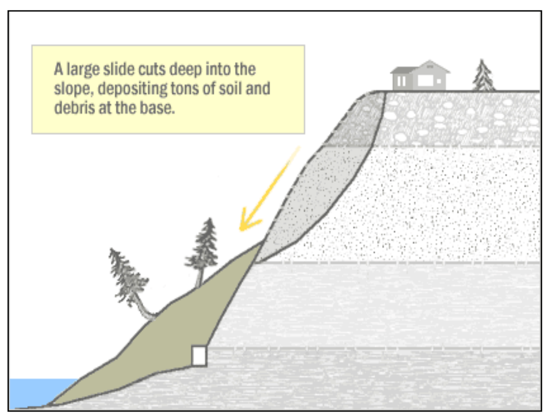

Figure 8-4 Large Slide

While a certain amount of erosion is natural and healthy for an ecosystem—such as gravel continuously moving downstream in watercourses—excessive erosion causes serious problems, such as receiving water sedimentation, ecosystem damage and loss of soil and slope stability. Erosion can cause a loss of forests and trees, which causes serious damage to aquatic life, irrigation, and power development by heavy silting of streams, reservoirs, and rivers. Concentrated surface water runoff in drainages and swales can lead to channel-confined slope failures, involving the rapid transport of fluidized debris, known as debris flows.

Mason County Classified Landslide Hazard Areas:

Within Mason County's Resource Ordinance (revised October 2017)[6], the following are classified as Landslide Hazard Areas:

a) Areas with any indications of earth movement such as debris slides, earthflows, slumps, and rock falls;
b) Areas with artificial over-steepened or un-engineered slopes, i.e. cuts or fills.
c) Areas with slopes containing soft or potentially liquefiable soils.
d) Areas over-steepened or otherwise unstable as a result of stream incision, stream bank erosion, and undercutting by wave action.
e) Slopes greater than 15% (8.5 degrees) and having the following:
    1. Hillsides intersecting geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock (e.g. sand overlying clay); and
    2. Springs or groundwater seepage.
f) Any area with a slope of forty percent or steeper and with a vertical relief of ten or more feet except areas composed of consolidated rock. A slope is delineated by establishing its toe and top and measured by averaging the inclination over at least ten feet of vertical relief.

8.2 HAZARD PROFILE

8.2.1 Extent and Location

The best predictor of where slides and earth flows might occur is the location of past movements. Past landslides can be recognized by their distinctive topographic shapes, which can remain in place for thousands of years. Most landslides recognizable in this fashion range from a few acres to several square miles. Most show no evidence of recent movement and are not currently active. A small portion of them may become active in any given year. The recognition of ancient dormant mass movement sites is important in the identification of areas susceptible to flows and slides because they can be reactivated by earthquakes or by exceptionally wet weather. Also, because they consist of broken materials and frequently involve disruption of groundwater flow, these dormant sites are vulnerable to construction-triggered sliding.

[6] Mason County Resource Ordinance. Accessed 8 Feb 2023. Available online at: [Microsoft Word - Resource Ordinance 10-02-2017.docx (masoncountywa.gov)]

Mason County is subject to landslides and soil erosion due to wind, water, and flooding at all times of the year; the landslides and soil erosion are largely concentrated on coastal bluffs on a fairly large percent of the total marine shoreline within the County (Washington State Department of Ecology, 1980).

Much of Mason County encompasses coastal communities or coastal areas (see Figure 8-5).[7] Mason County's shorelines include approximately 700 linear miles, which are composed of 217 miles of marine shoreline, 330 miles of river shoreline, and 150 miles of lakeshore (Mason County Cumulative Impact Analysis, 2017). Of those 96 miles, or 44 percent, were categorized as unstable (Mason County 2010 HMP; Washington State Department of Ecology Coastal Atlas, 1980). This equates to approximately 60 percent of the total marine shoreline (Washington Department of Ecology, 1980).

Areas of the County are subject to beach erosion of feeder bluffs, which is a coastal bluff that delivers sediment to the beach over an extended period time, and contributes sediment. Feeder Bluffs consist of actively eroding bluffs which provide sediments to nearby beaches. Bluff retreat by erosion can be more than 2 feet per year or can be less than 1 inch per year, but can be punctuated by landslides that can set a bluff back by more than 20 feet in a few hours (Thorsen and Shipman, 1998).

[7] Ibid.

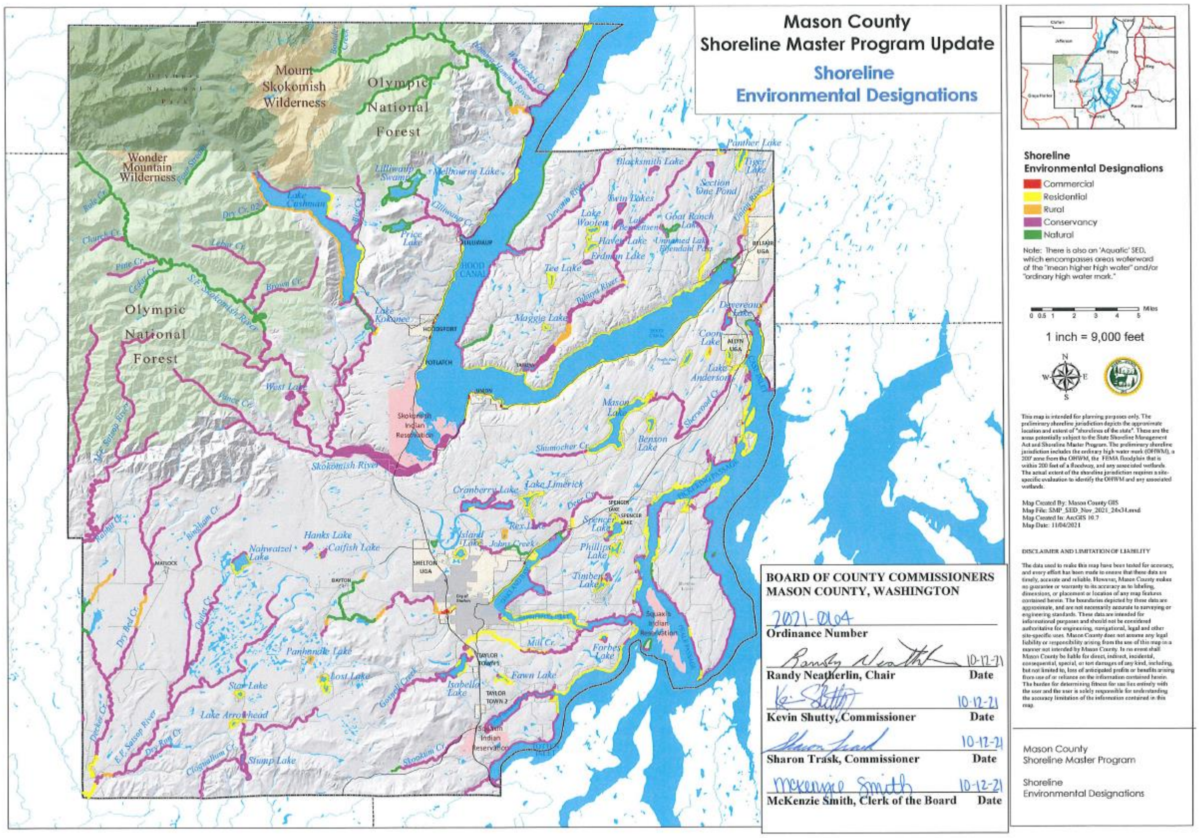

Figure 8-5 Mason County Shoreline Environmental Designations (2021)

The Hood Canal area has experienced significant slides in the past, with major efforts occurring to stabilize the landslides with drainage and structural improvements.

Figure 8-6 House destroyed by landslide in Lilliwaup Winter 1998-1999

Approximately 10% of the landscape in Mason County (excluding Olympic National Forest and Park areas) has a slope of 15-30%; approximately 3% has steeper slopes of 30-45% (Mason County COMP Plan, 2017). Within Mason County, slides may occur in association with fine grained lakebed or fluvial sediments Figure 8-6 illustrates a slide occurring within the County (photo courtesy of the Dept. of Ecology (5/8/1999, #99-25-2). Figure 8-7 illustrates the landslide hazard Critical Areas identified within the County's Comprehensive Plan (for reference purposes only) (Mason County Comprehensive Plan, 2017).

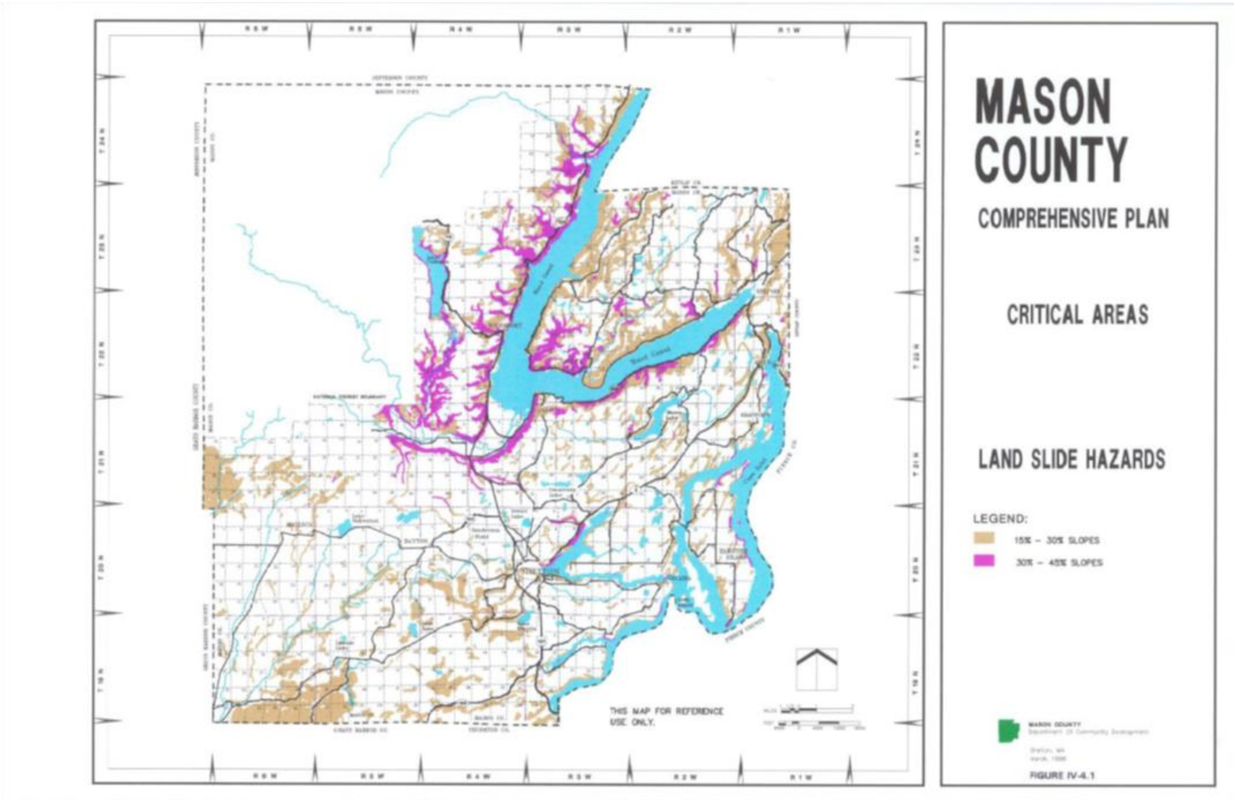

Figure 8-7 Comprehensive Plan Identified Critical Areas - Landslide Hazard Area

8.2.2 Previous Occurrences

Landslides within the planning area are fairly common, with landslides associated with disaster declarations for severe storms and flooding events in Mason County, as listed in Chapter 3. The County has never received a disaster declaration specifically typed *Landslide* by FEMA. There is one record of a fatality due to landslide in the County. This occurred when a landslide struck a residence during the 2007 storm event.

Since 1956, within Mason County, a total of 13 severe weather events have occurred, 11 of which have included impact from landslides. One landslide event has occurred since completion of the last plan in 2020, for which approximately $11 million dollars in PA funding has been distributed statewide. 2022 again saw some slides occurring, impacting roadways throughout the county.

The recorded landslide history to state highways in Mason County dates as far back as 1925. Impact to the highway system from landslide is one of the most significant issues with respect to the landslide hazard for the County, as it restricts ingress and egress in areas, causing isolation and, in some instances, suspending emergency response. The following synopsis identifies some historic landslide events impacting the County, as well as mitigation activities taken to correct issues. Thereafter are a series of photographs which illustrate some of the impact.

- Episodically active for decades followed by severe deformation and retrogression in 1997–8 and 1998–99, resulted in 5 month highway closure along SR 3 on the Allyn Curves. Realignment in 1993 and stabilization in 1999 costs totaled around $5 million.

- Winter storms of February 1999 caused the Jorstad Creek landslide at MP 322, impacting a 500 ft. long and 1,000 ft. wide section of US 101 (see Figure 8-8).[8]
- Winter storm February 1999 also impacted a 500 ft. long and 1,800 ft. wide section of US 101 at Lilliwaup, resulting in extensive drainage and retaining wall construction to stabilize the slope.
- October 2003 Heavy rainfall caused severe flooding and landslides in 15 counties. Landslides or ground failure caused temporary closures on nine state highways, with a debris flow blocking US 101 in Jefferson and Mason Counties.
- December 3, 2007 (DR 1734), which caused both Highways 101 and 106 to close several times in the vicinity of Lilliwaup, Eldon and Union. The Tahuya Peninsula was severely impacted by landslides. Landslides and erosion during this storm caused millions of dollars in damage.
    - As a result of the 2007 storm event, in Mason and Jefferson Counties, there were 214 landslides recorded. Of these slides, there were 80 shallow undifferentiated landslides, 23 debris flows, 108 debris slides, 1 deep-seated landslide, and two hyper-concentrated flows.
    - At least 12 houses were damaged during the storm.
    - U.S. Highway 101 was damaged or blocked by 16 slides.
    - State Route 106 was damaged or blocked by two (2) slides, and five (5) slides blocked or damaged various other roads.
    - In the aftermath of the December 2007 storm, 581 people applied for Individual and Household Assistance with FEMA. The amount approved for Mason County was $1,128,094.
- Winter 2009 - The incident was not a declared disaster event, but caused landslides throughout the planning area. Figure 8-9 illustrates a head scarp of a landslide which had approximately 4 feet of vertical movement and 2 feet of horizontal movement in sandy glacial till at Lake Kokanee. The head scarp was approximately 60 feet above the lake level. The crevasse formed by the scarp was approximately 3 feet deep, and based on the lack of forest debris and ravel in place at the time, it was estimated that the formation had been very recent, occurring within a few weeks of the photo being taken in April 2009.
- As a result of continued unstable slopes adjacent to US 101 in the Purdy Canyon area, in 2013, WSDOT removed 76,000 cubic yards (~7,600 dump truck loads) of dirt and material to reshape the slope of the adjacent hillside with the intent of slope stabilization. The area had been plagued with falling rocks and slope destabilization.
- Heavy rains during the week of December 8, 2014 washed out approximately 75 feet of the northbound US 101 shoulder 2.2 miles south of Beacon Point Road. Crews working for

[8] Photo Source: Department of Ecology 5/8/1999, #99-25-7

WSDOT built a large retaining wall and repaired a broken culvert on US 101 at milepost 316.5 to help stabilize a steep slope below the highway. By installing the retaining wall and repairing the broken culvert, the State reduced the potential for future slides. See Figure 8-10 for the before and after illustrations of the project.

- Figure 8-11 illustrates a portion of SR 302 (North of East Victor Road) that has been repeatedly damaged as a result of erosion under the surface of the highway. New culverts and replacement of the structure was completed in 2017. The culverts running under this section of SR 302 were moving downslope.
- January 2022 – Heavy rains caused several landslides along a 1.5 mile stretch of roadway along the Purdy Canyon Road south of the Skokomish Tribal Center.
- Heavy rains in February 2022 again impacted the county with road closures when Highway 302 east of Victor was again closed after sloughing of land beneath the roadway led to an 80-foot section to settle more than six inches (see Figure 8-12). While open to some local travelers, the roadway was closed to all travelers at attempting to connect between Highways 3 and 16, requiring a 22-mile detour via Highway 16 in Gorst. A WDOT spokesperson reported to the Kitsap Sun that portions of the highway are frequently impacted by a slow-moving "ancient" landslide (Kitsap Sun).[9]

Figure 8-8 Highway Closure at Jorstad Landslide – Winter 1998-1999

[9] Kitsap Sun. Highway 302 in Mason County Closed. March 1, 2022. Accessed 8 Feb 2023. Available online at: Highway 302 in Mason County closed following heavy rains (kitsapsun.com)

Figure 8-9 Lake Kokanee Landslide, South of Lake Cushman

Photo Courtesy of Washington State Division of Geology and Earth Resources Geologists, taken April 9, 2009

Figure 8-10 Before and After Pictures of SR 101/ 2.2 miles South of Beacon Pt. Road

Figure 8-11 SR 302 Slope Erosion Near Victor

Figure 8-12 Highway 302 Landslide East of Victor (2022)

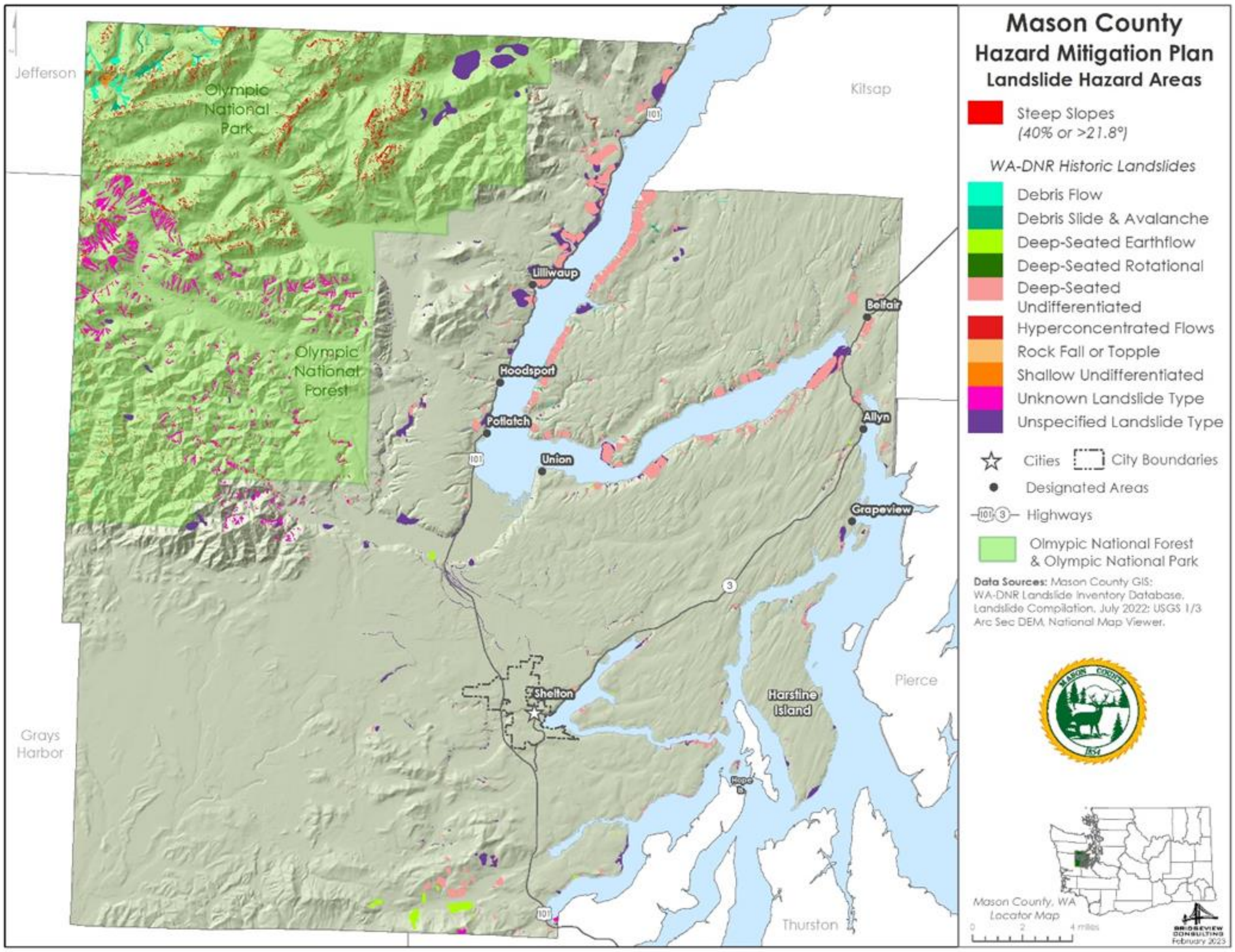

Figure 8-14 illustrates the areas of previous landslides, as well as areas of steep slopes of 40 percent or greater based on Washington State Department of Natural Resources data (2017, 2022). Figure 8-15 illustrates the landslide hazard areas with an aerial imagery background.

Information contained in Table 8-1 was captured from Washington State Department of Transportation (WDOT) sources, identifying some of the projects which have been completed in Mason County by WDOT in an effort to rectify on-going landslide issues. The table is not all inclusive of all efforts taken to restore roadways in the County.

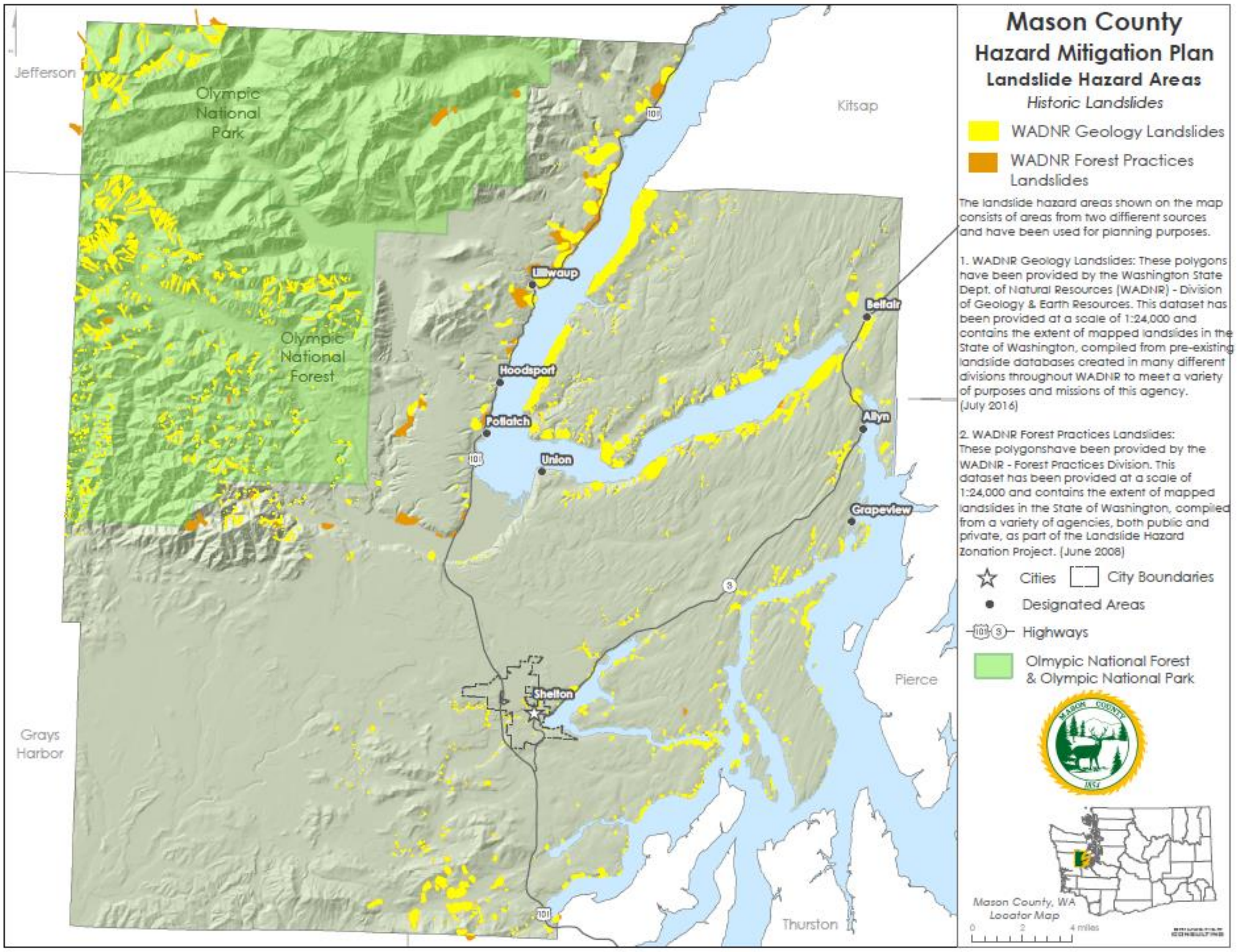

Figure 8-13 Washington DNR Recorded Landslide Data (2017)

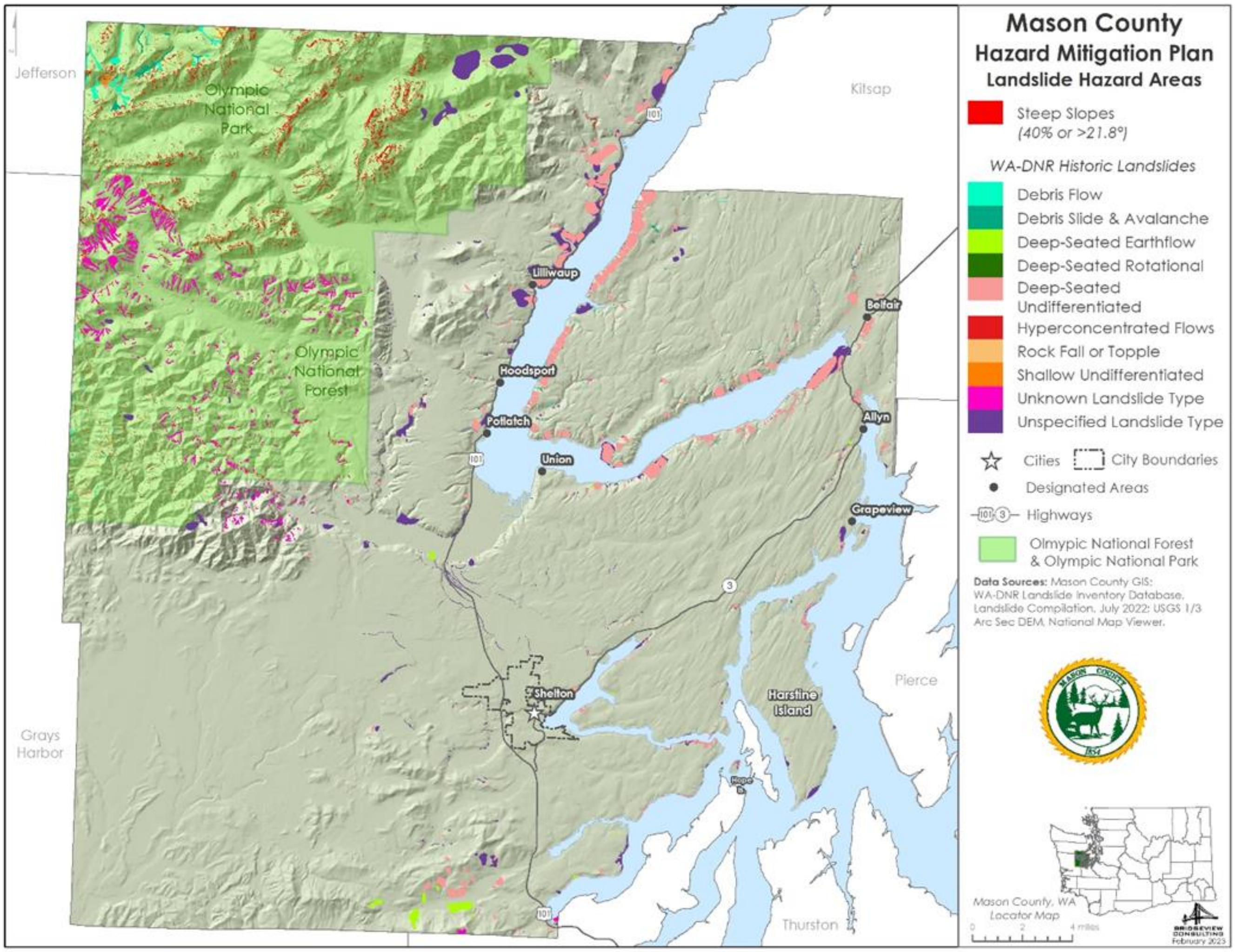

Figure 8-14 Steep Slope Landslide Hazard Areas (2023)

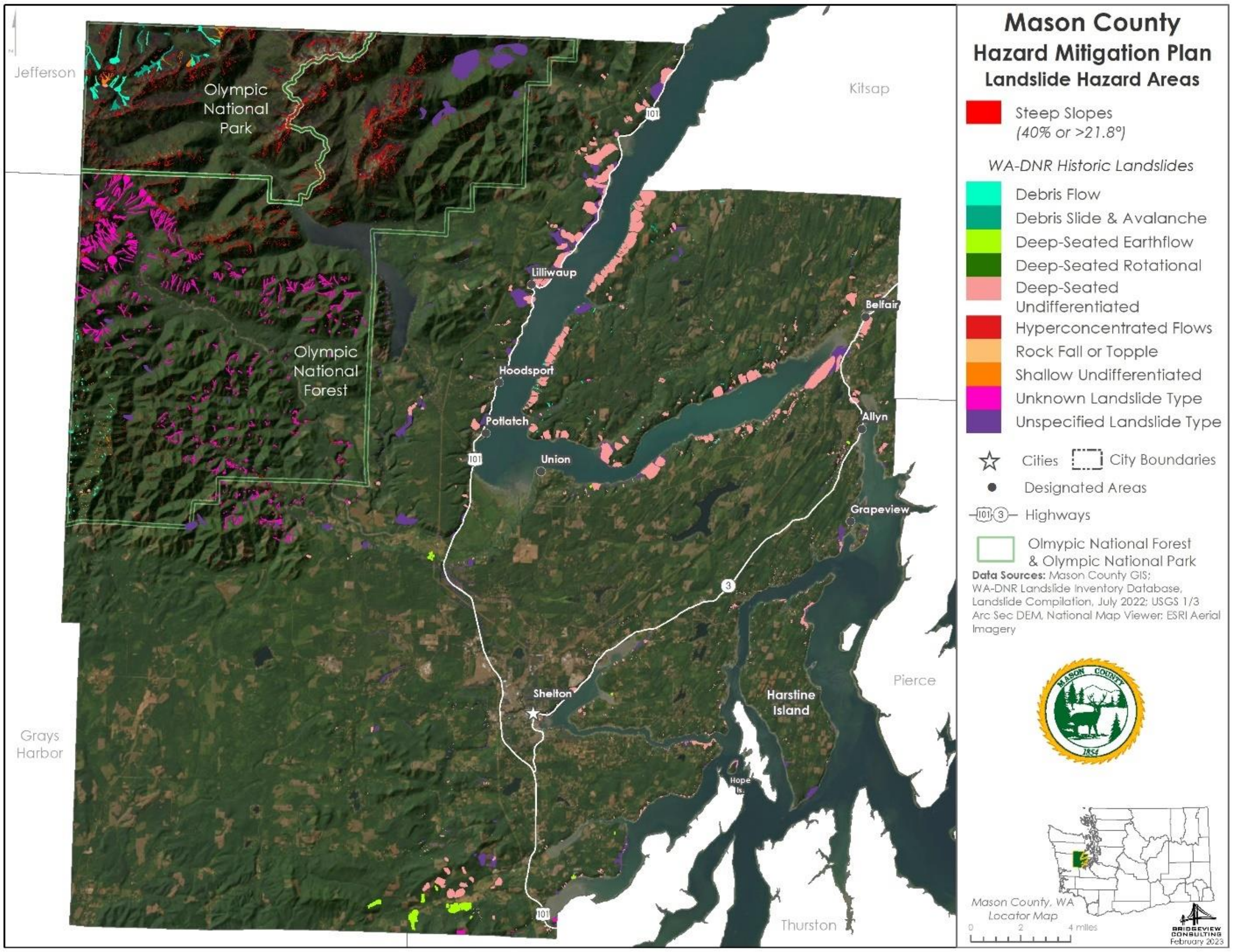

Figure 8-15 Landslide Hazard Area with Aerial Imagry

Table 8-1
Mason County State Highways Slide Repair Costs (1925-2009)

Route	Date	Project	Cost*
US 101	1925	Hoodsport/Duckabush Slides	$10,594.00
US 101	8/31/1965	Lilliwaup Slope Stabilization	$45,353.00
SR 3	5/13/1970	Belfair Vicinity Slide	$106,153.00
US 101	1/27/1975	Jorstad Creek Slide	$95,391.00
US 101	7/19/1999	Hoodsport Slide	$296,203.00
SR 3	11/29/2001	Allyn Vicinity Slide	$2,746,402.00
US 101	7/27/2000	Lilliwaup Vicinity Slide	$733,831.00
US 101	8/1/2000	MP 322.3 Slide	$576,067.00
US 101	2/5/2001	MP 321 and 322 vicinity slides	$3,371,919.00
US 101	1/28/2008	Lilliwaup Vicinity Slide	$940,916.00
US 101	8/1/2008	Sunnyside Slope	$420,659.00
US 101	2008	Holiday Hills	$463,095.00
US 101	2009	Hoodsport Vicinity Slope	$179,973.00
SR 108	2009	Slide Repair .8 miles West of Eich Road	$150,000.00
Total			**$10,136,556.00**

*Figures represent estimated contract costs from WSDOT files; design and construction oversight was additional; figures represent costs incurred at time of construction – not inflated.

8.2.3 Severity

Landslides destroy property and infrastructure, and can have a long-lasting effect on the environment and can take the lives of people. Nationally, landslides account for more than $2 billion in losses annually and result in an estimated 25 to 50 deaths a year (Spiker and Gori, 2003; Schuster and Highland, 2001; Schuster, 1996).

Washington is one of seven states listed by the Federal Emergency Management Agency as being especially vulnerable to severe land stability problems. Topographic and geologic factors cause certain areas of Mason County to be highly susceptible to landslides. Ground saturation and variability in rainfall patterns are also important factors affecting slope stability in areas susceptible to landslides. Strong earthquake shaking can cause landslides on slopes that are otherwise stable.

8.2.4 Frequency

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. Landslides typically occur during and after major storms, so the potential for landslides largely coincides with the potential for sequential severe storms and flood events that saturate steep, vulnerable soils.

While the County has not received a disaster declaration specifically for a landslide, there have been 11 disaster declarations which have included mud- or land-slides which occurred in conjunction with severe storm events since 1956. However, some type of landslide event occurs almost annually within the planning region, in some cases, more than 10 slides in the planning area have been reported as a result of a single weather event. A specific recurrence interval has not been established by geologists, but historical data indicates several successive years of slide activities, followed by dormant periods.

Landslides are most likely to occur during periods of higher than average rainfall. The ground in many instances is already saturated prior to the onset of a major storm, which increases the likelihood of significant landslides to occur.

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.

The ground must be saturated prior to the onset of a major storm for significant landslides to occur. Studies conducted by the USGS have identified two precipitation thresholds to help identify when landslides are likely (USGS, 2007) :[10]

- Cumulative Precipitation Threshold —A measure of precipitation over the last 18 days, indicating when the ground is wet enough to be susceptible to landslides. Rainfall of 3.5 to 5.3 inches is required to exceed this threshold, depending on how much rain falls in the last 3 days.
- Intensity Duration Threshold —A measure of rainfall during a storm, indicating when it is raining hard enough to cause multiple landslides if the ground is already wet.

These thresholds are most likely to be crossed during the rainy season. The 2007 USGS study indicates that by comparing recent and forecast rainfall amounts to the thresholds, meteorologists, geologists, and city officials can help people know when to be prepared for landslides. The thresholds as developed and tested are accurate, but imperfect indicators of when landslides may occur. During the study, statistical analysis of landslides that occurred between 1978 and 2003 showed that 85% occurred when the Cumulative Precipitation Threshold was exceeded. "While the thresholds are felt to work best in areas along the east side of Puget Sound, from Tacoma to Everett….they can also give preliminary guidance in the eastern part of Mason County" (USGS, 2007).

Review of historic disasters provides the following breakdown: January experienced five (5) landslides - the month in which most landslides historically have occurred, followed by

[10] USGS Landslide Hazards in the Seattle, Washington, Area. Accessed 1 March 2023. Available at: https://pubs.usgs.gov/fs/2007/3005/pdf/FS07-3005_508.pdf

December, with four (4) disaster-level recorded weather events which included landslide. March and November each recorded one (1) weather event which included landslide. It should be noted that while it is recorded as a single incident, there are most often many landslides associated with each event.

8.3 VULNERABILITY ASSESSMENT

8.3.1 Overview

Historical occurrences, combined with analysis of the slope and the type of soil, are the most effective indicator of areas at risk to landslide. The Washington Department of Natural Resources collects data for local municipalities to use in determining historical events and, to some extent, landslide vulnerability. At present, for Mason County, it serves as the most reliable source available for planning purposes.

Landslides have the potential to cause widespread damage throughout both rural and urban areas. While some landslides are more of a nuisance-type event, even the smallest of slides has the potential to injure or kill individuals and damage infrastructure. Given Mason County's relatively steep slopes in certain areas, the various types of soils, and its historical patterns of previous slide occurrences, the landslide hazard is a significant concern for the planning partners.

Review of the DNR data illustrates high areas of vulnerability in the Hood Canal area, as well as in the Olympic National Forest. Areas within Lilliwaup, Hoodsport, Potlatch, and Belfair all have a high number of previously reported landslides.

Landslide hazard areas are those identified by Washington State DNR as having previous landslide events, and includes areas of slopes with a slope greater than or equal to 40 percent (or 21.8 degrees).

It should be noted that t*his data is for mitigation planning purposes only, and should not be considered for life safety matters. No landslide hazard analysis was conducted, but rather, only reprojection of existing data. Additional landslide data is available at:* Landslides | WA - DNR

Warning Time

Unlike flood hazards which often are predictable, mass movements or landslides are generally unpredictable, with little or no advanced warning. The speed of onset and velocity associated with a slide event can have devastating impacts. While some methods used to monitor mass movements can provide an idea of the type of movement and provide some indicators (potentially) with respect to the amount of time prior to failure, exact science is not available.

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

- 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 (decks or patios) tilting 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;
- 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.

It is possible, based on historical occurrences, to determine what areas are at a higher risk. Assessing the geology, vegetation, and amount of predicted precipitation for an area can help in these predictions; such an analysis is beyond the scope of this planning effort. However, there is no practical warning system for individual landslides. Historical events remain the best indicators of potential landslide activity, but it is generally impossible to determine with precision the size of a slide event or when an event will occur. Increased precipitation in the form of snow or rain increases the potential for landslide activity. Steep slopes also increase the potential for slides, especially when combined with specific types of soil.

Within Washington State, in a partnership with the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service, Washington State Department of Natural Resources (WDNR) monitors conditions that could produce shallow landslides. Landslide warning information can be viewed at WDNR's website.

8.3.2 Impact on Life, Health, and Safety

Population vulnerable to landslides in the area would include not only the individuals living in the landslide prone areas, but also those traveling through the area given the high level of tourism, particularly when considering seasonal increases in tourism to the area, and the high number of vacation homes.

Also to be taken into account when determining affected population are the area-wide impacts on transportation systems and the isolation of residents who may not be directly impacted, but whose ability to ingress and egress is restricted, such as areas along Highway 101 in the Hood Canal Area (among others) which have a high transient population of tourists, especially during summertime months. Finally, Mason County's high population of retirees (higher than state average), may increase the level of first-responder requirements for residents whose structures were not directly impacted but who were affected by power outages or lack of logistical support, etc. Landslides can also damage water and wastewater treatment facilities, potentially harming water quality, and disrupt communication lines.

8.3.3 Impact on Property

Landslides affect private property and public infrastructure and facilities. The predominant land use in the planning area is single-family residential, much of it supporting multiple families. In addition, there are many small businesses in the area as well as large commercial industries and government facilities. Development in landslide hazard area is guided by building code and the critical area ordinance to prevent the acceleration of manmade and natural geological hazards, and to neutralize or reduce the risk to the property owner or adjacent properties from development activities.

The Mason County Resource Ordinance requires, a at a minimum, a geological assessment for development within 300 feet of slopes between 15% and 40%, and a geotechnical report for slopes over 40% (see [Microsoft Word - Resource Ordinance 10-02-2017.docx (masoncountywa.gov)]). The ordinance also requires a 50-foot vegetated buffer at the top or toe of a slope.

For mitigation planning purposes only, and not specific to the County's ordinance, the Washington State Department of Natural Resources Landslide Dataset was utilized to identify areas of historic events. In addition, slopes identified as being forty (40) percent or steeper were included in this analysis. The acres of the planning area exposed to the landslide hazard in the planning area are summarized in Table 8-2. Data presented in these maps and tables are not a substitute for site-specific investigations by qualified practitioners.

Table 8-2
Acres of Landslide Hazard Areas by Slope or Type

Jurisdiction	No Slope (< 15% or < 8.53°)	Gentle Slopes (15% - 40% or 8.53° - 21.8°)	Steep Slopes (40% or >21.8°)	Unknown Landslide Type	Type Not Specified/Blank	Shallow Undifferentiated Landslides	Hyperconcentrated Flows	Debris Flow	Debris Slide & Avalanches	Rock Fall or Topple	Deep-Seated Undifferentiated Landslides	Deep-Seated Earthflow Landslides	Deep-Seated Rotational Landslides
Mason County, WA	493,720	124,246	4,119	1,904	10,142	359	3.9	363	198	0.3	15,310.9	466	2.9
Unincorporated Mason Co.	486,609	124,189	4,119	1,900	8,516	359	3.9	363	198	0.3	7,998	386	1.5
City of Shelton	3,688	43.7	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	9.7	0.0	0.0
Town of Allyn	1,151	5.7	0.0	0.0	7.1	0.0	0.0	0.0	0.0	0.0	9.3	4.8	0.0
Town of Belfair	2,271	14.6	0.0	0.0	18.3	0.0	0.0	0.0	0.0	0.0	179.5	0.0	0.0

8.3.4 Impact on Critical Facilities and Infrastructure

Table 8-3 and Table 8-4 illustrate the critical facilities and infrastructure at risk within the various hazard areas as identified. Loss of these structures would have the potential to impact not only loss of services, but in some instances, loss of continuity of government due to the type of structure lost.

Table 8-3
Critical Facilities in Proximity to Historic Landslide or Unstable Slope Zones

Hazard Zone	Government Function	Communications	Medical	Hazardous Materials	Protective Services	Power	Other	Water	Wastewater	Total
Within Historic Landslide or Unstable Slope	0	0	0	0	0	0	0	6	0	**6**
Within 500 ft. of Historic Landslide or Unstable Slope	0	0	0	0	6	0	0	22	0	**28**
Within 1,000 ft. of Historic Landslide or Unstable Slope	1	0	0	0	5	2	0	16	2	**26**

Table 8-4
Critical Facilities within Proximity of Landslide Gentle & Steep Slope Zones

Hazard Zone	Government Function	Communications	Medical	Hazardous Materials	Protective Services	Power	Other	Water	Wastewater	Total
No Slope *(< 15% or < 8.53°)*	20	2	1	4	47	20	7	168	24	**293**
Gentle Slopes (15% - 40% or 8.53° - 21.8°)	0	0	0	0	0	0	0	0	0	**0**
Steep Slopes (40% or >21.8°)	0	0	0	0	0	0	0	1	0	**0**
Within 1,000 ft of Gentle Slopes (15% - 40% or 8.53° - 21.8°)	11	2	0	4	19	9	0	59	12	**116**

Several types of infrastructure are exposed to mass movements, including transportation facilities, airports, bridges, and water, sewer, and power infrastructure. Highly susceptible areas include mountain and coastal roads and transportation infrastructure. All infrastructure and transportation falling within the hazard areas are considered vulnerable until more information becomes available. Significant infrastructure in the planning region exposed to mass movements includes the following:

- **Roads**—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems and delays for public and private transportation. This can result in economic losses for businesses.
- **Bridges and Boat/Ferry Docks**—Landslides can significantly impact road bridges and boat/ ferry docks. Mass movements can knock out bridge and dock abutments, causing significant misalignment and restricting access and usages, as well as significantly weaken the soil supporting the structures, making them hazardous for use.
- **Power Lines**—Power lines are generally elevated above steep slopes, but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil beneath a tower, causing collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.

8.3.5 Impact on Economy

A landslide can have catastrophic impact on the private sector and governmental agencies. Economic losses include damage costs and lost revenue and taxes. Damaged bridges, roadways, marinas, boat docks, municipal airports all can have a significant impact on the economy. Damages in this capacity could have a significant economic impact on not only Mason County, but also other areas of the state.

The impact on commodity flow from a significant landslide shutting down major access routes would not only limit the resources available for citizens' use, but also would cause economic impact on businesses in the area. Debris could impact cargo staging areas and lands needed for business operations. With highway 101 serving as a primary transportation route in the area, use of the highway reduces travel time between the inland Puget Sound area and the peninsula region, compared to requiring vehicles to travel much greater distances around the sound on land. Impacts would also significantly reduce the tourism industry within the County.

8.3.6 Impact on Environment

Environmental problems as a result of mass movements are numerous. Landslides that fall into water bodies, wetlands or 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 of time due to landslides. With impact already occurring due to increased sediment loads in the floodplain, landslides could cause additional impact within the Skokomish River (and other) watersheds.

8.3.7 Impact from 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, raise sea levels, and increase beach. 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.

8.4 FUTURE DEVELOPMENT TRENDS

Under the Growth Management Act, the County is required to address geologic hazards within its Critical Areas Ordinance, which it does. Continued application of land use and zoning regulations, as well as implementation of the International Building Codes, will assist in reducing the risk of impact from landslide hazards. Certain areas of the County, such as Allyn, have experienced a higher than normal growth when compared to other areas of the County over the course of the last two years (post-COVID).

Mason County is also attempting to expand its business base, which will increase economic vitality by providing businesses that stimulate retail sales and services, and increased tourism. As a relatively high retirement and tourist destination for Washington, continued land use supported by regulatory authority which supports economic growth but practices smart planning will be vital. All planning partners are committed to assessing the landslide risk and developing mitigation efforts to reduce impact or enhance resiliency. There are four basic strategies to mitigate landslide risk:

- Stabilization
- Protection
- Avoidance
- Maintenance and monitoring.

Stabilization seeks to counter one or more key failure mechanisms necessary to prevent slope failure. The other three strategies seek to avoid, protect against or limit associated impacts. Development of this mitigation plan creates an opportunity to enhance and develop wise land use decision-making policies. It allows for the expansion of capital improvement plans to sustain future growth through the use of these four basic strategies.

Climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration which can saturate soils beyond capacity. Increase in global temperature could further exacerbate this by affecting the snowpack and its ability to hold and store water, further raising sea levels, and increasing beach erosion along the County's coastline. 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. As parts of the County maintain fairly dense forested areas, such an incident would be significant. All of these factors would increase the probability of landslides.

8.5 ISSUES

Landslides throughout the County occur as a result of soil conditions that have been affected by severe storms, groundwater, or human development. The worst-case scenario for landslide hazards in the planning area would generally correspond to a severe storm that had heavy rain and caused flooding. Landslides are most likely during late fall or early spring —months when the water tables are high. After heavy rains during October to April, soils become saturated with water. As water seeps downward through upper soils that may consist of permeable sands and gravels and accumulates on impermeable silt, it will cause weakness and destabilization in the slope. A short intense storm could cause saturated soil to move, resulting in landslides. As rains continue, the groundwater table rises, adding to the weakening of the slope. Gravity, a small tremor or earthquake, poor drainage, steep bank cutting, a rising groundwater table, and poor soil exacerbate hazardous conditions.

Mass movements are becoming more of a concern as development moves outside of urban centers and into areas less developed in terms of infrastructure. While most mass movements would be isolated events affecting specific areas, the areas impacted can be very large. It is probable that private and public property, including infrastructure, will be affected. Mass movements could affect bridges that pass over landslide prone ravines and knock out ferry services. Road obstructions caused by mass movements would create isolation problems for residents and businesses in sparsely developed areas, and impact commodity flows. Property owners exposed to steep slopes may suffer damage to property or structures. Landslides carrying vegetation such as shrubs and trees may cause a break in utility lines, cutting off power and communication access to residents; they may block ingress and egress to areas of the County, especially for areas with limited roadways.

Important issues associated with landslides throughout Mason County include the following:

- There are existing structures in landslide risk areas throughout the County. The degree of vulnerability of these structures depends on the codes and standards the structures were constructed to. Information to this level of detail is not currently available.
- Future development could lead to more homes in landslide risk areas.
- Portions of the County are surrounded by fairly steep banks and cliffs. Coastal erosion causes landslides as the ground washes away.
- Mapping and assessment of landslide hazards are constantly evolving. As new data and science become available, assessments of landslide risk should be re-evaluated. LiDAR data would greatly enhance the ability to determine landslide hazards, as well as other hazards.
- While the impact of climate change on landslides in general is uncertain, the impact of sea level rise caused by increased temperatures has already enhanced coastal erosion within the planning area. As climate change continues to impact atmospheric conditions, the exposure to landslide risks is likely to increase.
- Landslides cause many negative environmental consequences, including water quality degradation, degradation of fish spawning areas, and destruction of vegetation along waterways, ultimately impacting the flow of water bodies.
- The risk associated with the landslide hazard overlaps the risk associated with other hazards such as earthquake, flood, and wildfire. This provides an opportunity to seek mitigation goals with multiple objectives that can reduce risk for multiple hazards.

8.6 RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from Landslide throughout the area is highly likely, but the impact is more limited with respect to geographic extent. The area experiences some level of landslides annually. The coastal bluff areas, and areas within the unincorporated areas of the County have identifiable landslide risk.

While there are areas where no landslide risk is identified, landslides can nonetheless occur on fairly low slopes, and areas with no slopes can be impacted by slides at a distance. Construction in critical areas, which includes geologically sensitive areas such as landslide areas, is regulated; however, beyond the structural impact, secondary impact to infrastructure causing isolation or commodity shortages also has the potential to impact the region. Based on the potential impact, the Planning Team determined the CPRI score to be 2.95, with overall vulnerability determined to be a high level.

CHAPTER 9.
SEVERE WEATHER

Severe weather refers to any dangerous meteorological phenomena with the potential to cause damage, serious social disruption, or loss of human life. It includes thunderstorms, downbursts, wind, tornadoes, waterspouts, and snowstorms. Severe weather differs from extreme weather, which refers to unusual weather events at the extremes of the historical distribution.

General severe weather covers wide geographic areas; localized severe weather affects more limited geographic areas. The severe weather event that most typically impacts the planning area is a damaging windstorm, which causes storm surges exacerbating coastal erosion. Flooding associated with severe weather is discussed in Chapter 8.

DEFINITIONS

Freezing Rain—The result of rain occurring when the temperature is below the freezing point. The rain freezes on impact, resulting in a layer of glaze ice up to an inch thick. In a severe ice storm, an evergreen tree 60 feet high and 30 feet wide can be burdened with up to six tons of ice, creating a threat to power and telephone lines and transportation routes.

Hail Storm—Any thunderstorm which produces hail that reaches the ground is known as a hailstorm. Hail has a diameter of 0.20 inches or more. Hail is composed of transparent ice or alternating layers of transparent and translucent ice at least 0.04 inches thick. Although the diameter of hail is varied, in the United States, the average observation of damaging hail is between 1 inch and golf ball-sized 1.75 inches. Stones larger than 0.75 inches are usually large enough to cause damage.

Severe Local Storm—"Microscale" atmospheric systems. These storms may cause a great deal of destruction and even death, but their impact is generally confined to a small area. Typical impacts are on transportation infrastructure and utilities.

Thunderstorm—A storm featuring heavy rains, strong winds, thunder and lightning, typically about 15 miles in diameter and lasting about 30 minutes. Hail and tornadoes are also dangers associated with thunderstorms. Lightning is a serious threat to human life. Heavy rains over a small area in a short time can lead to flash flooding.

Tornado— Most tornadoes have wind speeds less than 110 miles per hour are about 250 feet across, and travel a few miles before dissipating. The most extreme tornadoes can attain wind speeds of more than 300 miles per hour, stretch more than two miles across, and stay on the ground for dozens of miles. They are measured using the Enhanced Fujita Scale, ranging from EF0 to EF5.

Windstorm—A storm featuring violent winds. Southwesterly winds are associated with strong storms moving onto the coast from the Pacific Ocean. Southern winds parallel to the coastal mountains are the strongest and most destructive winds. Windstorms tend to damage ridgelines that face into the winds.

Winter Storm—A storm having significant snowfall, ice, and/or freezing rain; the quantity of precipitation varies by elevation.

9.1 GENERAL BACKGROUND

Mason County has a predominantly maritime climate, influenced by the Olympic Mountain Range.

9.1.1 Semi-Permanent High- and Low-Pressure Areas Over the North Pacific Ocean

During summer and fall, the circulation of air around a high-pressure area over the north Pacific brings a prevailing westerly and northwesterly flow of comparatively dry, cool, and stable air into the Pacific Northwest. As the air moves inland, it becomes warmer and drier, resulting in a dry season. In the winter and spring, the high pressure is further south and low pressure prevails in the northeast Pacific. Circulation of air around both pressure centers brings a prevailing southwesterly and westerly flow of mild, moist air into the Pacific Northwest. Condensation occurs as the air moves inland over the cooler land and rises along the windward slopes of the mountains. This results in a wet season beginning in late October or November, reaching a peak in winter, and gradually decreasing by late spring.

West of the Cascade Mountains, summers are cool and relatively dry while winters are mild, wet, and generally cloudy. Measurable rainfall occurs on 150 days each year in interior valleys and on 190 days in the mountains and along the coast.

Thunderstorms occur up to 10 days each year over the lower elevations and up to 15 days over the mountains. Damaging hailstorms are rare in western Washington. During July and August, the driest months, two to four weeks can pass with only a few showers; however, in December and January, the wettest months, precipitation is frequently recorded on 25 days or more each month. Snowfall is light in the lower elevations and heavier in the mountains. During the wet season, rainfall is usually of light to moderate intensity and continuous over a long period rather than occurring in heavy downpours for brief periods; heavier intensities occur along the windward slopes of the mountains.

9.1.2 Atmospheric Phenomenon

Atmospheric rivers (see Figure 9-1) are relatively long, narrow regions in the atmosphere – like rivers in the sky – that transport most of the water vapor outside of the tropics. These columns of vapor move with the weather, carrying an amount of water vapor roughly equivalent to the average flow of water at the mouth of the Mississippi River. When the atmospheric rivers make landfall, they often release this water vapor in the form of rain or snow. Those that contain the largest amounts of water vapor, and the strongest winds can create extreme rainfall and floods, often by stalling over watersheds vulnerable to flooding. These events can disrupt travel, induce mudslides, and cause catastrophic damage to life and property. A well-known example is the "Pineapple Express," a strong atmospheric river that is capable of bringing moisture from the tropics near Hawaii over to the U.S. West Coast. [11]

El Niño-Southern Oscillation (ENSO) cycle is a scientific term that describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific. ENSO is one of the most important climate phenomena on Earth due to its ability to change the global atmospheric circulation, which in turn, influences temperature and precipitation across the globe. Though ENSO is a single climate phenomenon, it has three states, or phases, it can be in. The two opposite phases, "El Niño" and "La Niña," require certain changes in both the ocean and the atmosphere because ENSO is a coupled climate phenomenon. "Neutral" is in the middle of the continuum.

- La Nina (translated from Spanish as "little girl") is a natural ocean-atmospheric phenomenon marked by cooler-than-average sea surface temperatures across the central and eastern Pacific Ocean near the equator. La Nina typically brings above-average precipitation and colder-than-average temperatures along the northern tier of the U.S., along with below-average precipitation and above-average temperatures across the South.

[11] NOAA. What are atmospheric rivers? Accessed 9 Feb 2023. Available online at: https://www.noaa.gov/stories/what-are-atmospheric-rivers

- An El Nino (translated from Spanish as "little boy") is marked by warmer-than-average sea surface temperatures in the region. Typical El Niño effects are likely to develop over North America during the upcoming winter season. Those include warmer-than-average temperatures over western and central Canada, and over the western and northern United States. Wetter-than-average conditions are likely over portions of the U.S. Gulf Coast and Florida, while drier-than-average conditions can be expected in the Ohio Valley and the Pacific Northwest. The presence of El Niño can significantly influence weather patterns, ocean conditions, and marine fisheries across large portions of the globe for an extended period of time.

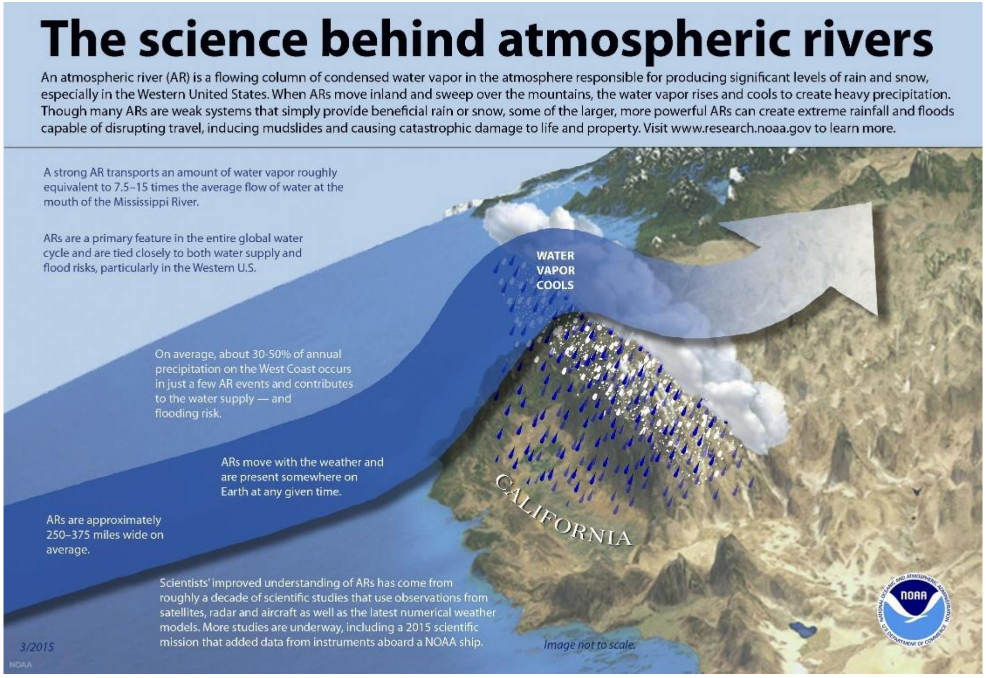

Figure 9-1 Atmospheric Rivers

9.1.3 Thunderstorms

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. Thunderstorms have three stages (see Figure 9-2):

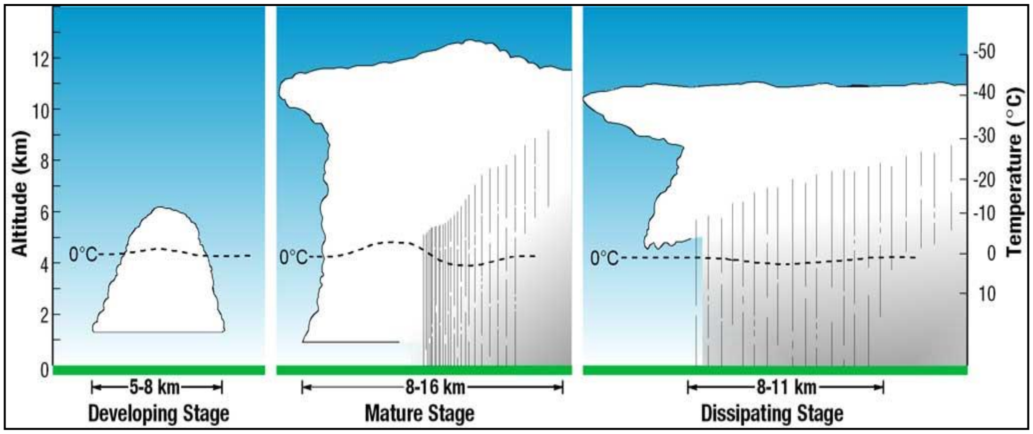

Figure 9-2 The Thunderstorm Life Cycle

Three factors cause thunderstorms: moisture, rising unstable air (air that keeps rising once 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 earth surface to the upper atmosphere (the process of convection). The water vapors 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 heard as thunder. 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, is a long line of storms with a continuous well-developed gust front at the leading edge. The storms can be solid, or have gaps and breaks in the line. Squall lines can produce hail up to golf-ball size, heavy rainfall, and weak tornadoes, but they are best known as the producers of strong downdrafts. Occasionally, a strong downburst will accelerate a portion of the squall line ahead of the rest of the line. This produces what is called 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.

As of 2021 (last full year reported) Washington ranked 48th nationwide for lightning strikes with 55,779 recorded (down five from 2020). For lightning strike density (by area), Washington ranked 50th. During 2021, NOAA reported 11 fatalities, below the previously recorded low of 16 deaths in 2017 (see Figure 9-3). None of the fatalities occurred in Washington State. Based on an analysis updated in 2021 by John Jensenius, Jr., of the National Lightning Safety Council, victims of lightning fatalities were again most often engaged in leisure activities (eight), followed by work-related activities (three). Of the 11 fatalities, all but one was male. On average, lightning strikes start 14 percent of wildfires annually in the United States, with those fires resulting in 58 percent of the acreage burned each year (Vaisala, 2021). 2021 also saw historic severe weather outbreaks impact central and eastern portions of the United States in mid-December, a month during which thunderstorms are customarily low.

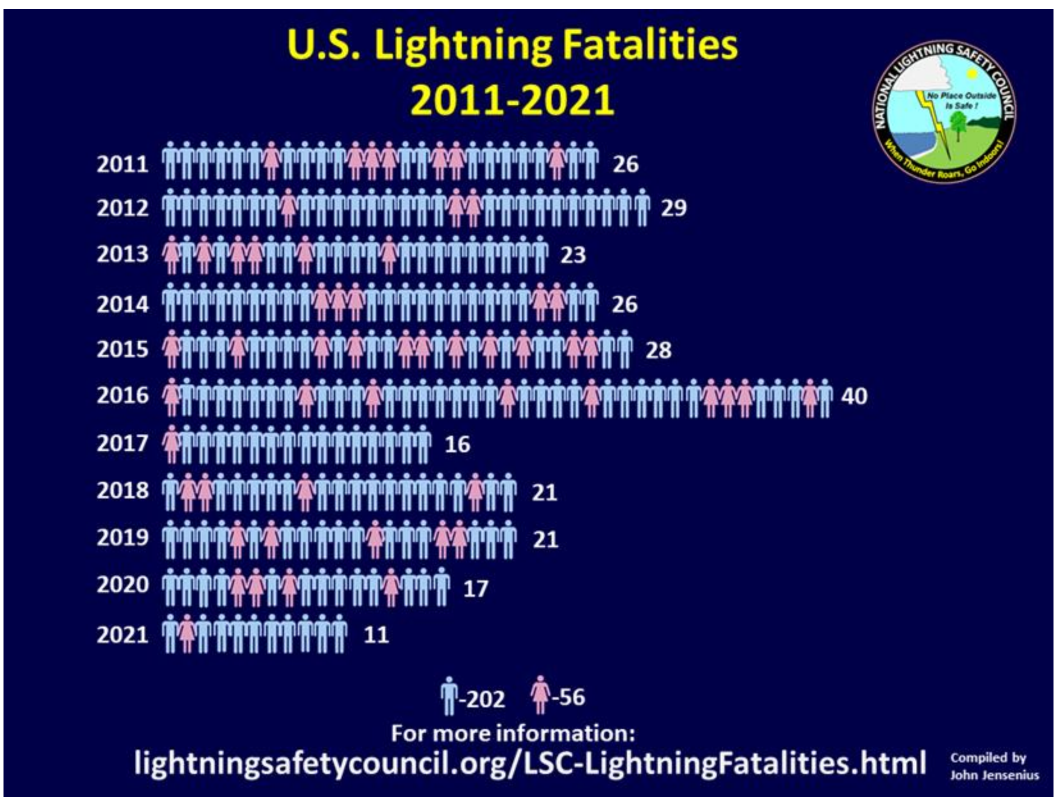

Figure 9-3 Lightening Fatalities 2011-2021

9.1.4 Damaging Winds

Damaging winds are classified as those exceeding 60 mph. Damage from such winds accounts for half of all severe weather reports in the lower 48 states and is more common than damage from tornadoes. Wind speeds can reach up to 100 mph and can produce a damage path extending for hundreds of miles. 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, common in places like the high plains and the intermountain west, 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 of Spanish origin 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.

There are four main types of windstorm tracks that impact the Pacific Northwest as identified in Figure 9-4. These four tracks are distinguished by two basic windstorm patterns that have emerged in the Puget Sound Region: the South Wind Event and the East Wind Event. South wind events are generally large-scale events that affect large portions of Western Washington and possibly Western Oregon. On occasional cases, they have reached as far south as Northern California.

Source: Oregon Climate Service, 2015

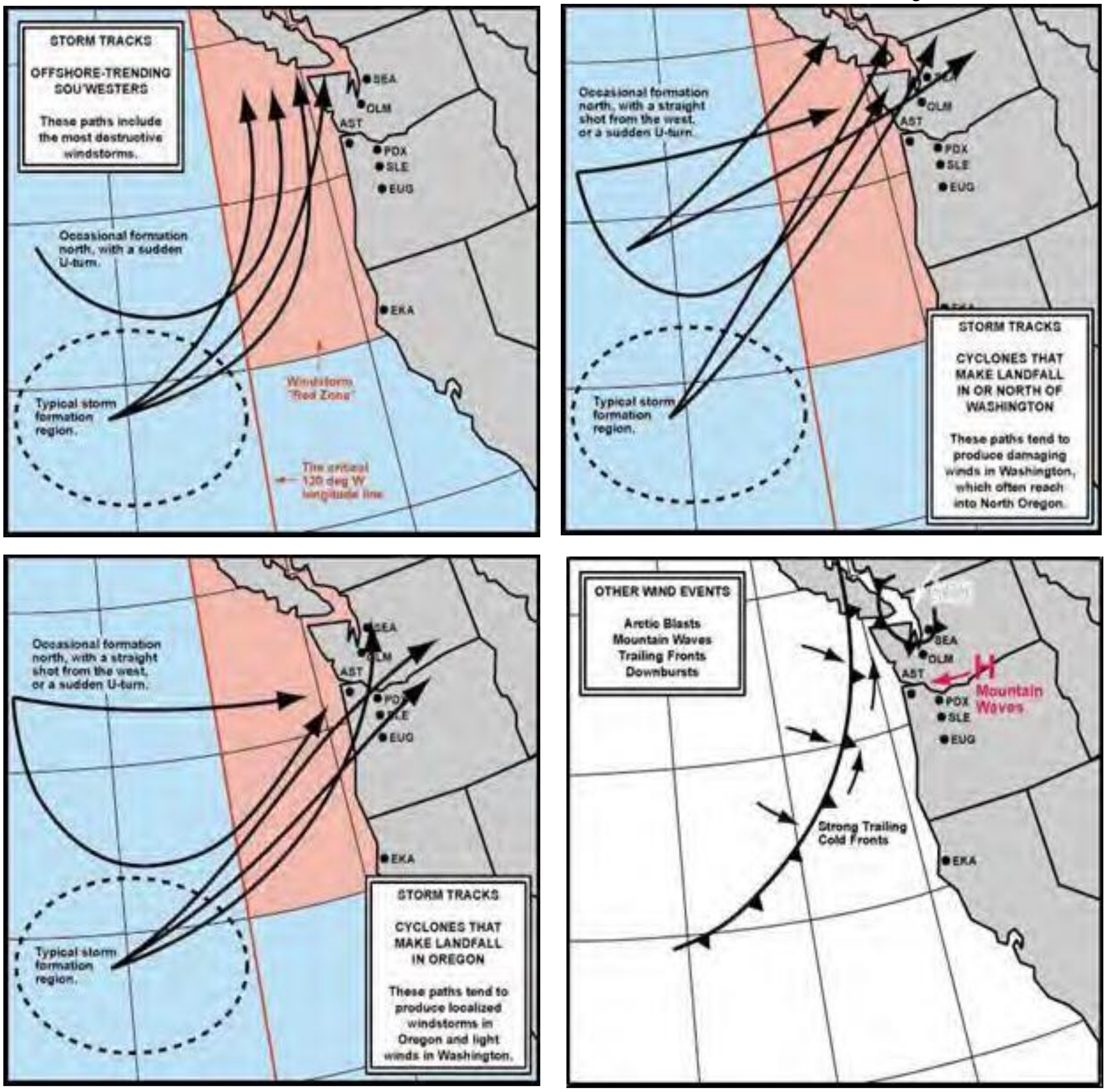

Figure 9-4 Windstorm Tracks Impacting the Pacific Northwest

In contrast, easterly wind events are more limited. High pressure on the east side of the Cascade Mountain Range creates airflow over the peaks and passes, and through the funneling effect of the valleys, the wind increases dramatically in speed. As it descends into these valleys and then exits into the lowlands, the wind can pick up enough speed to damage buildings, rip down power lines, and destroy fences. Once it leaves the proximity of the Cascade foothills, the wind tends to die down rapidly.

All of Mason County is in an 85-mph wind zone. Within this zone there are four (4) zones of exposure, three (3) of which are identified in Mason County and that are utilized to guide structure development (2006 International Building Code). These exposure zones further identify areas that are at higher risk from impacts of high winds. The closer development is to open waters and on top of steep cliffs, the higher the design criteria that is required through building code. Based on the

International Building Code, the zones are broken down into surface roughness categories and are defined as follows:

- <u>Surface Roughness B</u>. Urban and suburban areas, wooded areas or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.
- <u>Surface Roughness C</u>. Open terrain with scattered obstructions having heights generally less than 30 feet (9144 mm). This category includes flat open country, grasslands, and all water surfaces in hurricane-prone regions.
- <u>Surface Roughness D</u>. Flat, unobstructed areas, and water surfaces outside hurricane-prone regions. This category includes smooth mud flats, salt flats and unbroken ice.

Figure 9-5 Hanukkah Eve Peak Wind Gusts

Windstorms impact all of Mason County on a regular basis. The strongest winds are generally from the south or southwest and occur during fall and winter. Some are much more damaging than others. For those like the Hanukkah Eve Windstorm of 2006 (see Figure 9-5), the impact on the public can be severe.

Mason County was significantly impacted. Torrential rains overwhelmed sewage treatment plants, and when plants lost power, raw sewage flooded into Puget Sound in Mason County.

The strongest windstorm was the 1962 Columbus Day Storm, which was the strongest non-tropical windstorm to hit the lower 48 states. It traveled about 40 mph from Northern California to the Canadian border and east as far as Montana. The storm killed 46 people, destroyed more than 50,000 homes, left another 469,000 without power, caused $235 million in property damage and flattened 15 billion board feet of timber worth an estimated $750 million. Severe winds also occurred during the Inauguration Day storm of 1993 (see Figure 9-6) . Other severe storms that have severely impacted Mason County have occurred in 1971, 1973, 1979, 1980, 1985, 1986, 2006, 2007, 2009, 2012, 2015 (2 events), 2020, and 2021.

9.1.5 Hail Storms

Hail occurs when updrafts in thunderstorms carry raindrops upward into extremely cold areas of the atmosphere where they freeze into ice. Recent studies suggest that 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.

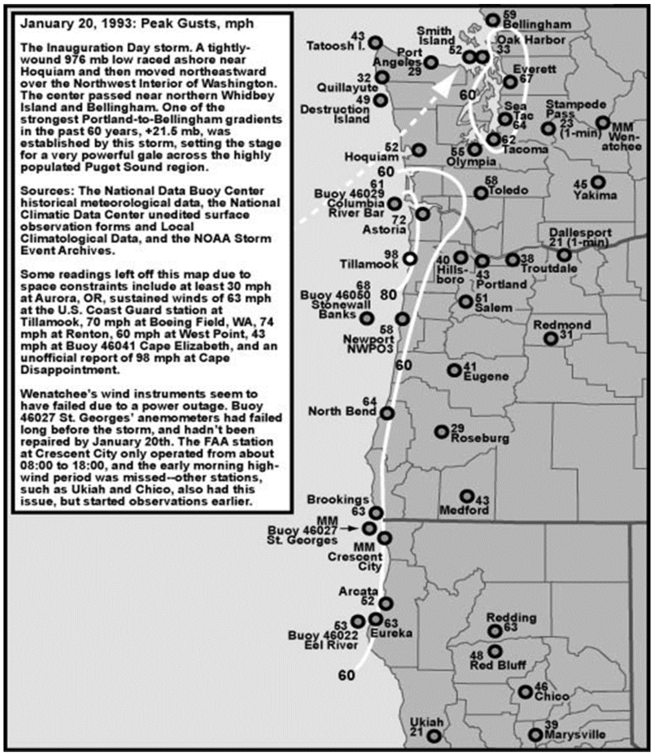

Figure 9-6 Inauguration Day Storm Peak Wind Gusts

9.1.6 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 9-7).

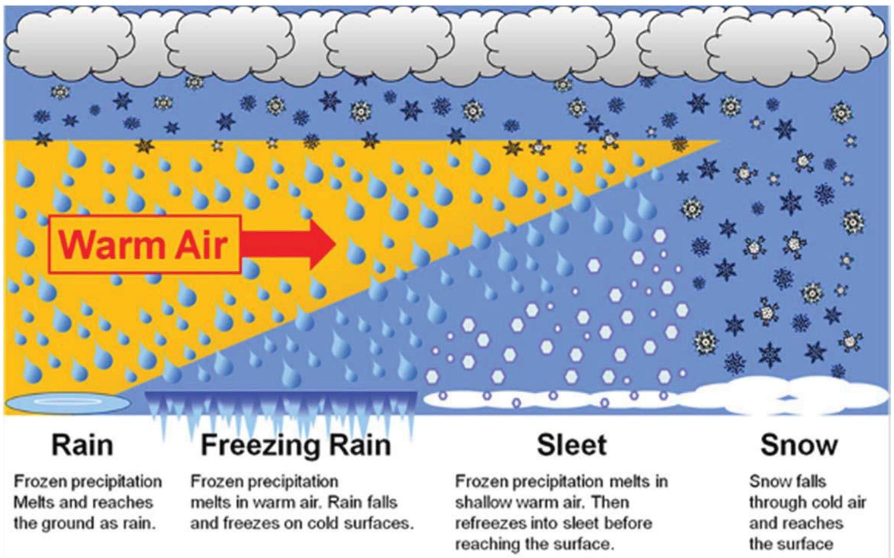

Figure 9-7 Types of Precipitation

9.1.7 Extreme Temperatures

Extreme temperature includes both heat and cold events, which can have a significant impact on human health, commercial/agricultural businesses and primary and secondary effects on infrastructure (e.g., burst pipes and power failure). What constitutes "extreme cold" or "extreme heat" can vary across different areas of the country, based on what the population is accustomed to within the region (CDC, 2014).

Extreme Cold

Extreme cold events are when temperatures drop well below normal in an area. In regions relatively unaccustomed to winter weather, near freezing temperatures are considered "extreme cold." Extreme cold can often accompany severe winter storms, with winds exacerbating the effects of cold temperatures by carrying away body heat more quickly, making it feel colder than is indicated by the actual temperature (known as wind chill). Figure 9-8 demonstrates the value of wind chill based on the ambient temperature and wind speed.

Exposure to cold temperatures, whether indoors or outside, can lead to serious or life-threatening health problems such as hypothermia, cold stress, frostbite or freezing of the exposed extremities such as fingers, toes, nose, and ear lobes. Hypothermia occurs when the core body temperature is <95ºF. If persons exposed to excessive cold are unable to generate enough heat (e.g., through shivering) to maintain a normal core body temperature of 98.6ºF, their organs (e.g., brain, heart, or kidneys) can malfunction. Extreme cold also can cause emergencies in susceptible populations, such as those without shelter, those who are stranded, or those who live in a home that is poorly insulated or without heat. Infants and the elderly are particularly at risk, but anyone can be affected.

Extremely cold temperatures often accompany a winter storm, so individuals may have to cope with power failures and icy roads. Although staying indoors can help reduce the risk of injury on the ice, individuals may also face indoor hazards. Many homes will be too cold—either due to a power failure or because the heating system is not adequate for the weather. The use of space heaters and fireplaces to keep warm increases the risk of household fires and carbon monoxide poisoning.

Temperature (ºF)

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

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

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

Effective 11/01/01

Figure 9-8 NWS Wind Chill Index

During cold months, carbon monoxide may be high in some areas because the colder weather makes it difficult for car emission control systems to operate effectively. Carbon monoxide levels are typically higher during cold weather because the cold temperatures make combustion less complete and cause inversions that trap pollutants close to the ground (USEPA, 2009).

Extreme Heat

Temperatures that hover 10 degrees or more above the average high temperature for the region and last for several days or weeks are defined as extreme heat (FEMA, 2006; CDC, 2006). An extended period of extreme heat of three or more consecutive days is typically called a heat wave and is often accompanied by high humidity (Ready America, Date Unknown; NWS, 2005). There is no universal definition of a heat wave because the term is relative to the usual weather in a particular area. The term heat wave is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century (Meehl and Tebaldi, 2004). A basic definition of a heat wave implies that it is an extended period of unusually high atmosphere-related heat stress, which causes temporary modifications in lifestyle and which may have adverse health consequences for the affected population (Robinson, 2000). Figure 9-9 identifies some of those consequences and associated temperatures.[12]

Certain populations are considered vulnerable or at greater risk during extreme heat events. These populations include, but are not limited to the following: the elderly age 65 and older, infants and young children under five years of age (see Figure 9-10), pregnant woman, the homeless or poor, the overweight, and people with mental illnesses, disabilities, and chronic diseases (NYS HMP, 2008).

[12] NCDC, 2000

Relative Humidity (%)	Temperature (°F) 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										

Category	Heat Index	Health Hazards
Extreme Danger	130 °F – Higher	Heat Stroke / Sunstroke is likely with continued exposure.
Danger	105 °F – 129 °F	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Extreme Caution	90 °F – 105 °F	Sunstroke, muscle cramps, and/or heat exhaustions possible with prolonged exposure and/or physical activity.
Caution	80 °F – 90 °F	Fatigue possible with prolonged exposure and/or physical activity.

Figure 9-9 Heat Stress Index

Wind-Chill Factor Chart (in Fahrenheit)

Air Temperature	Wind Speed in mph: Calm	5	10	15	20	25	30	35	40
40	40	36	34	32	30	29	28	28	27
30	30	25	21	19	17	16	15	14	13
20	20	13	9	6	4	3	1	0	-1
10	10	1	-4	-7	-9	-11	-12	-14	-15
0	0	-11	-16	-19	-22	-24	-26	-27	-29
-10	-10	-22	-28	-32	-35	-37	-39	-41	-43

Comfortable for out door play   Caution   Danger

Heat Index Chart (in Fahrenheit %)

Air Temperature (F)	Relative Humidity (Percent): 40	45	50	55	60	65	70	75	80	85	90	95	100
80	80	80	81	81	82	82	83	84	84	85	86	86	87
84	83	84	85	86	88	89	90	92	94	96	98	100	103
90	91	93	95	97	100	103	105	109	113	117	122	127	132
94	97	100	103	106	110	114	119	124	129	135			
100	109	114	118	124	129	130							
104	119	124	131	137									

Figure 9-10 Temperature Index for Children

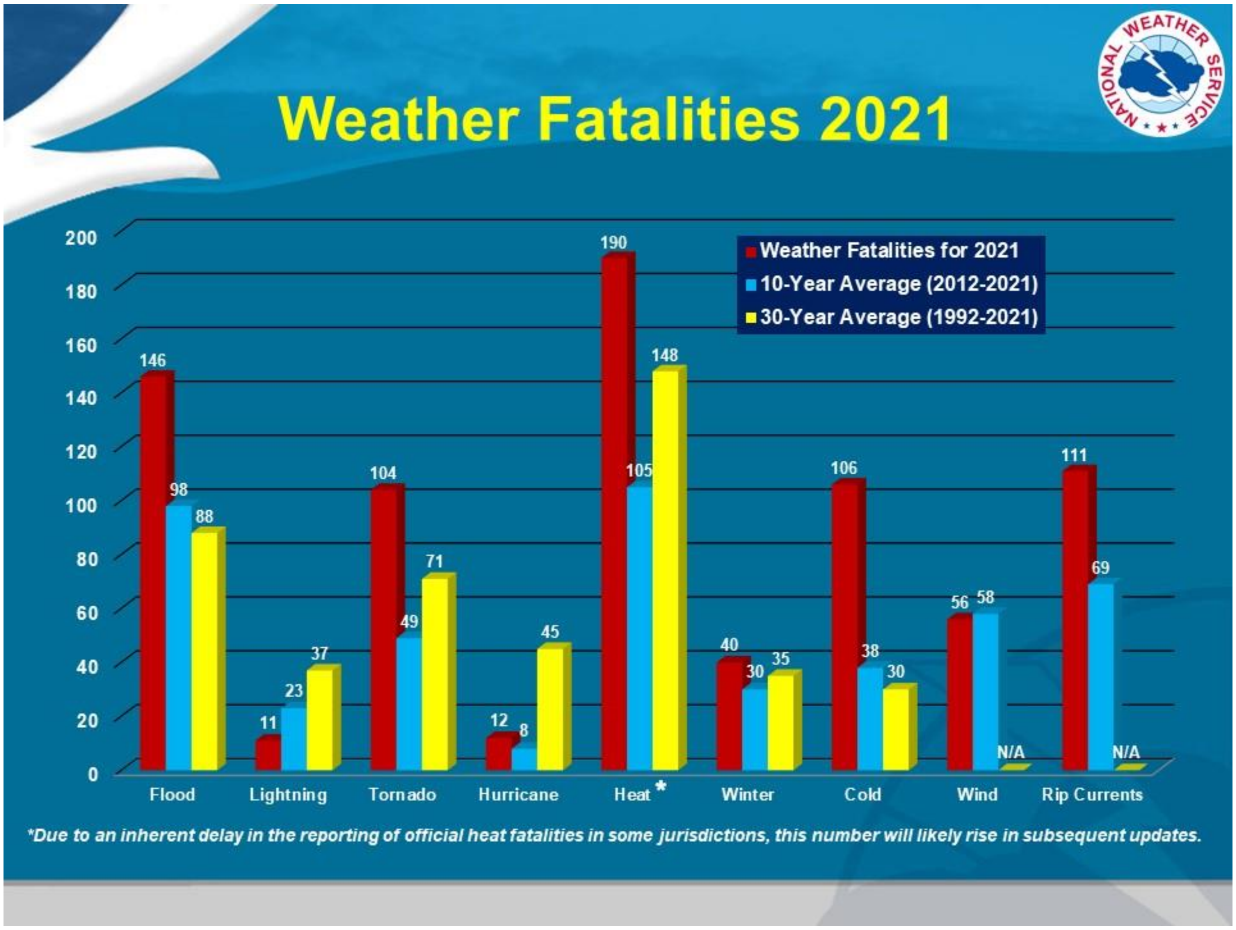

Figure 9-11 Weather Fatalities

Figure 9-11 illustrates the number of weather fatalities based on 10-year and 30-year averages.[13] Extreme heat is the number one weather-related cause of death in the U.S. over the 30-year average, followed by flood.

Depending on severity, duration, and location; extreme heat events can create or provoke secondary hazards including, but not limited to, dust storms, droughts, wildfires, water shortages and power outages (FEMA, 2006; CDC, 2006). This could result in a broad and far-reaching set of impacts throughout a local area or entire region. Impacts could include significant loss of life and illness; economic costs in transportation, agriculture, production, energy, and infrastructure; and losses of ecosystems, wildlife habitats and water resources (Adams, Date Unknown; Meehl and Tebaldi, 2004; CDC, 2006; NYSDPC, 2008).

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[13] NOAA, 2023 (http://www.nws.noaa.gov/om/hazstats.shtml) (Most recently available at time of update.)

9.2 HAZARD PROFILE

9.2.1 Extent and Location

The entire planning area is susceptible to the impacts of severe weather. Severe weather events customarily occur during the months of October to April, although they have occurred year-round. The County has been impacted by strong winds, rain, snow, or other precipitation, and often are accompanied by thunder or lightening (Mason County, 2010). Considerable snowfall does not customarily occur throughout the region.

Communities in low-lying areas next to coastlines, rivers, streams, or lakes are more susceptible to flooding as a result of storm surge. Wind events are most damaging to areas of Mason County. Winds coming off of the Pacific Coast can have a significant impact on the planning region as a result of both the wind and associated storm surge (Hood Canal area). For the planning region as a whole, wind events are one of the most common weather-related incidents to occur, often times leaving the area without power, although customarily not for long, extended periods.

Severe storms and weather affect transportation and utilities. Access across certain parts of the County is unpredictable as roads are vulnerable to damage from severe storms, storm surges, and landslide/erosion. Severe storms and storm surges can also cause flooding and channel migration.

9.2.2 Previous Occurrences

Types of severe weather occurring within Mason County vary due to the topography of the area encompassing the planning area, but some level of severe weather or storm event impacts the area at least once annually, although not to the level of a disaster declaration. Events include thunderstorms, hailstorms, heavy precipitation, straight line winds, and damaging downburst winds. Less frequent severe weather phenomena include ocean squalls (along the coastal areas), heavy snowstorms, and ice storms, although all have occurred in the planning area. The most recent snow event occurred in December 2021 (County declared an emergency event due to snow, ice/freezing temperatures and rain combination impacting several mobile homes, collapsing car ports, etc.), which was ultimately declared as a presidential declaration in December 2022. The County has not experienced any tornado events, although there have been reported tornadoes in the surrounding counties.

Since 1956, 12 severe weather events have been declared in the County. This equates to one declared incident every 5.4 years, with a probability of occurrence per year of 18.46 percent. One fatality has occurred, as a result of a severe storm event causing a landslide which struck a residence. Severe storms or weather events are the hazard which has impacted the county most frequently since 1956, followed by Flood events. FEMA ranks Severe Storms as the hazard of highest priority in the county.

9.2.3 Severity

The most common problems associated with severe storms are immobility and loss of utilities. As indicated, the County has experienced one fatality as a result of a severe weather event.

During severe storms, roads may become impassable due to flooding, downed trees, ice or snow, or a landslide, which regularly occurs as a result of ground saturation from heavy rains often associated with severe weather events.

Power lines may also 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 caused by wind, or by accumulation of snow or ice can also occur. Due to the limited amount of snow customarily received in the region, even a small accumulation of ice or snow can, and has, caused havoc on transportation systems due to hilly terrain, the level of experience of drivers to maneuver in snow and ice conditions, and the lack of snow clearing equipment and resources within the region, which is more rural in nature in many areas.

Ice storms, especially when accompanied by high winds, can have an especially destructive impact within the planning region, with both being able to close major transportation corridors and bridges. Accumulation of ice on trees, power lines, communication towers and wiring, or other utility services can be crippling, and create additional hazards for residents, motorists and pedestrians.

During the last 30 years, Western Washington has had an average annual snowfall of 11.4 inches per year, with the snowfall customarily occurring during November through March, although snow has fallen as late as April. Within Mason County, snowfall ranges an average of 3-5 inches, with approximately 2 days (averaged) per year with snow depths of 1 inch or more.[14] Historical records in Western Washington are as follows:

- January 1950 – One-day record for snow accumulation – 21 inches
- January 1950 – One-month record for snow accumulation – 57 inches
- 1968-1969 – Winter season record for snow accumulation – 67 inches

Windstorms are common in the planning area, occurring many times throughout the year within Mason County. They are especially concerning for PUDs 1 and 3. The predicted wind speed given for wind warnings issued by the National Weather Service is for a one-minute average, during which gusts may be 25 to 30 percent higher.

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 planning area, damage could be widespread. As a result of building stock age, fatalities could be high, with many people homeless for an extended period of time. Routine services such as telephone or power could be disrupted. Businesses could be forced to close for an extended period, impacting commodities available for citizens. As a result of the heavily forested areas, debris accumulations would be high, causing additional difficulties with access along major arterials connecting the area to other parts of the state, further impacting logistical support and commodities.

The extent (severity or magnitude) of extreme cold temperatures are generally measured through the wind chill temperature index. Wind Chill Temperature is the temperature that people and animals feel when outside and it is based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body is cooled at a faster rate causing the skin's temperature to drop (NWS, 2009).

[14] USA.Com Mason County Weather: http://www.usa.com/mason-county-wa-weather.htm#

9.2.4 Frequency

Of the 12 severe weather events for Mason County identified in Chapter 3, most are related to high winds and associated other winter storm-type events such as heavy rains and landslides, and to a much lesser extent, snow. The planning area can expect to experience exposure to some type of severe weather event at least annually, with declared events occurring on average every 5.4 years. The probability of a severe weather event of some type occurring on an annual basis is 18.46 percent.

Washington State Department of Ecology has estimated frequency intervals for wind speed as follows:

WIND SPEEDS EXCEED	FREQUENCY
55 MPH	Annually
76 MPH	~ 5 years
83 MPH	~10 years
92 MPH	~25 years
100 MPH	~50 years
108 MPH	~100 years

9.3 VULNERABILITY ASSESSMENT

9.3.1 Overview

Severe weather incidents can and regularly do occur throughout the entire planning area. Similar events impact areas within the planning region differently, even though they are part of the same system. While in some instances some type of advanced warning is possible, as a result of climatic differences, topographic and relative distance to the coastline, the same system can be much more severe in certain areas of the County. Therefore, preparedness plays a significant contributor in the resilience of the citizens to withstand such events.

A lack of data separating severe weather damage from flooding, windstorms, and landslide damage prevent a detailed analysis for exposure and vulnerability. For planning purposes, it is assumed that the entire planning area is exposed to some extent to severe weather. Certain areas are more exposed due to geographic location and local weather patterns, as well as the response capabilities of local first responders.

Warning Time

Meteorologists can often predict the likelihood of some severe storms. In some cases, this can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm, and the rapid changes which can also occur significantly increasing the impact of a weather event.

9.3.2 Impact on Life, Health and Safety

The entire planning area is susceptible to severe weather events. Populations living at higher elevations with large stands of trees or above-ground power lines may be more susceptible to wind damage and black out conditions, while populations in low-lying areas are at risk for possible flooding and landslides associated with the flooding as a result of heavy rains. Increased levels of precipitation in the form of snow also vary by area, with higher elevations being more susceptible to increased accumulations. Resultant secondary impacts from power outages during cold weather event, when combined with the high population of retired and elderly residents significantly impacts response capabilities and the risk factor associated with such weather incidents. Within the densely wooded areas, increased fire danger during extreme heat conditions increases the likelihood of fire, which increases fire danger.

Particularly vulnerable populations are the elderly and very young, low income, linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads. Extreme temperature variations, either heat or cold, are of significant concern on both the elderly and the young, increasing vulnerability of those populations.

A number of storm events have cut off primary access routes to areas of the County for days at a time, in some instances for over six months. These storm events include both declared and non-declared incidents, as even minor incidents have the potential to impact ingress and egress. Such issues are of concern as a result of limited access for evacuation purposes by first responder if vital ALS is required, as well as for general evacuation purposes during a period where power is out, and individuals attempt to leave the area. Travel time can be increased significantly if alternate routes are used.

PUDs 1 and 3 provide electricity to the planning area. Severe weather events can and have disrupted electricity in the planning area, on average though only a few times each year. When most power outages occur, they last for only a few hours, except in extreme outlying areas. The most significant event which caused power to be out for in excess of seven days was as a result of the 1996 ice storm. Since completion of the 2018 HMP, the area has been impacted by some form of severe winter storm or snow storm which have caused power outages lasting 12 hours or more. The December 2021-January 2022 Severe Winter Storm impacted the most number of residents, with power in some areas not restored for four days.

The large population of retirees and the higher rate of disabled individuals living in the area are of significant concern to the planning partners throughout the region when severe weather events occur due to the higher levels of vulnerable populations.

9.3.3 Impact on Property

Currently data identifies that there are in excess of 33,600 buildings in the planning area. Most of these buildings are residential. Within Mason County, approximately 58 percent of structures were built after 1980; however, in the City of Shelton, only 34 percent of structures were built after 1980, meaning a high percentage of structures in Shelton could be impacted by significant weather events as many were built without the influence of a structural building code with provisions for wind loads.

For planning purposes, all properties and buildings within the planning area are considered to be exposed to the severe weather hazard, but structures in poor condition or in particularly vulnerable locations (hilltops or exposed open areas) may be at risk for the most damage. The frequency and degree of damage will depend on specific locations and severity of the weather pattern impacting the region. It is improbable to determine the exact number of structures susceptible to a weather event, and therefore emergency managers and public officials should establish a maximum threshold, or worst-case scenario, of susceptible structures.

9.3.4 Impact on Critical Facilities and Infrastructure

All critical facilities are vulnerable to some degree. As many of the severe weather events include multiple hazards, information such as that identifying facilities exposed to flooding or landslides (see Flood and Landslide profiles) are also likely exposed to severe weather. Additionally, facilities on higher ground may also be exposed to wind damage or damage from falling trees. The most common problems associated with severe weather are loss of utilities. Downed power lines can cause blackouts, leaving large areas without power. Such was the case experienced as a result of the 1996 ice storm, which left much of the area without power for several days. The most recent long-term power outage was caused by the December 2021-January 2022 Severe Winter Storm.

As a result of historical events, the local utility providers continue their practice of tree-trimming operations to reduce the potential impact from wind, ice and snow events. In addition to power loss, the area can also experience a loss of phone (cell and land-line), water and sewer systems, which may not function properly during severe weather events. Loss of electricity and phone connection could also result in some residents being unable to call for emergency assistance as needed. Roads may also become impassable due to ice or snow, or from secondary hazards such as landslides. Within the planning region, Tacoma Public Utilities has two hydroelectric dams which produce a significant amount of power to areas well outside of the planning area. Major power lines travel from the various dams through a large swath of Mason County. As such, wind events occurring in Mason County also have the potential to impact power supplies in large metropolitan areas well outside of Mason County.

Incapacity and loss of roads are the primary transportation failures, most of which are associated with secondary hazards such as landslides. Landslides that block roads are caused by heavy prolonged rains, and often times reoccur in areas previously impacted. High winds can cause significant damage to trees and power lines, with obstructing debris blocking roads, incapacitating transportation, isolating populations, and disrupting ingress and egress. Snowstorms at higher elevations can impact the transportation system and the availability of public safety services. Of particular concern are roads providing access to isolated areas and to the elderly.

9.3.5 Impact on Economy

Prolonged obstruction of major routes due to severe weather can disrupt the shipment of goods and other commerce. Severe windstorms, downed trees, and ice can create serious impacts on power and above-ground communication lines. Freezing rain/snow on power and communication lines can cause them to break, disrupting electricity and communication, further impacting business within the region. Prolonged outages would impact consumer and tax base as a result of lost revenue, (food) spoilage, lack of production, etc. The County does have a fairly large forest harvesting industry as well as large shellfish farms which would be negatively impacted by severe weather events. Large, prolonged storms can have negative economic impacts for an entire region. All severe weather events have the potential to also impact tourism, an industry on which much of the planning region is dependent.

9.3.6 Impact on Environment

The environment is highly exposed to severe weather events. Natural habitats such as streams and trees are exposed to the elements during a severe storm and risk major damage and destruction. Prolonged rains can saturate soils and lead to slope failure. Flooding events caused by severe weather or snowmelt can produce river channel migration or damage riparian habitat, also impacting spawning grounds and fish populations for many years. Within the planning area, there are four fish hatcheries, which, if impacted, could result in decreased numbers of salmon and trout in the area, as the hatcheries release the fish annually. Should this occur, this would impact the area for years to come due to the life-cycle of the returning salmon. Storm surges can erode beachfront bluffs and redistribute sediment loads. Extreme heat can raise temperatures of rivers, impacting oxygen levels in the water, threatening aquatic life.

9.3.7 Impact from Climate Change

Climate change presents a challenge for risk management associated with severe weather. The frequency of severe weather events has increased steadily over the last century. The number of weather-related disasters during the 1990s was four times that of the 1950s, and cost 14 times as much in economic losses. Historical data shows that the probability for severe weather events increases in a warmer climate.

The last several years, and in particular 2021 and 2022, have seen record temperatures, with meteorologists predicting continued increase. This increase in average surface temperatures can also lead to more intense heat waves that can be exacerbated in urbanized areas by what is known as urban heat island effect. Additionally, the changing hydrograph caused by climate change could have a significant impact on the intensity, duration, and frequency of storm events. All of these impacts could have significant economic consequences.

With the increase in average ambient temperatures, since the 1980s, unusually cold temperatures have become less common in the contiguous 48 states. This trend is expected to continue, and the frequency of winter cold spells will likely decrease. 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.

9.4 FUTURE DEVELOPMENT TRENDS

All future development will be affected by severe storms. The ability to withstand impacts lies in sound land use practices and consistent enforcement of codes and regulations for new construction. The County does have land use regulations in place, which includes implementation of the International Building Codes as well as additional land use authority. These codes are equipped to deal with the impacts of severe weather incidents by identifying construction standards which address wind speed, roof load capacity, elevation and setback restrictions.

While under the Growth Management Act public power utilities are required by law to supply safe, cost effective and equitable service to everyone in the service area requesting service, most lines in the area are above-ground, causing them to be more susceptible to high winds or other severe weather hazards. However, growth management is also a constraint, which could possibly lead to increased outages or even potential shortages, as while most new development expects access to electricity, they do not want to be in close proximity to sub stations. The political difficulty in sighting these sub-stations makes it difficult for the utility to keep up with regional growth.

Land use policies currently in place, when coupled with informative risk data such as that established within this mitigation plan and such other projects like FEMA's new flood maps, will also address the severe weather hazard. With the land use tools currently in place, the County and its planning partners will be well-equipped to deal with future growth and the associated impacts of severe weather.

9.5 ISSUES

Important issues associated with a severe weather in the planning area include the following:

- 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 weather events such as windstorms.
- Redundancy of power supply must be evaluated and increased region-wide in order to more fully understand the vulnerabilities in this area.
- The capacity for backup power generation is limited and should be enhanced, especially in areas of potential isolation due to impact on major thoroughfares or evacuation routes.
- Isolated population centers exist.
- Climate change may increase the frequency and magnitude of winter flooding or storm surges, thus exacerbating severe winter events.
- Proximity to coastline enhances flooding potential through storm surges, as well as severe storms in general.

9.6 RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from a severe weather event throughout the area is highly likely. The area experiences some severe storm event annually, albeit not to the level of a disaster declaration, but nonetheless significant. While snow and ice do occur, impact historically has been somewhat limited. The more significant issue would be a severe storm which causes a landslide or flood event (particularly if occurring simultaneous with high-tide), isolating areas or blocking ingress and egress. Wind is also a significant factor, which can cause power outages. While the PUDs maintain excellent records for low incidents of long-term power outages, the possibility does exist. Based on the potential impact, the Planning Team determined the CPRI score to be 3.0, with overall vulnerability determined to be a high level.

CHAPTER 10. WILDFIRE

A wildfire is any uncontrolled fire occurring on undeveloped land that requires fire suppression. Wildfires can be ignited by lightning or by human activity such as smoking, campfires, equipment use, and arson. The wildfire season in Washington usually begins in April, picks up in early July, and generally ends in late September; however, wildfires have occurred every month of the year. Drought, snow pack, and local weather conditions can expand the length of the fire season.

People start most wildfires; major causes include arson, recreational fires that get out of control, smoker carelessness, debris burning, and children playing with fire. Wildfires started by lightning burn more state-protected acreage than any other cause. Fires during the early and late shoulders of the fire season usually are associated with human-caused fires; fires during the peak period of July, August and early September often are related to thunderstorms and lightning strikes.

As of this 2023 update, the County has applied for and is awaiting notification for a grant to develop a countywide CWPP. Should the award be received, the CWPP will take the place of the wildfire chapter of the HMP to reduce redundancy of effort as the CWPP will be much more encompassing.

10.1 GENERAL BACKGROUND

Wildland-Urban Interface Areas

The wildland urban-interface (WUI) is the area where development meets wildland areas. This can mean structures built in or near natural forests, or areas next to active timber and rangelands. The federal definition of a WUI community is an area where development densities are at least three residential, business, or public building structures per acre. For less developed areas, the wildland-intermix community has development densities of at least one structure per 40 acres.

In 2001, Congress mandated the establishment of a Federal Register which identifies all urban wildland interface communities within the vicinity of Federal lands, including Indian trust and restricted lands that are at high-risk from wildfire. The list assimilated information provided from States and Tribes, and is intended to identify those communities considered at risk. Review of the Federal Registry lists in excess of 10 communities within Mason County at high-risk within the vicinity of Federal lands.[15]

When identifying areas of fire concern, in addition to the Federal Register, the Washington Department of Natural Resources and its federal partners, the U.S. Forest Service, also determine communities at risk based on fire behavior potential, fire protection capability, and risk to social, cultural and community resources. These risk factors include areas with fire history, the type and density of vegetative fuels, extreme weather conditions, topography, number and density of

[15] https://www.federalregister.gov/documents/2001/01/04/01-52/urban-wildland-interface-communities-within-the-vicinity-of-federal-lands-that-are-at-high-risk-from

structures and their distance from fuels, location of municipal watersheds, and likely loss of housing or business. Based on these criteria, the wildfire risk for Mason County is illustrated in Figure 10-1 based on U.S. Forest Service analysis.

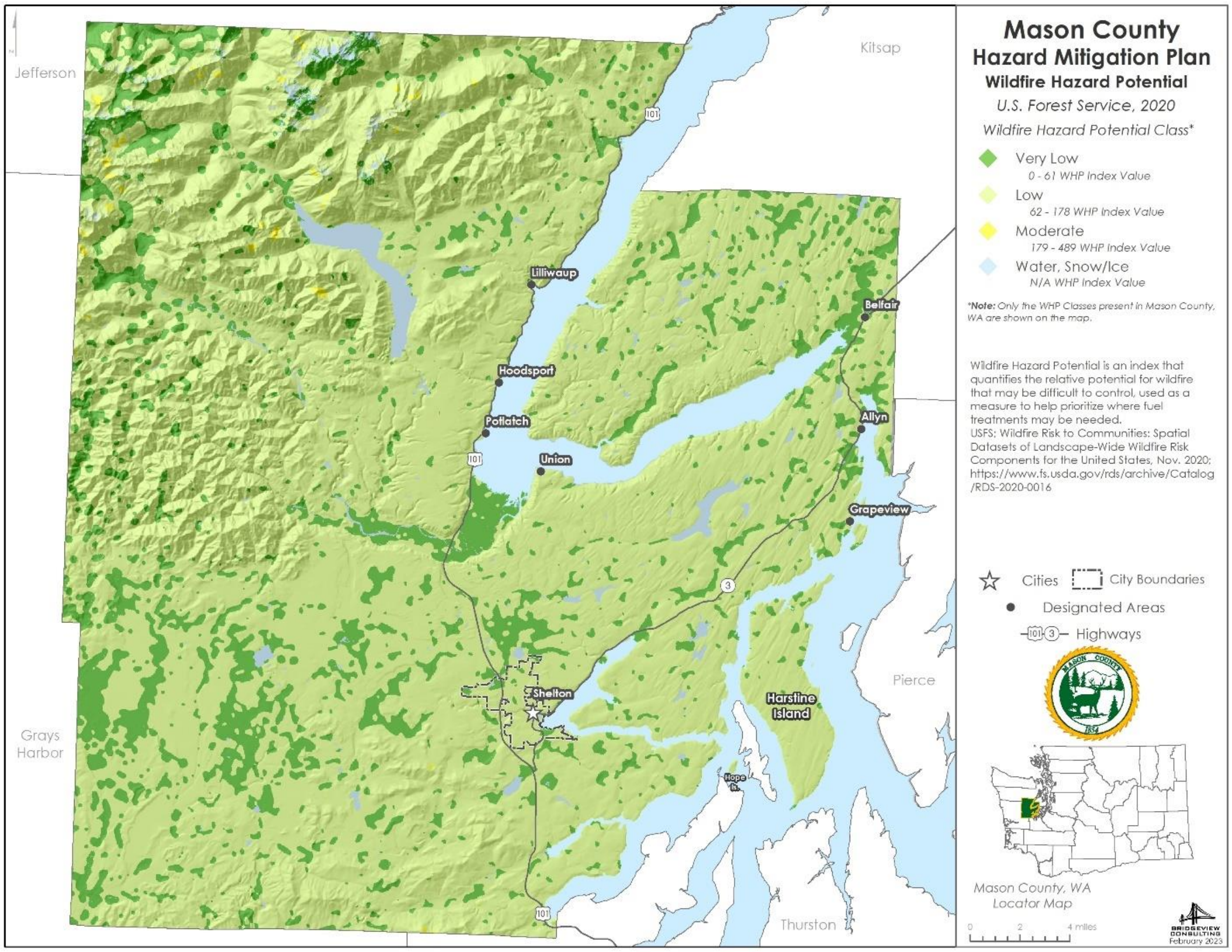

Figure 10-1 Wildfire Hazard Potential

The wildfire triangle (see Figure 10-2; DeSisto et al., 2009) is a simple graphic used in wildland firefighter training courses to illustrate how the environment affects fire behavior. Each point of the triangle represents one of three main factors that drive wildfire behavior: weather, vegetation type (which firefighters refer to as "fuels"), and topography. The sides represent the interplay between the factors. For example, drier and warmer weather combined with dense fuel loads (e.g., logging slash) and steeper slopes will cause more hazardous fire behavior than light fuels (e.g., short grass fields) on flat ground.

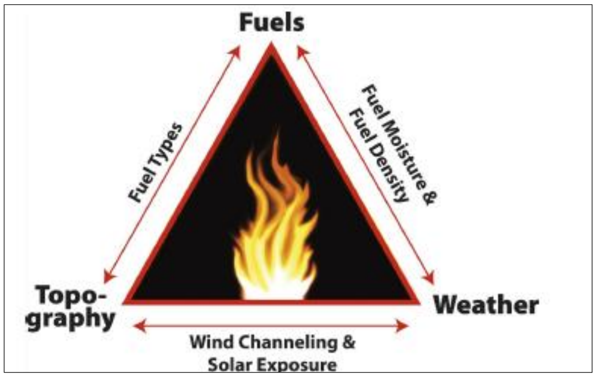

Figure 10-2 Wildfire Behavior Triangle

The following are key factors affecting wildfire behavior:

- **Fuel**—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. Snags and hazard trees—those that are diseased, dying, or dead—are larger but less prolific west of the Cascades than east of the Cascades. In 2002, about 1.8 million acres of the state's 21 million acres of forestland contained trees killed or defoliated by forest insects and diseases.
- **Weather**— Relevant weather conditions include temperature, relative humidity, wind speed and direction, cloud cover, precipitation amount and duration, and the stability of the atmosphere. Of particular importance for wildfire activity are wind and thunderstorms:
  - Strong, dry winds produce extreme fire conditions. Such winds generally reach peak velocities during the night and early morning hours. East wind events can persist up to 48 hours, with wind speed reaching 60 miles per hour. Being a coastal community, the County experiences significant winds on a fairly regular basis during all times of the year.
  - The thunderstorm season typically begins in June with wet storms, and turns dry with little or no precipitation reaching the ground as the season progresses into July and August.
- **Topography—**Topography includes slope, elevation and aspect. The topography of a region influences the amount and moisture of fuel; the impact of weather conditions such as temperature and wind; potential barriers to fire spread, such as highways and lakes; and elevation and slope of land forms (fire spreads more easily uphill than downhill).
- **Time of Day**—A fire's peak burning period generally is between 1 p.m. and 6 p.m.
- **Forest Practices—**In densely forested areas, stands of mixed conifer and hardwood stands that have experienced thinning or clear-cut provide an opportunity for rapidly spreading, high-intensity fires that are sustained until a break in fuel is encountered.

Fires can be categorized by their fuel types as follows:

- **Smoldering**—Involves the slow combustion of surface fuels without generating flame, spreading slowly and steadily. Smoldering fires can linger for days or weeks after flaring has ceased, resulting in potential large quantities of fuel consumed. They heat the duff and mineral layers, affecting the roots, seeds, and plant stems in the ground. These are most common in peat bogs, but are not exclusive to that vegetation.

- **Crawling**—Surface fires that consume low-lying grass, forest litter and debris.
- **Ladder**—Fires that consume material between low-level vegetation or forest floor debris and tree canopies, such as small trees, low branches, vines, and invasive plants.
- **Crown**—Fires that consume low-level surface fuels, transition to ladder fuels, and also consume suspended materials at the canopy level. These fires can spread rapidly through the top of a forest canopy, burning entire trees, and can be extremely dangerous (sometimes referred to as a “Firestorm”).

Wildfires may spread by jumping or spotting, as burning materials are carried by wind or firestorm conditions. Burning materials can also jump over roadways, rivers, or even firebreaks and start distant fires. Updraft caused by large wildfire events draws air from surrounding area, and these self-generated winds can also lead to the phenomenon known as a firestorm.

10.1.1 Wildfire Impact

Short-term loss caused by a wildfire can include the destruction of timber, wildlife habitat, scenic vistas, and watersheds. Long-term effects include smaller timber harvests, reduced access to affected recreational areas, and destruction of cultural and economic resources and community infrastructure. Vulnerability to flooding increases due to the destruction of watersheds. The potential for significant damage to life and property exists in WUI areas, where development is adjacent to densely vegetated areas (DeSisto et al., 2009).

Forestlands in the planning area are susceptible to disturbances such as logging slash accumulation, forest debris due to weather damage, and periods of drought and high temperature. Forest debris from western red cedar, western hemlock, and Sitka spruce can be especially problematic and at risk to wildfires when slash is accumulated on the forest floor, because such debris resists deterioration. When ignited, these fuels can be explosive and serve as ladder fuels carrying fire from the surface to the canopy.

10.1.2 Identifying Wildfire Risk

Risk to communities is generally determined by the number, size and types of wildfires that have historically affected an area; topography; fuel and weather; suppression capability of local and regional resources; where and what types of structures are in the WUI; and what types of pre-fire mitigation activities have been completed. Identifying areas most at risk to fire or predicting the course a fire will take requires precise science. The following data sets are most useful in assessing risk in the area:

- **Topography (slope and aspect) and Vegetation (fire fuels)**—These are two of the most important factors driving wildfire behavior.
- **Weather**—Regional and microclimate variations can strongly influence wildfire behavior. Because of unique geographic features, weather can vary from one neighborhood to another, leading to very different wildfire behavior.

- **Critical Facilities/Asset Location**—A spatial inventory of assets—including homes, roads, fire stations, and natural resources that need protection—in relation to wildfire hazard helps prioritize protection and mitigation efforts.

10.1.3 Secondary Hazards

Wildfires 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. Wildfires cause the contamination of reservoirs, destroy transmission lines and contribute to flooding. They strip slopes of vegetation, exposing them to greater amounts of runoff. This in turn can weaken soils and cause failures on slopes. Major landslides can occur several years after a wildfire. 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.

10.2 HAZARD PROFILE

10.2.1 Extent and Location

Mason County has never received a state or federal disaster declaration for a fire event. Given its rural land use complexity and its proximity to the various large park systems (both federal and state), the entire region is susceptible to impact from wildfire, either as a direct result, or as a secondary result from health or economic impact.

10.2.2 Previous Occurrences

Wildfires have been a common occurrence throughout Washington as a whole for thousands of years. Evidence from tree rings or fire-scarred trees indicates cycles of prehistoric fires burned in many locations in both Eastern and Western Washington. Natural fire occurrence is directly related, but not proportional, to lightning incidence levels. It is rare for a summer to pass without at least one period of lightning activity. Lightning incidence is greatest during July and August, though storms capable of igniting fires have occurred from early spring to mid-October. Lightning storms generally track across the park in a southwest to northeast direction. At a national level, lightning starts over 4,000 house fires each year, which can ignite wildland fires through ember ignition and as a result of proximity to wildland areas. Lightning-caused fires cause over 10 times more acreage damage than human-caused fires, requiring great resource allocation.

Within Washington, lightning storms are typically followed by light to moderate amounts of precipitation. The rainfall may extinguish the fires, while high fuel moisture inhibits spread. However, prolonged periods of warm, dry weather, especially in combination with east winds, often reveal numerous latent "sleepers." While most lightning fires are less than a quarter acre in size, occasional large fires during dry periods account for most of the burned acreage.

During the time period 2009-2021 (last full year of data available), Mason County as a whole had 850 wildfires occurring in the County (or for which the fire districts assisted with response since 2017), burning a total of ~2,006 acres. When averaged, that equates to ~71 fires per year occurring in the county and surrounding area. That figure does not reflect the recurrence interval for fires within the County, but rather an average calculation as to the number of wildland fires which have historically occurred within the planning area during the periods reflected. For the period 2017-2021, those numbers also reflect mutual aid response provided to surrounding areas, and is indicative of the increase in fire response calls and the need for mutual aid.

Table 10-1 identifies the wildfires occurring within Mason County (or the surrounding areas) which have burned 5 acres or more, as well as the typing of fires. Table 10-2 identifies the total number of fires, regardless of size, and the total acres burned. Additional historic events are identified in Table 10-3.

Table 10-1
Mason County Historic Fire Events 5 Acres or Greater

Date	Name	Acres Burned	Complexity
7/7/2004	Island Shore Fire	10.4	4
4/25/2006	Razor Fire	5.6	4
7/24/06	Bear Gulch	1,050	2
8/29/2006	South Loop Fire	15	4
9/2/2006	Dewatto 2 Fire	61	2
9/7/2006	Pipeline 2 Fire	5	4
7/12/2007	Shelton Valley Rd. Fire	13	3
7/1/2007	Martin Road Fire	15	4
9/7/2008	East Cushman	10	4
8/2/2009	Eels Hill Road	13.2	4
8/25/2009	Vance Creek	16.3	3
8/15/2010	Richert Road	84.4	3
8/17/2011	Eells Hill	51.20	3
9/11/2012	School	10.4	4
9/12/2012	Carney Lake	5	4
9/26/2012	Powerline	9.3	4
10/4/2012	Powerline 2	229	2
8/10/2014	Mill 5	21	4
8/11/2014	Haven Lake	185	2
9/6/2014	Boyer Road	11	4

Table 10-1
Mason County Historic Fire Events 5 Acres or Greater

Date	Name	Acres Burned	Complexity
11/16/2014	WC 131	37	4
6/22/2015	Kamilche	5	4
7/31/2015	Deckerville	107	3
8/27/2015	Sunnyside	58	3
5/27/2016	Lynch Pit	7.1	4
8/13/18	Maple Fire (USFS Fire)	3,300	2
9/21/22	High Steel Fire	26	3

Table 10-2
Total Number Wildfire Events 2009-2021

Year	Total Number of Wildland Fires	Total Acres Burned
2009	26	42.90
2010	17	91.31
2011	26	55.52
2012	42	262.94
2013	18	4.44
2014	33	261.77
2015	54	183.65
2016	53	25.8
2017*	40	15.51
2018*	76	170.09
2019*	150	207.8
2020*	161	484.24
2021*	154	199.98
Total	850	2,006

*Includes some incidents of fire response from the various Fire Districts within Mason County to areas outside of the county via mutual aid.

Table 10-3 Additional Historic Wildfire Incidents	
8/1985	One of the largest fires in area history began with an illegal campfire caused the Beaver Fire just north of Staircase. Approximately 400 firefighters and 3 water-dumping helicopters fought the blaze. Smoke from the fire drifted at least 140 miles and over the Cascade Mountains creating a haze as far away as Wenatchee in Eastern Washington. Twenty backcountry hikers were evacuated from the Flapjacks Lakes area and another forty people in the area were taken out by park rangers supported by packhorses. The blaze charred over 1,000 acres and thousands of trees – some 200 to 300 years old – were destroyed. Only three minor injuries were reported among firefighters. The cost to fight the fire was over $500,000.
9/1995	A blaze consumed 25 acres of logged land on Harstine Island and involved almost 150 firefighters and suppression support personnel costing $135,000 to fight. Cause of fire was from a hunter's cigarette. The following day 36 acres of reforested land burned at Morrow Lake, an area south of Lake Nahwatzel. East winds pushed flames in the opposite direction from homes along the shore. The cost of fighting the fire was $65,000. A total of 200 firefighters were involved in the two battles.
5/1997	The Lake Limerick fire, pushed by strong southwest winds, burned 594 acres, including 100 acres of wetlands, between Lake Limerick and Emerald Lake. The fire burned Christmas trees, slash, young replanted trees, wetland areas, and second growth Douglas fir trees. The cost of fighting the fire was approximately $94,000. Firefighters from districts in Mason, Kitsap and Pierce Counties assisted the effort along with 70 Cedar Creek Correctional Center inmates. ~112 people from DNR and Cedar Creek completed the firelines. At the same time a second blaze consumed about 8 acres off Eagle Point Road.
7/2006	A wildfire burned from July to December, blackening a total of 1,085 acres on steep terrain in the Bear Gulch area, threatening the Lake Cushman community. Cost of fighting the fire was approximately $1.8 million. US Forest Service Rd. was closed for about 1 year to prevent injuries from rock and debris slides. This road is the major access to the popular Staircase area and several summer homes located on the west side of Lake Cushman.

10.2.3 Severity

Potential losses from wildfire include human life, structures and other improvements, and natural resources. Smoke and air pollution from wildfires can be a health hazard, especially for sensitive populations such as children, the elderly and those with respiratory and cardiovascular diseases. Wildfire may also threaten the health and safety of those fighting the fires. Wildfire can lead to ancillary impacts such as landslides in steep ravine areas and flooding due to the impacts of silt in local watersheds. The destruction of forestlands can have a significant impact on salmon rearing for generations.

Extreme fires, when they occur, are characterized by more intense heat and preheating of surrounding fuels, stronger flame runs, potential tree crowning, increased likelihood of significant spot fires, and fire-induced weather (e.g., strong winds, lightning cells). Extreme fire behavior is significantly more difficult to combat and suppress, and can drastically increase the threat to homes and communities. Several factors contribute to the severity of a fire, most of which are utilized when completing a Community Wildfire Protection Plan (CWPP), and developing a component based hazard ranking.

Due to years of fire suppression, logging, and other human activities, the forests and rangelands have changed. Areas that historically experienced frequent, low-severity wildfires now burn with much greater intensity due to the build-up of understory brush and trees. At times, this equates to fires which are larger and more severe, killing the trees and vegetation at all levels. The combination of steep slopes, canyons, open rangeland, and fuel type have a history and potential for fast moving and fast spreading wildfires.

The Mason County planning area is vulnerable to wind-driven fires, whose embers could ignite grasses and weeds, and cause spot fires in more populated areas. Typical summer conditions could prove to be problematic due to a fire moving uphill from a structure fire on a lower slope, or from a wildland fire pushing upslope through the trees on a windy day, endangering multiple homes simultaneously in a very short period of time. Residents would have very short notice of an approaching fire.

Review of historic wildfires in the County demonstrate there are several different causes, the most common being debris burning and recreational-related fires.

10.2.4 Frequency

As previously indicated, none of Washington State's most significant wildfires have occurred in Mason County, although smaller fires have occurred in the region annually. Fires historically burn on a regular cycle, recycling carbon and nutrients stored in the ecosystem, and strongly affecting species within the ecosystem. The burning cycle in western Washington is approximately every 100 to 150 years.

Historically, drought patterns are related to large-scale climate patterns in the Pacific and Atlantic oceans. The El Niño–Southern Oscillation 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 and more fires.

Historic Fire Regime

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. A fire regime refers to the frequency and intensity of natural fires occurring in various ecosystem types. Alterations of historical fire regimes and vegetation dynamics have occurred in many landscapes in the U.S., including Mason County through the combined influence of land management practices, fire exclusion, insect and disease outbreaks, climate change, and the invasion of non-native plant species. Anthropogenic influences on wildfire occurrence have been witnessed through arson, incidental ignition from industry (e.g., logging, railroad, sporting activities), and other factors. Likewise, wildfire abatement practices have reduced the spread of wildfires after ignition. This has reduced the risk to both the ecosystem and the urban populations living in or near forestlands, such as portions of Mason County.

The LANDFIRE Project produces maps of simulated historical fire regimes and vegetation conditions using the LANDSUM landscape succession and disturbance dynamics model. The LANDFIRE Project also produces maps of current vegetation and measurements of current vegetation departure from simulated historical reference conditions. 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. The simulated historical mean fire return interval data layer quantifies the average number of years between fires under the presumed historical fire regime. This data is derived from simulations using LANDSUM. LANDSUM simulates fire dynamics as a function of vegetation dynamics, topography, and spatial context, in addition to variability introduced by dynamic wind direction and speed, frequency of extremely dry years, and landscape-level fire characteristics. The historical fire regime groups simulated in LANDFIRE categorize mean fire return interval and fire severities into five regimes defined in the Interagency Fire Regime Condition Class Guidebook:

- Regime 1: 0-35-year frequency, low to mixed severity
- Regime II: 0-35-year frequency, replacement severity
- Regime III: 35-200-year frequency, low to mixed severity
- Regime IV: 35 -200-year frequency, replacement severity
- Regime V: 200+ year frequency, any severity

Large wildfires have historically been infrequent in the coastal regions of the Pacific Northwest. While 269 fires have occurred in the planning area since 2009, due to firefighting efforts, many have been contained with limited impact on acreage burned (~928 acres). Fire regimes in Mason County are illustrated in Figure 10-3. It should be noted that not all regime classes fall within the county boundary.

The Mean Fire Return Interval (MFRI) layer quantifies the average period between fires under the presumed historical fire regime. MFRI is intended to describe one component of historical fire regime characteristics. As illustrated, the average Mean Fire Return Interval for the majority of Mason County is every 70-100 years.

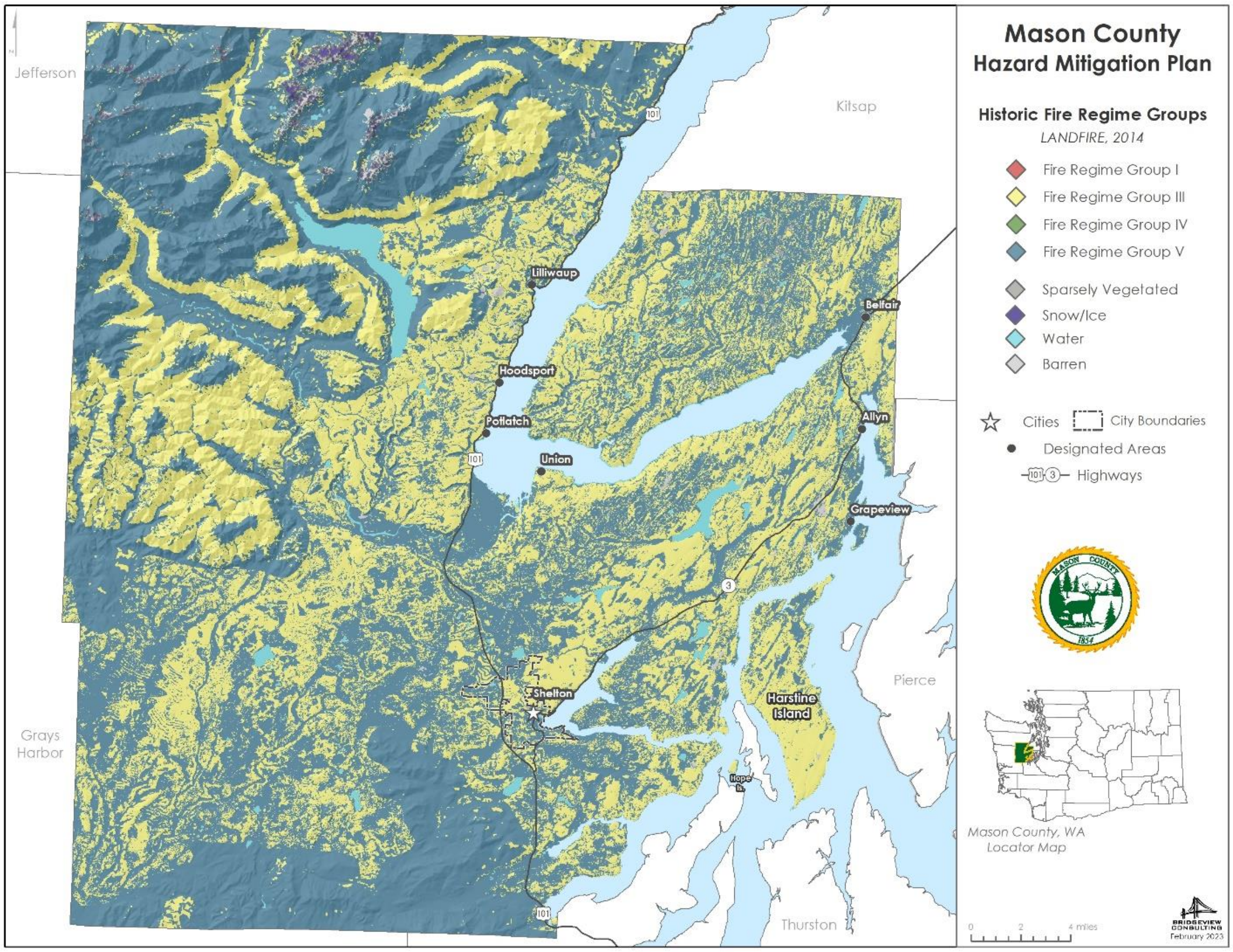

Figure 10-3 LANDFIRE Fire Regimes in Mason County

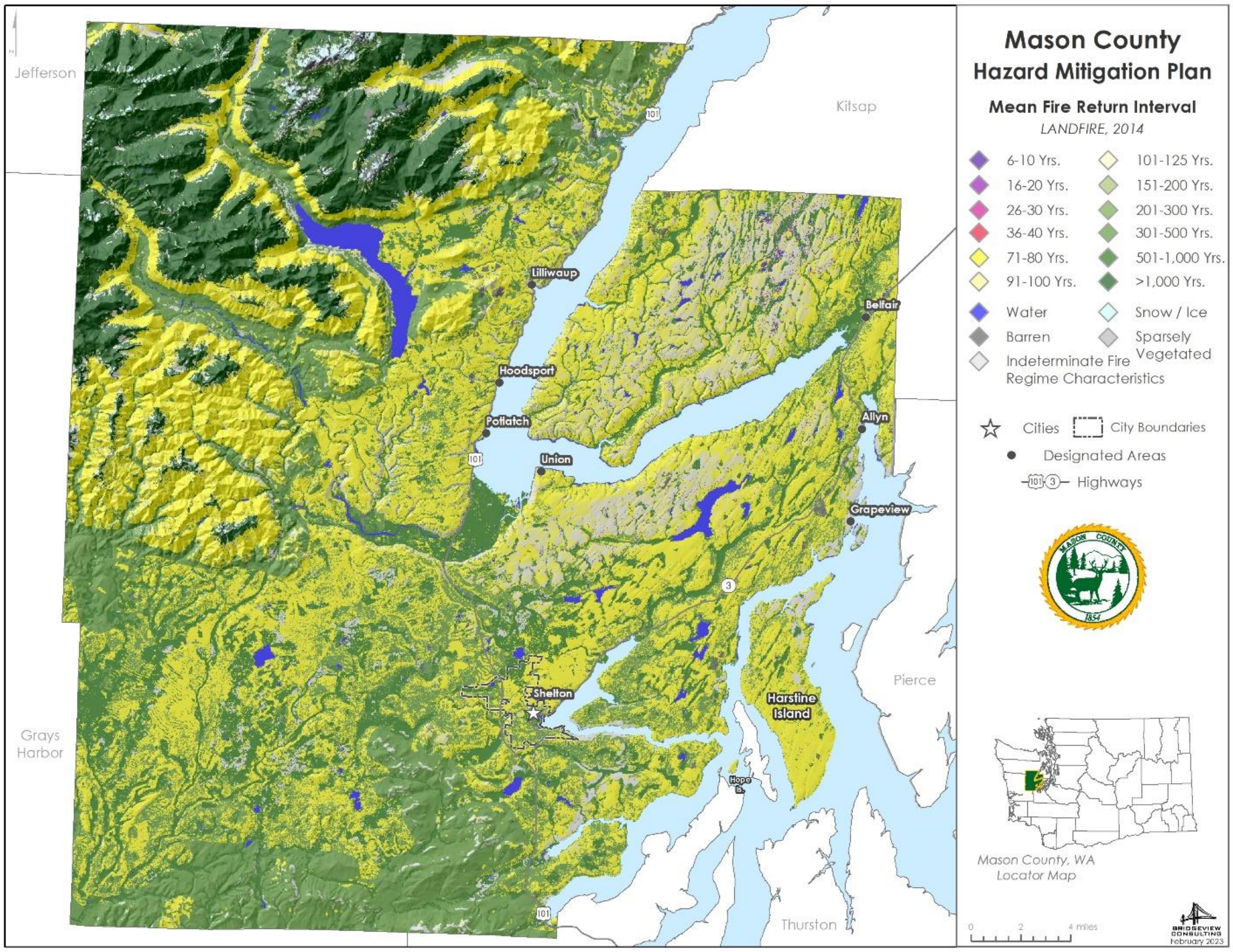

Figure 10-4 Mean Fire Return Interval

10.3 VULNERABILITY ASSESSMENT

10.3.1 Overview

Structures, above-ground infrastructure, critical facilities and natural environments are all vulnerable to the wildfire hazard. Understanding the relationship between weather, potential fire activity, and geographical features enhances the ability to prepare for the potential of wildfire events. This knowledge, when paired with emergency planning and appropriate mitigation measures, creates a safer environment.

Wildfire studies can analyze weather data to assist firefighters in understanding the relationship between weather patterns and potential fire behavior. Fire forecasting examines similarities between historical fire weather and existing weather and climate values. These studies have determined that for areas such as Mason County, any combination of two of the following factors can create more intense and potentially destructive fire behavior, known as extreme fire behavior:

- Sustained winds from the east
- Relative humidity less than 40 percent

- Temperature greater than 72º Fahrenheit
- Periods without precipitation greater than 14 days in duration
- 1,000-hour fuel moisture less than 17 percent.

If a fire breaks out and spreads rapidly, residents may need to evacuate within a short timeframe. A fire's peak burning period generally is between 1 p.m. and 6 p.m. In normal situations, fire alerting would commence quickly, helping to reduce the risk. However, in more remote locations of the County, or in areas where cell phone services are sporadic at times, warning time and calls for assistance may be reduced.

Warning Time

Wildfires are often caused by humans, intentionally or accidentally. There is no way to predict when one 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.

10.3.2 Impact on Life Health & Safety

Exposure to wildfire in Mason County is dependent upon many factors. The maps used in the analysis show areas of relative importance in determining fire risk, though they do not provide sufficient data for a statistical estimation of exposed population.

While there are no recorded fatalities from wildfire in the planning area, a statistical number of the population vulnerable to impact from fire is impossible to determine with any accuracy, due to the high number of variables that impact fire scenarios. The population at risk must also take into consideration tourists given the County's proximity to the parklands and other Washington high-tourist destinations. With its relatively high tourism rate, especially during summer months, there is an increase in the population vulnerability to fire. Given the increase in tourism during the summer months, when fire danger is at its greatest, increased consideration must be taken into account for fire response.

Smoke and air pollution from wildfires can be a severe health hazard, especially for sensitive populations, including children, the elderly and those with respiratory and cardiovascular diseases. Mason County has a high population of retirees and individuals over 65, further increasing the potential impact on the fire hazard. 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. Wildfire also threatens the health and safety of those fighting fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke. The county does have a high number of elderly citizens.

10.3.3 Impact on Property

Property damage from wildfires can be severe and can significantly alter entire communities. The potential exposure of the structures in the County should a fire occur is high, depending on the area, with the unincorporated county and the City of Shelton all having some degree of exposure to wildfire hazards. Some of the area fire districts are also volunteer, increasing the response times.

Density and the age of building stock in Mason County are contributing factors in assessing property vulnerability to wildfire. Many of the buildings in the planning area are of significant age, with many being constructed with wood frames and shingle roofs. Most do not have sprinkler systems. Table 10-4 identifies the acres within each fire regime group. Not all regimes fall within the County.

Table 10-4
LANDFIRE - Fire Regime Group Acres within Jurisdiction's Boundary

Jurisdiction	*Regime 1*	*Regime 2*	*Regime 3*	*Regime 4*	*Regime 5*	*Indeterminate Fire Regime Characteristics*	*Sparsely Vegetated*	*Snow/Ice*	*Barren*	*Water*
Mason County, WA	0.0	0.0	253,397.2	0.4	351,419.5	1,517.9	107.8	2,033.8	3,941.4	10,667.3
Unincorporated Mason Co.	0.0	0.0	249,819.7	0.4	347,767.3	1,510.5	107.8	2,033.2	3,904.7	10,425.8
City of Shelton	0.0	0.0	1,655.6	0.0	2,028.4	2.5	0.0	0.0	3.5	46.0
Town of Allyn	0.0	0.0	575.2	0.0	525.2	0.9	0.0	0.0	3.0	54.6
Town of Belfair	0.0	0.0	1,283.0	0.0	980.3	2.6	0.0	0.0	4.9	21.0

10.3.4 Impact on Critical Facilities and Infrastructure

Critical facilities of wood frame construction are especially vulnerable during wildfire events. In the event of wildfire, there would likely be little damage to most infrastructure. Most roads and railroads would be without damage except in the worst scenarios. Fueling stations could be significantly impacted, as could other structures maintaining hazardous materials. During a wildfire event, hazardous material storage containers could rupture due to excessive heat and act as fuel for the fire, causing rapid spreading and escalating the fire to unmanageable levels. In addition the materials could leak into surrounding areas, saturating soils and seeping into surface waters, having a disastrous effect on the environment. Power lines are also significantly 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 in Mason County could also impact wood-structured bridges, peers, and docks, which are utilized to moor watercraft, launch search and rescue vessels, dam safety inspections, shellfish harvesting, fishing vessels, or other private boats associated with tourism. Table 10-5 identifies critical facilities exposed to the wildfire hazard.

Table 10-5
Critical Facilities and Infrastructure Exposed to Fire Regime Areas

	Regime 1	Regime 3	Regime 4*	Regime 5
Medical and Health Services	0	1	0	0
Government Function	0	2	0	17
Protective Function	0	14	0	25
Hazmat	0	4	0	0
Other Critical Function	0	0	0	3
Water	0	9	0	7
Wastewater	0	14	0	12
Power	0	13	0	8
Communications	0	1	0	2
Total	0	58	0	74

*There is no Regime 2 in the County. There are no structures located in Regime 4.

10.3.5 Impact on Economy

Wildfire impact on the economy can be far reaching, ranging from damage to transportation routes to non-use of park facilities and campsites impacting tourism, to loss of structures influencing tax base from lost revenue. Fire within the County could also impact timber harvesting, as well as other agricultural businesses. Taylor Shellfish, a major employer within the county distributing shellfish nationwide, could also be impacted by both primary and secondary impacts to wildfire. Disruption of major thoroughfares in the area could impact distribution of goods. Secondary hazards associated with wildfire, such as environmental impact, or increased landslides and flooding potential, would further impact the economy.

10.3.6 Impact on Environment

Fire is a natural and critical ecosystem process in most terrestrial ecosystems, dictating in part the types, structure, and spatial extent of native vegetation. However, wildfires can cause severe environmental impacts:

- Damaged Fisheries—Critical fisheries can suffer from increased water temperatures, sedimentation, and changes in water quality.
- 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.
- 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.

10.3.7 Impacts from Climate Change

Fire 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. When climate alters fuel loads and fuel moisture, forest susceptibility to wildfires changes. 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.

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 and more fires.

Climate scenarios project summer temperature increases between 2ºC and 5°C and precipitation decreases of up to 15 percent. Such conditions would exacerbate summer drought and further promote high-elevation wildfires, releasing stores of carbon and further contributing to the buildup of greenhouse gases. Forest response to increased atmospheric carbon dioxide—the so-called "fertilization effect"—could also contribute to more tree growth and, thus, more fuel for fires, but the effects of carbon dioxide on mature forests are still largely unknown. High carbon dioxide levels should enhance tree recovery after fire and young forest regrowth, as long as sufficient nutrients and soil moisture are available, although the latter is in question for many parts of the western United States because of climate change.

10.4 FUTURE DEVELOPMENT TRENDS

The County is optimistic that increased population growth will continue to occur throughout the region. As areas of the County become more urbanized, the potential exists that the fire risk may increase as urbanization tends to alter the natural fire regime, and the growth will expand the urbanized areas into undeveloped wildland areas. However, the County feels that this expansion of the wildland-urban interface can be managed with strong land use and building codes. A growing body of research suggests that "the only effective home protection treatment is treatment in, on, and around the house (see Figure 10-5); homeowners must be responsible for protecting that property" (Nowicki 2001, p. 1:3). U.S. Forest Service research scientist, Jack Cohen has stated that "home ignitions are not likely unless flames and firebrand ignitions occur within 40 meters [131 feet] of the structure; the WUI fire loss problem primarily depends on the home and its immediate site."

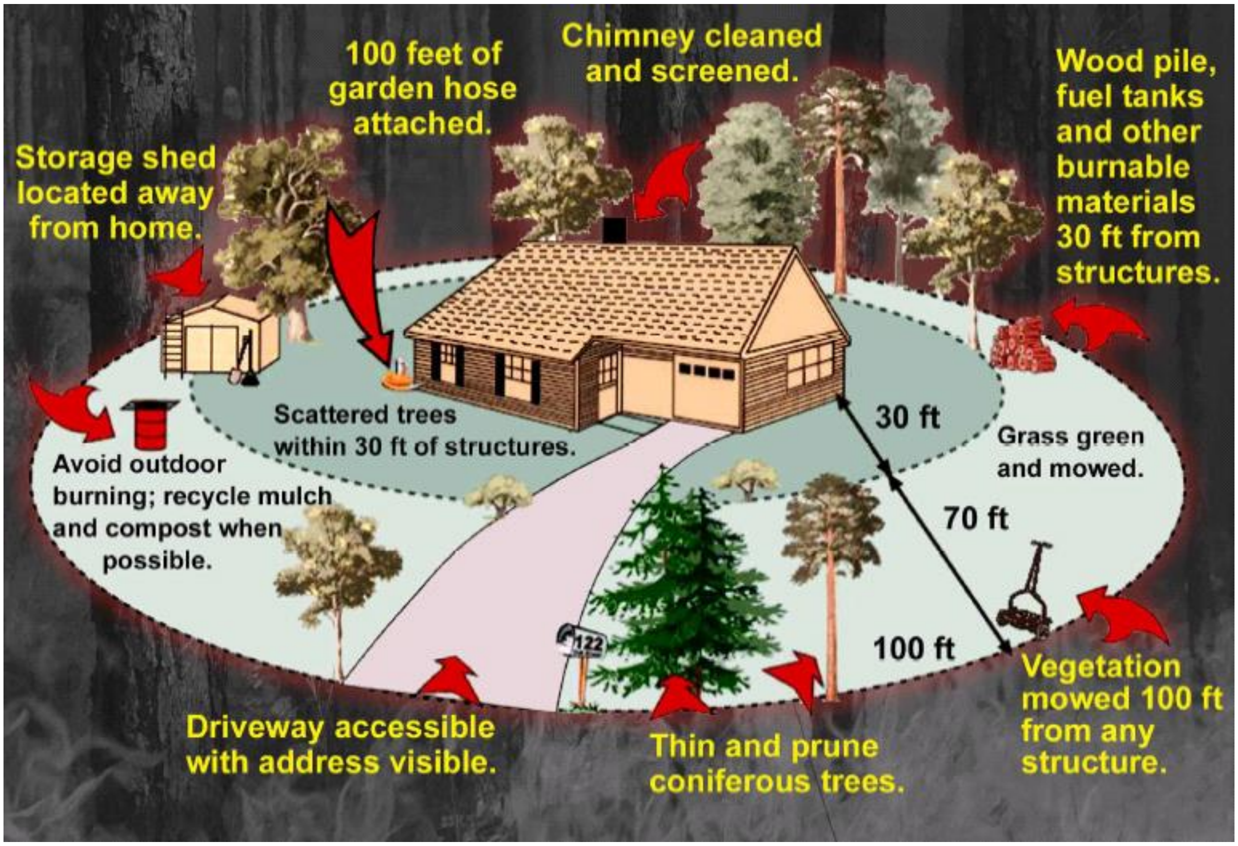

Figure 10-5 Measures to Protect Homes from Wildfire

10.5 ISSUES

The major issues for wildfire in Mason County are the following:

- Public education and outreach to people living in or near the fire hazard zones should include information about and assistance with mitigation activities such as defensible space, and advance identification of evacuation routes and safe zones.
- Wildfires could cause landslides as a secondary natural hazard.
- Climate change will affect the wildfire hazard.
- Future growth into interface areas should continue to be managed.
- Vegetation management activities should include enhancement through expansion of target areas as well as additional resources.
- Building code standards need to be enhanced, including items such as residential sprinkler requirements and prohibitive combustible roof standards.
- Increased fire department water supply is needed in high-risk wildfire areas.
- Obtain and maintain certifications and qualifications for fire department personnel. Ensure that firefighters are trained in basic wildfire behavior, basic fire weather, and that company officers and chief level officers are trained in the wildland command and strike team leader level.

A worst-case scenario would include an active fire season throughout the American west, spreading resources thin. Firefighting teams would be exhausted or unavailable. Many federal assets would be responding to other fires that started earlier in the season. While local fire districts would be extremely useful in the urban interface areas, they have limited wildfire capabilities or experience, and they would have a difficult time responding to the ignition zones. Even though the existence and spread of the fire is known, it may not be possible to respond to it adequately, so an initially manageable fire can become out of control before resources are dispatched.

To further complicate the problem, heavy rains could follow, causing flooding and landslides and releasing tons of sediment into rivers, permanently changing floodplains 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 the forests removed from the watershed, stream flows could easily double. Flood that could be expected every 50 years may occur every couple of years. With the streambeds unable to carry the increased discharge because of increased sediment, the floodplains and the flood elevations would increase.

10.6 RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from Wildfire throughout the area is likely, but the impact is more limited with respect to geographic extent. The area experiences some level of wildfire almost annually, but the acreage burned has, thankfully, been more limited in nature due in large part to response activities.

Construction into the wildfire hazard areas undoubtedly will continue to expand, thereby increasing the risk of fires. Implementation of mitigation strategies which help reduce wildfire risk, such as landscaping regulations and mandatory sprinkler systems, could potentially help reduce the number of structures at risk. Based on the potential impact, the Planning Team determined the CPRI score to be 2.60, with overall vulnerability determined to be a medium level.

CHAPTER 11.
HAZARD RANKING

11.1 CALCULATED PRIORITY RISK INDEX

In ranking the hazards, the Planning Team completed a Calculated Priority Risk Index (CPRI) worksheet for each hazard identified below. The index examines five criteria for each hazard as discussed in Chapter 4 (probability, magnitude/severity, extent/location, warning time, and duration), defines a risk index for each according to four levels, then applies a weighting factor. The result is a score that has been used to rank the hazards at the County level. All planning partners also completed their own hazard rankings, using the same process. Table 11-1 presents the results of the CPRI scoring for hazards Countywide. Table 11-2 is a summary of the hazard ranking for the jurisdiction planning partners.

Table 11-1
Countywide Calculated Priority risk Index ranking scores

Hazard	Probability	Magnitude and/or Severity	Extent and Location	Warning Time	Duration	Calculated Priority Risk Index Score
Climate Change	3	2	2	1	4	2.4
Drought	3	2	3	1	4	2.6
Earthquake	4	3	4	4	1	3.6
Flood	4	3	3	2	2	3.25
Landslide	4	2	2	4	1	2.95
Severe Weather	4	3	3	2	2	3.25
Wildfire	3	2	2	4	2	2.6

The CPRI scoring method has a range from 0 to 4. “0” being the least hazardous and “4” being the highest.

Table 11-2 (Pending Completion by Planning Partners)
Hazard Ranking Summary

	County		City of Shelton		PUD 1		PUD 3		FD 16		CMFE	
Hazard	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Climate Change	5	2.4			7	2.4						
Drought	4	2.6			5	2.6						
Earthquake	1	3.6			1	3.6						
Flood	2	3.25			3	3.25						
Landslide	3	2.95			2	2.8						
Severe Weather	2	3.25			4	3.55						
Wildfire	4	2.6			6	2.55						

11.1.1 Calculated Priority Rate Index

CPRI Category	Degree of Risk			Assigned Weighting Factor
	Impact/ Level ID	Description	Impact Factor	
Probability	Unlikely	• Rare with no documented history of occurrences or events. • Annual probability of less than 1% (~100 years or more).	1	40%
	Possible	• Infrequent occurrences; at least one documented or anecdotal historic event. • Annual probability that is between 1% and 10% (~10 years or more).	2	
	Likely	• Frequent occurrences with at least two or more documented historic events. • Annual probability that is between 10% and 90% (~10 years or less).	3	
	Highly Likely	• Common events with a well-documented history of occurrence. • Annual probability of occurring. (1% chance or 100% Annually).	4	
Magnitude/ Severity	Negligible	• People – Injuries and illnesses are treatable with first aid; minimal hospital impact; no deaths. Negligible impact to quality of life. • Property – Less than 5% of critical facilities and infrastructure impacted and only for a short duration (less than 24-36 hours such as for a snow event); no loss of facilities, with only very minor damage/clean-up. • Economy – Negligible economic impact. • Continuity of government operating at 90% of normal operations with only slight modifications due to diversion of normal work for short-term response activity. Disruption lasts no more than 24-36 hours. • Special Purpose Districts: No Functional Downtime.	1	25%
	Limited	• People – Injuries or illness predominantly minor in nature and do not result in permanent disability; some increased calls for service at hospitals; no deaths; 14% or less of the population impacted. Moderate impact to quality of life. • Property – Slight property damage -greater than 5% and less than 25% of critical and non-critical facilities and infrastructure. • Economy – Impact associated with loss property tax base limited; impact results primarily from lost revenue/tax base from businesses shut down during duration of event and short-term cleanup; increased calls for emergency services result in increased wages. • Continuity of government impacted slightly; 80% of normal operations; most essential services being provided. Disruption lasts >36 hours, but <1 week. • Special Purpose Districts: Functional downtime 179 days or less.	2	
	Critical	• People – Injuries or illness results in some permanent disability or significant injury; hospital calls for service increased significantly; no deaths. 25% to 49% of the population impacted. • Property – Moderate property damages (greater than 25% and less than 50% of critical and non-critical facilities and infrastructure). • Economy - Moderate impact as a result of critical and non-critical facilities and infrastructure impact, loss of revenue associated with tax base, lost income. • Continuity of government ~50% operational capacity; limited delivery of essential services. Services interrupted for more than 1 week, but <1 month. • Special Purpose Districts: Functional downtime 180-364 days.	3	
	Catastrophic	• People - Injuries or illnesses result in permanent disability and death to a significant amount of the population exposed to a hazard. >50% of the population impacted. • Property – Severe property damage >50% of critical facilities and non-critical facilities and infrastructure impacted. • Economy – Significant impact - loss of buildings /content, inventory, lost revenue, lost income. • Continuity of government significantly impacted; limited services provided (life safety and mandated measures only). Services disrupted for > than 1 month. • Special Purpose Districts: Functional Downtime 365 days or more.	4	
Geographic Extent and Location	Limited	Less than 10% of area impacted.	1	20%
	Moderate	10%-24% of area impacted.	2	
	Significant	25%-49% of area impacted.	3	
	Extensive	50% or more of area impacted.	4	
Warning Time / Speed of Onset	<6 hours	Self-explanatory.	4	10%
	6 to 12 hours	Self-explanatory.	3	
	12 to 24 hours	Self-explanatory.	2	
	> 24 hours	Self-explanatory.	1	
Duration	< 6 hours	Self-explanatory.	1	5%
	< 24 hours	Self-explanatory.	2	
	<1 week	Self-explanatory.	3	
	>1 week	Self-explanatory.	4	

11.2 SOCIAL VULNERABILITY

Once the hazard ranking was completed, the Planning Team then conducted a Social Vulnerability Assessment for those priority hazards identified in Table 11-1 and Table 11-2. Several different assessments were completed with respect to social vulnerability, including data contained within the Community Profile section (Chapter 3), within each hazard profile, within the various tables in this section, and a qualitative assignment based on the CPRI analysis.

When determining risk, it is significant to remember that risk is measured by not only the hazard, but also on how resilient a population is, or will be during the hazard. Resilience is influenced by many factors, including: age or income; available social networks, and neighborhood characteristics, all of which can be used to measure the social vulnerability of the area and its citizens. Factors that contribute to the level of vulnerability of a population are associated with four areas of impact, which, in part, are utilized within this assessment with a few modifications to the original study, as indicated:

- Socioeconomic status:
  - Below Poverty Level
  - Employment Status
  - Income level
  - No High School Diploma
- Household composition:
  - Age 65 or older
  - Age 5 or younger (the North Carolina study references age 17 or younger)
  - Disability (the North Carolina study referenced “Older than Age 5 with a Disability”)
  - Single Parent Households
- Minority Status and Language:
  - Minority – race or ethnicity
  - Language barrier (Speak English “Less than Well”)
- Housing/transportation:
  - Multi-Unit Structures, including Group Quarters
  - Mobile Homes
  - Crowding
  - No Vehicle

The purpose of the classifications is to better understand whose needs are not being addressed through traditional service providers or who cannot safely access and use the standard resources offered for disaster preparedness, relief and recovery. Special focus on these groups during emergency situations is crucial because not only are they more likely to be impacted by an event, but they are many times also less likely to recover. As this planning process expands over the next five years, the County intends to expand this section to include data for all vulnerable classifications.

11.2.1 Classifications

Socioeconomic status considers things such as income, poverty, employment status, and education level. Those who are economically disadvantaged will be affected by an event more significantly. The monetary value of their possessions may be less, but they represent a larger proportion of total household assets. These groups are less likely to have renters or homeowner's insurance, so their possession will be costlier to replace, and individuals are less likely to evacuate in order to ensure the protection of their belongings. In the event of injury or death, those who are unemployed will not have the benefits or the income to assist with costs for recovery. In addition, in most cases, the poor lack the assets and the resources to prepare for a disaster in advance, and once impacted, to recover.

Household composition and disability grouping is comprised of age (under the age of 5 and above 65), single parent homes, and any disability. These groups are more likely to need financial support, transportation, medical care, or assistance with daily activities during disasters. The elderly and the younger children often lack resources, knowledge, or life experiences to effectively address the situation and cannot protect themselves. Elderly living alone, and people with physical, sensory, or cognitive challenges are vulnerable during an incident. These groups often need a higher level of assistance than others, and may have caretakers who are less able to assist during a crisis if those caretakers have families of their own. This places a heavier burden on medical and first responders.

Minority status and language includes race, ethnicity, and proficiency of the English language. The social and economic marginalization of certain racial and ethnic groups have made these populations more likely to be vulnerable at all stages, and are automatically associated with a higher vulnerability rate. Many citizens are not fluent in English, which makes providing them with real time information difficult. Because Spanish is the most prominent second language, there are often translators available, and many times emergency notifications are provided in Spanish; however, those who speak other languages are at greater risk if notifications are not provided in the appropriate languages. These groups often rely on family, friends, neighbors and social media for information.

Housing and transportation considers the structure of the home (e.g., building codes, age of structure), crowding, and access to vehicles or public transportation. The quality of the housing is crucial when calculating vulnerability. Economically disadvantaged often live in poorly constructed houses or mobile homes which may not be designed to withstand storms events, ice/snow loads, wind, earthquakes, or flooding. Mobile homes are often located in places without easy access to transportation, are in cluster communities, and many times not secured to a foundation, all of which increase vulnerability. Multi-unit housing in densely populated areas are difficult to evacuate due to limited amounts of space and crowding. Urban areas often have a lower automobile ownership rate, especially in the lower income areas, which make evacuations more challenging. Despite the lower proportion of people with vehicles, urban areas often have to deal with congestion on highways and major roads because of crowding. Group quarters are another housing situation that cause concern during evacuations, especially nursing homes and long-term care facilities because many institutions are unprepared to quickly remove staff and residents, and as with private group/independent living homes, the data that such facilities exist is not publicly known and/or identified.

All of these factors contribute to a community's social vulnerability which impacts all phases of emergency management, and should be taken into consideration in various planning efforts. Table 11-3 identifies those factors and classifications which contribute to a community's social vulnerability. Table 11-4 identifies the percent of special population within the County based on US Census data, augmented with County-specific data where available.

11.2.2 Results and Discussion

For purposes of this assessment, summary of the vulnerable populations were identified through the social vulnerability analysis focusing on the classifications identified. This analysis will be further expanded to include additional data as time allows. For this HMP update, a generalized impact assessment of vulnerable populations and the potential spatial distribution of impact were discussed in Table 11-4.

Table 11-3
Vulnerable Populations

Population Group	Percent of Total Population
Households Children 5 and Under	5
Populations 65 and Older	23.7
Population In Poverty	13
Language Other Than English	8.1
With a disability under age 65	13.7
Households No Vehicles	5
Households No Telephone	2
Percent Housing Units Mobile Homes	18

Sources: Based on 2020 US Census and Washington State Office of Financial Management Data

The Planning Team conducted a qualitative assessment combining the value of the CPRI, and summarizing the potential impact based on past occurrences, spatial extent, and subjective damage and casualty potential. Those items were categorized into the following levels:

- Extremely Low—The occurrence and potential cost of damage to life and property is very minimal to nonexistent.
- Low—Minimal potential impact. The occurrence and potential cost of damage to life and property is minimal.
- Medium—Moderate potential impact. This ranking carries a moderate threat level to the general population and/or built environment. Here the potential damage is more isolated and less costly than a more widespread disaster.
- High—Widespread potential impact. This ranking carries a high threat to the general population and/or built environment. The potential for damage is widespread. Hazards in this category may have occurred in the past.
- Extremely High—Very widespread with catastrophic impact.

Table 11-4
Vulnerability Overview

Hazard	Synopsis of Potential Impact	Population Groups Impacted (By Group Type)							Level of Impact High, Medium, Low	Summarized Extent and Location
		Business	Children	Disabled	Elders	Families	Low Income	Language		
Climate Change	Climate change is measured in terms of impact on other hazards. Impact varies, but can include physical drought conditions, water shortage, increased flood incidents, or increased wildfire danger.	X	X	X	X	X	X	X	Medium	Climate change itself customarily does not impact structures; however, the entire population and natural resources of the area will be impacted by climate change.
Drought	Drought is typically measured in terms of water availability in a geographic area, and is not a sudden-onset hazard, allowing some preparation. Socioeconomic droughts occur when physical water shortage begins to affect people, individually and collectively. Social impacts mainly involve public safety, health, reduced quality of life, and inequities in the distribution of impacts and disaster relief. Many impacts identified as economic and/or environmental also have a social component. During warm seasons, water suppliers are often faced with more demand for water than they are able to distribute. This may lead to rationing and curtailment, with business that rely heavily on water usage suffering financially. Most socioeconomic definitions of drought associate it with supply, demand, and economic goods.	X	X	X	X	X	X	X	Medium	Drought customarily does not impact structures, but would adversely impact people, resources, and aqua- and agri-cultural businesses (among others) within the area. Therefore, all populations would be susceptible, although the degree would be determined by the severity of the drought in place, the availability of water, increased fire danger and response times, and the economic impact from water-dependent industries.

Table 11-4
Vulnerability Overview

Hazard	Synopsis of Potential Impact	Population Groups Impacted (By Group Type): Business	Children	Disabled	Elders	Families	Low Income	Language	Level of Impact High, Medium, Low	Summarized Extent and Location
Earthquake	Older structures (pre ~1970) have high probability of collapse due to building code standards; Non-English speakers may have issues gaining hazard information for preparedness. Low-income individuals may not be able to stockpile supplies or medications. Elderly populations are vulnerable due to health issues, the lack of physical strength to extricate themselves, etc. Businesses many times do not carry insurance which will help them recover from losses.	X	X	X	X	X	X	X	High	Many structures in the area were built pre-1970, when lower codes were in place, making the structures more vulnerable to collapse, increasing the potential for injury. Also of concern with earthquake are landslides and slope stability. Stability in the area could be significantly undermined. The majority of the entire area is susceptible to the impacts from an earthquake to some degree. Older structures would be more susceptible to collapse during shaking, increasing the number and degree of injuries. Elderly and young would be susceptible because of the decreased ability to survive injury, and the decreased ability to physically extract themselves from debris if buried beneath collapsed structures.

Table 11-4
Vulnerability Overview

Hazard	Synopsis of Potential Impact	Population Groups Impacted (By Group Type): Business	Children	Disabled	Elders	Families	Low Income	Language	Level of Impact High, Medium, Low	Summarized Extent and Location
Landslide	The probability for impact from Landslide is more limited with respect to geographic extent. The area experiences some level of landslides almost annually. The coastal bluff areas, and areas within the unincorporated areas of the County have identifiable landslide risk. While there are areas where no landslide risk, landslides can occur on fairly low slopes, and areas with no slopes can be impacted by slides at a distance. Construction in critical areas, which includes geologically sensitive areas such as landslide areas, is regulated; however, beyond the structural impact, secondary impact to infrastructure causing isolation or commodity shortages also has the potential to impact the region.		X	X	X	X	X	X	High	A significant portion of the planning area has some level of susceptibility to landslides, especially along the major roadways in the County. As such, evacuation in the area could be impacted by a landslide event. With the increased risk factor during the rainy season, a landslide could occur anywhere in the county where soils can become saturated. This could impact the ability of citizens to leave areas where flooding occurs, or evacuate after a major earthquake if a landslide has blocked major arterials. This could also impact responders accessing areas. Vulnerable populations would be less likely to be able to evacuate, increasing their risk.

Table 11-4
Vulnerability Overview

Hazard	Synopsis of Potential Impact	Population Groups Impacted (By Group Type): Business	Children	Disabled	Elders	Families	Low Income	Language	Level of Impact High, Medium, Low	Summarized Extent and Location
Flood	Year of construction will influence the building code and the height to which the structures were built when compared to the Base Flood Elevation. In most instances, weather patterns which cause flooding are identified in advance, allowing pre-planning for evacuation, thereby potentially reducing the individuals at risk. Individuals without homeowner's insurance which covers flooding may suffer extreme financial risk. Businesses impacted many times do not carry insurance which will help them recover from losses. In many instances, those businesses do not return to the area because they cannot overcome the financial loss.	X	X	X	X	X	X	X	High	Flooding in the area has been significant, especially within the Skokomish basin and the City of Shelton. Flooding in the area has also impacted transportation, causing roadways to be blocked, and causing landslides which also block major arterials. This has caused issues with evacuation in certain areas. All areas within the floodplain would be vulnerable. Given the higher-than-average population of elderly and young, the level of vulnerability is higher than when compared to other areas. The County also has increased populations from visitors who frequent the local Tribal Casino Resort (Little Creek), as well as increased populations to the Olympic National Forest, and the large campgrounds in the area. For planning purposes, a significant increase in citizens in the area should be considered especially during the summertime to include annual volumes of tourists and residents with vacation homes.

Table 11-4
Vulnerability Overview

Hazard	Synopsis of Potential Impact	Population Groups Impacted (By Group Type): Business	Children	Disabled	Elders	Families	Low Income	Language	Level of Impact High, Medium, Low	Summarized Extent and Location
Severe Weather – inclusive of heat, cold, wind, snow, ice, hail, Thunder-storm, lightening	Severe weather occurs regularly throughout the planning area. In most instances, weather patterns are forecasted in advance, allowing for preparation. Individuals with lower income may not have the ability to stock supplies, nor afford the cost of increased energy costs for both heating or cooling, depending on the weather event. In snow or ice conditions, secondary impacts from driving or shoveling snow increases the risk of impact. Elderly and young children are especially susceptible to ice and heat conditions. Lighting strikes also occur throughout the planning area, although in a limited capacity. In densely wooded areas, such as the Olympic National Forest, fires could go un-noticed for a period of time, allowing the fire to gain strength and severity, especially during drought situations. Lightning risk also increases due to the large waterbodies in the area, and the time it takes for boaters to get to safety. The area also has a number of golf courses, which are open and provide little cover from lightning strikes.	X	X	X	X	X	X	X	High	The entire region is susceptible to severe weather incidents, including impact to people, property, and the environment. Incidents of some nature and degree occur annually. Depending on the type of event, roadways may be impassible. Significant power outages do not occur often, and do not customarily last for a long period of time. However, when coupled with cold conditions, the impact to vulnerable populations increases. With extreme heat events, physical manifestation on the young and elderly rise. In addition, the increased fire danger impacts the entire area.

Table 11-4
Vulnerability Overview

Hazard	Synopsis of Potential Impact	Population Groups Impacted (By Group Type)							Level of Impact High, Medium, Low	Summarized Extent and Location
		Business	Children	Disabled	Elders	Families	Low Income	Language		
Wildfire	Impact from wildfires has increased over time due to effective suppression tactics. This has now caused fires to burn with greater intensity, with the traditional fire regimes being modified. Embers from wildfires can be carried significant distances (miles). With climate change impacting drought conditions, the potential for wildfire increases as moisture content is depleted. Lightning strikes and people are the major causes of wildfires, which can spread very quickly, leaving little to no time to evacuate. Individuals with access and functional needs, the young and elderly are at greater risk due to their potential dependence on others to assist with evacuation. Individuals, including the young and elderly, with health concerns are impacted significantly by smoke. Increased rates of death due to smoke is not uncommon.	X	X	X	X	X	X	X	Medium	Wildfire danger can impact the entire planning area; however, there has been limited impact to date. The various Fire Regimes do identify areas of higher levels of risk, although wildfires can occur in any area with vegetation. Not all Fire Regimes exist in the area. Due to the wind patterns in the area, including the shift of winds during afternoon hours, embers have the potential to travel great distances (miles) and ignite fires in areas which are densely wooded. In some instances, these fires can burn for periods of time, going un-noticed until ignition consumes a large area, making containment difficult. Elderly, young and individuals with breathing/health issues are more vulnerable due to smoke and particulates. Language may also be a barrier for non-English speaking populations due to the inability to understand evacuation orders, which can be very short-notice.