PART 2—RISK ASSESSMENT

CHAPTER 4.
IDENTIFIED HAZARDS OF CONCERN AND RISK ASSESSMENT METHODOLOGY

Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazards. It allows emergency management personnel to establish early response priorities by identifying potential hazards and vulnerable assets. The process focuses on the following elements:

- Hazard identification—Use all available information to determine what types of disasters may affect a jurisdiction, how often they can occur, and their potential severity.
- Vulnerability identification—Determine the impact of natural hazard events on the people, property, environment, economy and lands of the region.
- Cost evaluation—Estimate the cost of potential damage or cost that can be avoided by mitigation.

The risk assessment for this hazard mitigation plan evaluates the risk of natural hazards prevalent in Kittitas County and meets requirements of the DMA (44 CFR, Section 201.6(c)(2)).

4.1 IDENTIFIED HAZARDS OF CONCERN

For this plan, the steering committee 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. Based on the review, this plan addresses the following hazards of concern:

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

With the exception of dam failure, technological hazards (e.g., hazardous material incidents) and human-caused hazards (e.g., terrorist acts) are not addressed in this plan. At this time, DMA regulations do not require consideration of such hazards and the planning partnership chose not to include them in this plan.

4.2 CLIMATE CHANGE

Climate includes patterns of temperature, precipitation, humidity, wind and seasons. Climate plays a fundamental role in shaping natural ecosystems, and the human economies and cultures that depend on them. "Climate change" refers to changes over a long period of time. It is generally perceived that climate change will have a measurable impact on the occurrence and severity of natural hazards around the world. Impacts include the following:

- Snow cover losses will continue, and declining snowpack will affect snow-dependent water supplies and stream flow levels around the world.
- The risk of drought and the frequency, intensity, and duration of heat waves are expected to increase.
- More extreme precipitation is likely, increasing the risk of flooding.
- The world's average temperature is expected to increase.

Climate change will affect communities in a variety of ways. Impacts could include an increased risk for extreme events such as drought, storms, flooding, and forest fires; more heat-related stress; and the spread of existing or new vector-born disease into a community. In many cases, communities are already facing these problems to some degree. Climate change changes the frequency, intensity, extent, and/or magnitude of the problems.

This hazard mitigation plan addresses climate change as a secondary impact for each identified hazard of concern. Each chapter addressing one of the hazards of concern includes a section with a qualitative discussion on the probable impacts of climate change for that hazard. While many models are currently being developed to assess the potential impacts of climate change, there are currently none available to support hazard mitigation planning. As these models are developed in the future, this risk assessment may be enhanced to better measure these impacts.

4.3 METHODOLOGY

The risk assessments in Chapter 7 through Chapter 14 describe the risks associated with each identified hazard of concern. Each chapter describes the hazard, the planning area's vulnerabilities, and probable event scenarios. The following steps were used to define the risk of each hazard:

- Identify and profile each hazard—The following information is given for each hazard:
  - Geographic areas most affected by the hazard
  - Event frequency estimates
  - Severity estimates
  - Warning time likely to be available for response.
- 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 FEMA's hazard-modeling program called HAZUS-MH were used to perform this assessment for the flood, dam failure and earthquake hazards. Outputs similar to those from HAZUS were generated for other hazards, using maps generated by the HAZUS program.

4.4 RISK ASSESSMENT TOOLS

4.4.1 Dam Failure, Earthquake and Flood—HAZUS-MH

Overview

In 1997, FEMA developed the standardized Hazards U.S., or HAZUS, model to estimate losses caused by earthquakes and identify areas that face the highest risk and potential for loss. HAZUS was later expanded into a multi-hazard methodology, HAZUS-MH, with new models for estimating potential losses from hurricanes and floods.

HAZUS-MH is a GIS-based software program used to support risk assessments, mitigation planning, and emergency planning and response. It provides a wide range of inventory data, such as demographics, building stock, critical 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.

The version used for this plan was HAZUS-MH MR5, released by FEMA in 2010.

Levels of Detail for Evaluation

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

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

Application for This Plan

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

- **Flood**—A Level 2 general building stock analysis was performed. GIS building and assessor data (replacement cost values and detailed structure information) were loaded into HAZUS-MH. An updated inventory was used in place of the HAZUS-MH defaults for essential facilities, transportation and utilities. Digitized Kittitas County Flood Insurance Rate Maps (FIRMs) were used to delineate flood hazard areas and estimate potential losses from the 100- and 500-year flood events. Using the FIRM floodplain boundaries and a countywide 10-meter digital elevation model, flood depth grids were generated and integrated into the model. Flood exposure numbers were generated using County assessor data. Flood hazard vulnerability numbers were generated in HAZUS, using the updated census block general building stock data.
- **Dam Failure**—Dam failure inundation mapping for Kittitas County was collected where available. This data was imported into HAZUS-MH and a modified Level 2 analysis was run using the flood methodology described above.
- **Earthquake**—A Level 2 analysis was performed to assess earthquake risk and exposure. Earthquake shake maps and probabilistic data prepared by the U.S. Geological Survey (USGS) were used for the analysis of this hazard. An updated general building stock inventory was developed using replacement cost values and detailed structure information from assessor tables. An updated inventory of essential facilities, transportation and utility features was used in place of the HAZUS-MH defaults. National Earthquake Hazard Reduction Program (NEHRP) soil data and soil liquefaction data were incorporated into the model. Two scenario events and two probabilistic events were modeled:
  - The scenario events were a Magnitude-6.8 event on the Cle Elum Fault and a Magnitude-7.2 event on the Saddle Mountain Fault.
  - The standard HAZUS analysis for the 100- and 500-year probabilistic events was run.

4.4.2 Landslide, Severe Weather, Volcano and Wildfire

For some of the hazards evaluated in this risk assessment, historical data was not adequate to model future losses. However, HAZUS-MH is able to map hazard areas and calculate exposures if geographic information is available on the locations of the hazards and building inventories.

Local information was gathered from a variety of sources. Frequency and severity indicators include past events and the expert opinions of geologists, emergency management specialists and others. The primary data source was the Kittitas County GIS database, augmented with state and federal data sets. Additional data sources for specific hazards were as follows:

- **Landslide**— Kittitas County provided Washington Department of Natural Resources Forest Practice landslide data.
- **Severe Weather**—Severe weather data was downloaded from the Natural Resources Conservation Service and the National Climatic Data Center.
- **Volcano**—Volcanic hazard data was obtained from the USGS Cascade Volcano Observatory.
- **Wildfire**—Wildfire data was provided by Washington Department of Natural Resources.

4.4.3 Drought and Avalanche

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 more limited and qualitative than the assessment for the other hazards of concern. Similarly, the avalanche hazard was found to be minimal in developed areas, so the risk assessment for that hazard also was limited and qualitative.

4.4.4 Limitations

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, Kittitas County and its planning partners will collect additional data to assist in estimating potential losses associated with other hazards.

CHAPTER 5.
KITTITAS COUNTY PROFILE

Kittitas County is located in south-central Washington (see Figure 5-1). The county covers 2,315 square miles of highly varied terrain and climates. It is the 25th most populous county in the state and the eighth largest in area. The county is bounded to the north by Chelan and Snohomish Counties, to the south by Yakima County, to the east by Grant County, and to the west by King and Pierce Counties. The Pacific Crest Trail in the Cascade Range forms its western boundary, and the Columbia River forms its eastern boundary.

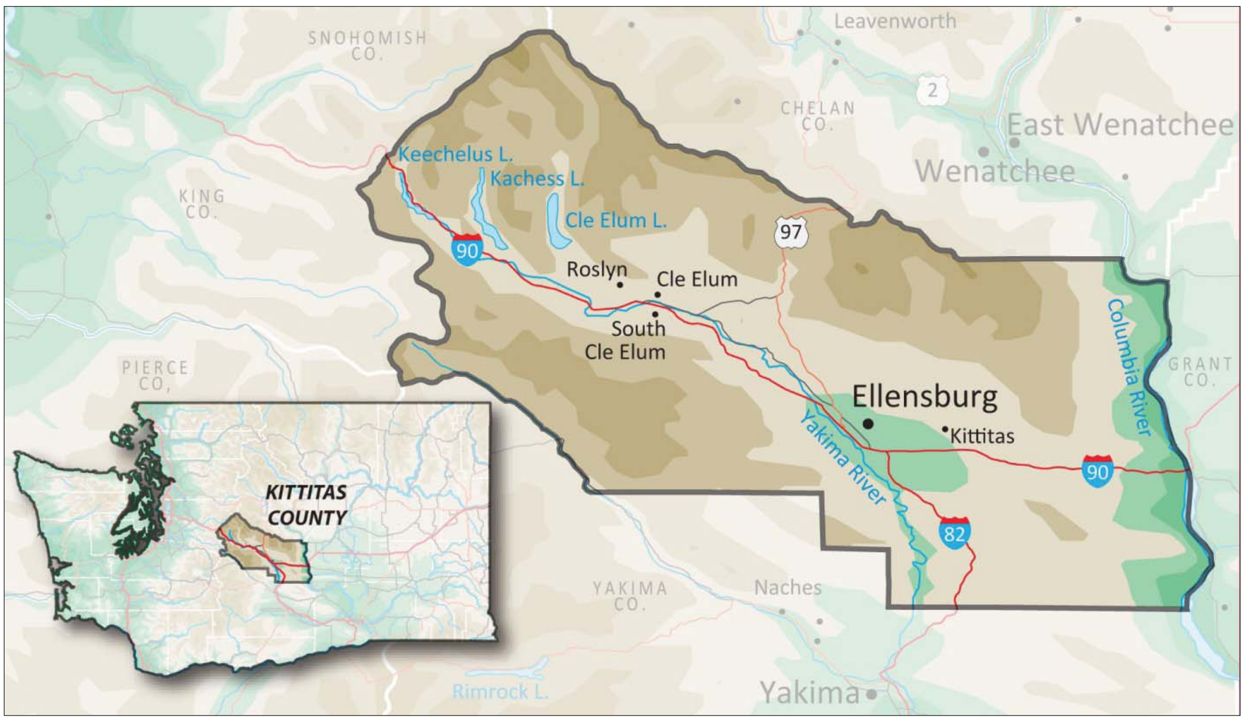


Figure 5-1. Main Features of Kittitas County

5.1 JURISDICTIONS AND ATTRACTIONS

Kittitas County contains 10 U.S. Census recognized communities, five of which are incorporated jurisdictions (Cle Elum, Ellensburg, Kittitas, Roslyn and South Cle Elum). The other areas include the towns of Easton, Ronald, Snoqualmie Pass, Thorp and Vantage. Ellensburg, in the southeast part of the county, is the county seat.

Kittitas County is one of the most geographically diverse areas in the Pacific Northwest. Its diverse terrain offers many recreational opportunities:

- Skiing, cross-country, snow-shoeing, snowmobiling
- Rafting, kayaking, boating, waterskiing
- Camping, horseback riding

- Fishing
- Hiking
- Biking
- Golf

In addition, the county offers historic attractions from the early days of Washington's mining and railroading industries in cities such as Roslyn, Cle Elum, Liberty, Easton, Thorp and Ellensburg. Ellensburg is also home to Central Washington University and the Ellensburg Rodeo.

5.2 HISTORICAL OVERVIEW

Kittitas County was part of the land ceded by the Yakama Tribe in 1855. Briefly part of Ferguson County (now defunct), then Yakima County, Kittitas County was established on November 24, 1883. The Kittitas Valley became a stopping place for cowboys driving herds north to mining camps in Canada and northwest to Seattle/Tacoma. By the late 1860s, cattle ranchers established land claims and cattle became the area's foremost industry. The completion of a wagon road over Snoqualmie Pass in 1867, the arrival of the Northern Pacific Railroad in 1887, the discovery of gold in Swauk Creek in 1873 and coal near Cle Elum in 1883, and the 1932 completion of the Kittitas (irrigation) Project were significant points in the county's history. Today the main industries are agriculture (including timothy hay to feed racehorses), manufacturing (food processing, lumber and wood products), and government (including employment at Central Washington University).

Interpretations of the meaning of the word Kittitas vary, but the name probably refers to the region's soil composition—perhaps shale rock, white chalk, or white clay. Another interpretation is that the bread made from the root kous was called kit-tit. Kous grew in the Kittitas Valley. "Tash" is generally accepted to mean "place of existence."

The first inhabitants of the Kittitas Valley were the Psch-wan-wap-pams (stony ground people), also known as the Kittitas band of the Yakama or Upper Yakama. Although the Kittitas were distinct from the Yakima (later renamed Yakama) Tribe, settlers and the federal government (for treaty purposes) grouped the Kittitas with the larger Yakama Tribe. The Kittitas Valley was one of the few places in Washington where both camas (sweet onion) and kous (a root used to make a bread) grew. These were staples that could be dried, made into cakes, and saved for winter consumption. Yakama, Cayous, Nez Perce, and other tribes gathered in the valley to harvest these foods, fish, hold council talks, settle disputes, socialize, trade goods, race horses, and play games. The west side of the Columbia River at what would eventually become the eastern border of Kittitas County was home to some dozen Wanapum villages.

Fur trader Alexander Ross was one of the earliest non-Indians to describe the Kittitas Valley. Along with a clerk, two French Canadian trappers, and the trappers' wives, Ross entered the Kittitas Valley in 1814 to trade for horses.

The abundant bunchgrass and clear streams of the Kittitas Valley gave rise to a prosperous cattle industry. Much of this success was foretold by local Indians who, before the advent of white settlement, grazed horses in the valley and sold them to neighboring tribes and white explorers and traders who passed through. As early as 1861, white ranchers from the Yakima Valley grazed their cattle in the Kittitas Valley before continuing on to mine districts in the north-central region and British Columbia. The mining towns eventually began raising their own cattle, but Puget Sound demand filled the vacuum; the cattle were herded to the Sound through Snoqualmie or Naches Pass.

By the late 1860s, cattle ranchers established land claims in Kittitas itself. Over the next 10 years, especially in the late 1870s, new ranches flourished and large herds of cattle grazed everywhere. The resulting overproduction led to declining beef prices. Prices, however, rose to earlier levels after the severe winter of 1880-81 killed more than half the herds. Although the number of cattle eventually returned to early levels, overgrazing was beginning to take its toll on the range. As a result, the federal government began to regulate grazing in 1897. This led to a gradual shift from open grazing to fenced pastures and hay feeding.

Two events—better rail transportation around the turn of the century and irrigation projects in the 1930s—helped expand the county's cattle industry. The railroads provided more effective transport of cattle to the nation's eastern markets. Irrigation projects enhanced the quality of pastures and spurred the growth of row crops, whose by-products were converted into inexpensive cattle feed. By the 1960s, the number of Kittitas County cattle had more than doubled, to approximately 70,000. However, price controls and rising feed costs in the early 1970s prompted many ranchers to change from cattle to hay and grain production.

5.3 MAJOR PAST HAZARD EVENTS

Presidential disaster declarations are typically issued for hazard events that cause more damage than state and local governments can handle without assistance from the federal government, although no specific dollar loss threshold has been established for these declarations. A presidential disaster declaration puts federal recovery programs into motion to help disaster victims, businesses and public entities. Some of the programs are matched by state programs. Kittitas County has experienced 11 events since 1964 for which presidential disaster declarations were issued. These events are listed in Table 5-1.

Review of these events helps identify targets for risk reduction and ways to increase a community's capability to avoid large-scale events in the future. Still, many natural hazard events do not trigger federal disaster declaration protocol but have significant impacts on their communities. These events are also important to consider in establishing recurrence intervals for hazards of concern. Seismic activity in the county has been recorded from the 1930s through the present, though earthquake damage has been low.

TABLE 5-1.
PRESIDENTIAL DISASTER DECLARATIONS FOR HAZARD EVENTS IN KITTITAS COUNTY

Type of Event	Disaster Declaration #	Date
Heavy Rains & Flooding	DR-185	12/29/1964
Severe Storms, Flooding	DR-492	12/13/1975
Severe storms, mudslides, flooding	DR-545	12/10/1977
Volcanic eruption, Mt. St. Helens	DR-623	5/21/1980
Flooding, Severe Storm	DR-883	11/26/1990
Storms/High Winds/Floods	DR-1079	01/03/1996
Severe Storms/Flooding	DR-1100	02/02/1996
Severe Winter Storms/Flooding	DR-1159	01/17/1997
Earthquake (Nisqually)	DR-1361	03/01/2001
Severe Winter Storm, Landslides, Mudslides, and Flooding	DR-1817	01/30/2009
Severe Winter Storm and Record and Near Record Snow	DR-1825	03/02/2009

5.4 PHYSICAL SETTING

5.4.1 Geology

Kittitas County possesses a diverse topography that is dominated by the Cascade and Wenatchee Mountains. From the high Cascades, the land slopes generally downward to the east and south to the Columbia River. The eastern part of the county consists of low, rolling to moderately steep glacial terraces and long, narrow valleys. The southeast section of the county is characterized by moderately steep to steep glacial terraces and steep, rough, broken mountain foothills.

The major geological features of Kittitas County are the Cascade and Wenatchee Mountains on the west and north portions, the south-central Yakima River Valley, and the Boylston and Saddle Mountains at the southeastern edge along the Columbia River. Within these elevations, slope, geologic and soil conditions vary dramatically, including steep mountain peaks, foothills, broad rich valleys, and near-desert areas.

Alpine and continental glaciers moved through this region shaping the mountains and depositing materials to create the geology and soils of the region. The primary types of glacial deposits in the county are outwash and till. Outwash consists of unconsolidated sand, gravel and rocks and results from runoff of melting glaciers. Outwash is usually loose and highly permeable. Glacial till, or hardpan, consists of unsorted clay, sand, grave, or rock that has been compacted by the weight of the glacial ice into a highly impervious, concrete-like material.

Bedrock geology in the county is varied. Underlying the Cle Elum River drainage is the non-marine sedimentary Swauk formation dating back to the Tertiary period of geologic time from 1.6 to 65 million years ago. Composed of conglomerate sandstone and shale interbeds, the Swauk formation extends as far north as Lake Wenatchee. As these interbeds were later subjected to the mountain-building forces during the emergence of the Cascades, a complex range of land forms was produced that created a history of geologic instability present to this day. Other major bedrock formations in Kittitas County include metamorphic rocks, granite intrusions, and thick sequences of volcanic and marine sedimentary rock.

5.4.2 Slope Stability

Slope stability refers to the potential of land slippage due to factors such as steepness, composition of materials, and water content within soils. Slopes that have been landscaped and altered from their natural vegetated state or saturated by septic tanks are also subject to sliding. Slumping can also occur when water infiltrates the soil and comes in contact with an impermeable layer. Although the upper layers of soil may not become saturated, water perches on the impermeable layer and causes a slippery interface resulting in the downward and outward movement of weak rock or unconsolidated material. Much of the western and northern portions of the county contain slopes of 15 percent or greater. Slopes less than 15 percent are generally found in the river basins in the eastern portions of the county.

5.4.3 Soils

Kittitas County soils were formed by the forces of water, heat, time, vegetation and animal life, acting on the geologic parent material. The principal parent material consists of sands and gravels associated with glacial till and outwash. Highly organic soils were developed in a moist climate under a rich covering of vegetation. There is currently no county soil map, although interim mapping is available (SCS, 1983). While this analysis is useful for planning and is helpful in determining general capacity of areas to support agricultural, residential, recreational and other land uses, it cannot be used directly for assessing the actual use of any particular site. The glaciated character of the soils creates too much variation within any particular soil type. Nonetheless, the soil maps are useful for determining general limitations and character of soils. Knowledge of soil characteristics and capabilities can assist in wise public and private investments, and can be useful in determining suitability of land for various uses. Still, planning-level mapping should not be substituted for specific onsite field inspections, which may produce findings different from more general accounts.

The load-bearing capacity of soil, its hydric properties, erosion potential, and other characteristics all play a significant role in the development of land. Hydric properties in soils indicate the existence of wetlands and signal the potential for other environmental concerns. Soil suitability for structural support and stability is also important in determining the potential for development. Area soil types vary considerably:

- Soils in western mountainous portion of the county are more suited for growing forest products than food-crop farming. These soils are strongly acidic, gravelly or rocky, saturated most of the year, and occur in steep areas at high elevations.
- Soils in the foothill areas with streams are ideal for growing native trees.
- Soils in the Yakima River Valley are more suited to agriculture and those on the south slopes of the valley are used for extensive fruit growing.
- Other areas have been designated as critical areas due to erosion and landslide potentials.

Suitability for Septic Tanks and Drainfields

For developments dependent on septic tank systems, soils are important in determining the degree of development feasible without contaminating groundwater and surface water supplies. Areas well-suited for liquid waste disposal contain gravelly, sandy soils approximately 4 to 6 feet in depth sitting over an impermeable layer, such as till. Several factors severely limit septic tank use in Kittitas County:

- Shallow soils cover much of the western portion of the county. If soils are too shallow, the decomposition process of septic tank effluent does not proceed far enough to avoid contaminating surface water or groundwater.
- High water tables exist in river valley areas, rendering the underground reservoirs susceptible to contamination from failing septic systems.
- Rainfall varies widely from one end of the county to the other.

Depth-to-Seasonal Water Table

Depth to seasonal water table is a measurement from the surface to the water table during the wet months of the year. A shallow depth between the ground surface and the water table may cause both foundation and septic tank effluent disposal problems. A high seasonal water table may inhibit septic tank effluent from being properly treated in the soil. It may also cause foundations to “float” on their footings, resulting in structural damage to buildings.

Glacially cemented hardpan layers and shallow depth to bedrock account for portions of the county having a shallow depth-to-seasonal water table, (0 to 3 feet below the ground level.) These areas are not perched water tables. They can be either level or sloped areas with a hardpan layer underneath.

Aquifer Recharge Potential

Aquifer recharge potential is the relative ability of the soil and underlying geology to transport rainwater into underground aquifers. This classification considers the water-intake rate of the topsoils, the permeability of subsoils, and parent materials. While it is not known if water falling on these areas actually reaches the aquifers, it is not unreasonable to assume that these areas do play a role in recharging underground water reservoirs. Aquifer recharge areas contain some of the most permeable soils.

Conflicts can arise between development and the proper functioning of these soils. Rooftops, driveways, walkways, and frontage roads all reduce the amount of land surface available to receive rainwater. In areas of extreme permeability, septic tank effluent may percolate faster than the ability of soil microorganisms to purify it, thus increasing the chance of groundwater contamination. Proper precautions should be taken when developing areas considered to have aquifer recharge potential so that the function of these areas may be maintained without depleting or contaminating groundwater supplies. The ability of soils to allow replenishment of groundwater reservoirs becomes an increasingly important consideration as more demand is placed on groundwater for commercial and domestic use.

Large areas of high aquifer recharge potential are found in the Yakima River Basin and its tributaries within Kittitas County. However, no critical aquifer recharge locations have been identified in Kittitas County, according to the Interim Critical Areas Development Ordinance 94-22.

Agricultural Suitability

The suitability of soils for agricultural production has been classified by the U.S. Soil Conservation Service into eight classes. These categories are determined by expected crop yields and required soil management techniques. Generally speaking, Class 1 through Class 4 soils produce the highest yields with the least amount of soil management. Class 5 through Class 8 soils require more costly soil management and lower yields are expected. Kittitas County contains a considerable diversity of soils with varying agricultural properties for growing crops and trees.

5.4.4 Seismic Features

Seismic events could pose limited landslide and liquefaction hazards in areas where steep or exposed slopes occur. Landslides occur when the structural integrity of a geological formation is damaged. There are known areas of landslide activity, which may or may not have resulted from seismic events, along the Yakima River. Soil liquefaction occurs when soil loses its strength and bearing capacity during an earthquake. This is most likely to occur on non-cohesive soils with high moisture content. These soils are poorly compacted and, in combination with moist conditions, are subject to liquefying during an earthquake. Structures built on liquefiable soils are subject to greater shaking and damage during an earthquake, but this damage can be minimized by engineering and construction methods.

Kittitas County has little potential for seismic events other than secondary effects from activity occurring west of the Cascades. The Uniform Building Code rates seismic risk from 1 (low risk) to 4 (high risk). Most of Kittitas County is within Seismic Zone 2. The Snoqualmie Pass area is within Zone 3.

5.4.5 Climate

Eastern Washington climate is a function of maritime and continental influences. The Yakima River basin's location just east of the Cascade crest places it in a rain shadow, with hotter summers, colder winters, a shorter growing season, and less precipitation than areas of similar latitude west of the Cascades. Temperatures generally increase and precipitation generally decreases from northwest to southeast and from high to low elevation.

Temperatures

Because of the variation in elevation, temperatures vary greatly in the Yakima River basin. In the Kittitas Valley, summers tend to be hot, with wide divergent fluctuations, and mild to severe winters. Data is scarce for higher elevations; however, those areas are generally characterized by cool summers and cold winters. For example, in the Subalpine Fir forest zone, which extends from approximately 2,000 feet to the timberline, mean July temperatures in the range of 55ºF to 65ºF can be expected.

Precipitation

As is typical of areas in the lee of large coastal mountain ranges, the Yakima River basin is generally arid. Precipitation varies with elevation and distance from the Cascades, from 150 inches annually at the Cascade crest to 10 inches at the Columbia River. Disparities in precipitation rates from one area to another affect runoff rates and the character of rivers in different drainages, which influence flooding and land-use potential.

Summers in Kittitas County tend to be dry; approximately two-thirds of the county's precipitation occurs between October and April, with much in the form of snow. In the winter, considerable snow often accumulates in the higher elevations. In the Kittitas Valley, snow season generally ranges from November through February, with significant variation from one season to the next.

5.4.6 Land Use

Kittitas County is characterized as rural, forested and range-land, with some densely populated areas. Settlers originally came to this area to take advantage of opportunities for logging, sawmills, farming and services for the resource industries. Today, traditional economic sectors such as logging and other forest-related industries are in decline due to restrictions on logging and the transition of land to conservation and parks. A large part of the growing economy is based on tourism and recreational activities. Much of the developed landscape reflects this and consists of vacation/recreational housing, single family units, highway-oriented service/retail commercial development, and recreational uses such as golf courses and parks. Most remaining nonfederal and non-state land is privately held forest and some agricultural land.

In the Snoqualmie Pass area, resource allocation, in the form of timber harvesting, is the predominant land use, with sporadic areas used for recreational purposes. Resource allocation is also predominant at the mid-elevations; however, residential development becomes more common in these areas. At lower elevations, agricultural activities are the main land use, with residential development intermixed. The Yakima Training Center, located in the southeastern portion of the county, makes up a large percentage of the ownership in the lower Kittitas Valley—approximately 164,132 acres. Table 5-2 lists existing zoning as identified in the 2011 County Comprehensive Plan.

TABLE 5-2.
EXISTING ZONING BY ACREAGE

Zone	Area (Acres)	Zone	Area (Acres)
Agricultural-3	18,218.4	Agriculture-20	110,828.2
Residential-2	42.8	Liberty Historic District	17
Rural-3	25,061.5	Limited Commercial	21.3
Rural-5	41.4	Highway Commercial	129.4
Suburban	3,299.1	General Commercial	399.9
Suburban-II	183.2	Light Industrial	347.9
Commercial Forrest-80	671,813.2	General Industrial	833.2
Forrest and Range-20	288,443.7	Planned Unit Development	1,016
Commercial Agriculture	357,778.6	Residential	865.7
Agriculture-5	551.4	Master Planned Resort	6,257.4
		Total	**1,486,150**

Under current zoning, densities range from one unit per 6,000 square feet to one unit per 80 acres. The Suburban zone allows a density of one unit per acre. The Rural-3, Agricultural-3, Rural-5, Agricultural-5, Agricultural-20, and Forest and Range Zones allow for a density range of one unit per 6,000 square feet to one unit per 20 acres. The lowest density in the county is in the Commercial Forest Zone, where the assigned density is one unit per 80 acres.

5.5 CRITICAL FACILITIES AND INFRASTRUCTURE

Critical facilities and infrastructure are those that are essential to the health and welfare of the population. These become especially important after a hazard event. Critical facilities typically include police and fire stations, schools and emergency operations centers. Critical infrastructure can include the roads and bridges that provide ingress and egress and allow emergency vehicles access to those in need, and the utilities that provide water, electricity and communication services to the community. Also included are "Tier II" facilities and railroads, which hold or carry significant amounts of hazardous materials with a potential to impact public health and welfare in a hazard event. Through a facilitated process, the steering committee defined critical facilities for this plan as follows:

- A critical facility is a local (non-state or federal) facility or infrastructure in either the public or private sector that provides essential products and services to the general public, such as preserving the quality of life in Kittitas County and fulfilling important public safety, emergency response, and disaster recovery functions. Loss of a critical facility would result in a severe economic or catastrophic impact and would affect the County's ability to provide essential services that protect life and property. The critical facilities profiled in this plan include the following:
  - Government facilities, such as departments, agencies, and administrative offices
  - Emergency response facilities, including police, fire, and emergency operations centers
  - Educational facilities, including K-12
  - Medical and care facilities, such as hospitals, nursing homes, continuing care retirement facilities and housing likely to contain occupants who may not be sufficiently mobile to avoid death or injury during a hazard event
  - Community gathering places, such as parks, museums, libraries, and senior centers
  - Public and private utilities and infrastructure vital to maintaining or restoring normal services to areas damaged by hazard events
  - Structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic, and/or water-reactive materials.

Map 5-1 shows the location of critical facilities in unincorporated areas of the county. Critical facilities within the cities participating in this plan are shown in maps for each city provided in Volume 2 of the plan. Due to the sensitivity of this information, a detailed list of facilities is not provided. The list is on file with each planning partner. Table 5-3 and Table 5-4 provide summaries of the general types of critical facilities and infrastructure, respectively, in each municipality and unincorporated county areas. All critical facilities/infrastructure were analyzed in HAZUS to help rank risk and identify mitigation actions. The risk assessment for each hazard qualitatively discusses critical facilities with regard to that hazard.

TABLE 5-3.
KITTITAS COUNTY CRITICAL FACILITIES EXPOSED TO THE EARTHQUAKE HAZARD

Jurisdiction	Medical and Health	Government Functions	Protective Functions	Schools	Hazmat	Other Critical Functions	**Total**
Cle Elum	5	4	9	0	0	0	**18**
Ellensburg	18	20	8	4	0	0	**50**
Kittitas	0	0	3	2	0	0	**5**
Roslyn	0	2	2	4	0	0	**8**
South Cle Elum	0	1	2	0	0	0	**3**
Unincorporated	0	4	43	6	0	0	**53**
Total	**23**	**31**	**67**	**16**	**0**	**0**	**137**

TABLE 5-4.
KITTITAS COUNTY CRITICAL INFRASTRUCTURE EXPOSED TO THE EARTHQUAKE HAZARD

Jurisdiction	Bridges	Water Supply	Wastewater	Power	Communications	Other	**Total**
Cle Elum	3	0	2	0	0	0	**5**
Ellensburg	13	9	0	3	3	0	**28**
Kittitas	0	0	1	0	0	0	**1**
Roslyn	0	1	1	0	0	0	**2**
South Cle Elum	0	1	0	0	0	0	**1**
Unincorporated	220	26	2	19	6	15	**288**
Total	**236**	**37**	**6**	**22**	**9**	**15**	**325**

5.6 DEMOGRAPHICS

Some populations are at greater risk from hazard events because of decreased resources or physical abilities. Elderly people, for example, may be more likely to require additional assistance. Research has shown that people living near or below the poverty line, the elderly (especially older single men), the disabled, women, children, ethnic minorities and renters all experience, to some degree, more severe effects from disasters than the general population. These vulnerable populations may vary from the general population in risk perception, living conditions, access to information before, during and after a hazard event, capabilities during an event, and access to resources for post-disaster recovery. Indicators of vulnerability—such as disability, age, poverty, and minority race and ethnicity—often overlap spatially and often in the geographically most vulnerable locations. Detailed spatial analysis to locate areas where there are higher concentrations of vulnerable community members would assist the County in extending focused public outreach and education to these most vulnerable citizens.

5.6.1 Kittitas County Population Characteristics

Knowledge of the composition of the population and how it has changed in the past and how it may change in the future is needed for making informed decisions about the future. Information about population is a critical part of planning because it directly relates to land needs such as housing, industry, stores, public facilities and services, and transportation. Kittitas County is the 25th largest of Washington's 39 counties. The Washington State Office of Financial Management estimated Kittitas County's population at 41,300 as of April 1, 2011.

Population changes are useful socio-economic indicators. A growing population generally indicates a growing economy, while a decreasing population signifies economic decline. Figure 5-2 shows the growth rate of Kittitas County from 1961 to 2011 compared to those of the United States and the State of Washington. Between 2000 and 2010, Washington's population grew by 14.8 percent (about 1.26 percent per year) while Kittitas County's population increased by 23.8 percent (1.96 percent per year). The County's population increased an average of 2.15 percent per year between 1990 and 2010, a total of 53 percent during that period.

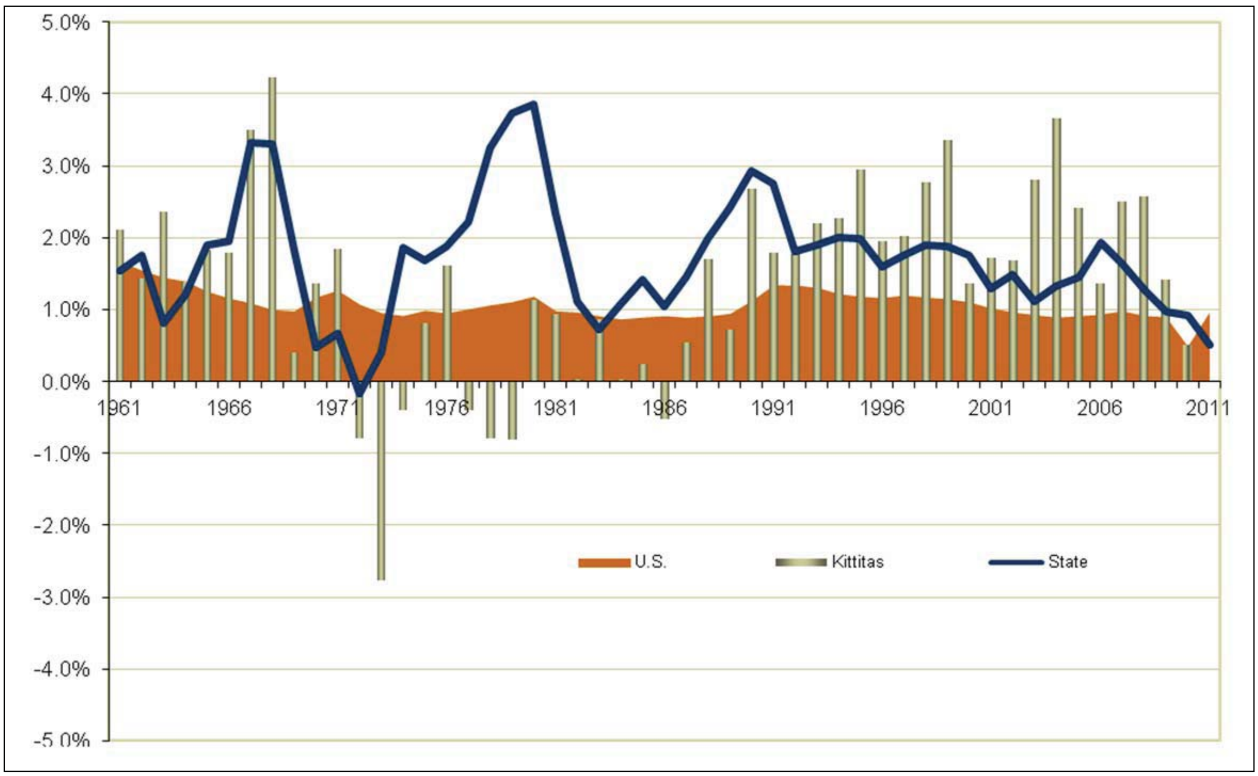


Figure 5-2. U.S., Washington and Kittitas County Population Growth Rates

Table 5-5 shows the population of incorporated municipalities and the combined unincorporated areas in Kittitas County from 2002 to 2010. In 2010, about 46 percent of Kittitas County's residents lived outside incorporated areas.

TABLE 5-5.
CITY AND COUNTY POPULATION DATA

	Cle Elum	Ellensburg	Kittitas	Roslyn	Unincorporated County	**Kittitas County Total**
2002	1,775	15,830	1,100	1,020	14,520	**34,800**
2003	1,775	15,940	1,120	1,020	14,785	**35,200**
2004	1,785	16,390	1,130	1,020	14,910	**35,800**
2005	1,800	16,700	1,135	1,020	15,375	**36,600**
2006	1,810	17,080	1,135	1,020	15,780	**37,400**
2007	1,835	17,220	1,135	1,020	16,510	**38,300**
2008	1,865	17,330	1,145	1,015	17,465	**39,400**
2009	1,870	17,230	1,150	1,015	18,060	**39,900**
2010	1,870	17,326	1,182	1,015	18,532	**40,500**

5.6.2 Income

In the United States, individual households are expected to use private resources to prepare for, respond to and recover from disasters to some extent. This means that households living in poverty are automatically disadvantaged when confronting hazards. Additionally, the poor typically occupy more poorly built and inadequately maintained housing. Mobile or modular homes, for example, are more susceptible to damage in earthquakes and floods than other types of housing. In urban areas, the poor often live in older houses and apartment complexes, which are more likely to be made of un-reinforced masonry, a building type that is particularly susceptible to damage during earthquakes. Furthermore, residents below the poverty level are less likely to have insurance to compensate for losses incurred from natural disasters. This means that residents below the poverty level have a great deal to lose during an event and are the least prepared to deal with potential losses. The events following Hurricane Katrina in 2005 illustrated that personal household economics significantly impact people's decisions on evacuation. Individuals who cannot afford gas for their cars will likely decide not to evacuate.

Based on the U.S. Census Bureau's American Community Survey (ACS) estimates for 2007-2009, per capita income in Kittitas County in 2009 was $23,377, and the median household income was $42,639. It is estimated that about 8.8 percent of households receive an income between $100,000 and $149,999 per year and over 4 percent of the county's household incomes are above $150,000 annually. About 30 percent of the households in Kittitas County make less than $25,000 per year and are therefore below the poverty level. The weighted average poverty threshold for a family of four in 2010 was $22,314; for a family of three, $17,374; for a family of two, $14,218; and for unrelated individuals, $11,139.

5.6.3 Age Distribution

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

Children under 14 are particularly vulnerable to disaster events because of their young age and dependence on others for basic necessities. Very young children may additionally be vulnerable to injury or sickness; this vulnerability can be worsened during a natural disaster because they may not understand the measures that need to be taken to protect themselves from hazards.

The overall age distribution for Kittitas County is illustrated in Figure 5-3. Based on U.S. Census estimates, 12.8 percent of Kittitas County's population is 65 or older, compared to the state average of 12.3 percent. Of the county's over-65 population, 38.1 percent has disabilities of some kind and 6.3 percent have incomes below the poverty line. It is also estimated that 15.2 percent of the county's population is 14 or younger, compared to the state average of 19.4 percent. Children under 18 account for 18.2 percent of individuals who are below the poverty line.

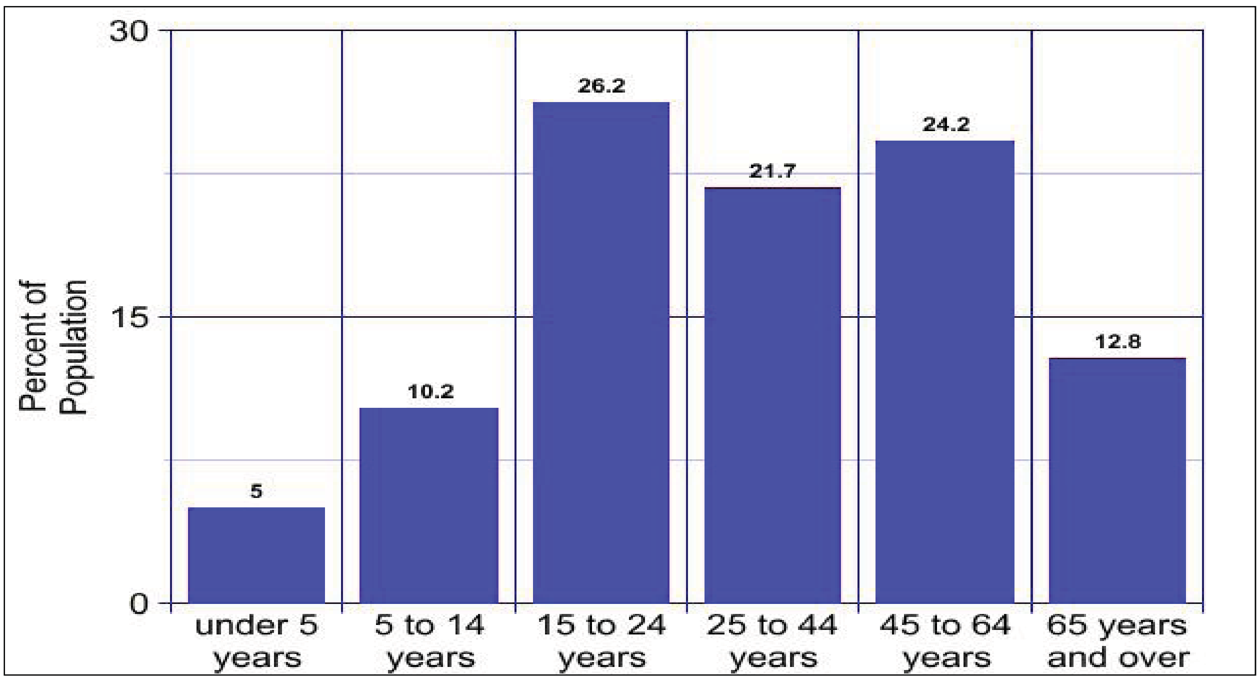


Figure 5-3. Kittitas County Age Distribution, 2010

5.6.4 Race, Ethnicity and Language

Research shows that minorities are less likely to be involved in pre-disaster planning and experience higher mortality rates during a disaster event. Post-disaster recovery can be ineffective and is often characterized by cultural insensitivity. Since higher proportions of ethnic minorities live below the poverty line than the majority white population, poverty can compound vulnerability. According to the 2010 ACS, the racial composition of Kittitas County is predominantly white, at about 89.3 percent. The largest minority population is Asian at 2.3 percent. The Hispanic population represents 7.5 percent of the county total. Figure 5-4 shows the racial distribution in Kittitas County.

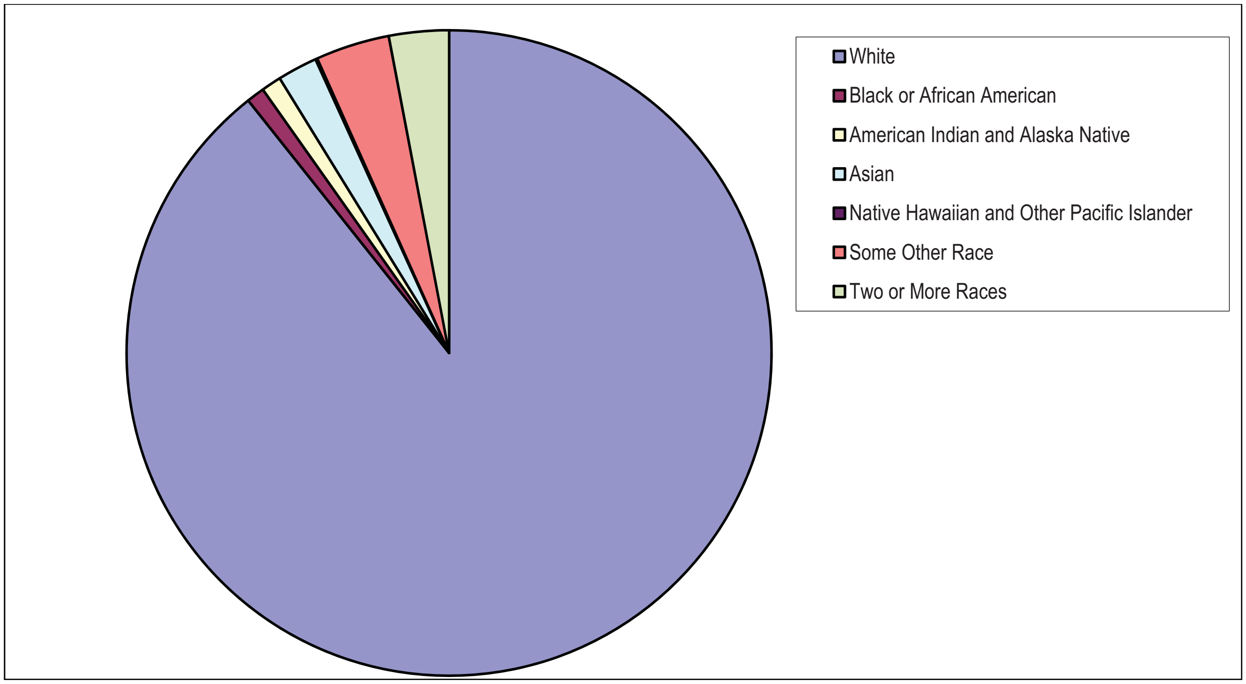


Figure 5-4. Planning Area Race Distribution

Kittitas County has a 5 percent foreign-born population. Other than English, the most commonly spoken language in Kittitas County is Spanish. The census estimates 3.9 percent of the county's residents speak English "less than very well."

5.6.5 Disabled Populations

People with disabilities are more likely than the general population to have difficulty responding to a hazard event. As disabled populations are increasingly integrated into society, they are more likely to require assistance during the 72 hours after a hazard event, the period generally reserved for self-help. There is no "typical" disabled person, which can complicate disaster-planning processes that attempt to incorporate them. Disability is likely to be compounded with other vulnerabilities, such as age, economic disadvantage and ethnicity, all of which mean that housing is more likely to be substandard.

Table 5-6 summarizes the estimates of disabled people in Kittitas County. According to 2008-2010 ACS data, 10.9 percent of the county's population has a disability.

**TABLE 5-6.
DISABILITY STATUS OF NON-INSTITUTIONALIZED POPULATION**

Age	Persons with a Disability	Percent of Age Group
Age 0 to 17 years	146	3.4
Age 18 to 64 years	2,421	8.7
Age 65 years and over	1,931	38.1

5.7 ECONOMY

5.7.1 Industry, Businesses and Institutions

According to the Washington State Department of Employment Security, Kittitas County's economy is strongly based in the State and Local Government industry, with 29 percent of employees, followed by Accommodation and Food Service at 17 percent and Retail Trade at 11 percent. Information, Educational Services, and Arts and Recreation make up the smallest sources of the county's economy. Figure 5-5 shows the breakdown of industry types in Kittitas County.

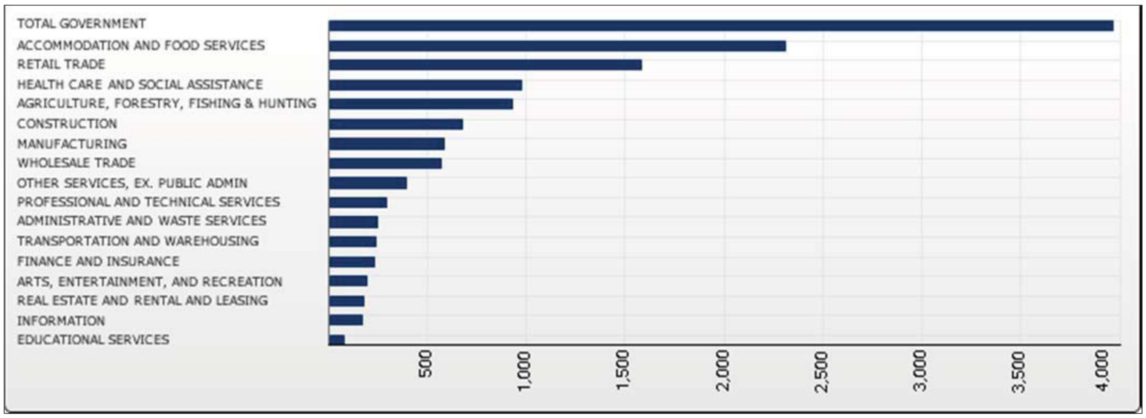


Figure 5-5. Industry Distribution in Kittitas County by Number Employed, 3rd Quarter 2010

The county benefits from a variety of business activity. Major public and private employers include Central Washington University, Kittitas Valley Community Hospital, Ellensburg School District, Kittitas County, Anderson Hay and Grain, Elmview Ellensburg, and Fred Meyer. Central Washington University is the major educational and research institution in the county, with a student enrollment of 10,750 and a staff and faculty of 1,438.

5.7.2 Employment Trends and Occupations

According to the 2010 ACS, about 60 percent of Kittitas County's population 16 years and over is in the labor force. Of the working-age population group (ages 20-64), 75.3 percent of men and 68.6 percent of women are in the labor force. Figure 5-6 compares Washington's and Kittitas County's unemployment trends from 2000 through 2010. Kittitas County's unemployment rate was lowest in October 2006, at 3.8 percent. Unemployment rates reached a peak of 11.7 percent in November 2010, but have since been on an downward trend.

Figure 5-7 shows the distribution of employment by occupation type. The largest employer in the county is Central Washington University, with 1,438 employees, followed by Kittitas Valley Community Hospital, which employs 470.

The U.S. 2007-2009 ACS estimates that over 69.8 percent of Kittitas County workers commute alone (by car, truck or van) to work, and mean travel time to work is 20.3 minutes (the state average is 25.4 minutes).

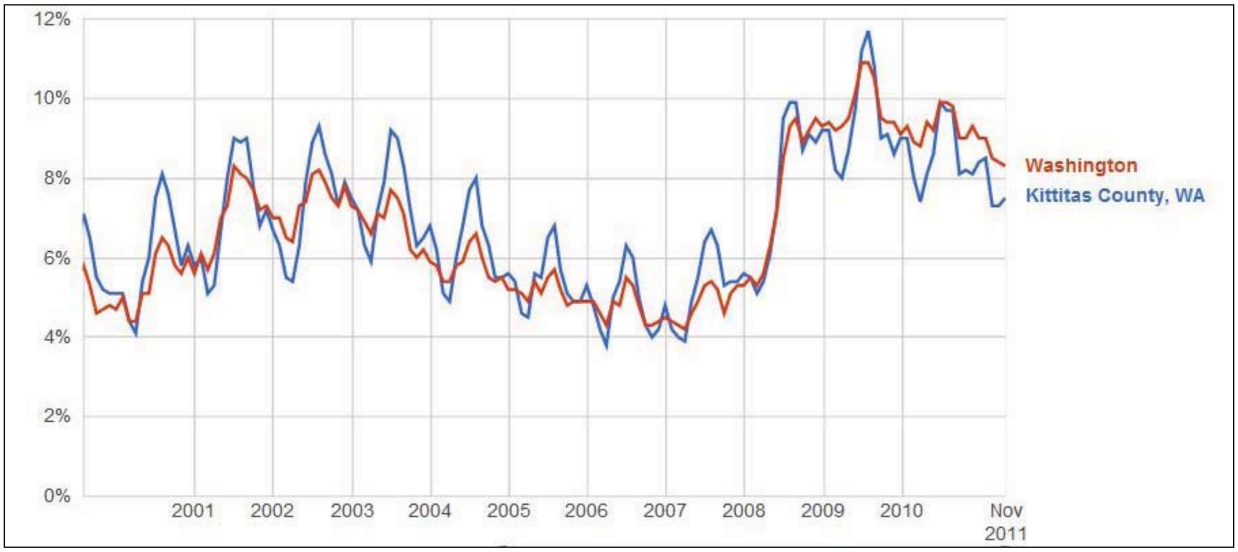


Figure 5-6. Washington and Kittitas County Unemployment Rate

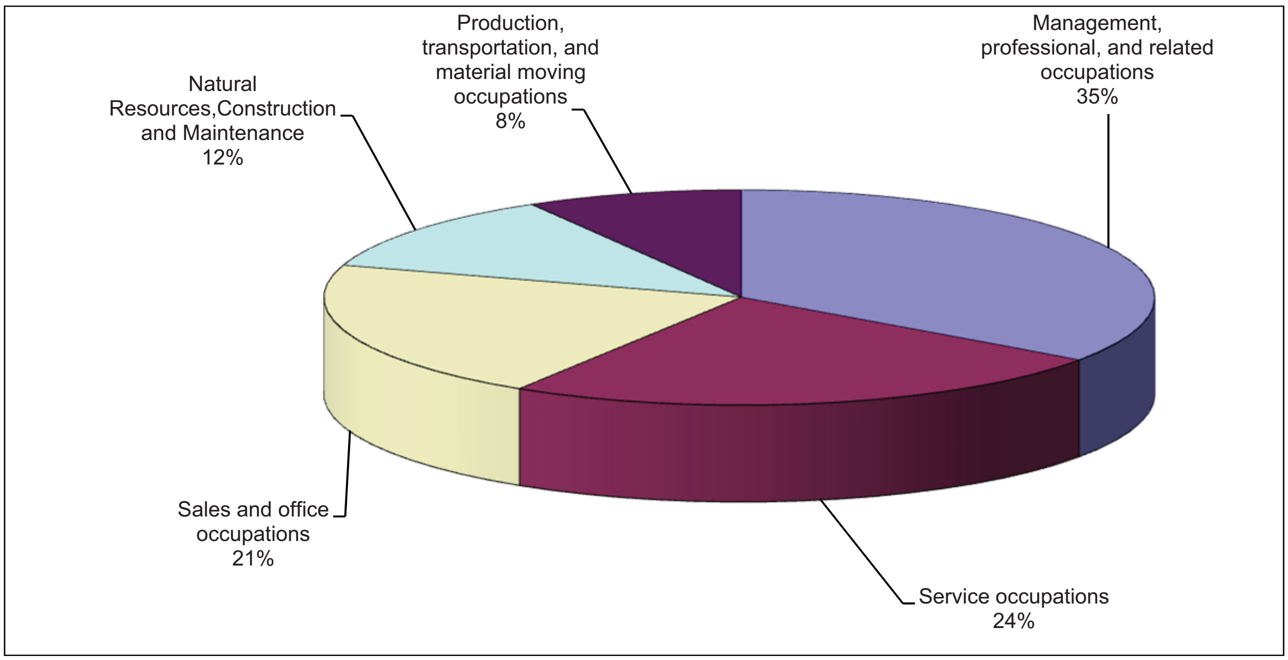


Figure 5-7. Occupations in Kittitas County

5.8 FUTURE TRENDS IN DEVELOPMENT

The County and its cities have adopted comprehensive plans that govern land use decision and policy making their jurisdictions. Decisions on land use will be governed by these programs. This plan will work together with these programs to support wise land use in the future by providing vital information on the risk associated with natural hazards in Kittitas County.

All municipal planning partners will seek to incorporate by reference the Kittitas County Hazard Mitigation Plan in their comprehensive plans. This will assure that all future trends in development can be established with the benefits of the information on risk and vulnerability to natural hazards identified in this plan.

5.9 LAWS AND ORDINANCES

Existing laws, ordinances and plans at the federal, state and local level can support or impact hazard mitigation initiatives identified in this plan. Hazard mitigation plans are required by 44 CFR to include a review and incorporation, if appropriate, of existing plans, studies, reports, and technical information as part of the planning process (Section 201.6.b(3)). Pertinent federal and state laws are described below. Each planning partner has individually reviewed existing local plans, studies, reports, and technical information in its jurisdictional annex, presented in Volume 2.

5.9.1 Federal

Disaster Mitigation Act

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

Endangered Species Act

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

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

The following are critical sections of the ESA:

- **Section 4: Listing of a Species**—The National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) is responsible for listing marine species; the U.S. Fish and Wildlife Service is responsible for listing terrestrial and freshwater aquatic species. The agencies may initiate reviews for listings, or citizens may petition for them. A listing must be made "solely on the basis of the best scientific and commercial data available." After a listing has been proposed, agencies receive comment and conduct further scientific reviews, after which they must decide if the listing is warranted. Economic impacts cannot be considered in this decision, but it may include an evaluation of the adequacy of local and state protections.
- **Section 7: Consultation**—Federal agencies must ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed or proposed species

or adversely modify its critical habitat. This includes private and public actions that require a federal permit. Once a final listing is made, non-federal actions are subject to the same review, termed a "consultation." If the listing agency finds that an action will "take" a species, it must propose mitigations or "reasonable and prudent" alternatives to the action; if the proponent rejects these, the action cannot proceed.

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

With the listing of salmon and trout species as threatened or endangered, the Pacific Coast states have been impacted by mandates, programs and policies based on the presumed presence of listed species. Most West Coast jurisdictions must now take into account the impact of their programs on habitat.

The Clean Water Act

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

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

National Flood Insurance Program

The National Flood Insurance Program (NFIP) provides federally backed flood insurance in exchange for communities enacting floodplain regulations. Participation and good standing under NFIP are prerequisites to grant funding eligibility under the Robert T. Stafford Act. The County and most of the partner cities for this plan participate in the NFIP and have adopted regulations that meet the NFIP requirements. At the time of the preparation of this plan, all participating jurisdictions in the partnership were in good standing with NFIP requirements.

5.9.2 State

Washington State Enhanced Mitigation Plan

The Washington State Enhanced Hazard Mitigation Plan approved by FEMA in 2010 provides guidance for hazard mitigation throughout Washington. The plan identifies hazard mitigation goals, objectives, actions and initiatives for state government to reduce injury and damage from natural hazards. By meeting federal requirements for an enhanced state plan (44 CFR parts 201.4 and 201.5), the plan allows the state to seek significantly higher funding from the Hazard Mitigation Grant Program following presidential declared disasters (20 percent of federal disaster expenditures vs. 15 percent with a standard plan).

Growth Management Act

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

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

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

Shoreline Management Act

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

Washington State Building Code

The Washington State Building Code Council adopted the 2006 editions of national model codes, with some amendments. The Council also adopted changes to the Washington State Energy Code and Ventilation and Indoor Air Quality Code. Washington's state-developed codes are mandatory statewide for residential and commercial buildings. The residential code exceeds the 2006 International Energy Conservation Code standards for most homes, and the commercial code meets or exceeds standards of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE 90.1-2004). For residential construction covered by ASHRAE 90.1-2007 (buildings with four or more stories), the state code is more stringent. The 2009 IBC went into effect as the Washington model code on July 1, 2010.

Comprehensive Emergency Management Planning

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

- Provides for emergency management by the state, and authorizes the creation of local organizations for emergency management in political subdivisions of the state.
- Confers emergency powers upon the governor and upon the executive heads of political subdivisions of the state.

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

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

Washington Administrative Code 118-30-060(1)

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

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

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

Washington State Floodplain Management Law

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

Flood Control Assistance Account Program

Washington's first flood control maintenance program was passed in 1951, and was called the Flood Control Maintenance Program (FCMP). In 1984, RCW 86.26 (State Participation in Flood Control

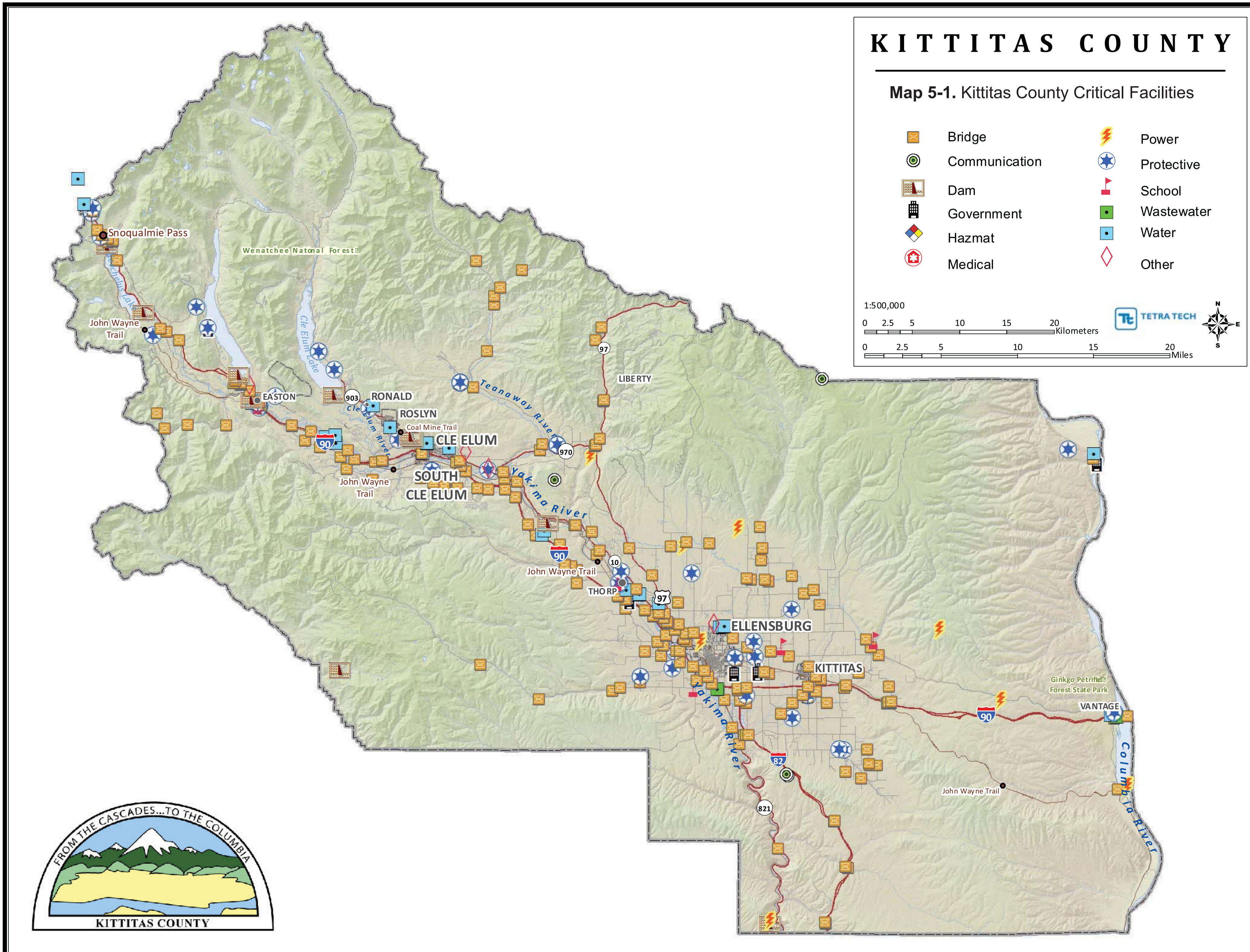
Maintenance) established the Flood Control Assistance Account Program (FCAAP), which provides funding for local flood hazard management. FCAAP rules are found in WAC 173-145. Ecology distributes FCAAP matching grants to cities, counties and other special districts responsible for flood control. This is one of the few state programs in the U.S. that provides grant funding to local governments for floodplain management. The program has been funded for $4 million per Biennium since its establishment, with additional amounts provided after severe flooding events.

To be eligible for FCAAP assistance, flood hazard management activities must be approved by Ecology in consultation with the Washington Department of Fish and Wildlife (WDFW). A comprehensive flood hazard management plan must have been completed and adopted by the appropriate local authority or be in the process of being prepared in order to receive FCAAP flood damage reduction project funds. This policy evolved through years of the FCMP and early years of FCAAP in response to the observation that poor management in one part of a watershed may cause flooding problems in another part.

Local jurisdictions must participate in the NFIP and be a member in good standing to qualify for an FCAAP grant. Grants up to 75 percent of total project cost are available for comprehensive flood hazard management planning. Flood damage reduction projects can receive grants up to 50 percent of total project cost, and must be consistent with the comprehensive flood hazard management plan. Emergency grants are available to respond to unusual flood conditions. FCAAP can also be used for the purchase of flood prone properties, for limited flood mapping and for flood warning systems. Funding currently is running about 60 percent for planning and 40 percent for projects.

5.9.3 Cities and County

Each planning partner has prepared a jurisdiction-specific annex to this plan (see Volume 2). In preparing these annexes, each partner completed a capability assessment that looked at its regulatory, technical and financial capability to carry out proactive hazard mitigation. Refer to these annexes for a review of regulatory codes and ordinances applicable to each planning partner.


KITTITAS COUNTY
Map 5-1. Kittitas County Critical Facilities
Bridge
Communication
Dam
Government
Hazmat
Medical
Power
Protective
School
Wastewater
Water
Other
1:500,000
0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles
TETRA TECH
N
E
S
Snoqualmie Pass
Wenatchee National Forest
John Wayne Trail
Cle Elum Lake
EASTON
RONALD
ROSLYN
Coal Mine Trail
CLE ELUM
SOUTH CLE ELUM
Teanaway River
Cle Elum River
Yakima River
LIBERTY
THORP
ELLENSBURG
KITTITAS
Ginkgo Petrified Forest State Park
VANTAGE
Columbia River
90
97
903
970
10
82
821
FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY

CHAPTER 6.
AVALANCHE

6.1 GENERAL BACKGROUND

Avalanches can occur whenever a sufficient depth of snow is deposited on slopes steeper than about 20 degrees, with the most dangerous coming from slopes in the 35- to 40-degree range. Avalanche-prone areas can be identified with some accuracy, since they typically follow the same paths year after year, leaving scarring on the paths. However, unusual weather conditions can produce new paths or cause avalanches to extend beyond their normal paths.

In the spring, warming of the snowpack occurs from below (from the warmer ground) and above (from warm air, rain, etc.). Warming can be enhanced near rocks or trees that transfer heat to the snowpack. The effects of a snowpack becoming weak may be enhanced in steeper terrain where the snowpack is shallow, and over smooth rock faces that may focus meltwater and produce "glide cracks." Such slopes may fail during conditions that encourage melt.

Wind can affect the transfer of heat into the snowpack and associated melt rates of near-surface snow. During moderate to strong winds, the moistening near-surface air in contact with the snow is constantly mixed with drier air above through turbulence. As a result, the air is continually drying out, which enhances evaporation from the snow surface rather than melt. Heat loss from the snow necessary to drive the evaporation process cools off near-surface snow and results in substantially less melt than otherwise might occur, even if temperatures are well above freezing.

When the snow surface becomes uneven in spring, air flow favors evaporation at the peaks, while calmer air in the valleys favors condensation there. Once the snow surface is wet, its ability to reflect solar energy drops dramatically; this becomes a self-perpetuating process, so that the valleys deepen (favoring calmer air and more heat transfer), while more evaporation occurs near the peaks, increasing the differential between peaks and valleys. However, a warm wet storm can quickly flatten the peaks as their larger surface area exposed to warm air, rain or condensation hastens their melt over the sheltered valleys.

DEFINITIONS

Avalanche—Any mass of loosened snow or ice and/or earth that suddenly and rapidly breaks loose from a snowfield and slides down a mountain slope, often growing and accumulating additional material as it descends.

Slab avalanches—The most dangerous type of avalanche, occurring when a layer of coherent snow ruptures over a large area of a mountainside as a single mass. Like other avalanches, slab avalanches can be triggered by the wind, by vibration, or even by a loud noise, and will pull in surrounding rock, debris and even trees.

Climax avalanches—An avalanche involving multiple layers of snow, usually with the ground as a bed surface.

Loose snow avalanches—An avalanche that occurs when loose, dry snow on a slope becomes unstable and slides. Loose snow avalanches start from a point and gather more snow as they descend, fanning out to fill the topography.

Powder snow avalanches—An avalanche that occurs when sliding snow has been pulverized into powder, either by rapid motion of low-density snow or by vigorous movement over rugged terrain.

Surface avalanches—An avalanche that occurs only in the uppermost snow layers.

Wet snow avalanche—An avalanche in wet snow, also referred to as a wet loose avalanche or a wet slab avalanche. Often the basal shear zone is a water-saturated layer that overlies an ice zone.

6.2 HAZARD PROFILE

6.2.1 Past Events

Avalanches occur frequently each year and kill one to two people annually in the Northwest (about 25 to 35 deaths annually in the U.S.). Avalanches have killed more people in Washington than any other hazard during the past century. In 90 percent of avalanche fatalities, the weight of the victim or someone in the victim's party triggers the slide. Avalanches have killed over 200 people in Washington since 1900, and 47 between 1985 and 2009. This exceeds the death toll of earthquakes and floods combined. Records of avalanches within or adjacent to Kittitas County are shown in Table 6-1.

**TABLE 6-1.
AVALANCHE HISTORY**

Date	Location	Description
1996/97	Snoqualmie Pass	Hundreds of travelers stranded after repeated avalanches closed Interstate 90 during the holidays.
1/24/2002	Source Lake, Snoqualmie Pass	2 overnight campers caught while in tent, both self-rescued without major injuries
1/27/2002	Gold Creek, Snoqualmie Pass	1 snowshoer caught, buried and rescued by own dog
3/10/2002	Granite Mt., Snoqualmie Pass	2 skiers out; 1 caught and buried; rescued
3/292003	Granite Mt. Snoqualmie Pass	1 skier caught, partly buried, seriously injured
12/13/2003	Snoqualmie Pass	One snowshoer caught, buried and killed. Victim found 12/20/03
1/12/2005	Alpental Ski Area, Snoqualmie Pass—Central WA Cascades	Two skiers caught and buried/partially buried; one killed and one self-rescued
12/2/2007	Source Lake, Snoqualmie Pass	Three hikers caught, 1 partly buried, injured & self-rescued, 2 completely buried and killed, central Washington Cascades near Snoqualmie Pass, WA. Party was returning from Snow Lake Ridge toward Source Lake when they triggered the avalanche.
4/29/2010	Kendall Peak near Snoqualmie Pass—Central WA Cascades	Two skiers caught and partially buried, 1 slightly injured, 1 critically injured
2/1/2011	Red Mt, Central WA Cascades just north of Snoqualmie Pass	Solo skier triggered cornice collapse and was caught, buried and killed by subsequent fall and loose avalanche
4/6/2011	Phantom path on Mt Snoqualmie, Central WA Cascades just north of Snoqualmie Pass	Party of five triggered 1.5- to 2-foot slab; slab caught and injured two seriously, one with minor injuries

6.2.2 Location

The Cascade Range in the western half of Kittitas County receives extensive precipitation due to its size and orientation to the flow of Pacific marine air. In the local maritime climate, it is common for air temperatures to rise above freezing and for precipitation to change from snow to rain during mid-winter storm cycles. Temperatures can change several degrees within minutes, causing abrupt changes in precipitation type. These conditions frequently cause the release of avalanches. Figure 6-1 shows avalanche hazard areas in Washington State, including the westernmost portion of Kittitas County.

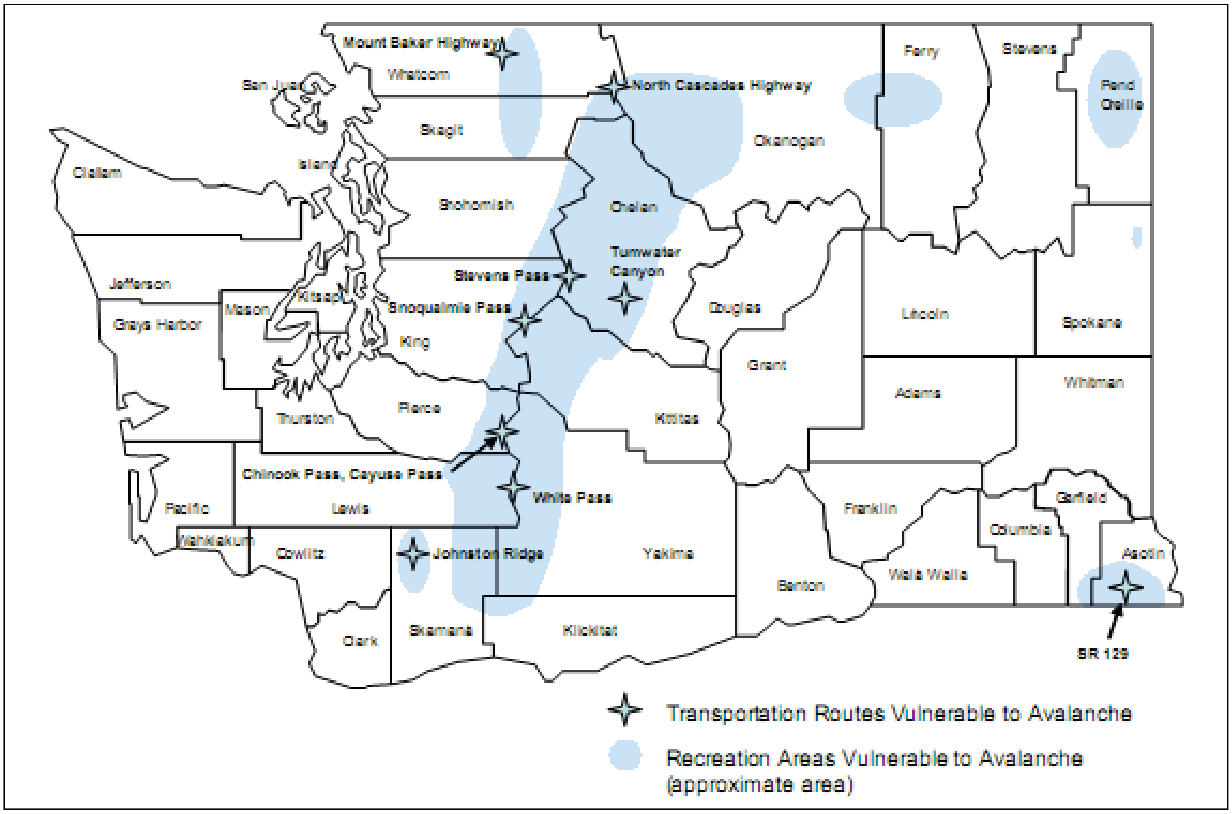


Figure 6-1. Areas Vulnerable to Avalanche

6.2.3 Frequency

Avalanches occur regularly every year in mountain areas. Many weather and terrain factors determine avalanche danger. Avalanches along two key mountain highway passes are limited due to ongoing mitigation to control slides during winter months. At lower elevations of the Cascades, the avalanche season begins in November and continues until the last remnants of snow have melted in early summer. In the high alpine regions, the hazard continues year-round. Hundreds of thousands of avalanches are thought to occur each year in the Cascades.

6.2.4 Severity

A number of weather and terrain factors determine avalanche severity and danger:

- Weather:
  - Storms—A large percentage of all snow avalanches occur during and shortly after storms.
  - Rate of snowfall—Snow falling at a rate of 1 inch or more per hour rapidly increases avalanche danger.
  - Temperature—Storms starting with low temperatures and dry snow, followed by rising temperatures and wetter snow, are more likely to cause avalanches than storms that start warm and then cool with snowfall.
  - Wet snow—Rainstorms or spring weather with warm, moist winds and cloudy nights can warm the snow cover, resulting in wet snow avalanches. Wet snow avalanches are more likely on sun-exposed terrain (south-facing slopes) and under exposed rocks or cliffs.

- Terrain:
  - Ground cover—Large rocks, trees and heavy shrubs help anchor snow.
  - Slope profile—Dangerous slab avalanches are more likely to occur on convex slopes.
  - Slope aspect—Leeward slopes are dangerous because windblown snow adds depth and creates dense slabs. South-facing slopes are more dangerous in the springtime.
  - Slope steepness—Snow avalanches are most common on slopes of 30 to 45 degrees.

The common factors contributing to the avalanche hazard are old snow depth, old snow surface, new snow depth, new snow type, density, snowfall intensity, precipitation intensity, settlement, wind direction and speed, temperature, and subsurface snow crystal structure.

6.2.5 Warning Time

The time of an avalanche release depends on the condition of the snow pack; which can change rapidly during a day and particularly during rainfall. Research done at Snoqualmie Pass showed that most natural avalanches occurred less than 1 hour after the onset of rain; in these cases the snow pack was initially weak (Washington Emergency Management Division, 1996). In cases where the snow pack was stronger, avalanche activity was delayed or did not occur. Nonetheless an avalanche can occur with little or no warning time, which makes them particularly deadly.

6.3 SECONDARY HAZARDS

Avalanches can cause several types of secondary effects, such as blocking roads, which can isolate residents and businesses and delay commercial, public and private transportation. This could result in economic losses for businesses. Other potential problems resulting from avalanches are power and communication failures. Avalanches also can damage rivers or streams, potentially harming water quality, fisheries and spawning habitat.

6.4 CLIMATE CHANGE IMPACTS

Snow avalanches are mainly ruled by temperature fluctuations, heavy precipitation and wind regimes. Climate change is likely to modify the frequency and magnitude of both ordinary and extreme avalanche events. However, these possible changes are not taken into account in current engineering practice: reference scenarios and return periods for avalanche hazard management are always computed under the assumption of a stationary process. Unlike other phenomena such as tropical storms, snow avalanches are rarely used as indicators of climate change.

6.5 EXPOSURE

There is minimal development in the high Cascade Range, which makes Kittitas County's exposure to an avalanche small. Most mountainous areas in the county are part of the Mount Baker-Snoqualmie National Forest and other protected forests.

6.5.1 Population

There are no major populations exposed to avalanches in the county. Most of the avalanche hazard area is uninhabited or has minimal development. Ski resorts are not considered to be exposed to avalanches due to their ski slope maintenance protocols; however, skiers who ski out of bounds in these areas are exposed to avalanches. People working in the mountains, such as miners and loggers, are exposed, as are recreational users, such as hikers and cross-country skiers.

6.5.2 Property

There is little property that is exposed to avalanches. Property and buildings exposed include National Forest huts and temporary structures belonging to mining and forestry operations.

6.5.3 Critical Facilities and Infrastructure

Interstate 90 could be blocked by avalanches, but the Washington Department of Transportation conducts active winter avalanche control or mitigation on Interstate 90. This means avalanches are triggered intentionally on slopes above the roadways in a controlled environment to minimize traffic disruption and promote public safety. The Department of Transportation also conducts passive avalanche control by building elevated roadways so avalanches can pass under highways, snow sheds so that avalanching snow flows over highways, catchment basins to stop avalanche flow, and diversion dams and berms to keep snow off highways.

Avalanche control is important along Snoqualmie Pass. I-90 is a heavily traveled corridors that connects major Puget Sound communities to Eastern Washington through the Cascade Mountains. Snoqualmie Pass is the state's only Interstate highway link through the Cascades. It averages nearly 450 inches of snow each winter and has a daily traffic volume of 32,000 vehicles (including 8,000 trucks). A two-hour closure of the pass costs the state's economy more than $1 million.

6.5.4 Environment

Avalanches are a natural event, but they can negatively affect the environment. This includes trees located on steep slopes. A large avalanche can knock down many trees and kill the wildlife that lives in them. In spring, this loss of vegetation on the mountains may weaken the soil, causing landslides and mudflows.

6.6 VULNERABILITY

In general, everything that is exposed to an avalanche event is vulnerable. More and more people are working and building in or using the high mountain areas of the Cascades in potential avalanche areas. These individuals often have little experience with, caution regarding, or preparation for, avalanche conditions. The increasing development of recreational sites in the mountains brings added exposure to the people using these sites and the access routes to them. The risk to human life is especially great at times of the year when rapid warming follows heavy, wet snowfall.

6.7 FUTURE TRENDS IN DEVELOPMENT

Future trends in development cannot be determined until the avalanche hazard areas are accurately mapped. From review of the buildable lands analysis, which projects the location and density of development based on current land use regulations, there is no significant housing or employment capacity that has the potential to be developed in these areas.

6.8 SCENARIO

In a worst-case scenario, an avalanche would occur in the Cascade Mountains after a series of storms. Storms starting with low temperatures and dry snow, followed by rising temperatures and wetter snow, are most likely to cause avalanches. Avalanches occurring in the Snoqualmie Pass vicinity, causing prolonged closure of Interstate 90, would have significant economic impact not only on Kittitas county, but also on all counties along the I-90 corridor.

6.9 ISSUES

The only issue of concern in the event of an avalanche is the threat to recreational users and property. The U.S. Forest Service, National Park Service, National Weather Service and Washington Department of Transportation currently have programs to monitor avalanche zones and forecast avalanche danger. However, there is no effective way to keep the public out of avalanche-prone areas, even during times of highest risk. A coordinated effort is needed among state, county and local law enforcement, fire, emergency management, public works agencies and media to provide winter snow pack and avalanche risk information to the public.

A national program to rate avalanche risk has been developed to standardize terminology and provide a common basis for recognizing and describing hazardous conditions. This United States Avalanche Danger Scale relates degree of avalanche danger (low, moderate, considerable, high, extreme) to descriptors of avalanche probability and triggering mechanism, degree and distribution of avalanche hazard, and recommended action in back country. Figure 6-2 shows key elements of the danger scale.

This information, updated daily, is available during avalanche season from the joint NOAA/U.S. Forest Service Northwest Weather and Avalanche Center and can be obtained from Internet, NOAA weather wire, and Department of Transportation sources. Avalanche danger scale information should be explained to the public and made available through appropriate county and local agencies and the media.

Measures that have been used in other jurisdictions to reduce avalanche threat include monitoring timber harvest practices in slide-prone areas to ensure that snow cover is stabilized as well as possible, and encouraging reforestation in areas near highways, buildings, power lines and other improvements. The development of a standard avalanche report form, and the maintenance of a database of potential avalanche hazards likely to affect proposed developments in mountain wilderness areas, would be of significant value to permitting agencies.

Avalanche Safety Basics

Avalanches don't happen by accident *and most human involvement is a matter of* ***choice*** *not chance. Slab avalanches, which are triggered by the victim or a member of the victim's party, cause most avalanche accidents. However, any avalanche may cause injury or death and even small slides may be dangerous. Hence, always practice safe route finding skills, be aware of changing conditions, and carry avalanche rescue gear. Learn and apply avalanche terrain analysis and snow stability evaluation techniques to help minimize your risk. Remember that avalanche danger rating levels are only general guidelines. Distinctions between geographic areas, elevations, slope aspect and slope angle are approximate, and transition zones between dangers exist. No matter what the current avalanche danger is, there are avalanche-safe areas in the mountains.*

UNITED STATES AVALANCHE DANGER DESCRIPTORS

Danger Level (Color)	Avalanche Probability and Avalanche Trigger	Degree and Distribution of Avalanche Danger	Recommended Action in the Back Country
Low (Green)	Natural Avalanches very unlikely. Human avalanches unlikely.	Generally stable snow. Isolated areas of instability.	Travel is generally safe. Normal caution advised.
Moderate (yellow)	Natural avalanches unlikely. Human triggered avalanches possible.	Unstable slabs possible on steep terrain.	Use caution on steeper terrain on certain aspects
Moderate to High (orange)	Natural avalanches possible. Human triggered avalanches possible.	Unstable slabs possible on steep terrain.	Be increasingly cautious in steep terrain.
High (red)	Natural and human triggered avalanches likely.	Unstable slabs likely on a variety of aspects and slope angles	Travel in avalanche terrain is not recommended. Safest travel on windward ridges of lower angle slopes without steeper terrain above.
Extreme (red with black border)	Widespread natural or human triggered avalanches are certain	Extremely unstable slabs are certain on most aspects and slope angles. Large destructive avalanches possible.	Travel in avalanche terrain should be avoided and travel confined to low angle terrain well away from avalanche path run-outs.

Figure 6-2. United States Avalanche Danger Scale

CHAPTER 7.
DAM FAILURE

7.1 GENERAL BACKGROUND

7.1.1 Causes of Dam Failure

Dam failures in the United States typically occur in one of four ways (see Figure 7-1):

- 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 Kittitas 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.

DEFINITIONS

Dam—Any artificial barrier and/or any controlling works, together with appurtenant works, that can or does impound or divert water. (Washington Administrative Code, Title 173, Chapter 175.)

Dam Failure—An uncontrolled release of impounded water due to structural deficiencies in dam.

Emergency Action Plan—A document that identifies potential emergency conditions at a dam and specifies actions to be followed to minimize property damage and loss of life. The plan specifies actions the dam owner should take to alleviate problems at a dam. It contains procedures and information to assist the dam owner in issuing early warning and notification messages to responsible downstream emergency management authorities of the emergency situation. It also contains inundation maps to show emergency management authorities the critical areas for action in case of an emergency. (FEMA 64)

High Hazard Dam—Dams where failure or operational error will probably cause loss of human life. (FEMA 333)

Significant Hazard Dam—Dams where failure or operational error will result in no probable loss of human life but can cause economic loss, environmental damage or disruption of lifeline facilities, or can impact other concerns. Significant hazard dams are often located in rural or agricultural areas but could be located in areas with population and significant infrastructure. (FEMA 333)

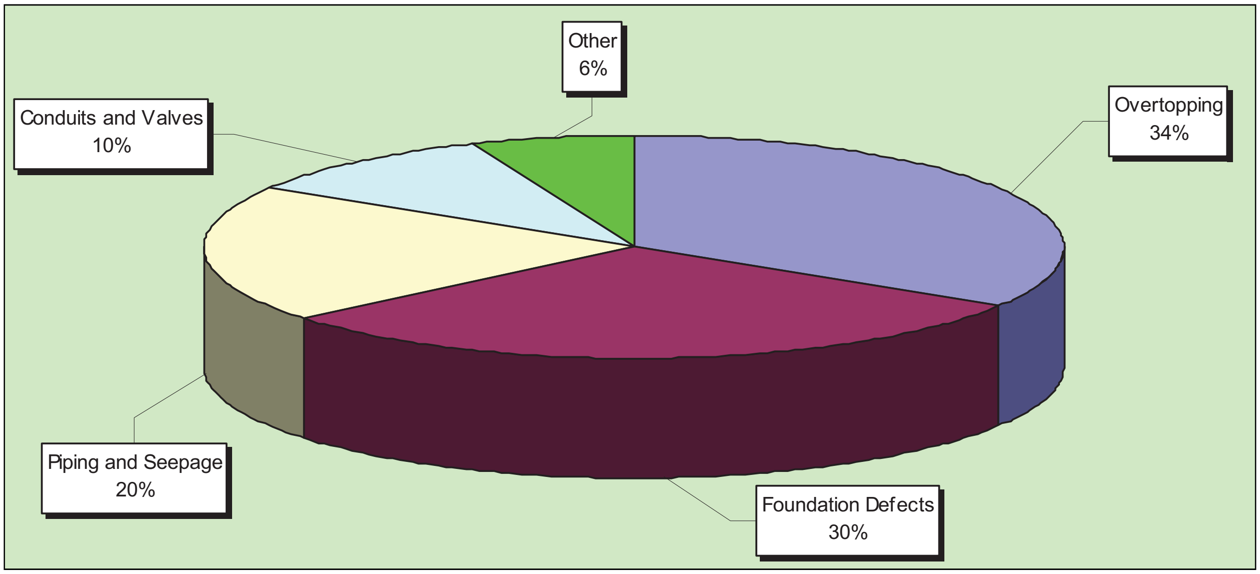


Figure 7-1. Historical Causes of Dam Failure

7.1.2 Regulatory Oversight

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 3,036 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 (10 meters), 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.

7.2 HAZARD PROFILE

7.2.1 Past Events

According to DSO records, 15 notable dam failure events occurred in Washington between 1918 and 2003. None of these occurred within or impacted Kittitas County.

7.2.2 Location

The DSO oversees 18 dams in Kittitas County, as listed in Table 7-1. Six are operated by federal agencies, and the remainder are under the jurisdiction of the state. Five of the dams are listed as high hazard, which means there are seven or more lives at risk downstream of the dam. The remainder of the dams are ranked as low risk, with no lives at risk downstream of the dam.

TABLE 7-1.
DAMS IN KITTITAS COUNTY

Name	National ID #	Water Course	Owner	Year Built	Dam Type[a]	Crest Length (feet)	Height (feet)	Surface Area (acres)	Drainage area (sq. mi.)	Hazard Class[b]
Brown Boys Effluent Pond	WA01836	Off-Stream-Yakima River	Brown Boy Feed, INC.	2000	RE	800	10	2.0	0.01	3
Childress-Winegar	WA01011	Tr-Morrison Creek	David and Roberta Israel	1964	RE	200	9	5.0	0.00	3
Cle Elum	WA00274	Cle Elum River	U.S. Bureau of Reclamation (BOR)	1933	RE	750	165	4,812	206	1A
Easton Diversion	WA00276	Yakima River	BOR	1929	CN, PG	248	66	275	185	1B
Kachess	WA00260	Kachess River	BOR	1912	RE	1,400	115	4,600	63.60	1A
Keechelus	WA00265	Yakima River	BOR	1917	RE	6,550	128	3,160	54.70	1A
Knudson	WA01015	Tr-Yakima River	WDFW	1966	RE	12	10	7	0.00	3
Lower Sunlight Lake	WA01805	Yakima River	Sunlight Waters Country Club	1967	RE	360	12	2.8	4.39	3
Milk Pond	WA00392	Tr-Milk Creek	Snoqualmie National Forrest	1983	RE	140	18	9.4	2.53	3
Porky Pig Farm	WA01618	Tr-Yakima River Off-Stream	Larry M. Howard	1970	RE	1340	16	25	0.01	3
Quilomene Creek	WA01030	Quilomene Creek	WDFW Real Estate Division	1964	RE	478	19	7	0.00	3
Reecer Creek Ranch	WA01617	Currier Creek	Van De Graaf	1977	RE	860	6	25	0.00	3
Reimer Pond	WA01083	Tr-Yakima River Off-Stream	James Etux P Roan	1951	RE	1000	19	3.7	0.01	3
Roslyn Wastewater Lagoon	WA01652	Crystal Creek-Off-Stream	City of Roslyn	1973	RE	2000	10	5.3	10	3
Roza Diversion	WA00275	Yakima River	BOR	1939	CN, PG	486	67	100	1,650	3
Snoqualmie Pass PUD-Sewer Lagoon #1	WA00472	Tr-Lake Keechelus-Off-Stream	Wenatchee National Forrest	1982	RE	1110	23	8.4	0.01	3
Tjossem Pond	WA01228	Wilson Creek-Off-Stream	Morris P. Sorenson	1890	RE	154	12	7.8	0.01	3
Upper Sunlight Lake	WA00666	Yakima River	Sunlight Waters Country Club	1967	RE	325	25	5	7.8	1C

a. RE = Earth Fill Dam; CN, PG = Concrete Gravity Dam
b. See Section 7.2.4 for definition of hazard classes

The DSO has prepared dam failure inundation mapping for the Hazard Class 1A and 1B dams. Individual mapping was created for the Class 1A Cle Elum Dam (Map 7-1) and Class 1B Easton Diversion Dam (Map 7-2). The DSO prepared a single inundation-area map for failure of the Class 1A Kachess and Keechelus Dams (Map 7-3). These inundation maps are used in the assessment of exposure and vulnerability for the dam failure hazard.

7.2.3 Frequency

Dam failures are infrequent and usually coincide with events that cause them, such as earthquakes or excessive rainfall. The probability of any type of dam failure is low in today's regulatory environment. There is a "residual risk" associated with dams that remains after safeguards have been implemented. The residual risk is associated with events beyond those that the facility was designed to withstand.

7.2.4 Severity

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 7-2. 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.

7.2.5 Warning Time

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

Kittitas County and its planning partners have established protocols for flood warning and response to imminent dam failure in the flood warning portion of adopted emergency operations plans. These protocols are tied to emergency action plans (EAPs) created by the dam owners. Not all dams have EAPs; only those rated as high hazard are mandated to do so by state and federal regulations.

7.3 SECONDARY HAZARDS

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure are landslides around the reservoir perimeter, bank erosion on the rivers, and destruction of downstream habitat.

**TABLE 7-2.
CORPS OF ENGINEERS HAZARD POTENTIAL CLASSIFICATION**

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

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

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

7.4 CLIMATE CHANGE IMPACTS

Potential changes to the hydrographs used to design dams due to the impacts of climate change are a growing concern for the safety of our nation's 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 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.

7.5 EXPOSURE

The Level 2 HAZUS-MH protocol was used to assess the risk and vulnerability to dam failure in the planning area. The model used census data at the block level and dam failure inundation data to estimate potential dam failure impacts. The inundation areas evaluated are for the Keechelus, Kachess, Cle Elum, and Easton dams, for which the DSO has prepared flood inundation mapping. Dam failure exposure numbers were generated using Kittitas County Assessor and parcel data. Where possible, the HAZUS-MH default data was enhanced using local GIS data from county, state and federal sources. All data sources have a level of accuracy acceptable for planning purposes.

7.5.1 Population

All populations in a dam failure inundation zone are exposed to the risk of a dam failure. Using GIS, residential structures that intersect the combined dam inundation area were identified, and an estimate of population was calculated by multiplying the number of residential structures by the Kittitas County average of 2.32 persons per household. Using this approach, the estimated population living in the mapped inundation areas is 5,060, or 12 percent of the county's population. Table 7-3 summarizes the at-risk population in the planning area by city.

TABLE 7-3.
POPULATION AT RISK FROM DAM FAILURE

City	Affected Population	% of City Population
Cle Elum	1,257	67%
Ellensburg	750	4%
Kittitas	0	0%
Roslyn	0	0%
South Cle Elum	566	98%
Unincorporated	2,486	13%
Total[a]	**5,060**	**12%**

a. Represents the total population in the combined inundation areas all dams.

7.5.2 Property

Property exposure numbers were based on an aggregated value for all mapped dam inundation areas. Based on assessor parcel data, the HAZUS-MH model estimated that there are 3,051 structures within the mapped dam failure inundation areas in the planning area. The value of exposed buildings in the planning area was generated using HAZUS-MH and is summarized in Table 7-4. It is estimated $1.46 billion worth of building-and-contents are exposed to dam failure inundation, representing 18 percent of the total assessed value of the planning area.

7.5.3 Critical Facilities

GIS analysis determined that 123 of the planning area's critical facilities (27 percent) are in the mapped inundation areas, as summarized in Table 7-5 and Table 7-6.

TABLE 7-4.
VALUE OF PROPERTY EXPOSED TO DAM FAILURE

City	Number of Buildings Exposed	Value Exposed			% of Total Assessed Value
		Building	Contents	**Total**	
Cle Elum	908	$213,324,320	$205,291,133	$418,615,453	66%
Ellensburg	754	$274,738,712	$275,813,441	$550,552,153	25%
Kittitas	0	0	0	0	0%
Roslyn	0	0	0	0	0%
South Cle Elum	244	$43,214,758	$34,676,236	$77,890,994	91%
Unincorporated	1145	$229,125,242	$187,913,408	$417,038,651	8%
Total	**3051**	**$760,403,033**	**$703,694,218**	**$1,464,097,251**	**18%**

TABLE 7-5.
CRITICAL FACILITIES IN DAM FAILURE INUNDATION AREAS

	Medical & Health Services	Government Function	Protective Function	Schools	Hazardous Materials	Other Critical Function	**Total**
Cle Elum	3	3	8	0	0	0	**14**
Ellensburg	2	4	2	0	0	0	**8**
Kittitas	0	0	0	0	0	0	**0**
Roslyn	0	0	0	0	0	0	**0**
South Cle Elum	0	1	2	0	0	0	**3**
Unincorporated	0	1	6	3	0	0	**10**
Total	**5**	**9**	**18**	**3**	**0**	**0**	**35**

TABLE 7-6.
CRITICAL INFRASTRUCTURE IN DAM FAILURE INUNDATION AREAS

	Bridges	Water Supply	Wastewater	Power	Communications	Other Infrastructure	**Total**
Cle Elum	2	0	2	0	0	0	**4**
Ellensburg	8	0	0	2	0	0	**10**
Kittitas	0	0	0	0	0	0	**0**
Roslyn	1	1	0	0	0	0	**2**
South Cle Elum	0	0	0	0	0	0	**0**
Unincorporated	60	6	1	2	1	4	**74**
Total	**71**	**7**	**3**	**4**	**1**	**4**	**90**

7.5.4 Environment

Reservoirs held behind dams affect many ecological aspects of a river. River topography and dynamics depend on a wide range of flows, but rivers below dams often experience long periods of very stable flow conditions or saw-tooth flow patterns caused by releases followed by no releases. Water releases from dams usually contain very little suspended sediment; this can lead to scouring of river beds and banks.

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

7.6 VULNERABILITY

7.6.1 Population

Vulnerable populations are all populations downstream from dam failures that are incapable of escaping the area within the allowable time frame. This population includes the elderly and young who may be unable to get themselves out of the inundation area. The vulnerable population also includes those who would not have adequate warning from a television or radio emergency warning system. The potential for loss of life is also affected by the capacity and number of evacuation routes available to populations living in areas of potential inundation.

7.6.2 Property

Vulnerable properties are those closest to the dam inundation area. These properties would experience the largest, most destructive surge of water. Low-lying areas are also vulnerable since they are where the dam waters would collect. Transportation routes are vulnerable to dam inundation and have the potential to be wiped out, creating isolation issues. This includes all roads, railroads and bridges in the path of the dam inundation. Those that are most vulnerable are those that are already in poor condition and would not be able to withstand a large water surge. Utilities such as overhead power lines, cable and phone lines could also be vulnerable. Loss of these utilities could create additional isolation issues for the inundation areas.

Vulnerability numbers are provided for each mapped dam inundation area, as summarized in Table 7-7 through Table 7-9:

- The estimated loss from the Cle Elum dam failure scenario is $127 million. This represents 8.6 percent of the total exposure within the inundation area, or 1.5 percent of the total assessed value of the planning area.
- The estimated loss from the Easton Diversion dam failure scenario is $51 million. This represents 3.7 percent of the total exposure within the inundation area, or 0.6 percent of the total assessed value of the planning area.
- The estimated loss from the Keechelus and Kachess dam failure scenario is $133 million. This represents 9 percent of the total exposure within the inundation area, or 1.6 percent of the total assessed value of the planning area.

**TABLE 7-7.
LOSS ESTIMATES FOR CLE ELUM DAM FAILURE**

City	Estimated Loss Potential			% of
	Building Loss	Contents Loss	**Total Loss**	Total Assessed Value
Cle Elum	$20,453,000	$32,574,000	**$53,027,000**	8.4%
Ellensburg	$12,707,000	$24,719,000	**$37,426,000**	1.7%
Kittitas	0	0	**0**	0.0%
Roslyn	0	0	**0**	0.0%
South Cle Elum	$6,129,000	$5,108,000	**$11,237,000**	13.2%
Unincorporated	$12,719,000	$12,508,000	**$25,227,000**	0.5%
Total	**$52,008,000**	**$74,909,000**	**$126,917,000**	**1.5%**

**TABLE 7-8.
LOSS ESTIMATES FOR EASTON DIVERSION DAM FAILURE**

City	Estimated Loss Potential			% of
	Building Loss	Contents Loss	**Total Loss**	Total Assessed Value
Cle Elum	$7,435,000	$15,811,000	**$23,246,000**	3.7%
Ellensburg	0	0	**0**	0.0%
Kittitas	0	0	**0**	0.0%
Roslyn	0	0	**0**	0.0%
South Cle Elum	$2,398,000	$2,461,000	**$4,859,000**	5.7%
Unincorporated	$13,199,000	$9,939,000	**$23,138,000**	0.5%
Total	**$23,032,000**	**$28,211,000**	**$51,243,000**	**0.6%**

**TABLE 7-9.
LOSS ESTIMATES FOR KEECHELUS AND KACHESS DAM FAILURE**

City	Estimated Loss Potential			% of
	Building Loss	Contents Loss	**Total Loss**	Total Assessed Value
Cle Elum	$17,579,000	$29,834,000	**$47,413,000**	7.5%
Ellensburg	$5,575,000	$12,631,000	**$18,206,000**	0.8%
Kittitas	0	0	**0**	0.0%
Roslyn	0	0	**0**	0.0%
South Cle Elum	$6,122,000	$5,133,000	**$11,255,000**	13.2%
Unincorporated	$30,420,000	$25,474,000	**$55,894,000**	1.1%
Total	**$59,696,000**	**$73,072,000**	**$132,768,000**	**1.6%**

7.6.3 Critical Facilities

On average, critical facilities would receive 5 percent damage to the structure and 20 percent damage to the contents during a dam failure event. The estimated time to restore these facilities to 100 percent of their functionality is 490 days.

7.6.4 Environment

The environment would be vulnerable to a number of risks in the event of dam failure. The inundation could introduce foreign elements into local waterways, resulting in destruction of downstream habitat and detrimental effects on many species of animals, especially endangered species such as coho salmon. The extent of the vulnerability of the environment is the same as the exposure of the environment.

7.7 FUTURE TRENDS IN DEVELOPMENT

Land use in the planning area will be directed by comprehensive plans adopted under Washington's GMA. These comprehensive plans, in conjunction with "critical areas" regulations adopted by municipal planning partners, provide the regulatory and planning capability to address the risks associated with dam failures. Dam failure is currently not addressed as a standalone hazard under these programs, but flooding is. Municipal planning partners have established comprehensive policies regarding sound land use in identified flood hazard areas. Most of the areas vulnerable to severe impacts from dam failure intersect the mapped flood hazard areas. Flood-related policies in the comprehensive plans will help reduce the risk associated with the dam failure hazard for all future development in the planning area.

7.8 SCENARIO

An earthquake in the region could lead to liquefaction of soils around a dam. This could occur without warning during any time of the day. A human-caused failure such as a terrorist attack also could trigger a catastrophic failure of a dam that impacts the planning area. While the probability of dam failure is very low, the probability of flooding associated with changes to dam operational parameters in response to climate change is higher. Dam designs and operations are developed based on hydrographs with historical record. If these hydrographs experience significant changes over time due to the impacts of climate change, the design and operations may no longer be valid for the changed condition. This could have significant impacts on dams that provide flood control. Specified release rates and impound thresholds may have to be changed. This would result in increased discharges downstream of these facilities, thus increasing the probability and severity of flooding.

7.9 ISSUES

The most significant issue associated with dam failure involves the properties and populations in the inundation zones. Flooding as a result of a dam failure would significantly impact these areas. There is often limited warning time for dam failure. These events are frequently associated with other natural hazard events such as earthquakes, landslides or severe weather, which limits their predictability and compounds the hazard. Important issues associated with dam failure hazards include the following:

- Federally regulated dams have an adequate level of oversight and sophistication in the development of emergency action plans for public notification in the unlikely event of failure. However, the protocol for notification of downstream citizens of imminent failure needs to be tied to local emergency response planning.
- Mapping for federally regulated dams is already required and available; however, mapping for non-federal-regulated dams that estimates inundation depths is needed to better assess the risk associated with dam failure from these facilities.

- Most dam failure mapping required at federal levels requires determination of the probable maximum flood. While the probable maximum flood represents a worst-case scenario, it is generally the event with the lowest probability of occurrence. For non-federal-regulated dams, mapping of dam failure scenarios that are less extreme than the probable maximum flood but have a higher probability of occurrence can be valuable to emergency managers and community officials downstream of these facilities. This type of mapping can illustrate areas potentially impacted by more frequent events to support emergency response and preparedness.
- The concept of residual risk associated with structural flood control projects should be considered in the design of capital projects and the application of land use regulations.
- Addressing security concerns and the need to inform the public of the risk associated with dam failure is a challenge for public officials.

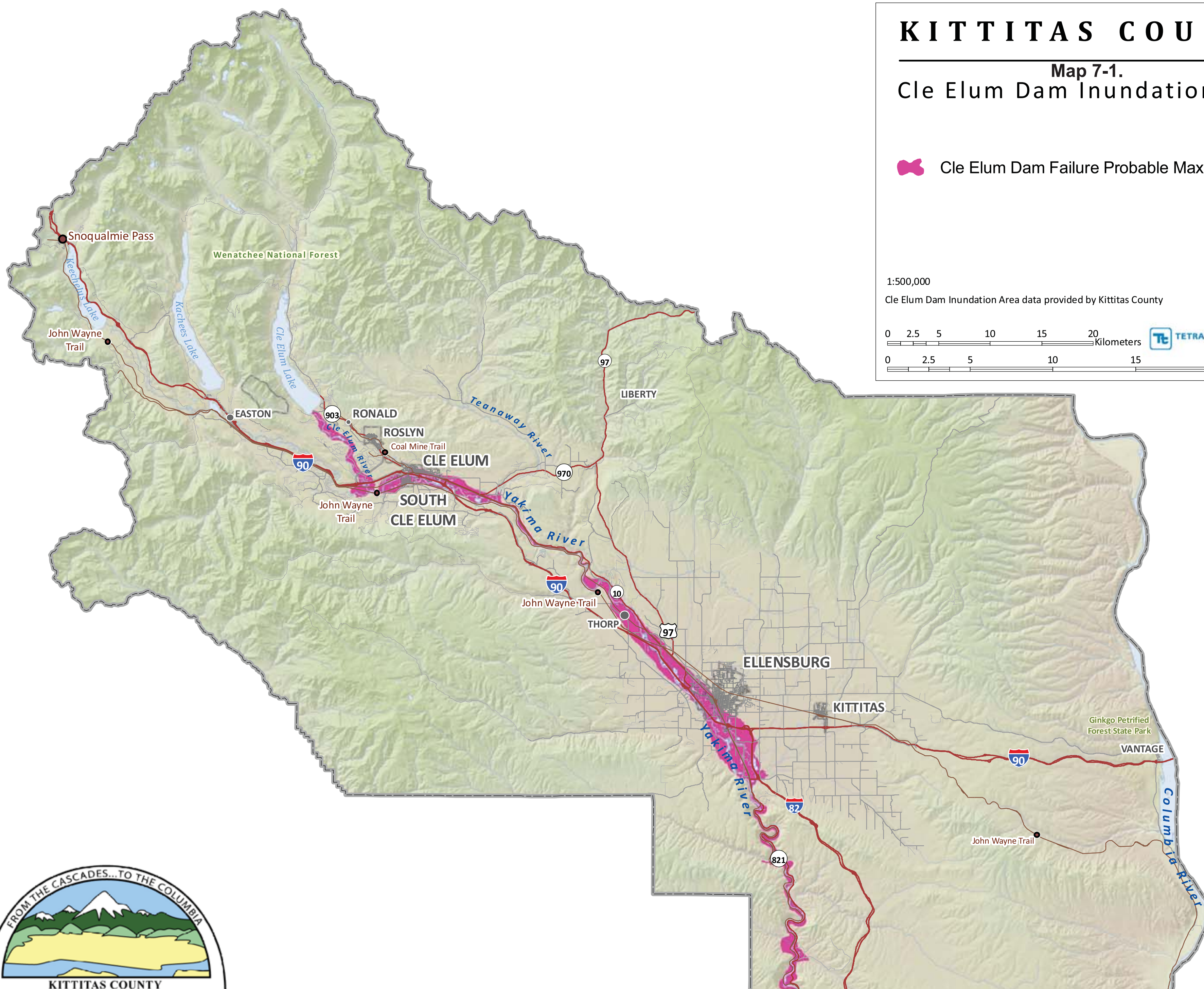
KITTITAS COUNTY

Map 7-1.
Cle Elum Dam Inundation Area

Cle Elum Dam Failure Probable Maximum Flood

1:500,000

Cle Elum Dam Inundation Area data provided by Kittitas County



KITTITAS COUNTY

Map 7-2.
Easton Diversion Dam
Inundation Area

Easton Diversion Dam Failure
Probable Maximum Flood

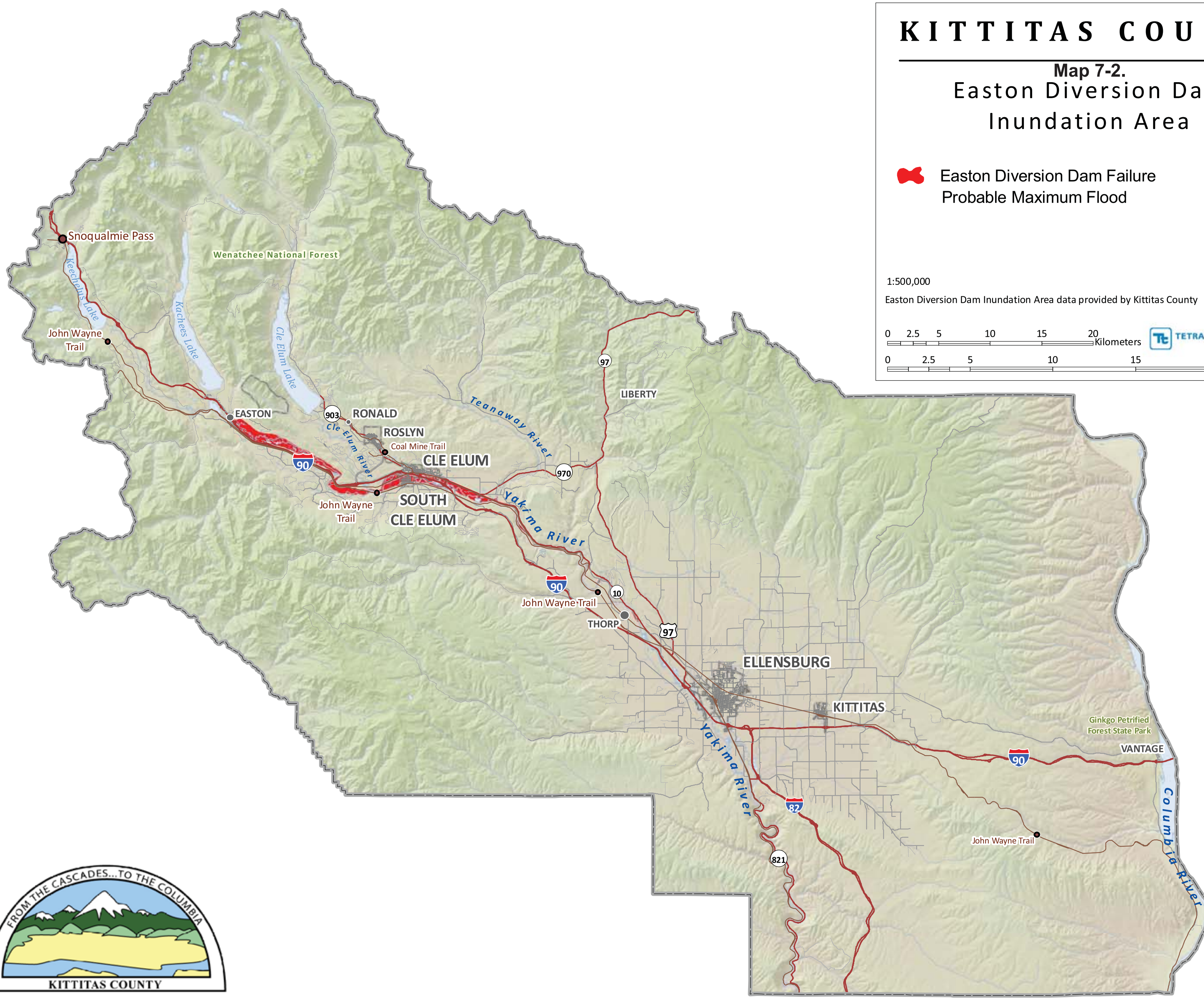
1:500,000

Easton Diversion Dam Inundation Area data provided by Kittitas County

0 2.5 5 10 15 20 Kilometers

0 2.5 5 10 15 20 Miles

TETRA TECH



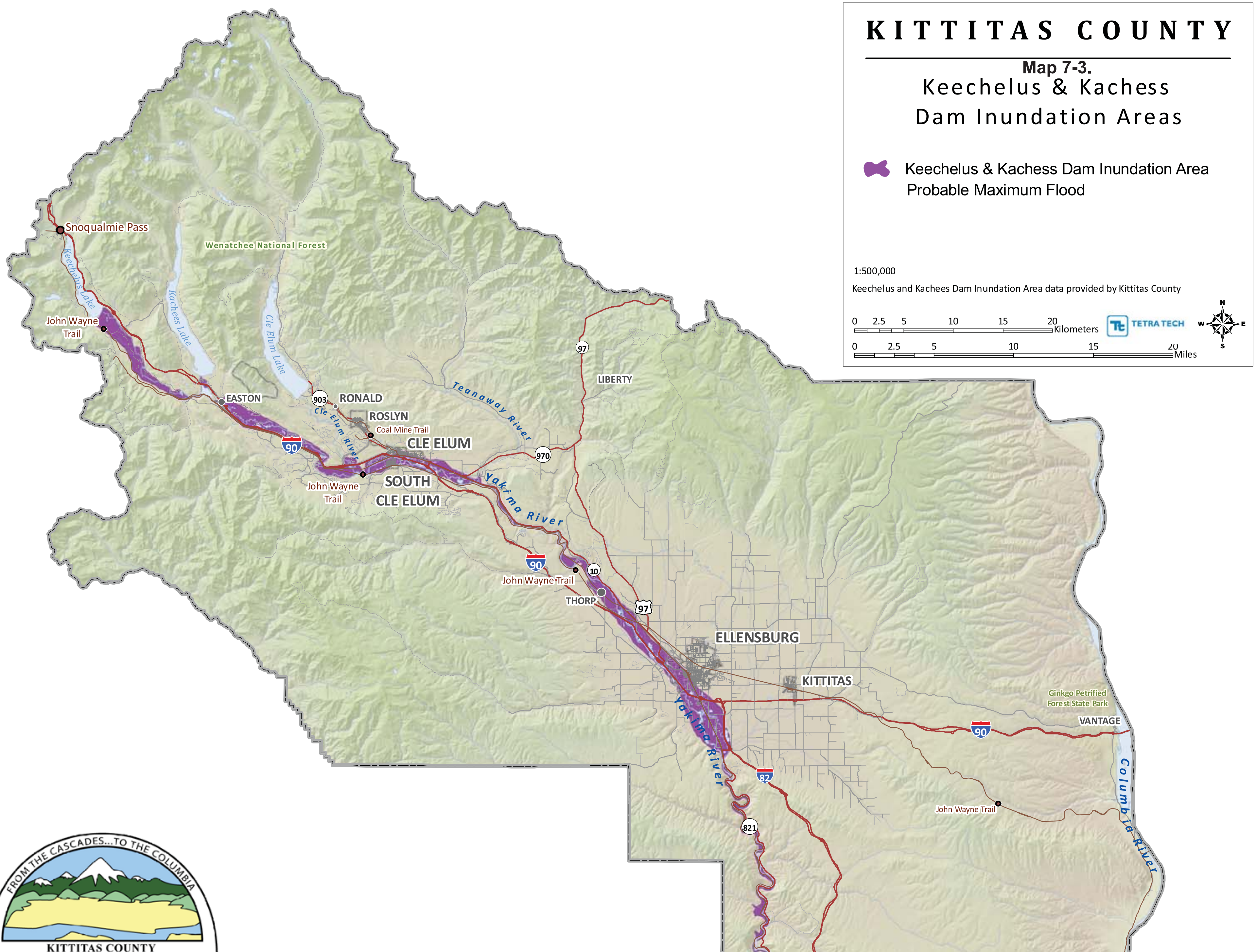
KITTITAS COUNTY

Map 7-3.
Keechelus & Kachess Dam Inundation Areas

Keechelus & Kachess Dam Inundation Area Probable Maximum Flood

1:500,000

Keechelus and Kachees Dam Inundation Area data provided by Kittitas County



CHAPTER 8.
DROUGHT

8.1 GENERAL BACKGROUND

> **DEFINITIONS**
>
> **Drought**—The cumulative impacts of several dry years on water users. It can include deficiencies in surface and subsurface water supplies and generally impacts 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 normal phase in the climatic cycle of most geographical regions. According to the National Drought Mitigation Center, drought originates from a deficiency of precipitation over an extended period of time, usually a season or more. This results in a water shortage for some activity, group or environmental sector. Drought is the result of a significant decrease in water supply relative to what is "normal" in a given location. There are four generally accepted "operational" definitions of drought (National Drought Mitigation Center, 2006):

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

It should be noted that water supply is controlled not only by precipitation, but also by other factors, including evaporation (which is increased by higher than normal heat and winds), transpiration (the use of water by plants), and human use.

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.
- Water supply—Drought threatens supplies of water for irrigated crops and for communities.

- 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. The droughts of 1977 and 2001, the worst and second worst in state history, provide good examples of how drought can affect the state. On average, the nationwide annual impacts of drought are greater than the impacts of any other natural hazard. They are estimated to be between $6 billion and $8 billion annually in the United States and 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.

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 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 could pay more for water if utilities increase their rates.

8.2 HAZARD PROFILE

Droughts originate from a deficiency of precipitation resulting from an unusual weather pattern. If the weather pattern lasts a short time (a few weeks or a couple 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.

8.2.1 Past Events

Droughts recur every few years. Unlike floods and earthquakes, droughts not easily defined as "events." Over the last 30 years there have been at least three defined major droughts affecting the state and Kittitas County: in 1977, 2001 and 2005. According to the 2010 Washington State Enhanced Hazard Mitigation Plan, Kittitas County has experienced serious or extreme drought conditions 10 to 15 percent of the time from 1895 to 1995. The total social and economic impacts of these events on the Kittitas County planning area are not known at this time.

8.2.2 Location

The National Oceanic and Atmospheric Administration (NOAA) has developed several indices to measure drought impacts and severity and 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 8-1 shows this index for March 2011.
- The ***Palmer Drought Index (PDI)*** measures the duration and intensity of long-term drought-inducing circulation patterns. Long-term drought is cumulative, so the intensity of drought during a given month is dependent on the current weather patterns plus the cumulative patterns of previous months. Weather patterns can change quickly from a long-term drought pattern to a long-term wet pattern, and the PDI can respond fairly rapidly. Figure 8-2 shows this index for March 2011.
- 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 (PHDI)***, another long-term index, was developed to quantify hydrological effects. The PHDI responds more slowly to changing conditions than the PDI. Figure 8-3 shows this index for March 2011.
- While the Palmer indices consider precipitation, evapotranspiration and runoff, the ***Standardized Precipitation Index (SPI)*** considers only precipitation. In the SPI, an index of zero indicates the median precipitation amount; the index is negative for drought and positive for wet conditions. The SPI is computed for time scales ranging from one month to 24 months. Figure 8-4 shows the 24-month SPI map for April 2009 through March 2011.

8.2.3 Frequency

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. 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 depends on interactions between the atmosphere and the oceans, soil moisture and land surface processes, topography, internal dynamics, and the accumulated influence of weather systems on the global scale. 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.

Based on Washington's history with drought from 1895 to 1995, the state as a whole can expect severe or extreme drought at least 5 percent of the time. All of Eastern Washington, except for the Cascade Mountain's eastern foothills, can expect severe or extreme drought 10 to 15 percent of the time. The east slopes of the Cascades can expect severe or extreme drought from 5 to 10 percent of the time.

The Washington State Hazard Mitigation Plan determined that from 1895 to 1995, Kittitas County experienced serious or extreme drought at least 10 to 15 percent of the time. Thus it can be predicted that Kittitas County may experience the effects of drought at least once every decade. This may be changing, however. For the period from 1985 to 1995, Kittitas County experienced the effects of drought at least 30 percent of the time, and during the 1977 drought, the county experienced its effect 30 to 40 percent of the time. There are no data available regarding of how much effect the 2001 drought had on the county.

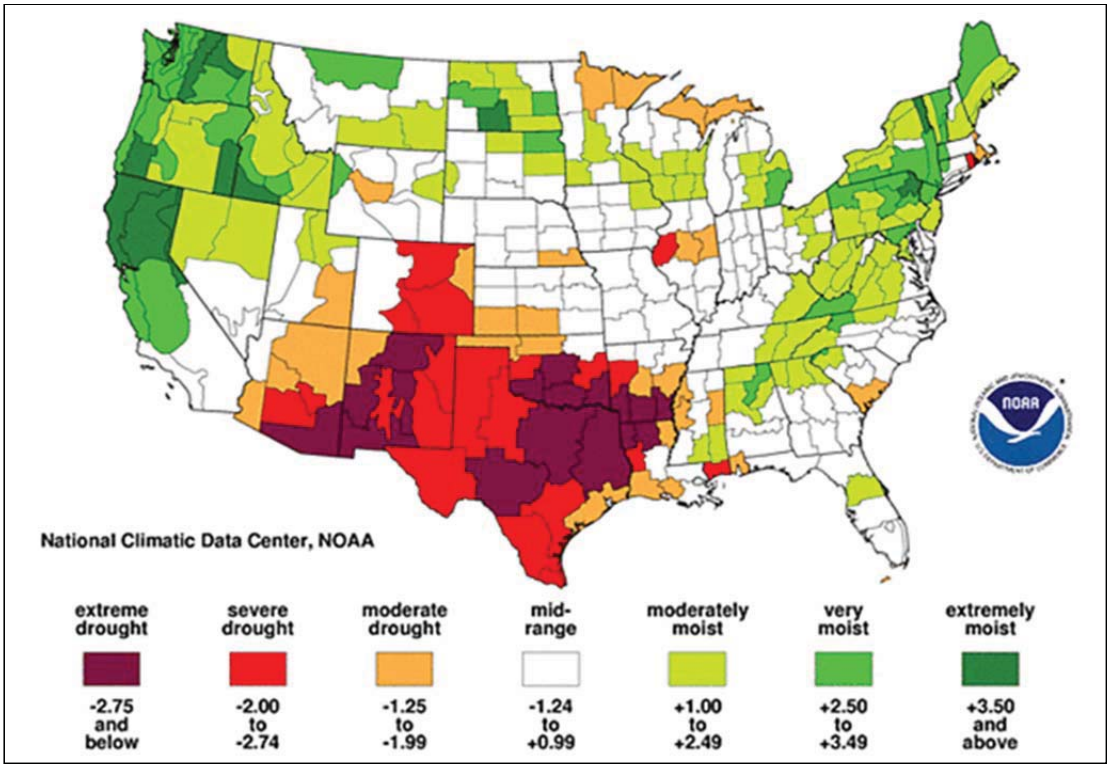


Figure 8-1. Palmer Z Index Short-Term Drought Conditions (March 2011)

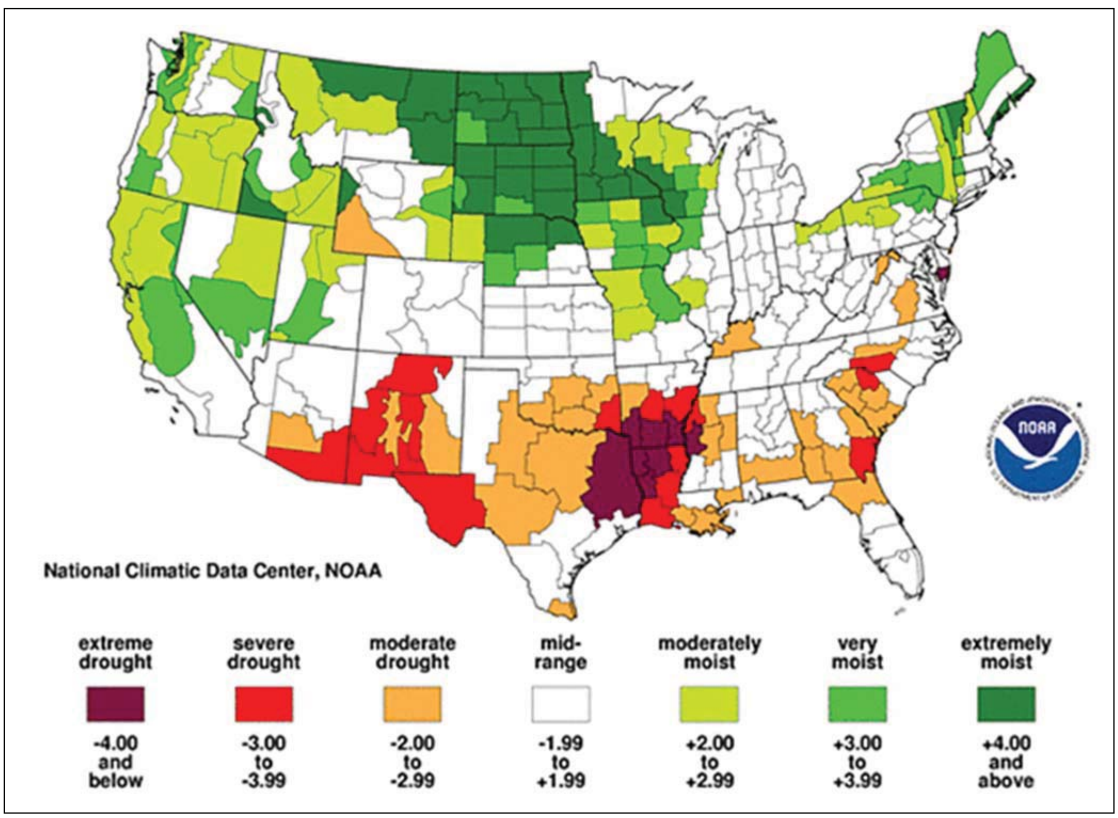


Figure 8-2. Palmer Drought Index Long-Term Drought Conditions (March 2011)

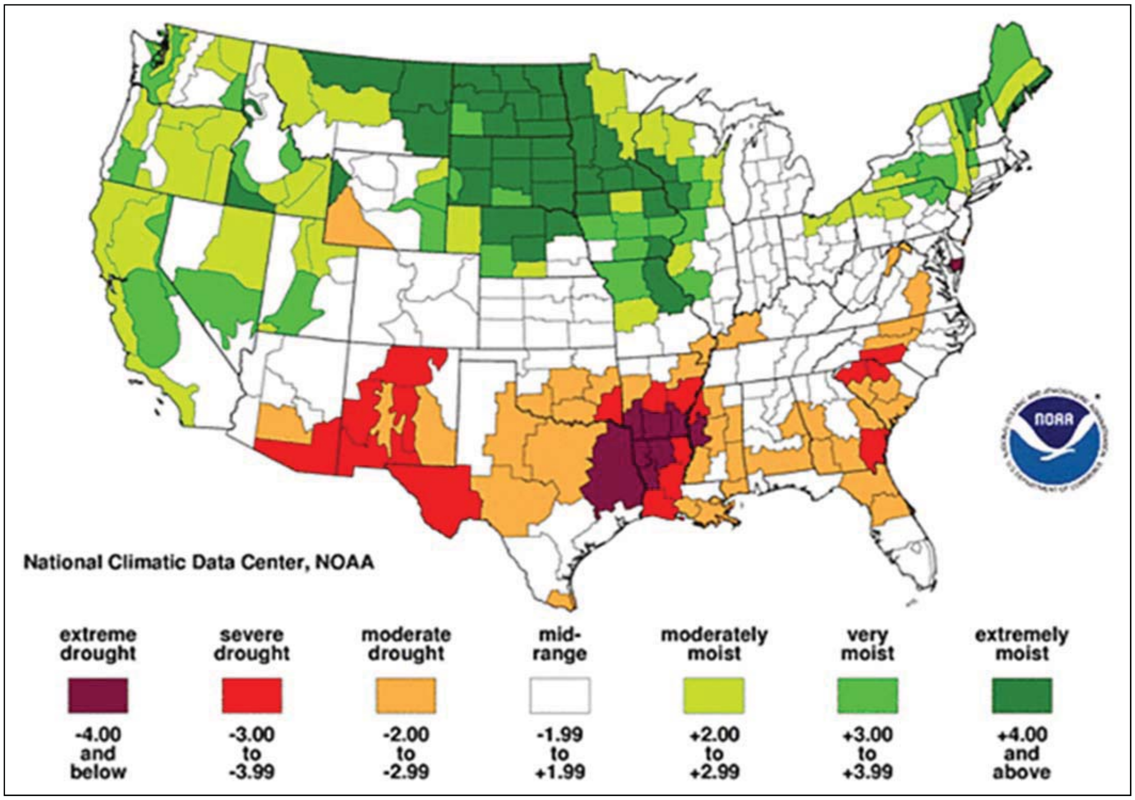


Figure 8-3. Palmer Hydrological Drought Index Long-Term Hydrologic Conditions (March 2011)

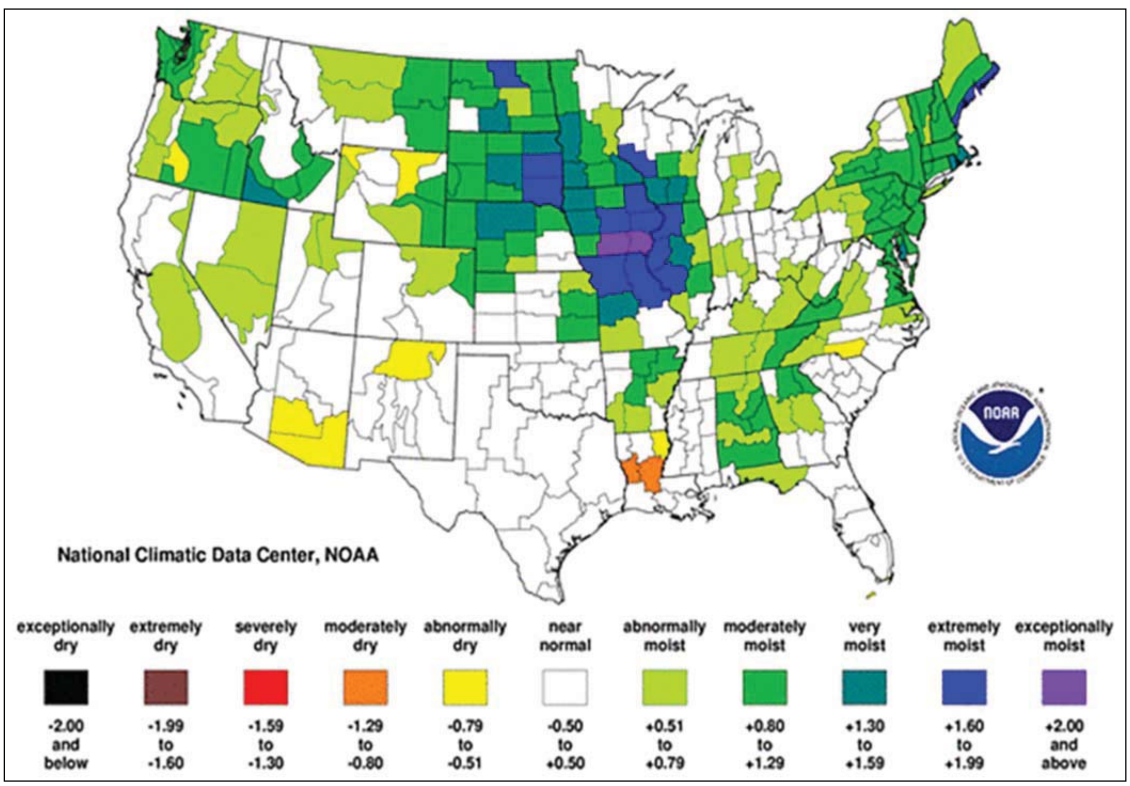


Figure 8-4. 24-Month Standardized Precipitation Index (April 2009—March 2011)

8.2.4 Severity

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, which can impact people indirectly. When measuring the severity of droughts, analysts typically look at economic impacts on a planning area.

8.2.5 Warning Time

Droughts are climatic patterns that occur over long periods of time. Only generalized warning can take place due to the numerous variables that scientists have not pieced together well enough to make accurate and precise predictions.

8.3 SECONDARY HAZARDS

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

8.4 CLIMATE CHANGE IMPACTS

Research conducted by the Climate Impacts Group at the University of Washington indicates that the temperature of Eastern Washington is increasing. As temperatures increase there will be less water stored as ice and snow. This reduction may not result in a net change in annual precipitation, but it will result in lower late spring and summer river flows. Accordingly there will be increased competition between power, sport fishing and environmentalists, and farmers dependent on irritation.

The long-term effects of climate change on regional water resources are unknown, but global water resources are already experiencing the following stresses without climate change:

- Growing populations
- Increased competition for available water
- Poor water quality
- Environmental claims
- Uncertain reserved water rights
- Groundwater overdraft
- Aging urban water infrastructure.

With a warmer climate, droughts could become more frequent, more severe, and longer-lasting. From 1987 to 1989, losses from drought in the U.S. totaled $39 billion (OTA, 1993). More frequent extreme events such as droughts could end up being more cause for concern than the long-term change in temperature and precipitation averages.

The best advice to water resource managers regarding climate change is to start addressing current stresses on water supplies and build flexibility and robustness into any system. Flexibility helps to ensure a quick response to changing conditions, and robustness helps people prepare for and survive the worst conditions. With this approach to planning, water system managers will be better able to adapt to the impacts of climate change.

8.5 EXPOSURE

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

8.6 VULNERABILITY

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

The Washington State Hazard Mitigation plan defines counties as being vulnerable to drought if they meet at least five of the following criteria:

- History of severe or extreme drought conditions:
    1. The county must have been in serious or extreme drought at least 10-15 percent of the time from 1895 to 1995.
- Demand on water resources based on:
    2. Acreage of irrigated cropland. The acreage of the county's irrigated cropland must be in top 20 in the state.
    3. Percentage of harvested cropland that is irrigated. The percentage of the county's harvested cropland that is irrigated must be in top 20 in the state.
    4. Value of agricultural products. The value of the county's crops must be in the top 20 in the state.
    5. Population growth greater than the state average. The county's population growth from 2000 to 2006 must be greater than state average of 8.17 percent.
- A County's inability to endure the economic conditions of a drought, based on:
    6. The county's median household income being less than 75 percent of the state median income of $51,749 in 2005.
    7. The county being classified as economically distressed in 2005 because its unemployment rate was 20 percent greater than the state average from January 2002 through December 2004.

As summarized in Table 8-1, Kittitas County is among nine counties in the state that meet at least five of the criteria and are considered to be vulnerable to drought.

8.6.1 Population

The planning partnership has the ability to minimize any impacts on residents and water consumers in the county should several consecutive dry years occur. No significant life or health impacts are anticipated as a result of drought within the planning area.

**TABLE 8-1.
KITTITAS COUNTY VULNERABILITY TO DROUGHT**

Criterion	Value for Kittitas County	Meets Drought Vulnerability Criterion?
Percent of Time in Serious or Extreme Drought, 1895 – 1995	10 – 15	Yes
Irrigated Cropland (acres) Statewide Ranking for Irrigated Cropland Area	91,944 7	Yes
Percent of Harvested Cropland That Is Irrigated Statewide Ranking for Irrigated Cropland Percentage	137.8% 1	Yes
Market Value of Crops Statewide Ranking for Market Value of Crops	$38,432,000 18	Yes
Population Growth, 2000 – 2006	12.1%	Yes
Median Household Income	$34,669	Yes
Unemployment Rate 20% Greater Than State Average	No	No

8.6.2 Property

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

8.6.3 Critical Facilities

Critical facilities as defined for this plan will continue to be operational during a drought. 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.

8.6.4 Environment

Environmental losses from drought are associated with damage to plants, animals, wildlife habitat, and air and water quality; forest and range fires; degradation of landscape quality; loss of biodiversity; and soil erosion. Some of the effects are short-term and conditions quickly return to normal following the end of the drought. Other environmental effects linger for some time or may even become permanent. Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes and vegetation. However, many species will eventually recover from this temporary aberration. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological productivity. Although environmental losses are difficult to quantify, growing public awareness and concern for environmental quality has forced public officials to focus greater attention and resources on these effects.

8.6.5 Economic Impact

Economic impact will be largely associated with industries that use water or depend on water for their business. For example, landscaping businesses were affected in the droughts of the past as the demand for service significantly declined because landscaping was not watered. Agricultural industries will be impacted if water usage is restricted for irrigation.

8.7 FUTURE TRENDS IN DEVELOPMENT

Each municipal planning partner in this effort has an established comprehensive plan that includes policies directing land use and dealing with issues of water supply and the protection of water resources. 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.

8.8 SCENARIO

An extreme multiyear drought more intense than the 1977 drought could impact the region with little warning. Combinations of low precipitation and unusually high temperatures could occur over several consecutive years. Intensified by such conditions, extreme wildfires could break out throughout Kittitas County, increasing the need for water. Surrounding communities, also in drought conditions, could increase their demand for water supplies relied upon by the planning partnership, causing social and political conflicts. If such conditions persisted for several years, the economy of Kittitas County could experience setbacks, especially in water dependent industries.

8.9 ISSUES

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

- Identification and development of alternative water supplies
- Utilization of groundwater recharge techniques 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.

CHAPTER 9.
EARTHQUAKE

9.1 GENERAL BACKGROUND

9.1.1 How Earthquakes Happen

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

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

Earthquakes in the Pacific Northwest have been studied extensively. 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 9-1. More than 90 percent of Pacific Northwest earthquakes occur along the boundary between the Juan de Fuca plate and the North American plate.

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. Although there are probably still some unrecognized active faults, nearly all the movement between the two plates, and therefore the majority of the seismic hazards, are on the well-known active faults.

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.

Seiche—A standing wave in an enclosed or partly enclosed body of water and normally caused by earthquake activity and can affect harbors, bays, lakes, rivers and canals. These events usually don't occur in proximity to the epicenter of a quake, but possibly hundreds of miles away due to the fact that the shock waves a distance away is of a lower frequency.

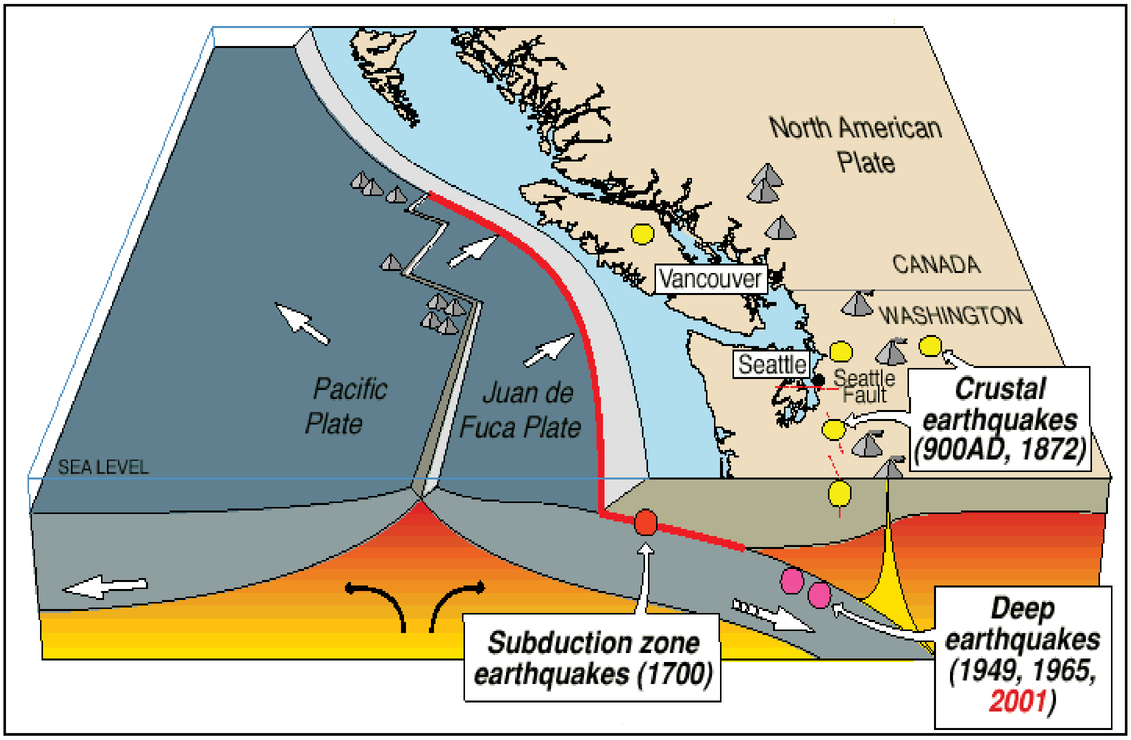


Figure 9-1. Earthquake Types in the Pacific Northwest

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

9.1.2 Earthquake Classifications

Earthquakes are typically classified in one of two ways: By the amount of energy released, measured as **magnitude**; or by the impact on people and structures, measured as **intensity**.

Magnitude

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

Currently the most commonly used intensity scale is the modified Mercalli intensity scale, with ratings defined as follows (USGS, 1989):

- 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.
- 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.
- XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

9.1.3 Ground Motion

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

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

TABLE 9-1.
MERCALLI SCALE AND PEAK GROUND ACCELERATION COMPARISON

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

a. PGA measured in percent of g, where g is the acceleration of gravity
Sources: USGS, 2008; USGS, 2010

9.1.4 Effect of Soil Types

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

9.2 HAZARD PROFILE

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.

TABLE 9-2.
NEHRP SOIL CLASSIFICATION SYSTEM

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

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.

9.2.1 Past Events

Table 9-3 lists past seismic events that have impacted the planning area with a magnitude of 3.0 or greater since 1971.

9.2.2 Location

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

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

Mapping that shows the impacts of these components was used to assess the risk of earthquakes within the planning area. 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. 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.

**TABLE 9-3.
HISTORICAL EARTHQUAKES IMPACTING THE PLANNING AREA**

	Location			
Date	Latitude	Longitude	Depth (km)	Magnitude
08/18/1971	47.6488	-120.1457	13.23	3.20
06/15/1976	47.6247	-120.3268	0.75	3.0
07/13/1977	47.0902	-120.9840	3.26	3.90
06/27/1978	46.8767	-120.9717	12.38	3.60
04/07/1979	46.9785	-120.4512	16.89	3.00
02/18/1981	47.1973	-120.8925	3.37	4.20
09/26/1982	46.8673	-121.0477	3.25	3.40
12/05/1983	46.9148	-120.7130	7.76	3.80
04/11/1984	47.5350	-120.1855	8.02	4.30
08/24/1984	47.6495	-120.9548	0.75	3.00
01/05/1985	47.0638	-120.0942	0.34	3.30
01/31/1985	47.0595	-120.0838	0.29	3.30
04/19/1985	46.8972	-120.2837	5.35	3.20
06/17/1985	47.0580	-120.0770	0.28	3.00
10/01/1985	46.7963	-120.0478	1.09	3.0
10/01/1985	46.7887	-120.0473	1.71	3.00
06/11/1987	46.7775	-120.6940	17.23	3.00
07/30/1988	47.6497	-120.0742	0.02	3.20
12/15/1990	46.8022	-119.9925	3.14	3.10
12/22/1990	46.7990	-119.9923	3.31	3.40
02/01/1991	46.8133	-120.5578	6.55	3.40
02/22/1991	46.8708	-120.6518	13.26	3.20
07/06/1991	46.9367	-120.3385	4.08	3.40
07/07/1991	46.9300	-120.3380	3.84	3.30
11/24/1991	47.6042	-120.2410	7.18	3.20
10/26/1992	46.8402	-120.7118	0.04	3.50
06/18/1994	47.6212	-121.2697	0.04	4.30
03/09/1995	47.1907	-1209552	1.61	3.00
06/30/1995	47.1065	-120.5275	11.23	3.00
12/17/1995	47.5950	-120.2192	12.42	3.10
01/01/1997	46.7768	120.4545	19.03	3.70
12/25/1999	47.6333	-120.2015	6.91	3.00
07/25/2006	47.638	-120.2070	6.71	3.10

Source: Advanced National Seismic System, 2012.

Ground motion and intensity maps are derived from peak ground motion amplitudes recorded on seismic sensors (accelerometers), with interpolation based on estimated amplitudes where data are lacking, and site amplification corrections. Color-coded instrumental intensity maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity. Two types of shake map are typically generated from the data:

- A probabilistic seismic hazard map shows the hazard from earthquakes that geologists and seismologists agree could occur. The maps are expressed in terms of probability of exceeding a certain PGA, 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. Map 9-1 shows the estimated ground motion for the 100-year probabilistic earthquake in Kittitas County.
- Earthquake scenario maps describe the expected ground motions and effects of hypothetical large earthquakes for a region. Two scenarios were chosen for this plan:
  - Cle Elum Fault Scenario—A Magnitude 6.8 event with a shallow depth and epicenter located 13 miles southwest of Ellensburg (see Map 9-2)
  - Saddle Mountain Fault Scenario—A Magnitude 7.3 event with an epicenter 23 miles southeast of Ellensburg (see Map 9-3).

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. Map 9-4 shows NEHRP soil classifications in the county.

Liquefaction Maps

Soil liquefaction maps are useful tools to assess potential damage from earthquakes. When the ground liquefies, sandy or silty materials saturated with water behave like a liquid, causing pipes to leak, roads and airport runways to buckle, and building foundations to be damaged. In general, areas with NEHRP Soils D, E and F are also susceptible to liquefaction. If there is a dry soil crust, excess water will sometimes come to the surface through cracks in the confining layer, bringing liquefied sand with it, creating sand boils. Map 9-5 shows the liquefaction susceptibility in Kittitas County.

9.2.3 Frequency

Because of its location at the boundary of two major tectonic plates, Washington State is particularly vulnerable to earthquakes. FEMA has determined that Washington State ranks second (behind only California) among states most susceptible to damaging earthquakes. According to the Washington State Enhanced Hazard Mitigation Plan, the probability of future occurrence for earthquakes similar to the 1965 Magnitude 6.5 Seattle-Tacoma event and the 2001 Magnitude 6.8 Nisqually event is about once every 35 years. The USGS has estimated that there is an 84-percent chance of a Magnitude 6.5 or greater deep earthquake over the next 50 years.

The USGS database shows that there is a 30.7-percent chance of a major earthquake within 50 kilometers of Kittitas within the next 50 years. The largest earthquake within 100 miles of Kittitas was a Magnitude 5.5 event in 1996. Earthquake probabilities for different magnitude events within 50 kilometers of the planning area over the next 50 years are shown in Table 9-4

**TABLE 9-4.
EARTHQUAKE PROBABILITIES WITHIN 50 YEARS**

Earthquake Magnitude	Probability of Occurrence within 50 Km of Kittitas within 50 Years
5.0	30.67%
5.5	13.88%
6.0	6.11%
6.5	2.17%
7.0	0.14%
7.5	0.01%

9.2.4 Severity

The severity of an earthquake can be expressed in terms of intensity or magnitude. Intensity represents the observed effects of ground shaking on people, buildings and natural features. Magnitude is related to the amount of seismic energy released at the hypocenter of an earthquake. It is determined by the amplitude of the earthquake waves recorded on instruments. Whereas intensity varies depending on location with respect to the earthquake epicenter, magnitude is represented by a single, instrumentally determined value for each earthquake event. The severity of an earthquake event can be measured in the following terms:

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

The severity of a seismic event is directly correlated to the stability of the ground close to the event's epicenter. The difference in severity between intensity ranges can be immense. A poorly built structure on a stable site is far more likely to survive a large earthquake than a well-built structure on an unstable site. Thorough geotechnical site evaluations should be the rule of thumb for new construction in the planning area until creditable soils mapping becomes available.

The USGS has created ground motion maps based on current information about several fault zones. These maps show the PGA that has a certain probability (2 percent or 10 percent) of being exceeded in a 50-year period. Figure 9-2 shows the PGAs with a 10-percent exceedance chance in 50 years in Washington. South-central Washington is a medium- to high-risk area.

9.2.5 Warning Time

There is currently no reliable way to predict the day or month that an earthquake will occur at any given location. Research is being done with 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.

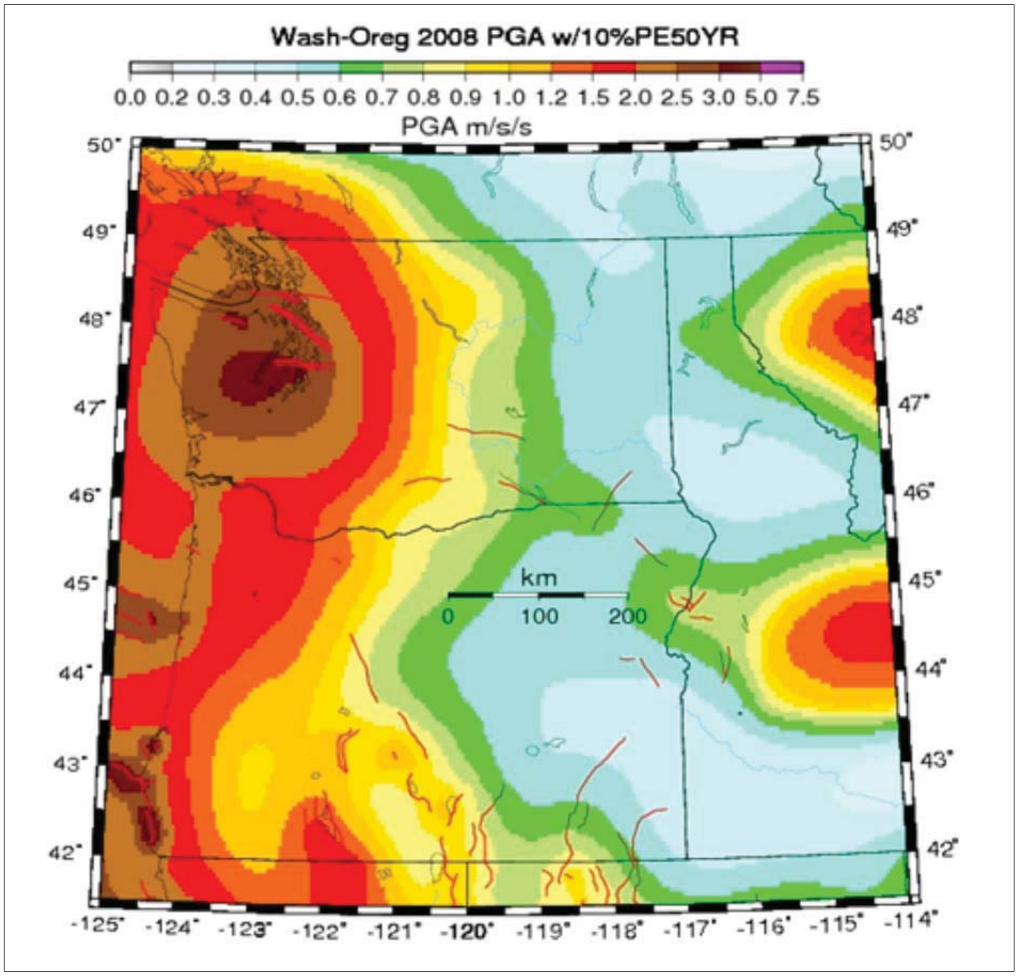


Figure 9-2. PGA with 2-Percent Probability of Exceedance in 50 Years, Northwest Region

9.3 SECONDARY HAZARDS

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

9.3.1 Seiche

A seiche is a standing wave in an enclosed or partly enclosed body of water, normally caused by earthquake activity, though also possibly caused by other factors such as wind. The effect is caused by resonances in a body of water that has been disturbed. Vertical harmonic motion results, producing an impulse that travels the length of the basin at a velocity that depends on the depth of the water. The impulse is reflected back from the end of the basin, generating interference. Repeated reflections produce standing waves with one or more nodes, or points, that experience no vertical motion.

The waves in a seiche are stationary in the horizontal plane; they move up and down, but not forward like wind waves at sea. That is why these waves are called standing waves. The frequency of the oscillation is determined by the size of the basin, its depth and contours, and the water temperature.

Seiches can occur in harbors, bays, lakes, rivers and canals. They are often imperceptible to the naked eye, and observers in boats on the surface may not notice that a seiche is occurring due to the extremely long wavelengths. These events usually do not occur near the epicenter of a quake, but often hundreds of miles away. This is due to the fact that earthquake shock waves close to the epicenter consist of high-frequency vibrations, while those at much greater distances are of lower frequency, which can enhance the rhythmic movement in a body of water. The biggest seiches develop when the period of the ground shaking matches the frequency of oscillation of the water body.

With three large reservoirs and a risk of seismic events, there is potential for seiches to occur in Kittitas County. The degree of vulnerability to this secondary hazard is difficult to gage without hazard mapping that illustrates extent, location and potential severity of probabilistic events.

9.4 CLIMATE CHANGE IMPACTS

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

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could experience liquefaction 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.

9.5 EXPOSURE

9.5.1 Population

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

9.5.2 Property

The Kittitas County Assessor estimates that there are 18,573 buildings in Kittitas County, with a total assessed value of $8.32 billion. Since all structures in the planning area are susceptible to earthquake impacts to varying degrees, this total represents the countywide property exposure to seismic events. Most of the buildings (90 percent) are residential.

9.5.3 Critical Facilities and Infrastructure

All critical facilities in Kittitas County are exposed to the earthquake hazard. Table 5-3 and Table 5-4 list the number of each type of facility by jurisdiction. 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 neighborhoods 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.

9.5.4 Environment

Secondary hazards associated with earthquakes will likely have some of the most damaging effects on the environment. Earthquake-induced landslides can significantly impact surrounding habitat. It is also possible for streams to be rerouted after an earthquake. This can change the 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.

9.6 VULNERABILITY

Earthquake vulnerability data was generated using a Level 2 HAZUS-MH analysis. Once the location and size of a hypothetical earthquake are identified, HAZUS-MH estimates the intensity of the ground shaking, the number of buildings damaged, the number of casualties, the damage to transportation systems and utilities, the number of people displaced from their homes, and the estimated cost of repair and clean up.

9.6.1 Population

Two population groups are particularly vulnerable to earthquake hazards:

- **Population Below Poverty Level**—Approximately 1,300 households in the planning area census blocks on NEHRP D and E soils are listed as being below the poverty level. This is about 16 percent of all households in these census blocks. These households may lack the financial resources to improve their homes to prevent or mitigate earthquake damage. Poorer residents are also less likely to have insurance to compensate for losses in earthquakes.
- **Population Over 65 Years Old**—Approximately 1,000 residents in the planning area census blocks on NEHRP D and E soils are over 65 years old. This is about 5 percent of all residents in these census blocks. This population group is vulnerable because they are more likely to need special medical attention, which may not be available due to isolation caused by earthquakes. Elderly residents also have more difficulty leaving their homes during earthquake events and could be stranded in dangerous situations.

Impacts on persons and households in the planning area were estimated for the 100-year earthquake and the two scenario events through the Level 2 HAZUS-MH analysis. Table 9-5 summarizes the results.

9.6.2 Property

Building Age

Table 9-6 identifies significant milestones in building and seismic code requirements that directly affect the structural integrity of development. The planning team used HAZUS to identify the number of structures within the county by date of construction and group them according to these time periods.

**TABLE 9-5.
ESTIMATED EARTHQUAKE IMPACT ON PERSON AND HOUSEHOLDS**

	Number of Displaced Households	Number of Persons Requiring Short-Term Shelter
100-Year Earthquake	12	10
Cle Elum Fault Earthquake Scenario	68	53
Saddle Mountain Fault Earthquake Scenario	47	39

**TABLE 9-6.
AGE OF STRUCTURES IN KITTITAS COUNTY**

Time Period	Number of Current County Structures Built in Period	Significance of Time Frame
Pre-1933	3,416	Before 1933, there were no explicit earthquake requirements in building codes.
1933-1940	632	In 1940, the first strong motion recording was made.
1941-1960	1,376	In 1960, the Structural Engineers Association of California published guidelines for earthquake provisions.
1961-1975	2,294	In 1975, significant improvements were made to lateral force requirements.
1976-1994	4,161	In 1994, the Uniform Building Code was amended to include provisions for seismic safety.
1994—present	6,694	Seismic code is currently enforced.
Total	**18,573**	

The number of structures does not reflect the number of total housing units, as many multi-family units and attached housing units are reported as one structure. Approximately 36 percent of the planning area's structures were constructed after the Uniform Building Code was amended in 1994 to include seismic safety provisions. Approximately 18.4 percent were built before 1933 when there were no building permits, inspections, or seismic standards.

Loss Estimates

Property losses were estimated through the Level 2 HAZUS-MH analysis for the 100-year earthquake and the two scenario events. Table 9-7 and Table 9-8 show the results for two types of property loss:

- Structural loss, representing damage to building structures
- Non-structural loss, representing the value of lost contents and inventory, relocation, income loss, rental loss, and wage loss.

TABLE 9-7.
EARTHQUAKE BUILDING LOSS POTENTIAL—100-YEAR PROBABILISTIC EARTHQUAKE

	Estimated Earthquake Loss Potential		
Jurisdiction	Structural	Non-Structural	**Total**
Ellensburg Area	$6,929,350	$2,563,687	**$9,493,037**
Upper County	$2,462,045	$698,590	**$3,160,635**
Lower County	$298,066	$40,422	**$338,488**
Total	**$9,689,461**	**$3,302,699**	**$12,992,159**

TABLE 9-8.
EARTHQUAKE BUILDING LOSS POTENTIAL—SCENARIO EVENTS

	Estimated Earthquake Loss Potential					
	6.8 M Cle Elum Fault			7.2 M Saddle Mountain Fault		
Jurisdiction	Structural	Non-Structural	**Total**	Structural	Non-Structural	**Total**
Ellensburg Area	$25,111,715	$11,166,975	**$36,278,690**	$19,072,753	$8,676,267	**$27,749,020**
Upper County	$74,579,203	$33,027,604	**$107,606,807**	$856,727	$601,244	**$1,457,971**
Lower County	$1,050,135	$517,031	**$1,567,166**	$46,896,496	$16,441,866	**$63,338,362**
Total	**$100,741,053**	**$44,711,610**	**$145,452,663**	**$66,825,976**	**$25,719,377**	**$92,545,353**

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

- For a 100-year probabilistic earthquake, the estimated damage potential is $13.0 million, or 0.16 percent of the total assessed value for the planning area.
- For a 6.8-magnitude event on the Cle Elum Fault, the estimated damage potential is $145.4 million, or 1.8 percent of the total assessed value for the planning area.
- For a 7.2-magnitude event on the Saddle Mountain Fault, the estimated damage potential is $92.5 million, or 1.1 percent of the total assessed value for the planning area.

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

TABLE 9-9.
ESTIMATED EARTHQUAKE-CAUSED DEBRIS

	Debris to Be Removed (tons)
100-Year Earthquake	4.16
Cle Elum Fault Earthquake Scenario	32.8
Saddle Mountain Fault Earthquake Scenario	31

9.6.3 Critical Facilities and Infrastructure

Level of Damage

HAZUS-MH classifies the vulnerability of critical facilities to earthquake damage in five categories: no damage, slight damage, moderate damage, extensive damage, or complete damage. The model was used to assign a vulnerability category to each critical facility in the planning area except hazmat facilities and "other infrastructure" facilities, for which there are no established damage functions. The analysis was performed for the 100-year event and the Cle Elum Fault scenario, which have, respectively, the highest probability of occurrence and the largest potential impact on the planning area. Table 9-10 and Table 9-11 summarize the results.

TABLE 9-10.
CRITICAL FACILITY VULNERABILITY TO 100-YEAR EARTHQUAKE EVENT

Category	No Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage
Medical and Health	37.1%	54.2%	6.6%	1.8%	0.4%
Government Functions	30.1%	56.4%	9.7%	3.0%	0.7%
Protective Functions	23.7%	59.2%	12.2%	4.0%	0.9%
Schools	25.5%	57.1%	12.4%	4.0%	1.0%
Other Critical Functions	55.9%	42.0%	1.9%	0.2%	0.0%
Bridges	98.3%	1.0%	0.4%	0.2%	0.1%
Water supply	83.0%	14.0%	2.8%	0.2%	0.0%
Wastewater	74.7%	20.2%	4.6%	0.3%	0.0%
Power	81.7%	15.9%	2.3%	0.1%	0.0%
Communications	90.3%	8.2%	1.4%	0.1%	0.0%
Total	**60.0%**	**32.8%**	**5.4%**	**1.4%**	**0.3%**

TABLE 9-11.
CRITICAL FACILITY VULNERABILITY TO CLE ELUM FAULT SCENARIO

Category[a]	No Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage
Medical and Health	2.2%	46.1%	29.0%	16.2%	6.4%
Government Functions	3.8%	47.0%	27.8%	15.3%	6.1%
Protective Functions	7.1%	50.8%	24.4%	12.7%	5.0%
Schools	3.4%	50.6%	26.8%	13.8%	5.3%
Other Critical Functions	20.6%	64.4%	11.4%	3.0%	0.6%
Bridges	88.8%	2.9%	3.9%	3.1%	1.2%
Water supply	38.6%	37.7%	19.7%	3.5%	0.5%
Wastewater	41.2%	37.6%	18.0%	2.7%	0.4%
Power	56.9%	31.9%	9.3%	1.6%	0.3%
Communications	36.4%	40.0%	20.2%	3.1%	0.4%
Total	**29.9%**	**40.9%**	**19.1%**	**7.5%**	**2.6%**

Time to Return to Functionality

HAZUS-MH estimates the time to restore critical facilities to fully functional use. Results are presented as probability of being functional at specified time increments: 1, 3, 7, 14, 30 and 90 days after the event. For example, HAZUS-MH may estimate that a facility has 5 percent chance of being fully functional at Day 3, and a 95-percent chance of being fully functional at Day 90. The analysis of critical facilities in the planning area was performed for the 100-year and Cle Elum Fault earthquake events. Table 9-12 and Table 9-13 summarize the results.

**TABLE 9-12.
FUNCTIONALITY OF CRITICAL FACILITIES FOR 100-YEAR EVENT**

Planning Unit	# of Critical Facilities	Probability of Being Fully Functional (%) at Day 1	at Day 3	at Day 7	at Day 14	at Day 30	at Day 90
Medical and Health	23	37.0	38.3	89.9	91.2	97.8	98.7
Government Functions	31	30.1	31.4	85.2	86.5	96.2	97.7
Protective Functions	67	23.7	25.0	81.5	82.9	95.0	97.0
Schools	16	25.5	26.8	81.5	82.8	94.9	96.9
Other Critical functions	15	98.5	99.4	99.7	99.7	99.8	99.9
Bridges	236	99.1	99.5	99.6	99.7	99.7	99.8
Water supply	37	93.0	99.0	99.7	99.8	99.9	99.9
Wastewater	6	81.6	95.4	99.2	99.6	99.6	99.9
Power	22	89.8	98.7	99.9	99.9	99.9	99.9
Communications	9	99.1	99.8	99.9	99.9	99.9	99.9
Total/Average	**462**	**67.8**	**71.3**	**93.6**	**94.2**	**98.3**	**99.0**

**TABLE 9-13.
FUNCTIONALITY OF CRITICAL FACILITIES FOR CLE ELUM FAULT EVENT**

Planning Unit	# of Critical Facilities	Probability of Being Fully Functional (%) at Day 1	at Day 3	at Day 7	at Day 14	at Day 30	at Day 90
Medical and Health	23	2.2	3.2	47.2	48.3	77.3	85.4
Government Functions	31	3.8	4.9	49.7	50.8	78.6	86.2
Protective Functions	67	7.0	8.2	56.7	57.9	82.2	88.6
Schools	16	3.4	4.6	52.8	54.0	80.8	87.8
Other Critical functions	15	89.7	95.1	97.0	97.1	97.4	98.9
Bridges	236	92.2	94.1	95.6	95.8	96.1	97.7
Water supply	37	68.1	91.2	96.4	97.9	98.9	99.4
Wastewater	6	55.5	83.6	95.3	96.9	97.2	99.3
Power	22	80.4	94.4	98.7	99.2	99.4	99.7
Communications	9	86.9	97.0	98.1	99.2	99.7	99.9
Total/Average	**462**	**48.9**	**57.6**	**78.7**	**79.7**	**90.8**	**94.3**

9.6.4 Environment

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

9.7 FUTURE TRENDS IN DEVELOPMENT

The land use elements of the comprehensive plans adopted by the municipal planning partners provide a long-range guide to the physical development of the planning area and its urban growth area. As one of the faster growing counties in Washington, Kittitas County and its planning partners will need to manage growth in a way that accounts for impacts from potential earthquakes. With tools such as the Washington State Building Code and local critical areas ordinances that define seismic hazard areas, the planning partners are prepared to deal with future growth.

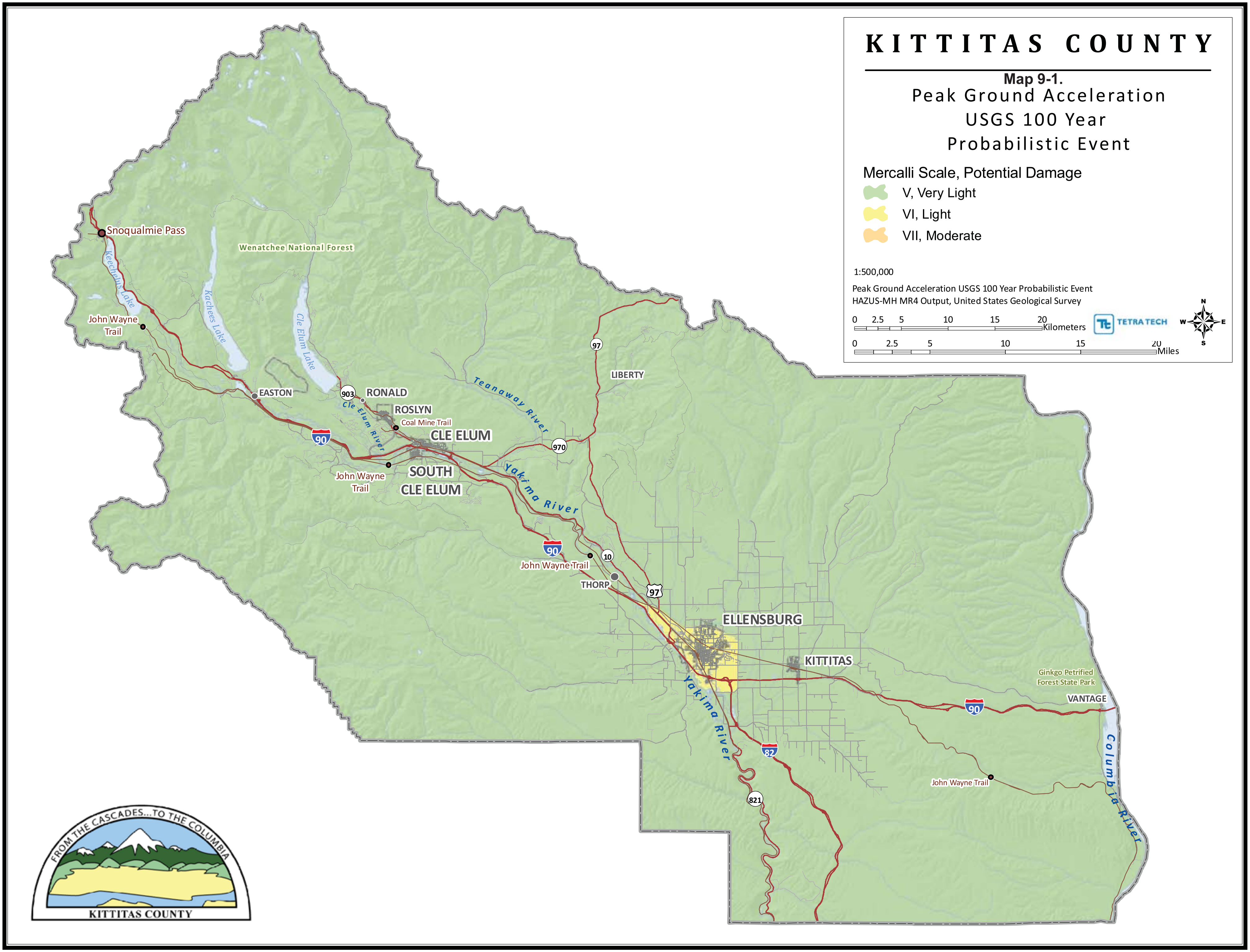
9.8 SCENARIO

Any seismic activity of Magnitude 6.0 or greater on faults within the planning area would have significant impacts. The seismic event likely to have the largest impact is a Magnitude 6.8 or greater event on the Cle Elum fault. Potential warning systems could give 40 seconds' notice that a major earthquake is about to occur; this would not provide adequate time for preparation. Earthquakes of this magnitude or higher would lead to significant structural failure of property on unstable soils. With the abundance of floodplain within the planning area, liquefaction impacts in these areas could be widespread. Un-engineered canal embankments would likely fail, representing a loss of critical infrastructure. The structural integrity of the numerous earthen dams within the planning area could be jeopardized as well. These events could cause secondary hazards, including landslides and mudslides. 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.

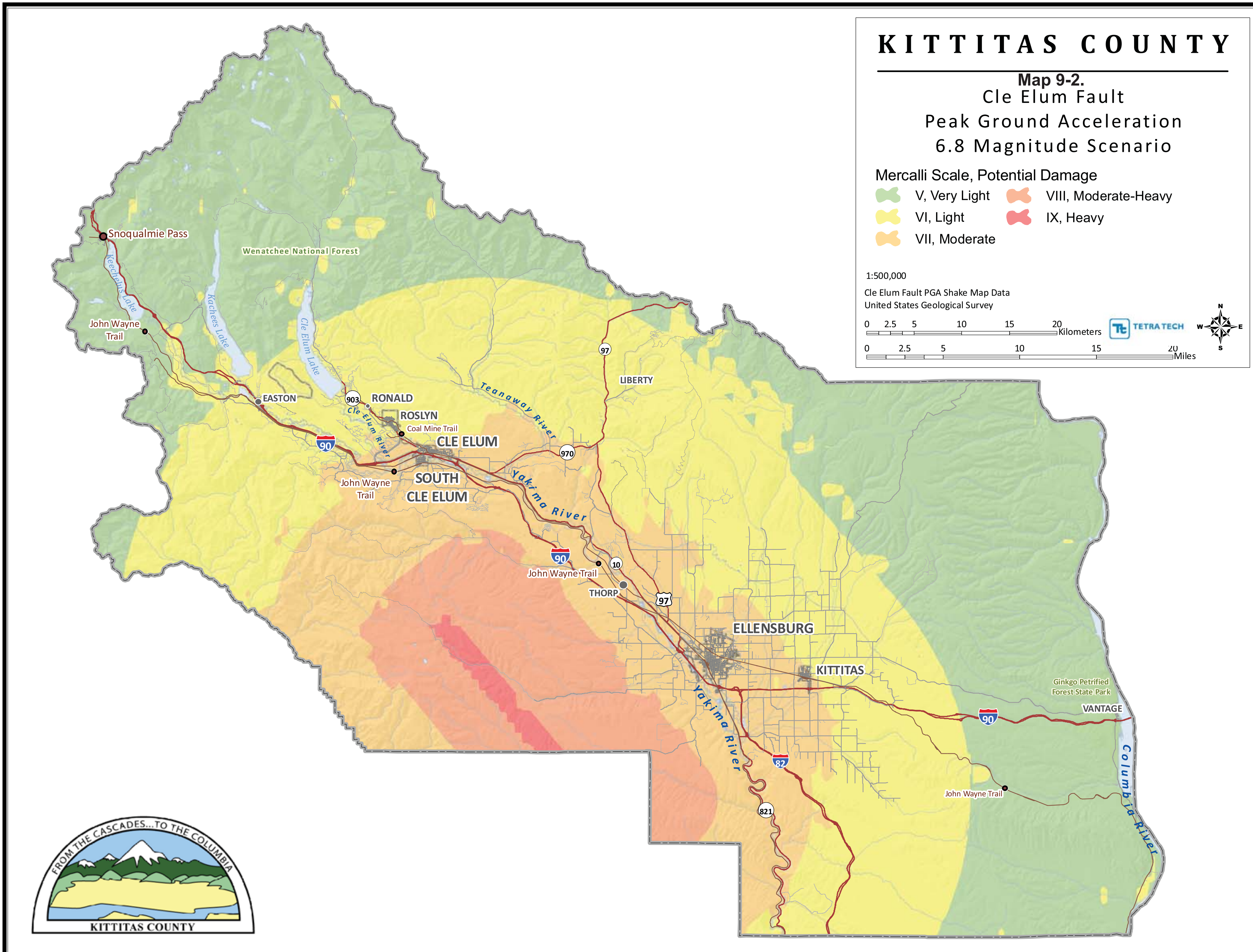
9.9 ISSUES

Important issues associated with an earthquake include but are not limited to the following:

- Approximately 42 percent of the planning area's building stock was built prior to 1975, when seismic provisions became uniformly applied through building codes.
- Critical facility owners should be encouraged to create or enhance continuity of operations plans using the information on risk and vulnerability contained in this plan.
- Geotechnical standards should be established that take into account the probable impacts from earthquakes in the design and construction of new or enhanced facilities.
- Major infrastructure crossing vulnerable soils, such as roads, bridges and railroads, is at risk.
- Landslides could have a widespread effect on the city and its surrounding areas.
- The county has over 330 miles of canals that were not constructed to engineering standards. The structural integrity of these facilities as it pertains to seismic impacts is not known.
- Until additional data on the impacts of events typical for this region are developed, non-structural retrofitting techniques should be considered and promoted by the partnership.
- More information is needed on the known and unknown faults in Eastern Washington. A systematic assessment of earthquake hazards in Eastern Washington started in 2008. The findings of ongoing research on surface faults may lead to an assessment of greater earthquake risk in parts of Eastern Washington.



KITTITAS COUNTY
Map 9-1.
Peak Ground Acceleration
USGS 100 Year
Probabilistic Event
Mercalli Scale, Potential Damage
V, Very Light
VI, Light
VII, Moderate
1:500,000
Peak Ground Acceleration USGS 100 Year Probabilistic Event
HAZUS-MH MR4 Output, United States Geological Survey
0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles
TETRA TECH
N
E
S
W
Snoqualmie Pass
Wenatchee National Forest
Keechelus Lake
Kachees Lake
Cle Elum Lake
John Wayne Trail
EASTON
RONALD
ROSLYN
Coal Mine Trail
CLE ELUM
SOUTH CLE ELUM
Cle Elum River
Teanaway River
Yakima River
LIBERTY
THORP
ELLENSBURG
KITTITAS
Ginkgo Petrified Forest State Park
VANTAGE
Columbia River
90
97
903
970
10
82
821
FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY


KITTITAS COUNTY
Map 9-2.
Cle Elum Fault
Peak Ground Acceleration
6.8 Magnitude Scenario
Mercalli Scale, Potential Damage
V, Very Light
VI, Light
VII, Moderate
VIII, Moderate-Heavy
IX, Heavy
1:500,000
Cle Elum Fault PGA Shake Map Data
United States Geological Survey
0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles
TETRA TECH
N E S W
Snoqualmie Pass
Keechelus Lake
Kachees Lake
Cle Elum Lake
Wenatchee National Forest
John Wayne Trail
EASTON
RONALD
ROSLYN
Coal Mine Trail
CLE ELUM
SOUTH CLE ELUM
Cle Elum River
Teanaway River
Yakima River
LIBERTY
THORP
ELLENSBURG
KITTITAS
Ginkgo Petrified Forest State Park
VANTAGE
Columbia River
90
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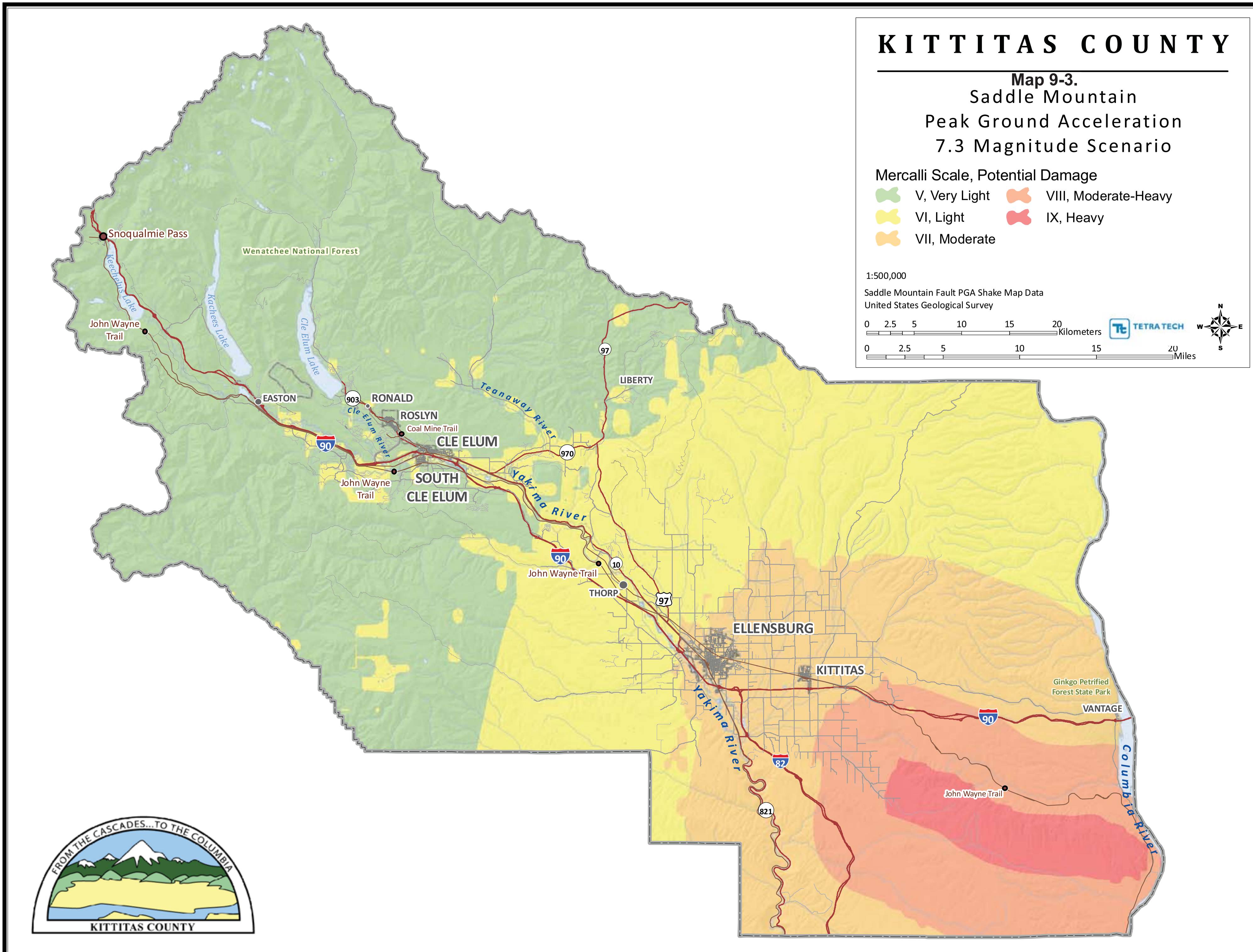
FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY


KITTITAS COUNTY
Map 9-3.
Saddle Mountain
Peak Ground Acceleration
7.3 Magnitude Scenario
Mercalli Scale, Potential Damage
V, Very Light
VI, Light
VII, Moderate
VIII, Moderate-Heavy
IX, Heavy
1:500,000
Saddle Mountain Fault PGA Shake Map Data
United States Geological Survey
0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles
TETRA TECH
Snoqualmie Pass
Wenatchee National Forest
Keechelus Lake
Kachess Lake
Cle Elum Lake
John Wayne Trail
EASTON
RONALD
ROSLYN
Coal Mine Trail
CLE ELUM
SOUTH CLE ELUM
Cle Elum River
Teanaway River
Yakima River
LIBERTY
THORP
ELLENSBURG
KITTITAS
Ginkgo Petrified Forest State Park
VANTAGE
Columbia River
FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY

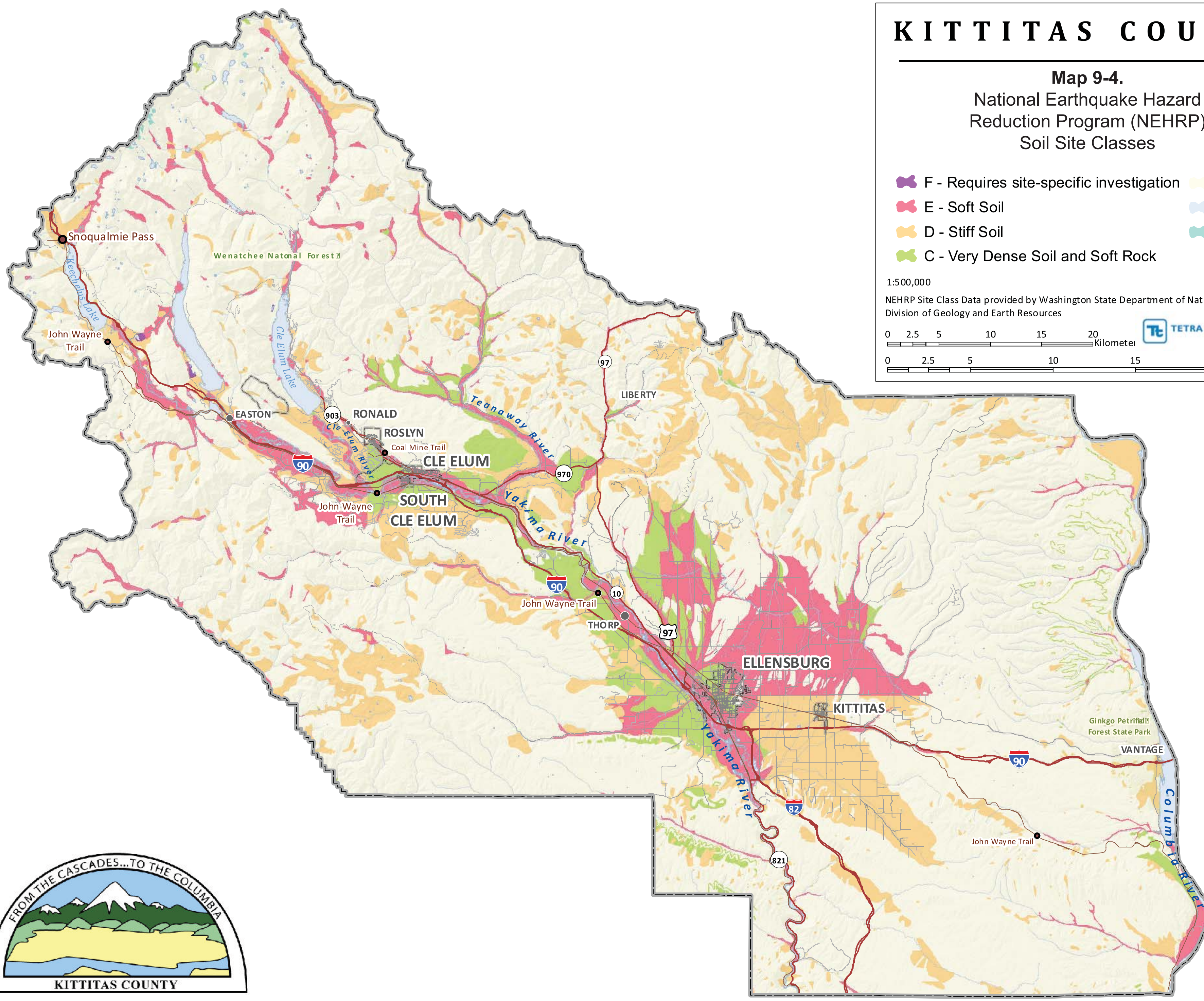
KITTITAS COUNTY

Map 9-4.
National Earthquake Hazard Reduction Program (NEHRP) Soil Site Classes

- F - Requires site-specific investigation
- E - Soft Soil
- D - Stiff Soil
- C - Very Dense Soil and Soft Rock
- B - Rock
- Water
- Ice

1:500,000

NEHRP Site Class Data provided by Washington State Department of Natural Resources, Division of Geology and Earth Resources



KITTITAS COUNTY

Map 9-5.
Liquefaction Susceptibility

- High
- Moderate to High
- Moderate
- Low to Moderate
- Low
- Very Low to Low
- Very Low
- Bedrock
- Peat
- Water
- Ice

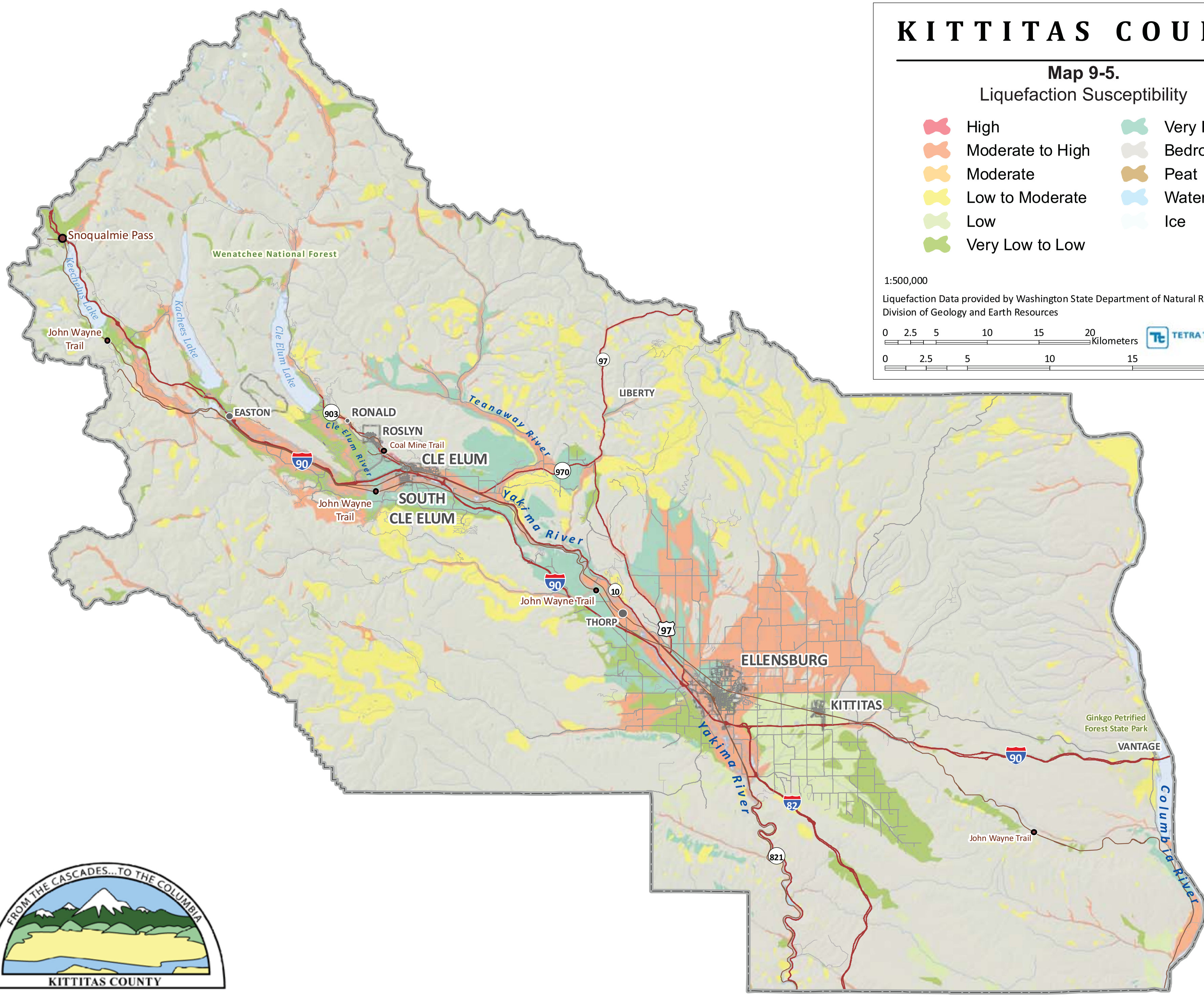
1:500,000

Liquefaction Data provided by Washington State Department of Natural Resources, Division of Geology and Earth Resources

0 2.5 5 10 15 20 Kilometers

0 2.5 5 10 15 20 Miles

TETRA TECH



CHAPTER 10.
FLOOD

10.1 GENERAL BACKGROUND

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.

Return Period—The average number of years between occurrences of a hazard (equal to the inverse of the annual likelihood of occurrence).

Riparian Zone—The area along the banks of a natural watercourse.

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.

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

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

10.1.1 Measuring Floods and Floodplains

The frequency and severity of flooding are measured using a discharge probability, which is 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 flood frequency equals 100 divided by the discharge probability. For example, the 100-year discharge has a 1-percent chance of being equaled or exceeded in any given year. The “annual flood” is the greatest flood event expected to occur in a typical year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. The same flood can have different recurrence intervals at different points on a river.

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 (SFHA), this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities. Many communities have maps that show the extent and likely depth of flooding for the base flood. Corresponding water-surface elevations describe the elevation of water that will result from a given discharge level, which is one of the most important factors used in estimating flood damage.

10.1.2 Floodplain Ecosystems

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.

10.1.3 Effects of Human Activities

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

10.1.4 Federal Flood Programs

National Flood Insurance Program

The NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in participating communities. For most participating communities, FEMA has prepared a detailed Flood Insurance Study (FIS). 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.

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

Kittitas County entered the NFIP on May 5, 1981. Structures permitted or built in the county before then are called “pre-FIRM” structures, and structures built afterwards are called “post-FIRM.” The insurance rate is different for the two types of structures. The effective date for the current countywide FIRM is June 16, 2009. This map is a DFIRM (digital flood insurance rate map).

All incorporated cities in Kittitas County also participate in the NFIP. The county and cities are currently in good standing with the provisions of the NFIP. Compliance is monitored by FEMA regional staff and by the Department of Ecology under a contract with FEMA. Maintaining compliance under the NFIP is an important component of flood risk reduction. All planning partners that participate in the NFIP have identified initiatives to maintain their compliance and good standing.

The Community Rating System

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

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

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

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

Figure 10-1 shows the nationwide number of CRS communities by class as of May 1, 2010, when there were 1,138 communities receiving flood insurance premium discounts under the CRS program.

CRS activities can help to save lives and reduce property damage. Communities participating in the CRS represent a significant portion of the nation’s flood risk; over 66 percent of the NFIP’s policy base is located in these communities. Communities receiving premium discounts through the CRS range from small to large and represent a broad mixture of flood risks, including both coastal and riverine flood risks. There are currently no communities within Kittitas County participating in the CRS program.

10.2 HAZARD PROFILE

In Kittitas County, the Yakima River is the principle hydraulic feature. Its basin covers 1,594 square miles of the county. The major Yakima River tributaries include the Cle Elum and Teanaway Rivers (all forks) and many creeks including, but not limited to, Silver, Manastash, Taneum, Naneum, Wilson, Reecer, Mercer, Big, and Little. Understanding the hydrology of the basin helps planners to estimate the likely frequency and magnitude of flooding and to locate sites where erosion may be a hazard. Hydrology of an area is largely affected by climate, topography, geology and glacial history.

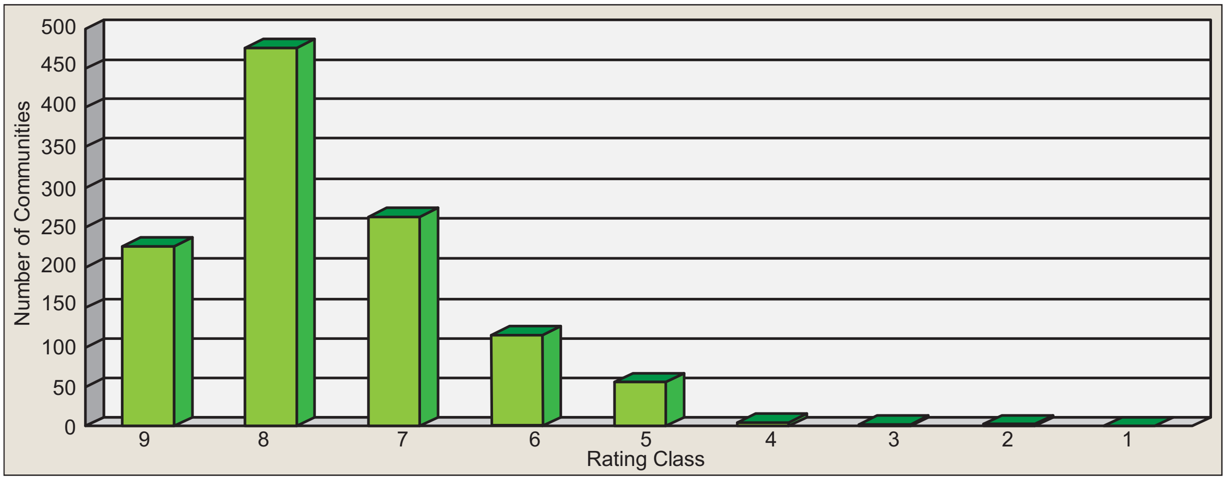


Figure 10-1. CRS Communities by Class Nationwide as of May 1, 2010

Temperatures and precipitation shape the flood hazard potential in Kittitas County. The amount of snowfall and snowmelt runoff rates are critical in determining flood potentials. Most flooding in the Yakima and Teanaway River basins follows periods in which large amounts of wet snow accumulate and is associated with rain-on-snow events during which runoff cannot percolate into the soil because the soil has been saturated or because the ground is frozen.

10.2.1 Geomorphology

Geomorphology refers to the relationship between the shape and other physical characteristics of a river and the rocks and sediments of the valley in which it flows. The river creates its channel, which reflects the force of the flowing water and the material of which the bed and banks are made. Changes in watershed conditions can affect the amount of runoff and the amount and size of sediment that enters the river. Changes in runoff and sediment loading affect the river's behavior, including flood characteristics.

The Yakima River's character changes in response to local geology as it flows downstream. Much of the river is braided, with interlaced channels and gravel bars and an active channel area; however, there are areas where basalt geology constricts the lateral movement of the river. All forks of the Teanaway River generally are constrained in their upper reaches. Moving downstream to the Teanaway River valley, the river is fairly channelized, but has free lateral movement.

10.2.2 Stream Flow

During ordinary years, much of the precipitation in Kittitas County remains as snowpack for several months after it falls, providing for higher flows during the spring thaw; however, much of the runoff is stored in one of the three reservoirs for irrigation purposes later in the year. In high precipitation years, rain-on-snow events decrease the snowpack and increase stream flow to the point of flood events. This was most apparent during the 1990, 1995, and 1995 flood events.

Cool spring temperatures increase peak stream flows, as snow remains in the mountains throughout the early spring, then melts and runs off more quickly when temperatures increase in later spring or early summer. When large amounts of water runoff at one time, high flows occur. Higher peak flows increase the possibility of flooding.

Exchanges between surface water and groundwater also drive stream flow in the Yakima River basin, but the relationships between the two are complex. Permeable glacial sediments are thought to provide for a high degree of hydraulic continuity between surface water and groundwater in most parts of the basin. Where surface water and groundwater are in continuity, the condition of the river corridor will have strong impact on groundwater resources as well as on flooding. Riparian vegetation both slows flows and helps water percolate to the zone from which it can recharge the aquifer. Similarly, changes in land use that affect groundwater quantity and quality and aquifer recharge potential will be reflected in the river.

10.2.3 Principal Flooding Sources

Riverine Flooding

There are many flood problem areas in Kittitas County. Large-scale developments with urban densities adjacent to the Yakima and Teanaway Rivers—specifically, Elk Meadows, Elk Meadows Park, Pine Glen, Sun Island, Sun Country, Teanaway Acres, and the Teanaway Wagon Wheel—have experienced substantial flood damage. The county also has numerous streams with large and unpredictable floodplains and flood capacities. These include, but are not limited to, Cabin, Cole, Big, Little, Silver, Gold, Manastash, Taneum, Wilson and Reecer Creeks.

Floods on the Yakima, Teanaway and Cle Elum Rivers occur as the result of snowmelt in spring and early summer and occur after heavy rains in November and December. Ice and debris can have an impact on flood stages when culverts and bridges are obstructed. The spring/summer snowmelt floods are characterized by slow rise and long duration of high flow; river stages may be increased by ice and debris jams. The fall/winter flood crests are reduced because flood storage is available after the irrigation season in Kachess, Keechelus, and Cle Elum Lakes. However, these reservoirs control only a small part of the runoff, and storage may not be available if two winter flood events occur in short succession. The three reservoirs have a combined storage capacity of 833,700 acre-feet (157,800 acre-feet in Keechelus Lake; 239,000 acre-feet in Kachess Lake; and 436,900 acre-feet in Cle Elum Lake). These reservoirs were constructed for irrigation purposes, but are also operated for flood control on the basis of runoff forecasts.

Irrigation Facilities

Ellensburg and Kittitas are surrounded by a complex irrigation system consisting of the North Branch, Town and Cascade canals; the Whipple Wasteway; and Reecer, Currier, Whiskey, Mercer, Wilson, Cooke and Caribou Creeks. Covering over 330 miles, this system distributes water for irrigation and was designed to provide some flood control. However, the system has a decreasing capacity downstream and can become overtaxed when used to route floodwaters. Significant floods have occurred in the past when this system diverted floodwaters from one basin to another.

Urban Flooding

Kittitas County has experienced rapid change due to urban development in once rural areas. Drainage facilities in recently urbanized areas are a series of pipes, roadside ditches and channels. Urban flooding occurs when these conveyance systems lack the capacity to convey rainfall runoff to nearby creeks, streams and rivers. As drainage facilities are overwhelmed, roads and transportation corridors become conveyance facilities. The key factors that contribute to urban flooding are rainfall intensity and duration. Topography, soil conditions, urbanization and groundcover also play an important role.

Urban floods can be a great disturbance of daily life in urban areas. Roads can be blocked and people may be unable to go to work or school. Economic damage can be high, but casualties are usually limited because of the nature of the flooding. On flat terrain, the flow speed is low and people can still drive through it. The water rises relatively slowly and usually does not reach life endangering depths.

10.2.4 Past Events

Since 1862, approximately 20 major floods have occurred on the Yakima River and its tributaries. Five of the highest peak discharges were measured at USGS Station 12484500 on the Yakima River at Umtanum, 10 miles south of Ellensburg, on the following dates:

- November 1906 (41,000 cubic feet per second (cfs))
- December 1933 (32,200 cfs)
- May 1948 (27,700 cfs)
- December 1975 (16,600 cfs)
- December 1977 (21,500 cfs).

The most recent floods were in November 1990, November 1995 and February 1996. During these floods many of the developments adjacent to the Yakima and Teanaway Rivers had to be evacuated. In November 1995, the estimated water level of the Yakima River was at 34 feet. This flood threatened the SR 970 and Lambert Road bridges over the Teanaway River and broke through dikes on both rivers, damaging both private and public property. During the February 1996 flood, private property and county roads and bridges were damaged throughout the valley, including, but not limited to, the Manastash, Swauk, Taneum, and lower Badger Pocket areas. A total of 22 bridges sustained damage in the county, in addition to approximately 120 road damage sites. Table 10-1 summarizes flood events in the planning area since 1955. Since 1964, nine presidential-declared flood events in the county have caused in excess of $20 million in property damage.

**TABLE 10-1.
KITTITAS COUNTY FLOOD EVENTS**

Date	Declaration #	Type of event	Estimated Damage[a]
12/29/1964	DR-185	Heavy Rains & Flooding	$130,000
06/10/1972	--	Flooding – Hail – Severe Storm/Thunder Storm [a]	$10,000
12/13/1975	DR-492	Severe Storms, Flooding	
12/10/1977	DR-545	Severe storms, Mudslides, Flooding	
07/25/1987	--	Flooding – Lightning [a]	$5,000
08/21/1990	--	Flooding [a]	$11,500
11/26/1990	DR-883	Flooding, Severe Storms	
01/03/1996	DR-1079	Storms/High Winds/Floods	Over $23 million statewide
02/09/1996	DR-1100	Severe Storms/Flooding	Over $33 million statewide
01/17/1997	DR-1159	Severe Winter Storms/Flooding	
05/04/2004	--	Flash flooding [a]	$90,000
01/30/2009	DR-1817	Severe Winter Storm, Landslides, Mudslides, and Flooding	$10,000,000
03/25/2011	DR-1963	Severe Winter Storm, Flooding, Landslides, and Mudslides (see Figure 10-2)	$4,000,000

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

Figure 10-2. Home in West Ellensburg Surrounded by Floodwaters, January 18, 2011

10.2.5 Location

The major floods in Kittitas County have resulted from intense weather rainstorms between November and March. The flooding that has occurred in portions of the county has been extensively documented by gage records, high water marks, damage surveys and personal accounts. This documentation was the basis for the October 15, 1981 FIRMs generated by FEMA for Kittitas County. The 2009 Flood Insurance Study is the sole source of data used in this risk assessment to map the extent and location of the flood hazard, as shown in Map 10-1.

10.2.6 Frequency

Kittitas County experiences episodes of river flooding almost every winter. Large floods that can cause property damage typically occur every three to seven years. Urban portions of the county annually experience nuisance flooding related to drainage issues.

10.2.7 Severity

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

TABLE 10-2.
SUMMARY OF PEAK DISCHARGES WITHIN KITTITAS COUNTY

	Discharge (cubic feet/second)			
Source/Location	10-Year	50-Year	100-Year	500-Year
Yakima River[a]				
At downstream study limit	20,000	29,300	33,900	45,400
Upstream of Wilson Creek	19,000	28,000	32,300	46,600
At confluence with Manastash Creek	18,900	27,700	32,000	43,200
At confluence with Dry Creek	18,500	27,100	31,400	42,400
At confluence with Teanaway River	17,100	25,100	29,100	39,600
Upstream of confluence with Teanaway River	14,700	21,700	25,200	34,300
Upstream of confluence with Crystal Creek	14,500	21,400	24,700	33,800
At confluence with the Cle Elum River	14,200	21,000	24,300	33,200
Upstream of confluence with Big Creek	7,220	10,600	12,200	16,600
At Easton	6,580	9,660	11,200	15,200
Upstream of confluence with Kachess River	4,900	7,180	8,290	11,300
Upstream of confluence with Cabin Creek	3,740	5,480	6,300	8,600
Kachess River at mouth[a]	**2,300**	**3,360**	**3,860**	**5,180**
Silver Creek at mouth	**260**	**370**	**425**	**560**
Cle Elum River				
At mouth	8,020	11,800	13,600	18,600
At upstream study limit	7,540	11,100	12,800	17,400
Manastash Creek				
At apex of alluvial fan	1,400	2,030	2,310	3,030
At confluence with N. Fork Manastash Creek	1,240	1,780	2,040	2,670
At upstream study limit	967	1,400	1,590	2,100
Crystal Creek at mouth	**150**	**220**	**250**	**320**
Naneum Creek at mouth	**920**	**1,310**	**1,480**	**1,890**
Wilson Creek				
At mouth[b]	3,100	4,250	4,750	5,900
Upstream of confluence with Cherry Creek	2,050	2,750	3,000	3,700
Upstream of confluence with Naneum Creek[b]	1,550	2,170	2,360	2,950
Upstream study limit	475	680	770	986
Right Channel Wilson Creek[b]	**1,260**	**1,610**	**1,725**	**2,045**
Reecer Creek at downstream limit	**280**	**400**	**450**	**560**
Currier Creek				
At downstream limit	280	400	450	560
At Dry Creek connection road	180	255	290	360
Whiskey Creek				
At 5th street	75	105	175[c]	275[c]
At upstream limit	75	105	118	147
Mercer Creek				
At mouth	110	150	220 [c]	310 [c]
At Railroad Ave	110	150	170	210
Caribou Creek at downstream study limit	**294**	**417**	**471**	**595**
Teanaway River				
At Mouth	5,300	6,700	7,350	8,700
Upstream of confluence with N. Fork Teanaway River	2,400	3,000	3,300	3,900

TABLE 10-2.
SUMMARY OF PEAK DISCHARGES WITHIN KITTITAS COUNTY

	Discharge (cubic feet/second)			
Source/Location	10-Year	50-Year	100-Year	500-Year
N. Fork Teanaway River at mouth	**2,900**	**3,700**	**4,000**	**4,750**
Middle Fork Teanaway River at mouth	**1,250**	**1,570**	**1,700**	**2,020**
West Fork Teanaway River at Mouth	**1,300**	**1,640**	**1,780**	**2,080**

a. Discharges reflect regulated conditions
b. Includes overflow from Yakima River, Reecer, and Currier Creeks
c. Includes overflow from Reecer Creek

10.2.8 Warning Time

Floods are the number one natural disaster in the United States in terms of loss of life and property. Floods are generally classed as either slow-rise or flash floods. Slow-rise may be preceded by a warning time from several hours, to days, to possibly weeks. Evacuation and sandbagging for a slow-rise flood may lessen flood damage. Flash floods are the most difficult to prepare for, due to the extremely short warning time, if any is given at all. Flash flood warnings usually require evacuation within an hour.

Each watershed has unique qualities that affect its response to rainfall. A hydrograph, which is a graph or chart illustrating stream flow in relation to time (see Figure 10-3), is a useful tool for examining a stream's response to rainfall. Once rainfall starts falling over a watershed, runoff begins and the stream begins to rise. Water depth in the stream channel (stage of flow) will continue to rise in response to runoff even after rainfall ends. Eventually, the runoff will reach a peak and the stage of flow will crest. It is at this point that the stream stage will remain the most stable, exhibiting little change over time until it begins to fall and eventually subside to a level below flooding stage.

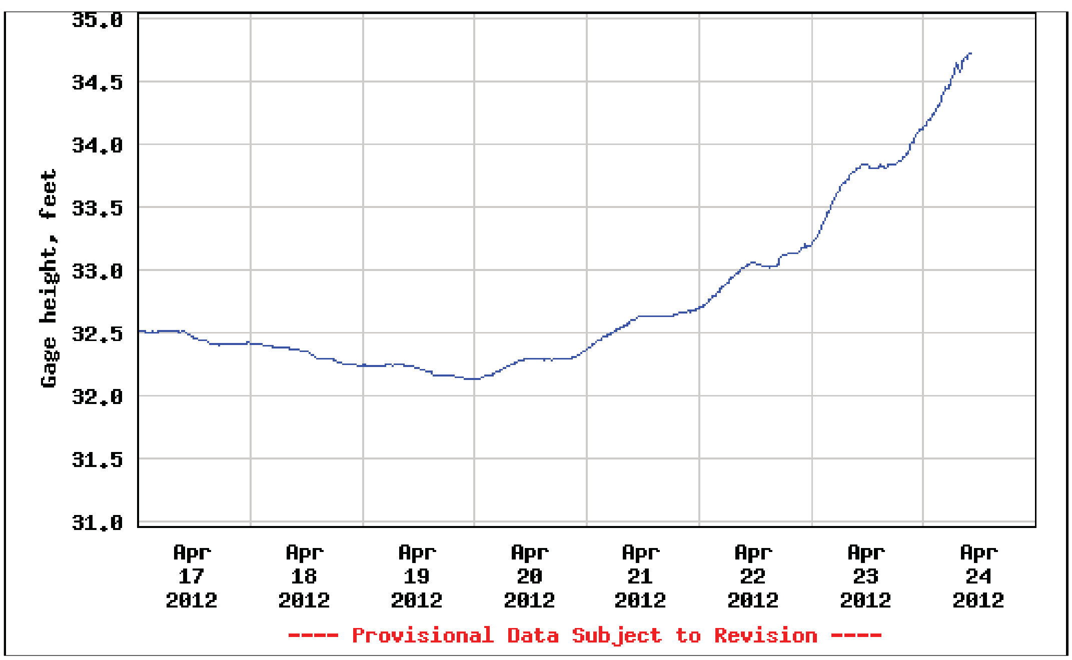


Figure 10-3. Yakima River Hydrograph at Umtanum (USGS Station 12484500)

The potential warning time a community has to respond to a flooding threat is a function of the time between the first measurable rainfall and the first occurrence of flooding. The time it takes to recognize a flooding threat reduces the potential warning time to the time that a community has to take actions to protect lives and property. Another element that characterizes a community's flood threat is the length of time floodwaters remain above flood stage.

The Kittitas County flood threat system consists of a network of precipitation gages throughout the watershed and stream gages at strategic locations on the Yakima River that constantly monitor and report stream levels. This information is fed into a USGS forecasting program, which assesses the flood threat based on the amount of flow in the stream (measured in cubic feet per second). In addition to this program, data and flood warning information is provided by the National Weather Service. All of this information is analyzed to evaluate the flood threat and possible evacuation needs.

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

10.3 SECONDARY HAZARDS

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

10.4 CLIMATE CHANGE IMPACTS

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

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

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

As hydrology changes, what is currently considered a 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, floodways, bypass channels and levees, as well as the design of local sewers and storm drains.

10.5 EXPOSURE

The Level 2 HAZUS-MH protocol was used to assess the risk and vulnerability to flooding in the planning area. The model used census data at the block level and FEMA floodplain data, to estimate potential flooding impacts. Flood exposure numbers were generated using Kittitas County assessor and parcel data. Where possible, the HAZUS-MH default data was enhanced using local GIS data from county, state and federal sources. All data sources have a level of accuracy acceptable for planning purposes

10.5.1 Population

Population counts of those living in the floodplain were generated by analyzing County assessor and parcel data that intersect with the 100-year and 500-year floodplains identified on FIRMs. Using GIS, residential structures that intersected the floodplain were identified, and an estimate of population was calculated by multiplying the residential structures by the average Kittitas County household size of 2.32 persons per household.

Using this approach, it was estimated that the exposed population for the entire county is 3,327 within the 100-year floodplain (7.9 percent of the total county population) and 7,000 within the 500-year floodplain (16.6 percent of the total).

10.5.2 Property

Structures in the Floodplain

Table 10-3 and Table 10-4 summarize the total area and number of structures in the floodplain by municipality. Using GIS, it was determined that there are 1,649 structures within the 100-year floodplain and 3,188 structures within the 500-year floodplain. In the 100-year floodplain, about 60 percent of these structures are in unincorporated areas. Eighty-seven percent are residential, and 13 percent are commercial, industrial or agricultural.

Exposed Value

Table 10-5 and Table 10-6 summarize the estimated value of exposed buildings in the planning area. This methodology estimates over $658 million worth of building-and-contents exposure to the 100-year flood, representing 7.9 percent of the total assessed value of the planning area, and $1.3 billion worth of building-and-contents exposure to the 500-year flood, representing 16 percent of the total.

TABLE 10-3.
AREA AND STRUCTURES WITHIN THE 100-YEAR FLOODPLAIN

	Area in Floodplain (Acres)	Number of Structures in Floodplain							
		Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	**Total**
Cle Elum	450	61	24	1	0	0	0	0	**86**
Ellensburg	1,051	220	84	63	2	0	0	0	**369**
Kittitas	67	59	6	0	0	0	0	0	**65**
Roslyn	66	20	1	0	0	0	0	0	**21**
South Cle Elum	115	135	0	0	0	0	0	0	**135**
Unincorporated	42,753	939	23	7	4	0	0	0	**973**
Total	**44,502**	**1,434**	**138**	**71**	**6**	**0**	**0**	**0**	**1,649**

TABLE 10-4.
AREA AND STRUCTURES WITHIN THE 500-YEAR FLOODPLAIN

	Area in Floodplain (Acres)	Number of Structures in Floodplain							
		Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	**Total**
Cle Elum	567	197	202	72	0	2	1	0	**474**
Ellensburg	1,435	1,021	335	87	2	6	2	1	**1,454**
Kittitas	67	59	6	0	0	0	0	0	**65**
Roslyn	66	20	1	0	0	0	0	0	**21**
South Cle Elum	125	155	1	0	0	0	1	0	**157**
Unincorporated	44,192	983	23	7	4	0	0	0	**1,017**
Total	**46,452**	**2,435**	**568**	**166**	**6**	**8**	**4**	**1**	**3,188**

TABLE 10-5.
VALUE OF EXPOSED BUILDINGS WITHIN 100-YEAR FLOODPLAIN

	Estimated Flood Exposure			% of Total Assessed Value
	Structure	Contents	**Total**	
Cle Elum	$14,576,720	$12,683,968	**$27,260,687**	4.32%
Ellensburg	$94,300,294	$94,302,103	**$188,602,397**	8.50%
Kittitas	$8,609,734	$7,025,742	**$15,635,477**	12.47%
Roslyn	$3,906,790	$3,235,850	**$7,142,640**	2.44%
South Cle Elum	$24,021,060	$19,216,848	**$43,237,908**	50.67%
Unincorporated	$209,810,401	$166,866,330	**$376,676,732**	7.58%
Total	**$355,225,000**	**$303,330,841**	**$658,555,841**	**7.92%**

TABLE 10-6. VALUE OF EXPOSED BUILDINGS WITHIN 100-YEAR FLOODPLAIN				
	Estimated Flood Exposure			% of Total Assessed Value
	Structure	Contents	**Total**	
Cle Elum	$128,311,154	$131,021,188	**$259,332,342**	41.13%
Ellensburg	$311,586,821	$293,227,636	**$604,814,457**	27.26%
Kittitas	$8,609,734	$7,025,742	**$15,635,477**	12.47%
Roslyn	$3,906,790	$3,235,850	**$7,142,640**	2.44%
South Cle Elum	$27,792,207	$22,239,027	**$50,031,235**	58.63%
Unincorporated	$220,382,851	$174,780,444	**$395,163,296**	7.96%
Total	**$700,589,558**	**$631,529,888**	**$1,332,119,447**	**16.01%**

Zoning in the 100-Year Floodplain

Some land uses are more vulnerable to flooding, such as residential, while others are less vulnerable, such as agricultural land or parks. Table 10-7 shows the general zoning of parcels in the 100-year and 500-year floodplain. About 16 percent of the parcels in the 100-year floodplain are zoned for agricultural uses. These are favorable, lower-risk uses for the floodplain. The amount of the floodplain that contains vacant, developable land is not known. This would be valuable information for gauging the future development potential of the floodplain.

TABLE 10-7. GENERAL ZONING WITHIN THE FLOODPLAIN (UNINCORPORATED COUNTY)				
	100-Year Floodplain		500-Year Floodplain	
Zoning	Area (acres)	% of total	Area (acres)	% of total
Agriculture	7,043	16.47%	7,475	16.91%
Commercial	9,771	22.86%	10,333	23.38%
Flooded	1,173	2.74%	1,173	2.65%
Forest & Range	7,506	17.56%	7,624	17.25%
Industrial	155	0.36%	159	0.36%
Master Planned Resort	795	1.86%	840	1.90%
Planned Mixed Use	1	0.00%	1	0.00%
Planned Unit Development	114	0.27%	130	0.29%
Public Reserve	6	0.01%	6	0.01%
Residential	4,041	9.45%	4,268	9.66%
Right of Way	12,148	28.41%	12,185	27.57%
Total	**42,753**	**100.00%**	**44,192**	**100.00%**

10.5.3 Critical Facilities and Infrastructure

Table 10-8 through Table 10-11 summarize the critical facilities and infrastructure in the 100-year and 500-year floodplains of Kittitas County. Details are provided in the following sections.

TABLE 10-8.
CRITICAL FACILITIES IN THE 100-YEAR FLOODPLAIN

Jurisdiction	Medical and Health Services	Government Function	Protective	Hazardous Materials	Schools	Other	**Total**
Cle Elum	0	0	0	0	0	0	**0**
Ellensburg	0	2	0	0	0	0	**2**
Kittitas	0	0	0	0	0	0	**0**
Roslyn	0	0	0	0	0	0	**0**
South Cle Elum	0	1	1	0	0	0	**2**
Unincorporated	0	0	0	0	0	0	**0**
Total	**0**	**3**	**1**	**0**	**0**	**0**	**4**

TABLE 10-9.
CRITICAL FACILITIES IN THE 500-YEAR FLOODPLAIN

Jurisdiction	Medical and Health Services	Government Function	Protective	Hazardous Materials	Schools	Other	**Total**
Cle Elum	2	3	6	0	0	0	**11**
Ellensburg	1	13	4	0	1	0	**19**
Kittitas	0	0	0	0	0	0	**0**
Roslyn	0	0	0	0	0	0	**0**
South Cle Elum	0	1	1	0	0	0	**2**
Unincorporated	0	0	4	0	0	0	**4**
Total	**3**	**17**	**15**	**0**	**1**	**0**	**36**

TABLE 10-10.
CRITICAL INFRASTRUCTURE IN THE 100-YEAR FLOODPLAIN

Jurisdiction	Bridges	Water Supply	Wastewater	Power	Communications	Other	**Total**
Cle Elum	0	0	2	0	0	0	**2**
Ellensburg	4	0	0	1	0	0	**5**
Kittitas	0	0	1	0	0	0	**1**
Roslyn	0	0	0	0	0	0	**0**
South Cle Elum	0	0	0	0	0	0	**0**
Unincorporated	80	3	1	13	0	4	**101**
Total	**84**	**3**	**4**	**14**	**0**	**4**	**109**

**TABLE 10-11.
CRITICAL INFRASTRUCTURE IN THE 500-YEAR FLOODPLAIN**

Jurisdiction	Bridges	Water Supply	Wastewater	Power	Communications	Other	**Total**
Cle Elum	0	0	2	0	0	0	**2**
Ellensburg	4	1	0	1	0	0	**6**
Kittitas	0	0	1	0	0	0	**1**
Roslyn	0	0	0	0	0	0	**0**
South Cle Elum	0	0	0	0	0	0	**0**
Unincorporated	82	3	1	13	0	4	**103**
Total	**86**	**4**	**4**	**14**	**0**	**4**	**112**

Tier II Facilities

Tier II facilities are those that use or store materials that can harm the environment if damaged by a flood. During a flood event, containers holding these materials can rupture and leak into the surrounding area, having a disastrous effect on the environment as well as residents.

Utilities and Infrastructure

It is important to determine who may be at risk if infrastructure is damaged by flooding. Roads or railroads that are blocked or damaged can isolate residents and can prevent access throughout the county, including for emergency service providers needing to get to vulnerable populations or to make repairs. Bridges washed out or blocked by floods or debris also can cause isolation. Water and sewer systems can be flooded or backed up, causing health problems. Underground utilities can be damaged. Dikes can fail or be overtopped, inundating the land that they protect. The following sections describe specific types of critical infrastructure.

Roads

The following major roads in Kittitas County pass through the 100-year floodplain and thus are exposed to flooding:

- Interstate 82
- Interstate 90
- State Route 10
- State Route 821
- State Route 970
- U.S. Route 97

Some of these roads are built above the flood level, and others function as levees to prevent flooding. Still, in severe flood events these roads can be blocked or damaged, preventing access to some areas.

Bridges

Flooding events can significantly impact road bridges. These are important because often they provide the only ingress and egress to some neighborhoods. An analysis showed that there are 84 bridges that are in or cross over the 100-year floodplain and 86 bridges in the 500-year floodplain.

Water and Sewer Infrastructure

Water and sewer systems can be affected by flooding. Floodwaters can back up drainage systems, causing localized flooding. Culverts can be blocked by debris from flood events, also causing localized urban flooding. Floodwaters can get into drinking water supplies, causing contamination. Sewer systems can be backed up, causing wastewater to spill into homes, neighborhoods, rivers and streams.

Levees

Levees have historically been used to control flooding in potions of Kittitas County. According to County GIS records, there are approximately 17 miles of earthen levees in the county. There are also levees on many smaller rivers, streams and creeks that protect small areas of land. Many of the levees are older and were built under earlier flood management goals. Many of these older levees are exposed to scouring and failure due to old age and construction methods.

Environment

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

10.6 VULNERABILITY

Many of the areas exposed to flooding may not experience serious flooding or flood damage. This section describes vulnerabilities in terms of population, property, infrastructure and environment.

10.6.1 Population

A geographic analysis of demographics, using the HAZUS-MH model and data from the U.S. Census Bureau and Dun & Bradstreet, identified populations vulnerable to the flood hazard as follows:

- **Economically Disadvantaged Populations**—It is estimated that 7 percent of the people within the 100-year floodplain are economically disadvantaged, defined as having household incomes of $10,000 or less.
- **Population over 65 Years Old**—It is estimated that 5 percent of the population in the census blocks that intersect the 100-year floodplain are over 65 years old.
- **Population under 16 Years Old**—It is estimated that 9 percent of the population within census blocks located in or near the 100-year floodplain are under 16 years of age.

10.6.2 Property

HAZUS-MH calculates losses to structures from flooding by looking at depth of flooding and type of structure. Using historical flood insurance claim data, HAZUS-MH estimates the percentage of damage to structures and their contents by applying established damage functions to an inventory. For this analysis, local data on facilities was used instead of the default inventory data provided with HAZUS-MH. The analysis is summarized in Table 10-12 and Table 10-13 for the 100-year and 500-year flood events, respectively.

**TABLE 10-12.
ESTIMATED FLOOD LOSS FOR THE 100-YEAR FLOOD EVENT**

	Estimated Flood Loss Potential			% of Total Assessed Value
	Structural	Contents	**Total**	
Cle Elum	$2,186,508	$2,915,344	**$5,101,852**	0.81%
Ellensburg	$14,145,044	$18,860,059	**$33,005,103**	1.49%
Kittitas	$1,291,460	$1,721,947	**$3,013,407**	2.40%
Roslyn	$586,019	$781,358	**$1,367,377**	0.47%
South Cle Elum	$3,603,159	$4,804,212	**$8,407,371**	9.85%
Unincorporated	$31,471,560	$41,962,080	**$73,433,640**	1.48%
Total	**$53,283,750**	**$71,045,000**	**$124,328,750**	**1.49%**

**TABLE 10-13.
ESTIMATED FLOOD LOSS FOR THE 500-YEAR FLOOD EVENT**

	Estimated Flood Loss Potential			% of Total Assessed Value
	Structural	Contents	**Total**	
Cle Elum	$24,379,119	$29,511,565	**$53,890,685**	8.55%
Ellensburg	$59,201,496	$71,664,969	**$130,866,465**	5.90%
Kittitas	$1,635,850	$1,980,239	**$3,616,089**	2.88%
Roslyn	$742,290	$898,562	**$1,640,852**	0.56%
South Cle Elum	$5,280,519	$6,392,208	**$11,672,727**	13.68%
Unincorporated	$41,872,742	$50,688,056	**$92,560,798**	1.86%
Total	**$133,112,016**	**$161,135,598**	**$294,247,615**	**3.54%**

It is estimated that there would be up to $124.3 million of flood loss from a 100-year flood event in the planning area. This represents 18 percent of the total exposure to the 100-year flood and 1.49 percent of the total assessed value for the county. It is estimated that there would be $294.2 million of flood loss from a 500-year flood event, representing 22 percent of the total exposure to a 500-year flood event and 3.54 percent of the total assessed value.

National Flood Insurance Program

Table 10-14 lists flood insurance statistics that help identify vulnerability in Kittitas County. Six communities in the planning area participate in the NFIP, with 752 flood insurance policies providing $157 million in coverage. According to FEMA statistics, 243 flood insurance claims were paid between January 1, 1978 and November 30, 2011, for a total of $2.6 million, an average of $10,718 per claim.

Properties constructed after a FIRM has been adopted are eligible for reduced flood insurance rates. Such structures are less vulnerable to flooding since they were constructed after regulations and codes were adopted to decrease vulnerability. Properties built before a FIRM is adopted are more vulnerable to flooding because they do not meet code or are located in hazardous areas. The first FIRMs in Kittitas County were available in 1981.

**TABLE 10-14.
FLOOD INSURANCE STATISTICS FOR KITTITAS COUNTY**

Jurisdiction	Date of Entry Initial FIRM Effective Date	# of Flood Insurance Policies as of 11/30/2011	Insurance In Force	Total Annual Premium	Claims, 1/1/1978 to 11/30/2011	Value of Claims paid, 1/1/1978 to 11/30/2090
Cle Elum	05/05/1981	37	$7,188,700	$21,838	13	$202,790
Ellensburg	05/05/1981	129	$29,171,400	$120,993	26	$194,495
Kittitas	04/15/1982	45	$5,707,700	$37,819	10	$8,611
Roslyn	06/05/1985	6	$1,083,700	$4,948	0	$0
South Cle Elum	05/05/1981	67	$11,942,800	$49,745	1	$83,74
Kittitas County	05/05/1981	468	$101,911,700	$353,812	193	$2,198,527
Total		**752**	**$157,006,000**	**$589,155**	**243**	**$2,604,580**

The following information from flood insurance statistics is relevant to reducing flood risk:

- The use of flood insurance in Kittitas County is below the national average. About 23 percent of insurable buildings in the county are covered by flood insurance. According to an NFIP study, about 49 percent of single-family homes in special flood hazard areas are covered by flood insurance nationwide.
- The average claim paid in the planning area represents about 5 percent of the 2011 average assessed value of structures in the floodplain.
- The percentage of policies and claims outside a mapped floodplain suggests that not all of the flood risk in the planning area is reflected in current mapping. Based on information from the NFIP, 53.5 percent of policies in the planning area are on structures within an identified SFHA, and 46.5 percent are for structures outside such areas. Of total claims paid, 18.5 percent were for properties outside an identified 100-year floodplain.

Repetitive Loss

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

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

Repetitive loss properties make up only 1 to 2 percent of flood insurance policies in force nationally, yet they account for 40 percent of the nation's flood insurance claim payments. In 1998, FEMA reported that the NFIP's 75,000 repetitive loss structures have already cost $2.8 billion in flood insurance payments and that numerous other flood-prone structures remain in the floodplain at high risk. The government has instituted programs encouraging communities to identify and mitigate the causes of repetitive losses. A recent report on repetitive losses by the National Wildlife Federation found that 20 percent of these properties are outside any mapped 100-year floodplain. The key identifiers for repetitive loss properties are the existence of flood insurance policies and claims paid by the policies.

FEMA-sponsored programs, such as the CRS, require participating communities to identify repetitive loss areas. A repetitive loss area is the portion of a floodplain holding structures that FEMA has identified as meeting the definition of repetitive loss. Identifying repetitive loss areas helps to identify structures that are at risk but are not on FEMA's list of repetitive loss structures because no flood insurance policy was in force at the time of loss. Map 10-2 shows the repetitive loss areas in Kittitas County. FEMA's list of repetitive loss properties identifies 16 such properties in the Kittitas County planning area as of January 19, 2012. None of these properties have been identified as "severe repetitive loss" according to FEMA criteria. The breakdown of the properties by jurisdiction is presented in Table 10-15.

Six of the properties on the repetitive loss list are outside the County's special flood hazard area. All of these properties are on the outer fringes of the SFHA in the 500-year floodplain, and no localized flooding issues have been identified. They were most likely flooded by flood events typical for the floodplain they are adjacent to. Therefore it can be concluded that the overall cause of repetitive flooding is the same as has been identified for the river basins in which each repetitive loss area is found. With the potential for flood events every three to seven years, the County and its planning partners consider all of the mapped floodplain areas as susceptible to repetitive flooding.

**TABLE 10-15.
REPETITIVE LOSS PROPERTIES IN KITTITAS COUNTY**

Jurisdiction	Repetitive Loss Properties	Properties That Have Been Mitigated	Number of Corrections	Corrected Number of Repetitive Loss Properties
Cle Elum	2	0	0	2
Ellensburg	0	0	0	0
Kittitas	1	0	0	1
Roslyn	0	0	0	0
South Cle Elum	0	0	0	0
Unincorporated	13	0	0	13
Total	**16**	**0**	**0**	**16**

Based on FEMA Report of Repetitive Losses, 1/19/2012

10.6.3 Critical Facilities and Infrastructure

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

- **100-year flood event**—On average, critical facilities would receive 7.3 percent damage to the structure and 28.2 percent damage to the contents during a 100-year flood event. The estimated time to restore these facilities to 100 percent of their functionality is 490 days.
- **500-year flood event**—A 500-year flood event would damage the structures an average of 8.6 percent and the contents an average 32.7 percent. The estimated time to restore these facilities to 100 percent of their functionality after a 500-year event is 510 days.

10.6.4 Environment

The environment vulnerable to flood hazard is the same as the environment exposed to the hazard. Loss estimation platforms such as HAZUS-MH are not currently equipped to measure environmental impacts of flood hazards. The best gauge of vulnerability of the environment would be a review of damage from past flood events. Loss data that segregates damage to the environment was not available at the time of this plan. Capturing this data from future events could be beneficial in measuring the vulnerability of the environment for future updates.

10.7 FUTURE TRENDS

Kittitas County and its planning partner cities are subject to the provisions of the Washington GMA, which regulates identified critical areas. County critical areas regulations include frequently flooded areas, defined as the FEMA 100-year mapped floodplain. The GMA establishes programs to monitor the densities at which commercial, residential and industrial development occurs under local GMA comprehensive plans and development regulations.

As participants in the NFIP, Kittitas County and the partner cities have adopted flood damage prevention ordinances pursuant to the participation requirements. While these ordinances do not prohibit new development within the floodplain, they include new development provisions that account for the risk inherent to the floodplain.

The combination of the GMA provisions, critical areas regulations and NFIP flood damage prevention provisions equips the municipal planning partners with adequate tools to address new development in the floodplain. As pressures mount for growth into areas with flood risk, these tools could be enhanced with higher regulatory standards to increase the level of risk reduction on new development.

10.8 SCENARIO

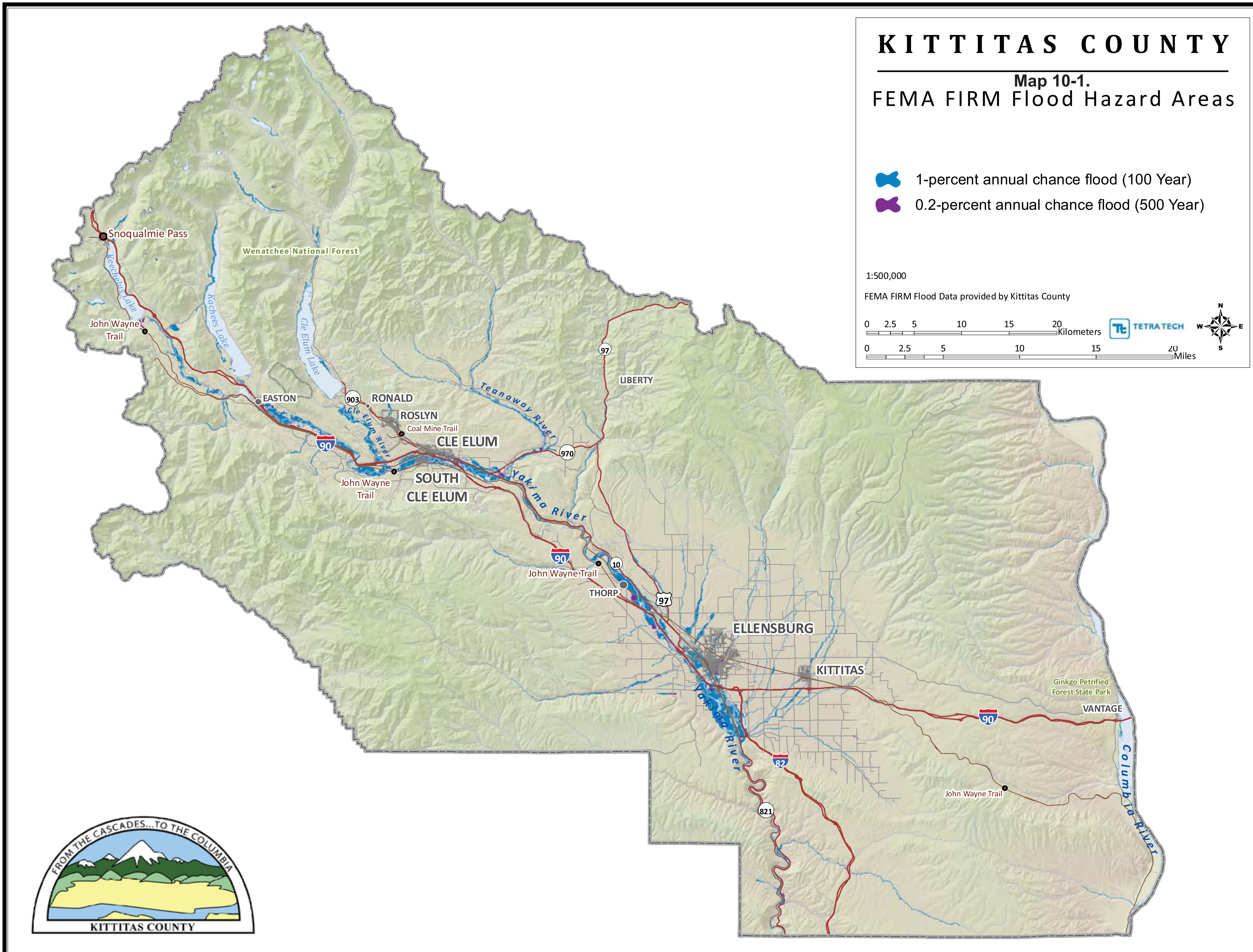
The primary water courses in Kittitas County have the potential to flood at irregular intervals, generally in response to a succession of intense winter rainstorms. Storm patterns of warm, moist air usually occur between early November and late March. A series of such weather events can cause severe flooding in the planning area. The worst-case scenario is a series of storms that flood numerous drainage basins in a short time. This could overwhelm the response and floodplain management capability within the planning area. Major roads could be blocked, preventing critical access for many residents and critical functions. High in-channel flows could cause water courses to scour, possibly washing out roads and creating more isolation problems. In the case of multi-basin flooding, the County would not be able to make repairs quickly enough to restore critical facilities and infrastructure.

10.9 ISSUES

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

- The accuracy of the existing flood hazard mapping produced by FEMA in reflecting the true flood risk within the planning area is questionable. Flood maps need to be updated utilizing the best available data, science and technology
- The extent of flood-protection provided by flood control facilities (dams, dikes and levees) is not known due to the lack of an established national policy on flood protection standards.
- The risk associated with the flood hazard overlaps the risk associated with other hazards such as earthquake, landslide and fishing losses. This provides an opportunity to seek mitigation alternatives with multiple objectives that can reduce risk for multiple hazards.

- There is no consistency of land-use practices within the planning area or the scope of regulatory floodplain management beyond the minimum requirements of the NFIP.
- Potential climate change could alter flood conditions in Kittitas County.
- More information is needed on flood risk 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 jurisdictions affected by flood hazards in the county.
- Floodplain residents need to continue to be educated about flood preparedness and the resources available during and after floods.
- The concept of residual risk should be considered in the design of future capital flood control projects and should be communicated with residents living in the floodplain.
- The promotion of flood insurance as a means of protecting private property owners from the economic impacts of frequent flood events should continue.
- Existing floodplain-compatible uses such as agricultural and open space need to be maintained. There is constant pressure to convert these existing uses to more intense uses within the planning area during times of moderate to high growth.
- The economy affects a jurisdiction's ability to manage its floodplains. Budget cuts and personnel losses can strain resources needed to support floodplain management.
- A buildable-lands analysis that looks at vacant lands and their designated land use would be a valuable tool in helping decision-makers make wise decisions about future development.
- The risk associated with flooding due to canal failure is unknown at this time. Data on this risk need to be gathered to better support communities' preparedness and response efforts.


KITTITAS COUNTY
Map 10-1.
FEMA FIRM Flood Hazard Areas
1-percent annual chance flood (100 Year)
0.2-percent annual chance flood (500 Year)
1:500,000
FEMA FIRM Flood Data provided by Kittitas County
0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles
TETRA TECH
N E S W
Snoqualmie Pass
Wenatchee National Forest
Keechelus Lake
Kachees Lake
Cle Elum Lake
John Wayne Trail
EASTON
RONALD
ROSLYN
Coal Mine Trail
CLE ELUM
SOUTH CLE ELUM
Cle Elum River
Teanaway River
Yakima River
LIBERTY
THORP
ELLENSBURG
KITTITAS
Ginkgo Petrified Forest State Park
VANTAGE
Columbia River
90
82
97
970
903
10
821
FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY

KITTITAS COUNTY

Map 10-2.
Repetitive Loss Areas

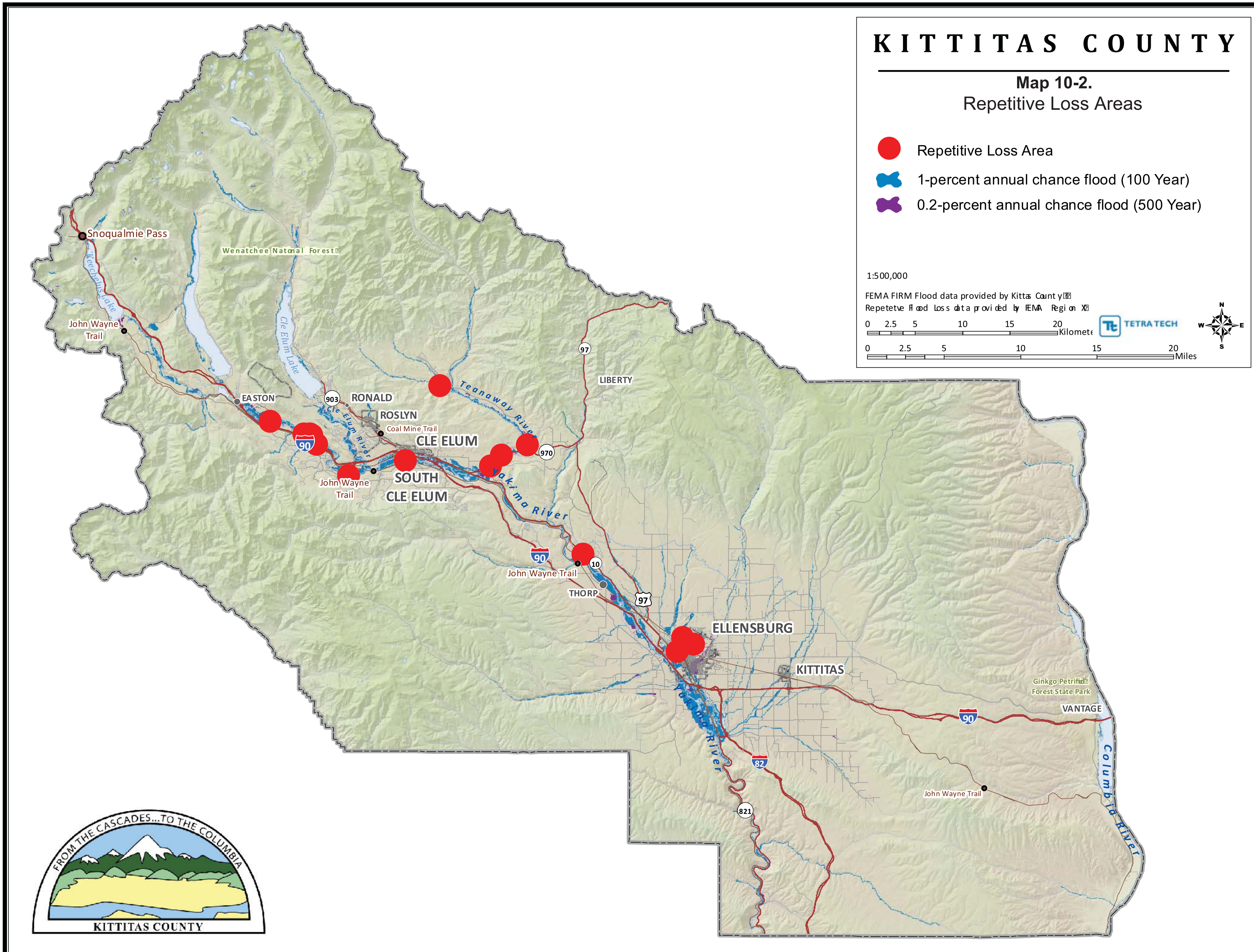
- Repetitive Loss Area
- 1-percent annual chance flood (100 Year)
- 0.2-percent annual chance flood (500 Year)

1:500,000

FEMA FIRM Flood data provided by Kittitas County
Repetitive Flood Loss data provided by FEMA Region X

0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles

TETRA TECH



CHAPTER 11.
LANDSLIDE

11.1 GENERAL BACKGROUND

A landslide is a mass of rock, earth or debris moving down a slope. Landslides may be minor or very large, and can move at slow to very high speeds. They can be initiated by storms, earthquakes, fires, volcanic eruptions or human modification of the land.

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.

DEFINITIONS

Landslide—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, 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.

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.

11.2 HAZARD PROFILE

Landslides are caused by one or a combination of the following factors: 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. 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:

- A slope 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 or potential for snow avalanches
- 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. Figure 11-1 through Figure 11-4 show common types of slides. The most common is the shallow colluvial slide, occurring particularly in response to intense, short-duration storms. The largest and most destructive are deep-seated slides, although they are less common than other types.

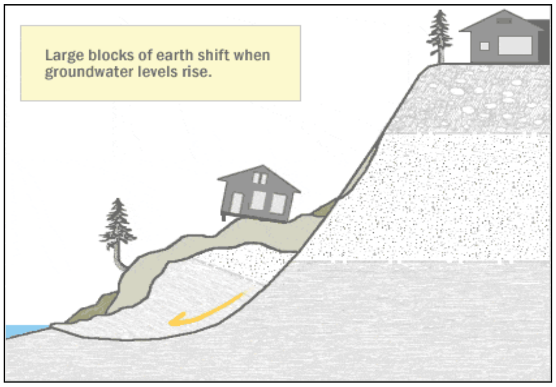


Figure 11-1. Deep Seated Slide

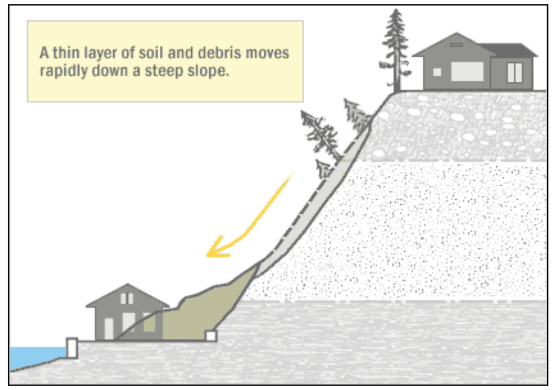


Figure 11-2. Shallow Colluvial Slide

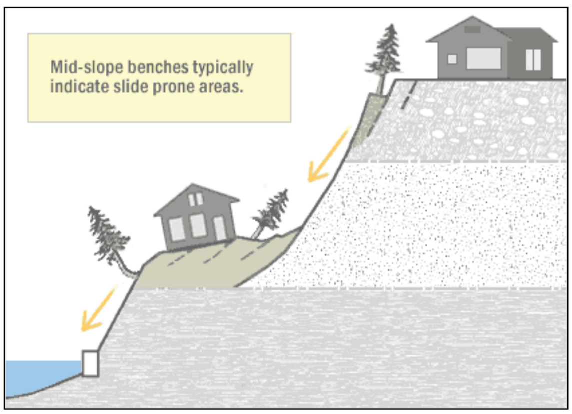


Figure 11-3. Bench Slide

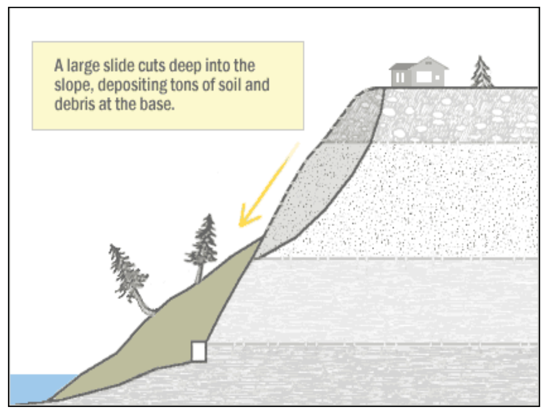


Figure 11-4. Large Slide

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.

11.2.1 Past Events

There is little recorded information regarding landslides in Kittitas County. According to the Spatial Hazard Events and Losses Database for the United States (SHELDUS), there have been three recorded landslide events in Kittitas County since 1960. These events occurred on January 26, 1965, October 11, 2009 and March 25, 2011. All of these events coincided with presidential disaster declarations for severe storms and flooding. The combined estimated damage for these three events exceeded $15 million. There are no records in the county of fatalities attributed to mass movement. However, deaths have occurred across the west coast as a result of slides and slope collapses.

11.2.2 Location

The best available predictor of where movement of 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 proportion of them may become active in any given year, with movements concentrated within all or part of the landslide masses or around their edges.

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.

The basis for the mapping for this risk assessment is the Landslide Hazard Zonation Project prepared by the Forest Practices Division of the Washington Department of Natural Resources. Identification of unstable slopes to aid in mitigation of landslide hazards is now an integral part of land management and regulation in Washington. Permanent rules adopted by the Washington Forest Practices Board in 2001 address landslide hazards from specific landforms across the state (WAC 222-16-050 (1)(d)). This methodology was developed to provide standardized methods for landslide inventories and for producing hazard maps to identify unstable slopes in support of forest practices rules. It also provides a framework for monitoring the success of new forest practices related to unstable slopes. The Landslide Hazard Zonation Project maps for the planning area are shown in Map 11-1.

11.2.3 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. In Kittitas County, landslides typically occur during and after major storms, so the potential for landslides largely coincides with the potential for sequential severe storms that saturate steep, vulnerable soils. Landslide events occurred during the winter storms of 2009 and 2011. According to SHELDUS records, the planning area has been impacted by severe storms at least once every other year since 1960. Until better data is generated specifically for landslide hazards, this severe storm frequency is appropriate for the purpose of ranking risk associated with the landslide hazard.

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 landsliding to occur. Most local landslides occur in January after the water table has risen during the wet months of November and December. Water is involved in nearly all cases; and human influence has been identified in more than 80 percent of reported slides.

11.2.4 Severity

Landslides destroy property and infrastructure and can take the lives of people. Slope failures in the United States result in an average of 25 lives lost per year and an annual cost to society of about $1.5 billion. According to SHELDUS, the 2009 and 2011 storms caused in excess of $15 million in property damage due to landslides, mudslides and debris flows. This was about half of all damage caused by the storm. The landslides caused by the storm also caused tens of millions of dollars of damage to road infrastructure.

11.2.5 Warning Time

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. Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. It is also possible to determine what areas are at risk during general time periods. Assessing the geology, vegetation and amount of predicted precipitation for an area can help in these predictions. However, there is no practical warning system for individual landslides. The current standard operating procedure is to monitor situations on a case-by-case basis, and respond after the event has occurred. 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 such as decks and patios tilting and/or moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still falling or just recently stopped
- Sticking doors and windows, and visible open spaces indicating jambs and 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.

11.3 SECONDARY HAZARDS

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

11.4 CLIMATE CHANGE IMPACTS

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

11.5 EXPOSURE

11.5.1 Population

Population could not be examined by landslide hazard area because census block group areas do not coincide with the hazard areas. A population estimate was made using the structure count of residential buildings within the landslide hazard area and applying the census value of 2.32 persons per household for Kittitas County. Using this approach, the estimated population living in the landslide hazard area is 988. This approach could understate the exposure by as much as a factor of two.

11.5.2 Property

Table 11-1 shows the number and assessed value of structures exposed to the landslide risk. There are 426 structures on parcels in the landslide risk areas, with an estimated value of $183.6 million. Over 98 percent of the exposed structures are dwellings. Predominant zoning in cities is for single-family, vacant and manufactured homes. Table 11-2 shows the general zoning of parcels exposed to landslides in unincorporated portions of the County. Lands zoned for commercial forest uses are most vulnerable.

TABLE 11-1.
KITTITAS COUNTY STRUCTURES IN LANDSLIDE HAZARD AREAS

Jurisdiction	Buildings Exposed	Assessed Value Structure	Assessed Value Contents	Assessed Value **Total**	% of AV
Cle Elum	0	0	0	**0**	0.0%
Ellensburg	0	0	0	**0**	0.0%
Kittitas	0	0	0	**0**	0.0%
Roslyn	0	0	0	**0**	0.0%
South Cle Elum	0	0	0	**0**	0.0%
Unincorporated	426	$102,970,780	$80,693,764	**$183,664,544**	3.7%
Total	**426**	**$102,970,780**	**$80,693,764**	**$183,664,544**	**2.2%**

11.5.3 Critical Facilities and Infrastructure

Table 11-3 summarizes the critical facilities exposed to the landslide hazard. No loss estimation of these facilities was performed due to the lack of established damage functions for the landslide hazard. A significant amount of infrastructure can be exposed to mass movements:

- **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**—Landslides can significantly impact road bridges. Mass movements can knock out abutments or significantly weaken the soil supporting them, 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 under a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.

**TABLE 11-2.
GENERAL ZONING IN LANDSLIDE RISK AREAS OF UNINCORPORATED COUNTY**

	Landslide Risk Area	
Zoning	Area (acres)	% of total
Agriculture	9,888	7.87%
Commercial Forest	98,770	78.60%
Forest & Range	14,019	11.16%
Master Planned Resort	148	0.12%
Planned Unit Development	129	0.10%
Residential	2,224	1.77%
Right of Way	323	0.26%
Wind Farm Overlay	155	0.12%
Total	**125,658**	**100%**

**TABLE 11-3.
CRITICAL FACILITIES EXPOSED TO LANDSLIDE HAZARDS**

	Number of Exposed Critical Facilities in Risk Area
Medical and Health Services	0
Government Function	0
Protective Function	0
Schools	0
Hazmat	0
Other Critical Function	1
Bridges	0
Water	0
Wastewater	0
Power	1
Communications	0
Total	**2**

11.5.4 Environment

Environmental problems as a result of mass movements can be numerous. Landslides that fall into streams may significantly impact fish and wildlife habitat, as well as affecting water quality. Hillsides that provide wildlife habitat can be lost for prolong periods of time due to landslides.

11.6 VULNERABILITY

11.6.1 Population

Due to the nature of census block group data, it is difficult to determine demographics of populations vulnerable to mass movements. In general, all of the estimated 988 persons exposed to higher risk landslide areas are considered to be vulnerable. Increasing population and the fact that many homes are built on view property atop or below bluffs and on steep slopes subject to mass movement, increases the number of lives endangered by this hazard.

11.6.2 Property

Although complete historical documentation of the landslide threat in Kittitas County is lacking, the landslides of 2009 and 2011 suggest a significant vulnerability to such hazards. The millions of dollars in damage countywide attributable to mass movement during those storms affected private property and public infrastructure and facilities.

Loss estimations for the landslide hazard are not based on modeling utilizing damage functions, because no such damage functions have been generated. Instead, loss estimates were developed representing 10 percent, 30 percent and 50 percent of the assessed value of exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 11-4 shows the general building stock loss estimates for landslide risk areas.

**TABLE 11-4.
ESTIMATED LOSSES IN LANDSLIDE RISK AREAS**

			Estimated Loss Potential		
Jurisdiction	Building Count	Assessed Value	10% Damage	30% Damage	50% Damage
Cle Elum	0	0	0	0	0
Ellensburg	0	0	0	0	0
Kittitas	0	0	0	0	0
Roslyn	0	0	0	0	0
South Cle Elum	0	0	0	0	0
Unincorporated	426	$183,664,544	$18,366,454	$55,099,363	$91,832,272
Total	**426**	**$183,664,544**	**$18,366,454**	**$55,099,363**	**$91,832,272**

11.6.3 Critical Facilities and Infrastructure

There are two critical facilities exposed to the landslide hazard to some degree. A more in-depth analysis of the mitigation measures taken by these facilities to prevent damage from mass movements should be done to determine if they could withstand impacts of a mass movement.

Several types of infrastructure are exposed to mass movements, including transportation, water and sewer and power infrastructure. Highly susceptible areas of the county include mountain and coastal roads and transportation infrastructure. At this time all infrastructure and transportation corridors identified as exposed to the landslide hazard are considered vulnerable until more information becomes available.

11.6.4 Environment

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

11.7 FUTURE TRENDS IN DEVELOPMENT

Landslide hazard areas are included in "geologically hazardous areas," one category of critical areas regulated under the state GMA for Kittitas County. They are defined as follows:

> "Landslide hazard areas" means areas potentially subject to mass earth movement based on a combination of geologic, topographic, and hydrologic factors, with a vertical height of 10 feet or more. These include the following:
>
> – Areas of historical landslides as evidenced by landslide deposits, avalanche tracks, and areas susceptible to basal undercutting by streams, rivers or waves
>
> – Areas with slopes steeper than 15 percent that intersect geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock, and which contain springs or groundwater seeps
>
> – Areas located in a canyon or an active alluvial fan, susceptible to inundation by debris flows or catastrophic flooding.

Kittitas County and its planning partners appear to be well equipped to deal with future growth and development within the planning area. The landslide hazard portions of the planning area are regulated by County Code (Title 17A.06) as well as by the International Building Code. Development will occur in landslide hazards within the planning area, but it will be regulated such that the degree of risk will be reduced through building standards and performance measures.

11.8 SCENARIO

Major landslides in Kittitas 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 winter when the water table is high. After heavy rains from November to December, 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, poor drainage, a rising groundwater table and poor soil exacerbate hazardous conditions.

Mass movements are becoming more of a concern as development moves outside of city centers and into areas less developed in terms of infrastructure. Most mass movements would be isolated events affecting specific areas. 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 rail service through the county. Road obstructions caused by mass movements would create isolation problems for residents and businesses in sparsely developed areas. 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.

Continued heavy rains and flooding will complicate the problem further. As emergency response resources are applied to problems with flooding, it is possible they will be unavailable to assist with landslides occurring all over Kittitas County.

11.9 ISSUES

Important issues associated with landslides in Kittitas County include the following:

- There are existing homes in landslide risk areas throughout the county. The degree of vulnerability of these structures depends on the codes and standards to which the structures were constructed. Information to this level of detail is not currently available.
- Future development could lead to more homes in landslide risk areas.
- Mapping and assessment of landslide hazards are constantly evolving. As new data and science become available, assessments of landslide risk should be reevaluated.
- The impact of climate change on landslides is uncertain. If climate change impacts atmospheric conditions, then exposure to landslide risks is likely to increase.
- Landslides may cause negative environmental consequences, including water quality degradation.
- 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 alternatives with multiple objectives that can reduce risk for multiple hazards.

KITTITAS COUNTY

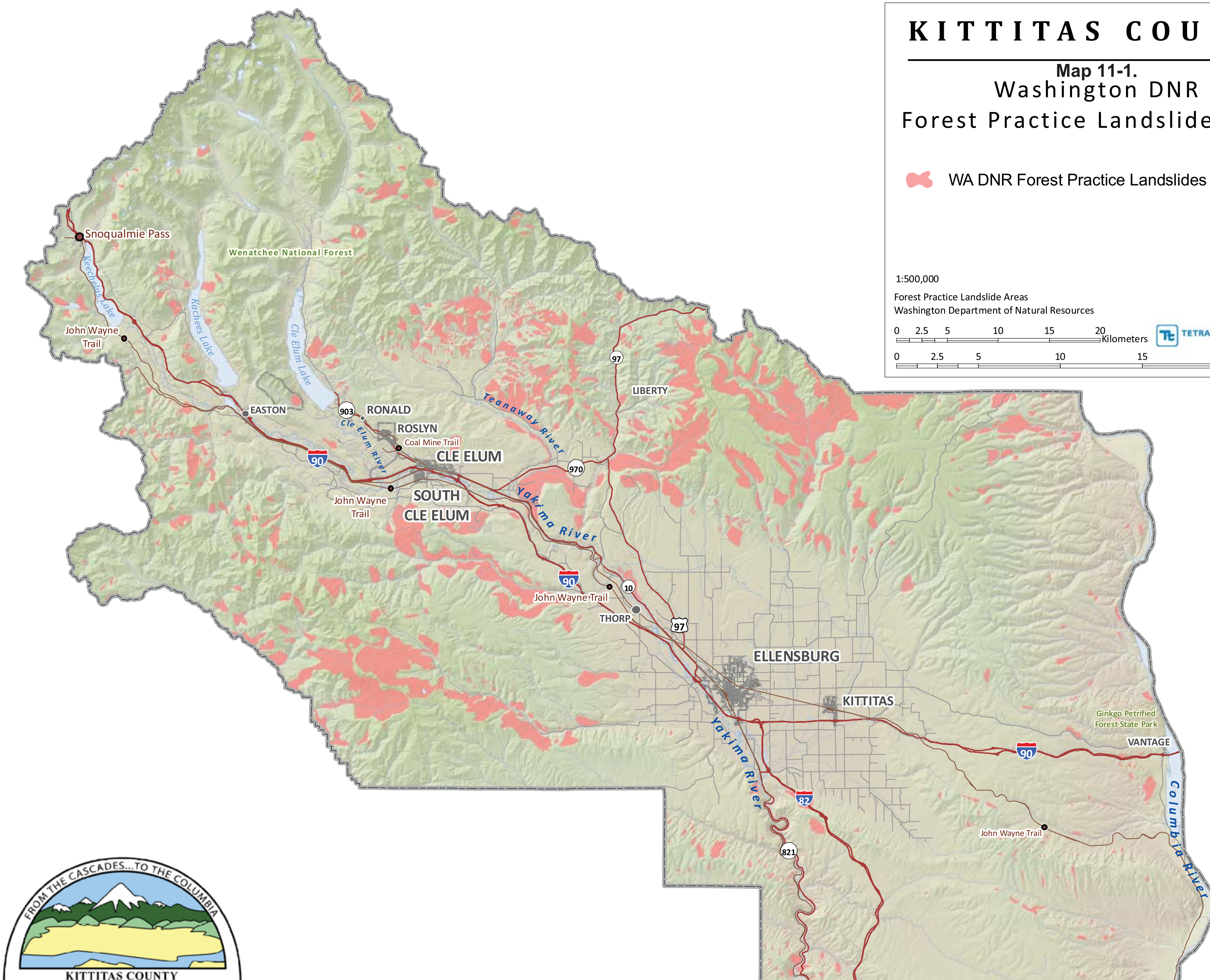
Map 11-1.
Washington DNR
Forest Practice Landslide Areas

WA DNR Forest Practice Landslides

1:500,000

Forest Practice Landslide Areas
Washington Department of Natural Resources

0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles



CHAPTER 12.
SEVERE WEATHER

12.1 GENERAL BACKGROUND

Severe weather refers to any dangerous meteorological phenomena with the potential to cause damage, serious social disruption, or loss of human life. It includes thunderstorms, downbursts, tornadoes, waterspouts, snowstorms, ice storms, and dust storms.

Severe weather can be categorized into two groups: those that form over wide geographic areas are classified as general severe weather; those with a more limited geographic area are classified as localized severe weather. Severe weather, technically, is not the same as extreme weather, which refers to unusual weather events are at the extremes of the historical distribution for a given area.

Five types of severe weather events typically impact Kittitas County: thunderstorms, damaging winds, hail storms, heavy snowfall associated with winter storms and flash flooding. Flooding issues associated with severe weather are discussed in Chapter 10. The other four types of severe weather common to Kittitas County are described in the following sections.

12.1.1 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.

Three factors cause thunderstorms to form: moisture, rising unstable air (air that keeps rising when disturbed), and a lifting mechanism to provide the disturbance. The sun heats the surface of the earth, which warms the air above it. If this warm surface air is forced to rise (hills or mountains can cause rising motion, as can the interaction of warm air and cold air or wet air and dry air) it will continue to rise as long as it weighs less and stays warmer than the air around it. As the air rises, it transfers heat from the surface of the earth to the upper levels of the atmosphere (the process of convection). The water vapor it contains begins to cool and it condenses into a cloud. The cloud eventually grows upward into areas where the temperature is below freezing.

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.

Severe Local Storm—”Microscale” atmospheric systems, including tornadoes, thunderstorms, windstorms, ice storms and snowstorms. 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—Funnel clouds that generate winds up to 500 miles per hour. They can affect an area up to three-quarters of a mile wide, with a path of varying length. Tornadoes can come from lines of cumulonimbus clouds or from a single storm cloud. They are measured using the Fujita Scale, ranging from F0 to F5.

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.

Some of the water vapor turns to ice and some of it turns into water droplets. Both have electrical charges. Ice particles usually have positive charges, and rain droplets usually have negative charges. When the charges build up enough, they are discharged in a bolt of lightning, which causes the sound waves we hear as thunder. Thunderstorms have three stages (see Figure 12-1):

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

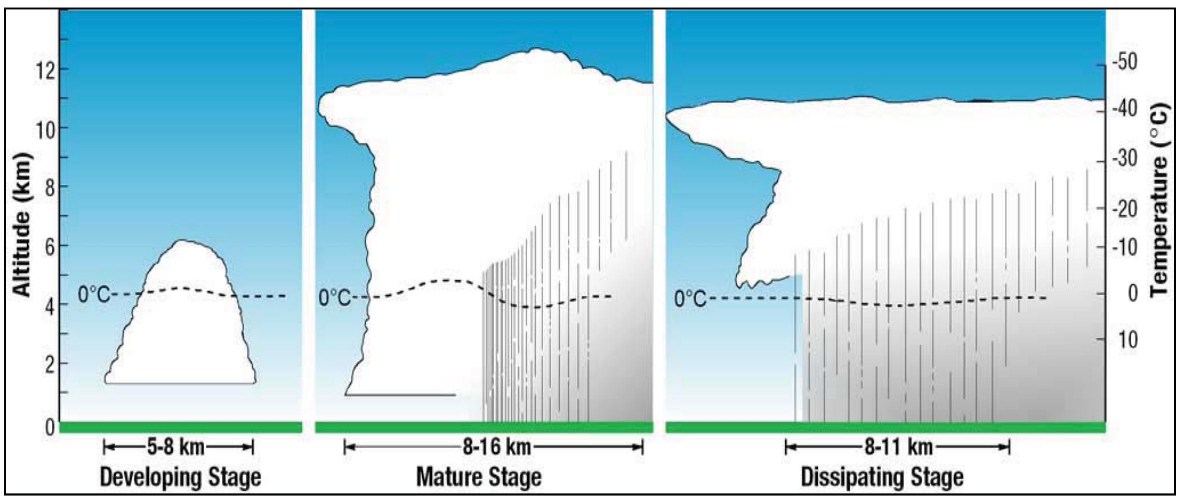


Figure 12-1. The Thunderstorm Life Cycle

There are four types of thunderstorms:

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

- **Multi-Cell Squall Line—**A multi-cell line storm, or squall line, consists of a long line of storms with a continuous well-developed gust front at the leading edge. The line of storms can be solid, or there can be gaps and breaks in the line. Squall lines can produce hail up to golf-ball size, heavy rainfall, and weak tornadoes, 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.

12.1.2 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.

12.1.3 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.

Hailstones can have layers like an onion if they travel up and down in an updraft, or they can have few or no layers if they are "balanced" in an updraft. One can tell how many times a hailstone traveled to the top of the storm by counting its layers. Hailstones can begin to melt and then re-freeze together, forming large and very irregularly shaped hail.

12.1.4 Winter Storms/Heavy Snow

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

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

Strong storms crossing the North Pacific sometimes slam into the coast from California to Washington. The Pacific provides a virtually unlimited source of moisture for storms. If the air is cold enough, snow falls over Washington and Oregon and sometimes in California. As the moisture rises into the mountains, heavy snow closes the mountain passes and can cause avalanches. Cold air from the north has to filter through mountain canyons into the basins and valleys to the south. If the cold air is deep enough, it can spill over the mountain ridge. As the air funnels through canyons and over ridges, wind speeds can reach 100 mph, damaging roofs and taking down power and telephone lines. Combining these winds with snow results in a blizzard.

Heavy snow can immobilize a region and paralyze a city, stranding commuters, stopping the flow of supplies, and disrupting emergency and medical services. Accumulations of snow can collapse buildings and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and unprotected livestock may be lost. In the mountains, heavy snow can lead to avalanches. The cost of snow removal, repairing damages, and loss of business can have large economic impacts on cities and towns.

Areas most vulnerable to winter storms are those affected by convergence of dry, cold air from the interior of the North American continent, and warm, moist air off the Pacific Ocean. Typically, significant winter storms occur during the transition between cold and warm periods.

12.2 HAZARD PROFILE

12.2.1 Past Events

Table 12-1 summarizes severe weather events in Kittitas County since 1970, as recorded by the National Oceanic and Atmospheric Administration (NOAA).

**TABLE 12-1.
SEVERE WEATHER EVENTS IMPACTING PLANNING AREA SINCE 1970**

Date	Type	Deaths or Injuries	Property Damage
11/1/1994	Heavy Snow	0	NR
Description: *Snowfall from a daylong storm averages 2 to 3 feet in the Cascades.*			
11/19/1996	Heavy Snow	1	NR
Description: *14 inches of snow fell in Yakima, knocking out power to 15,000 homes, and canceling all bus service for the first time in 20 years. One person died when a carport collapsed due to heavy snow. Ellensburg got 18-22 inches of snow. Road crews in Ellensburg could not keep up with the snowfall and a roof collapsed at a hay brokerage firm. 27 trucks jackknifed on I-82 between Yakima and Ellensburg.*			
12/28/1996	Heavy Snow	0	$30 Million
Description: *Yakima had a new record for snow depth with 27” on the ground. Warehouse roofs experienced millions of dollars in damage and dozens of buildings had partially collapsed roofs. I-82 from Yakima to Ellensburg was closed. In Cle Elum snow removal crews were ran of room to plow the snow. Mail delivery was held up because some trucks could not get to or find buried mail boxes.*			
12/15/2000	High Wind	0	$14,285
Description: *A spotter in East Kittitas estimated sustained winds of 45 to 50 mph.*			
5/19/2001	High Wind	0	$20,000
Description: *High pressure west of the Washington Cascades, combined with a cold front moving through the Columbia basin, brought high winds to the Kittitas Valley. The automated weather sensor at the airport in Ellensburg measured sustained winds of over 40 mph for a couple of hours beginning around noon. At 12:15 pm, a large tent at the Ellensburg National Art Show and Auction was damaged, prompting an evacuation. Shortly before 1 pm, wind gusts estimated between 50 and 60 mph toppled a tree onto power lines along Kittitas Road east of Ellensburg.*			
10/23/2001	High Wind	0	$30,000
Description: *Locally strong winds between 40 and 42 mph were measured by an automated weather sensor at the airport in Ellensburg.*			
11/28/2001	Heavy Snow	0	$100,000
Description: *Heavy snow fell during the morning in the Yakima and Kittitas Valleys. Interstate 82 and State Routes 82 and 821 were intermittently closed throughout the day due to accidents. 9 inches of snow fell in Ellensburg.*			

**TABLE 12-1.
SEVERE WEATHER EVENTS IMPACTING PLANNING AREA SINCE 1970**

Date	Type	Deaths or Injuries	Property Damage
11/9/2003	High Wind	0	$5,000
Description: *A cold front brought about a sudden burst of high winds in Ellensburg. At 4:24 AM, a northwest wind of 47 MPH with a gust to 60 MPH was recorded.*			
4/27/2004	High Wind	0	$1,000
Description: *A peak wind gust of 56 MPH was recorded by automated weather sensor at the Ellensburg Airport. These strong winds knocked down two power poles in Ellensburg.*			
12/15/2006	Winter Storm	0	$150,000
Description: *Cold air along the east slopes of the Cascades combined with a warm front moving north to produce heavy snowfall. Five to 7 inches occurred in the Ellensburg area and 8 to 10 inches fell in the Cle Elum-Roslyn area. The storm caused 168 vehicle collisions in Kittitas County with 5 minor injuries. The snow was accompanied by strong winds that downed trees and power lines. At least 9500 customers lost power in Kittitas County*			
1/7/2007	High Wind	0	$25,000
Description: *A brief period of high winds around 4:00 PM knocked down power poles and lines from 1 mile north of Kittitas to 10 miles south of Kittitas.*			
7/1/2008	Hail	0	NR
Description: *Hail started as penny size and grew to nickel size. A severe thunderstorm produced nickel-sized hail over southwest Kittitas County.*			
8/15/2008	Excessive Heat	0	NR
Description: *An upper level ridge and dry air brought excessive heat into eastern Washington. Locations that experienced multiple days of at least 100 degree temperatures included Ellensburg (102, 105, 106), Yakima (101, 101, 103), and Satus Pass (100, 100).*			
1/6/2009	High Wind	0	NR
Description: *Tight surface gradients and strong winds aloft combined to produce damaging winds across central and southeast Washington. Wind gusts in mph include Goldendale (80), Pasco (60), 10 miles north northeast of Yakima (76) and Umtanum Ridge (71). Damage included trees down near Ellensburg and buildings damaged in Kennewick.*			
9/19/2010	Lightning	0	$60,000
Description: *Lightning struck an 80 foot fir tree and started a house fire. The lightning split the tree and the energy was transferred into the cast iron sewer pipe and into the home, catching the house on fire. A large piece of the split tree hit a car that was parked across the street.*			
2/12/2011	High Wind	0	$10,000
Description: *A fast moving cold front brought high winds. Tree branches up to 1.5 inches in diameter were downed 8 miles west northwest of Connell. A wildfire in White Swan, fanned by winds up to 69 mph, was carried from a house to a logging mill and into the town. The wildfire burned 20 homes. A trailer was blown over west of Ellensburg.*			
5/14/2011	Lightning	0	$300,000
Description: *Lightning started a roof fire that damaged a few other rooms of a residence. Moist and unstable conditions ahead of an upper level low pressure system triggered widespread thunderstorms with heavy rainfall and isolated large hail. This combined with the abundant spring snow-pack and wet ground to cause flooding.*			

12.2.2 Location

Severe weather events have the potential to happen anywhere in the planning area. Communities in low-lying areas next to streams or lakes are more susceptible to flooding. Wind events are most damaging to areas that are heavily wooded. Maps 12-1, 12-2, 12-3 and 12-4 show the distribution of average weather conditions over Kittitas County.

12.2.3 Frequency

The severe weather events for Kittitas County shown in Table 12-1 are often related to high winds associated with winter storms and thunderstorms. The planning area can expect to experience exposure to some type of severe weather event at least annually. According to the Washington State Enhanced Hazard Mitigation Plan, Kittitas County has a winter storm recurrence rate of 125 percent, which means that historically, the county experiences at least one damaging winter storm every year

12.2.4 Severity

The most common problems associated with severe storms are immobility and loss of utilities. The National Weather Service refers to winter storms as "Deceptive Killers" because most deaths are indirectly related to the storm. Instead, people die in traffic accidents on icy roads and of hypothermia from prolonged exposure to cold. It is important to be prepared for winter weather before it strikes.

Roads may become impassable due to flooding, downed trees, ice or snow, or a landslide. Power lines may be downed due to high winds or ice accumulation, and services such as water or phone may not be able to operate without power. Lightning can cause severe damage and injury.

Windstorms can be a frequent problem in the planning area and have been known to cause damage to utilities. The predicted wind speed given in wind warnings issued by the National Weather Service is for a one-minute average; gusts may be 25 to 30 percent higher.

Tornadoes are potentially the most dangerous of local storms, but they are not common in the planning area. If a major tornado were to strike within the populated areas of the county, damage could be widespread. Businesses could be forced to close for an extended period or permanently, fatalities could be high, many people could be homeless for an extended period, and routine services such as telephone or power could be disrupted. Buildings may be damaged or destroyed. Compared with other states, Washington ranks 43rd for frequency of tornadoes, 29th for number of deaths, 27th for injuries, and 46th for cost of damages. Based on frequency per square mile, Washington ranks 47th for the frequency of tornadoes, 32nd for fatalities, 31st for injuries per area and 47th for damage cost.

12.2.5 Warning Time

Meteorologists can often predict the likelihood of a severe storm. This can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some storms may come on more quickly and have only a few hours of warning time.

12.3 SECONDARY HAZARDS

The most significant secondary hazards associated with severe local storms are floods, falling and downed trees, landslides and downed power lines. Rapidly melting snow combined with heavy rain can overwhelm both natural and man-made drainage systems, causing overflow and property destruction. Landslides occur when the soil on slopes becomes oversaturated and fails.

12.4 CLIMATE CHANGE IMPACTS

Climate change presents a significant 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 (see Figure 12-2). 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.

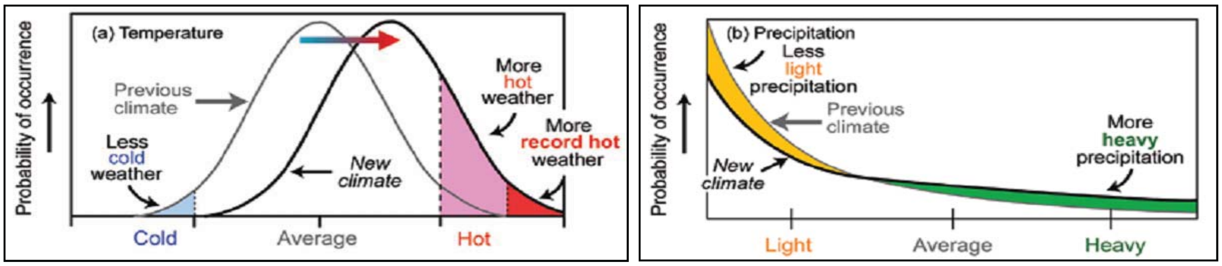


Figure 12-2. Severe Weather Probabilities in Warmer Climates

12.5 EXPOSURE

12.5.1 Population

A lack of data separating severe weather damage from flooding and landslide damage prevented a detailed analysis for exposure and vulnerability. However, it can be assumed that the entire planning area is exposed to some extent to severe weather events. Certain areas are more exposed due to geographic location and local weather patterns. Populations living at higher elevations with large stands of trees or power lines may be more susceptible to wind damage and black out, while populations in low-lying areas are at risk for possible flooding.

12.5.2 Property

According to the Kittitas County assessor, there are 18,573 buildings within the census tracts that define the planning area. Most of these buildings are residential. All of these buildings are considered to be exposed to the severe weather hazard.

12.5.3 Critical Facilities and Infrastructure

All critical facilities exposed to flooding (Chapter 10) are also likely exposed to severe weather. Additional 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 isolated. Phone, water and sewer systems may not function. Roads may become impassable due to ice or snow or from secondary hazards such as landslides.

12.5.4 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. Storm surges can erode beachfront bluffs and redistribute sediment loads.

12.6 VULNERABILITY

12.6.1 Population

Vulnerable populations are the elderly, low income or linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads. Power outages can be life threatening to those dependent on electricity for life support. Isolation of these populations is a significant concern. These populations face isolation and exposure during severe weather events and could suffer more secondary effects of the hazard.

12.6.2 Property

All property is vulnerable during severe weather events, but properties in poor condition or in particularly vulnerable locations may risk the most damage. Those in higher elevations and on ridges may be more prone to wind damage. Those that are located under or near overhead lines or near large trees may be vulnerable to falling ice or may be damaged in the event of a collapse.

Loss estimates for the severe weather hazard were developed representing 10 percent, 30 percent and 50 percent of the assessed value of exposed structures. This allows emergency managers to select a range of potential economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction. Table 12-2 lists the loss estimates to the general building stock.

TABLE 12-2.
LOSS ESTIMATES FOR BUILDINGS EXPOSED TO SEVERE WEATHER HAZARD

		Estimated Loss Potential		
	Assessed Value	10% Damage	30% Damage	50% Damage
Cle Elum	$630,479,103	$63,047,910	$189,143,731	$315,239,551
Ellensburg	$2,218,994,244	$221,899,424	$665,698,273	$1,109,497,122
Kittitas	$125,383,922	$12,538,392	$37,615,177	$62,691,961
Roslyn	$293,096,242	$29,309,624	$87,928,873	$146,548,121
South Cle Elum	$85,339,152	$8,533,915	$25,601,746	$42,669,576
Unincorporated	$5,001,535,372	$500,153,537	$1,500,460,612	$2,500,767,686
Total	**$8,354,828,036**	**$835,482,804**	**$2,506,448,411**	**$4,177,414,018**

12.6.3 Critical Facilities and Infrastructure

Incapacity and loss of roads are the primary transportation failures resulting from severe weather, mostly associated with secondary hazards. Landslides caused by heavy prolonged rains can block roads are. High winds can cause significant damage to trees and power lines, blocking roads with debris, incapacitating transportation, isolating population, and disrupting ingress and egress. Snowstorms in higher elevations can significantly 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.

Prolonged obstruction of major routes due to landslides, snow, debris or floodwaters can disrupt the shipment of goods and other commerce. Large, prolonged storms can have negative economic impacts for an entire region.

Severe windstorms, downed trees, and ice can create serious impacts on power and above-ground communication lines. Freezing of power and communication lines can cause them to break, disrupting electricity and communication. Loss of electricity and phone connection would leave certain populations isolated because residents would be unable to call for assistance.

12.6.4 Environment

The vulnerability of the environment to severe weather is the same as the exposure.

12.7 FUTURE TRENDS IN DEVELOPMENT

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 planning partners have adopted the International Building Code in response to Washington mandates. This code is equipped to deal with the impacts of severe weather events such as wind and snow loads. Land use policies identified in comprehensive plans within the planning area also address many of the secondary impacts (flood and landslide) of the severe weather hazard. With these tools, the planning partnership is well equipped to deal with future growth and the associated impacts of severe weather.

12.8 SCENARIO

The focus of severe local storms is on secondary impacts caused by flooding and landslides. However, the frequency of these storms dictates repeated response by the planning partnership. A worst-case event would involve prolonged high winds during a winter storm accompanied by thunderstorms. Such an event would have both short-term and longer-term effects. Initially, schools and roads would be closed due to power outages caused by high winds and downed tree obstructions. In more rural areas, some subdivisions could experience limited ingress and egress. Prolonged rain could produce flooding, overtopped culverts with ponded water on roads, and landslides on steep slopes. Flooding and landslides could further obstruct roads and bridges, further isolating residents.

12.9 ISSUES

Important issues associated with a severe weather in the Kittitas County 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.
- The capacity for backup power generation is limited.
- Isolated population centers.
- Public education on dealing with the impacts of severe weather.
- Snow removal
- Debris management (downed trees, etc.).

KITTITAS COUNTY

Map 12-1.
Average Annual Precipitation

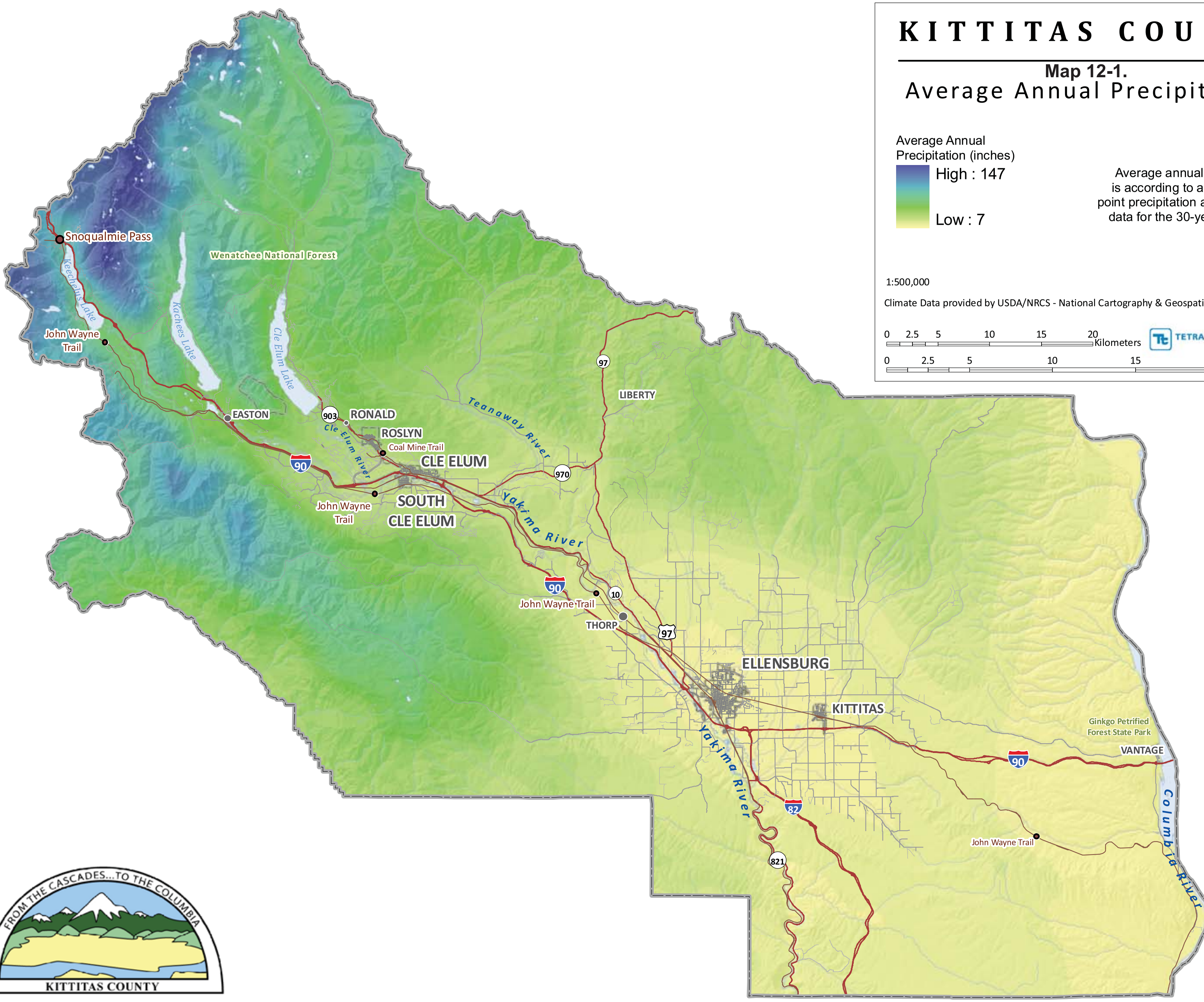
Average Annual Precipitation (inches)
High : 147
Low : 7

Average annual precipitation is according to a model using point precipitation and elevation data for the 30-year period of 1971-2000.
USDA/NRCS

1:500,000

Climate Data provided by USDA/NRCS - National Cartography & Geospatial Center

0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles

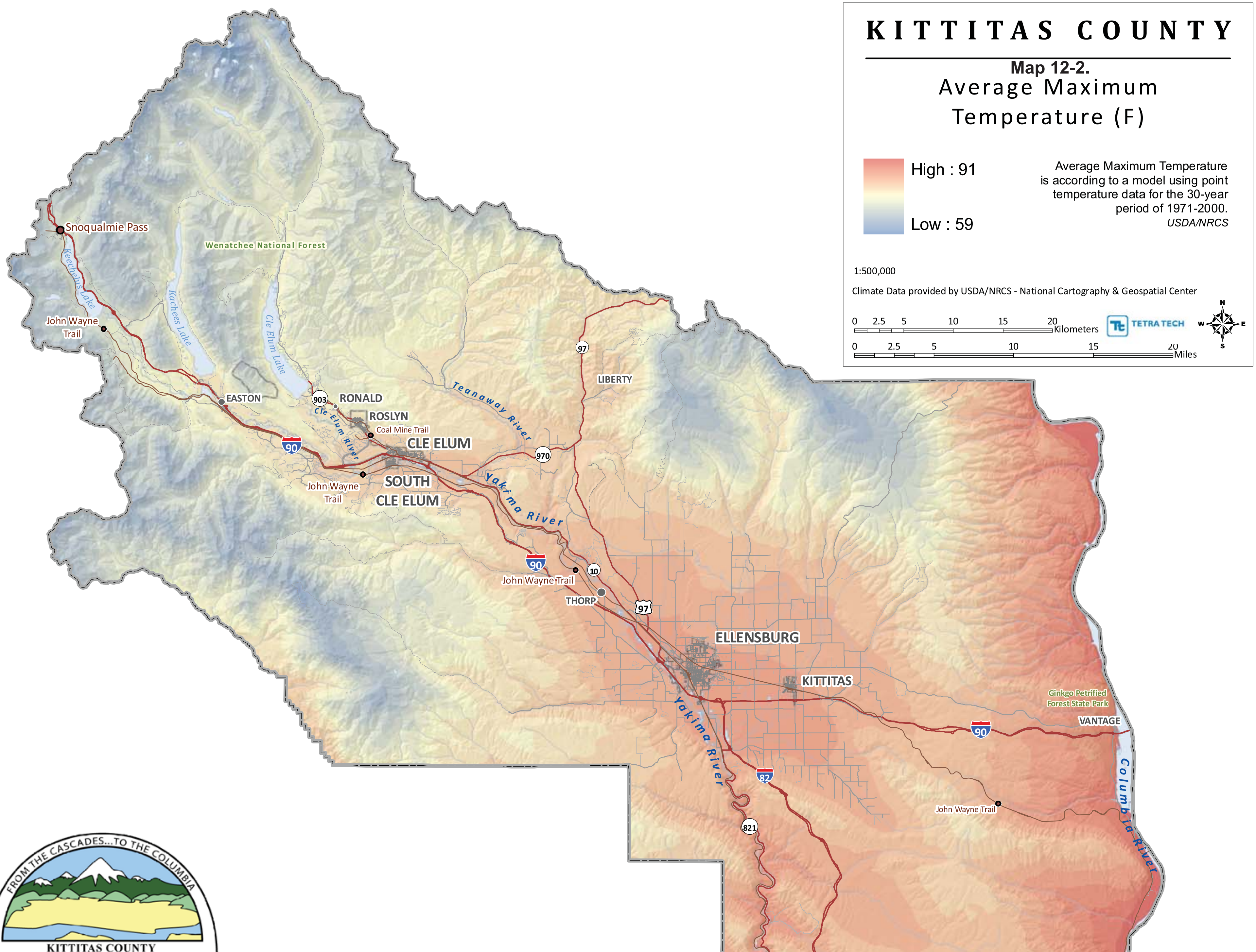


TETRA TECH

FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY

KITTITAS COUNTY

Map 12-2.
Average Maximum Temperature (F)



KITTITAS COUNTY

Map 12-3.
Average Minimum Temperature (F)

High : 25

Low : 15

Average Minimum Temperature is according to a model using point temperature data for the 30-year period of 1971-2000.
USDA/NRCS

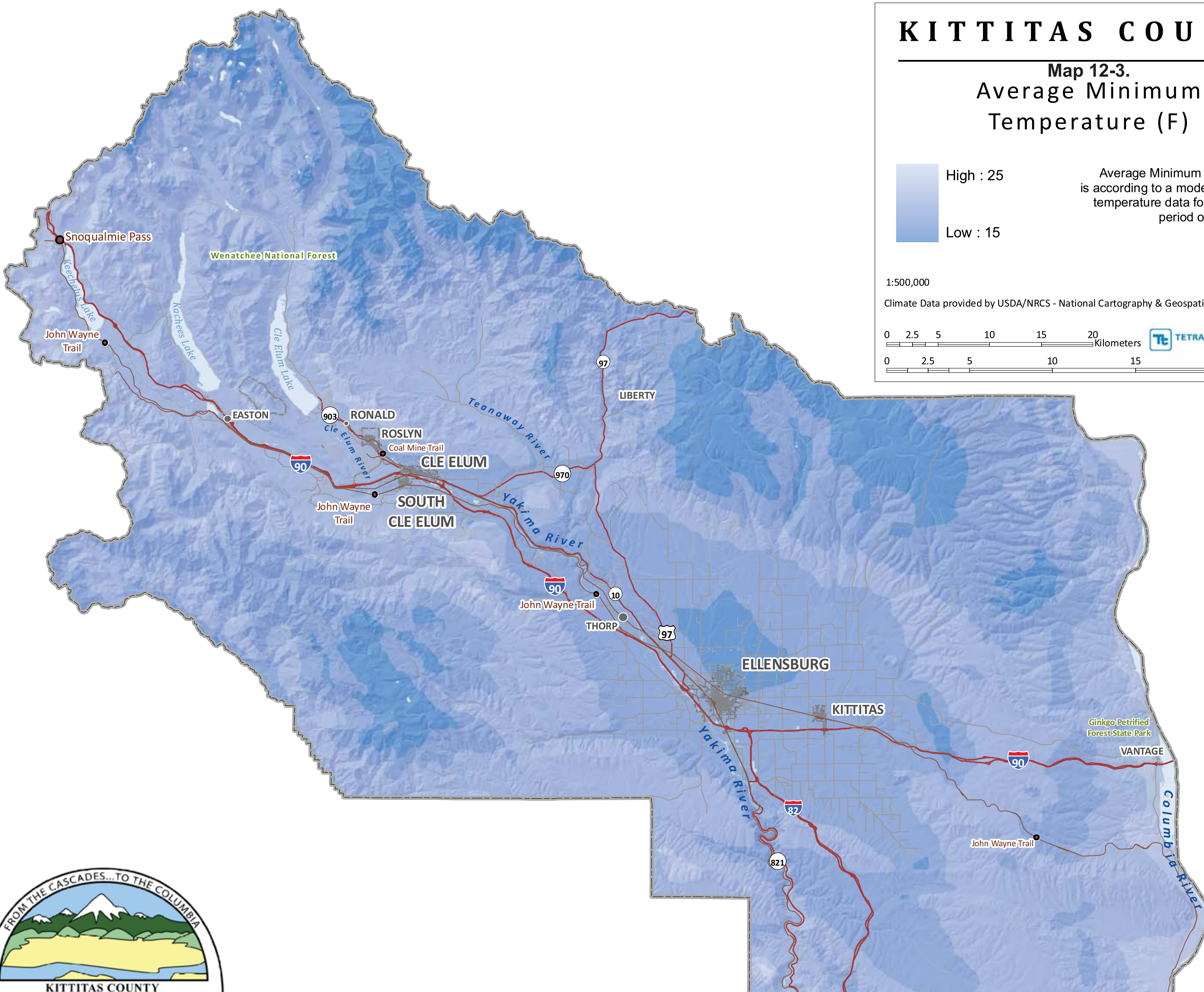
1:500,000

Climate Data provided by USDA/NRCS - National Cartography & Geospatial Center

0 2.5 5 10 15 20 Kilometers

0 2.5 5 10 15 20 Miles

TETRA TECH



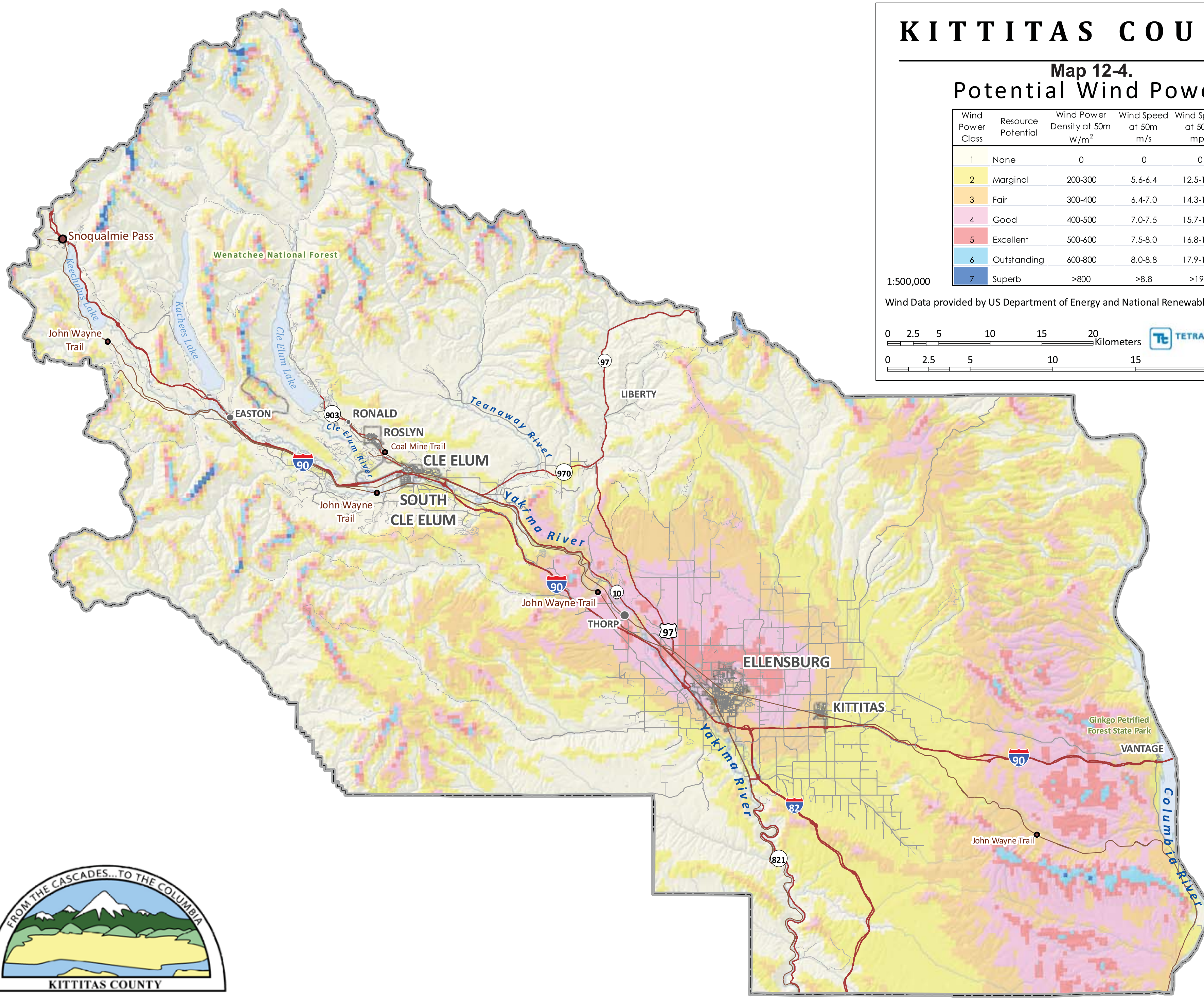
KITTITAS COUNTY

Map 12-4. Potential Wind Power

Wind Power Class	Resource Potential	Wind Power Density at 50m W/m^2	Wind Speed at 50m m/s	Wind Speed at 50m mph
1	None	0	0	0
2	Marginal	200-300	5.6-6.4	12.5-14.3
3	Fair	300-400	6.4-7.0	14.3-15.7
4	Good	400-500	7.0-7.5	15.7-16.8
5	Excellent	500-600	7.5-8.0	16.8-17.9
6	Outstanding	600-800	8.0-8.8	17.9-19.7
7	Superb	>800	>8.8	>19.7

1:500,000

Wind Data provided by US Department of Energy and National Renewable Energy Laboratory



TETRA TECH

FROM THE CASCADES...TO THE COLUMBIA

KITTITAS COUNTY

CHAPTER 13.
VOLCANO

13.1 GENERAL BACKGROUND

Hazards related to volcanic eruptions are distinguished by the different ways in which volcanic materials and other debris are emitted from the volcano. The molten rock that erupts from a volcano (lava) forms a hill or mountain around the vent. The lava may flow out as a viscous liquid, or it may explode from the vent as solid or liquid particles. Ash and fragmented rock material can become airborne and travel far from the erupting volcano to affect distant areas.

Washington State has five active volcanoes: Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens, and Mount Adams. These volcanoes are all capable of generating destructive lahars, ash fall, lava, pyroclastic flows, and debris avalanches. The phenomena that pose the greatest threat are ash fall and lahars. Mount Hood in Oregon also poses a threat to communities along the Washington side of the Columbia River. All of these volcanoes pose a high to very high threat to life, property, the environment, and civil and military aviation in areas more than a few miles from the mountains' slopes.

DEFINITIONS

Lahar—A rapidly flowing mixture of water and rock debris that originates from a volcano. While lahars are most commonly associated with eruptions, heavy rains, and debris accumulation, earthquakes may also trigger them.

Lava Flow—The least hazardous threat posed by volcanoes. Cascades volcanoes are normally associated with slow moving andesite or dacite lava.

Stratovolcano—Typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs, rising as much as 8,000 feet above their bases. The volcanoes in the Cascade Range are all stratovolcanoes.

Tephra—Ash and fragmented rock material ejected by a volcanic explosion

Volcano—A vent in the planetary crust from which magma (molten or hot rock) and gas from the earth's core erupts.

13.2 HAZARD PROFILE

13.2.1 Past Events

All five of Washington's volcanoes have been active in the last 4,000 years, with Mount St. Helens (more than a dozen eruptive events) and Glacier Peak (at least six eruptions) the most active. Mount St. Helens has been the most active in the past 40 years, with a massive eruption in 1980, followed by dome building eruptions in the 1980-1986 and 2004-present periods. In the 1980 Mount St. Helens eruption, 23 square miles of volcanic material buried the North Fork of the Toutle River and there were 57 human fatalities. All Washington volcanoes have had eruptions in the past 300 years that generated ash fall and/or lahars. Figure 13-1 and Table 13-1 summarize past eruptions in the Cascades.

13.2.2 Location

Figure 13-1 shows the location of the Cascade Range volcanoes, most of which have the potential to produce a significant eruption. The Cascade Range extends more than 1,000 miles from southern British Columbia into northern California and includes 13 potentially active volcanic peaks in the U.S.

**TABLE 13-1.
PAST ERUPTIONS IN WASHINGTON**

Volcano	Number of Eruptions	Type of Eruptions
Mount Adams	3 in the last 10,000 years, most recent between 1,000 and 2,000 years ago	Andesite lava
Mount Baker	5 eruptions in past 10,000 years; mudflows have been more common (8 in same time period)	Pyroclastic flows, mudflows, ash fall in 1843.
Glacier Peak	8 eruptions in last 13,000 years	Pyroclastic flows and lahars
Mount Rainier	14 eruptions in last 9000 years; also 4 large mudflows	Pyroclastic flows and lahars
Mount St Helens	19 eruptions in last 13,000 years	Pyroclastic flows, mudflows, lava, and ash fall

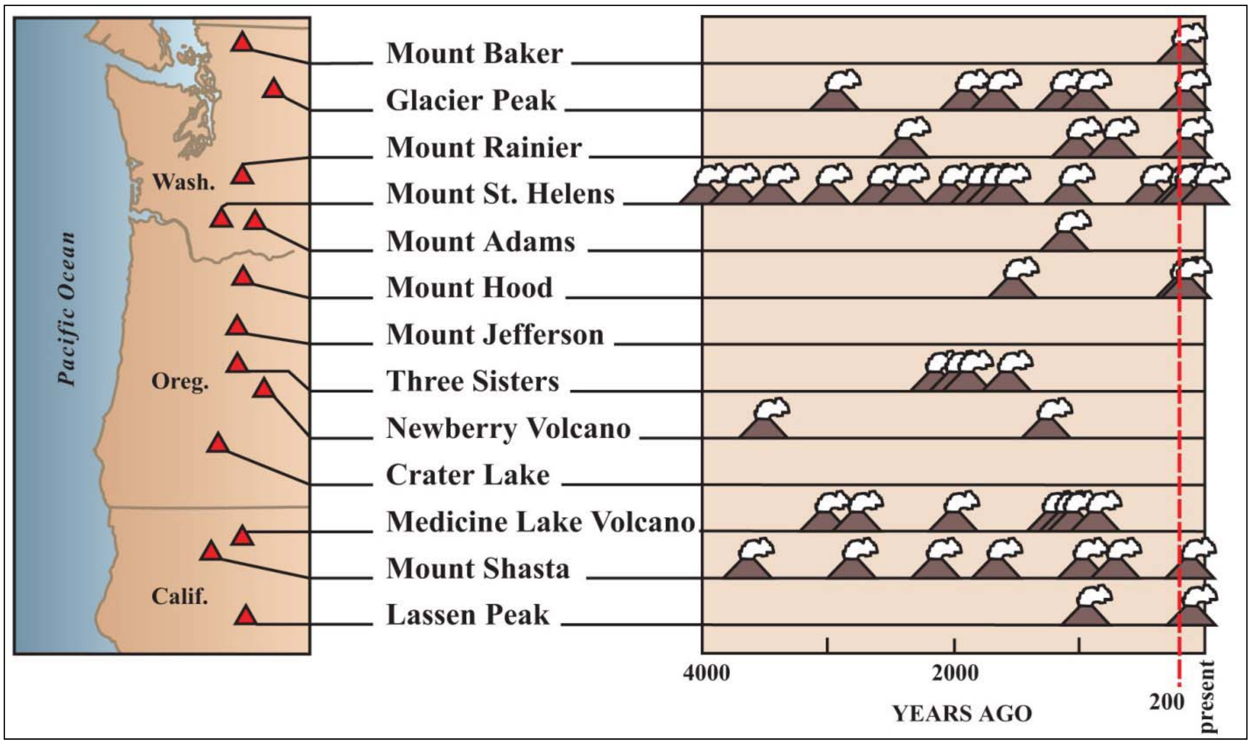


Figure 13-1. Past Eruptions in the Cascade Range

Four major Cascade volcanoes are relatively close to the Kittitas County planning area:

- Glacier Peak approximately 80 miles north-northwest of Ellensburg
- Mount Rainer approximately 58 miles west of Ellensburg
- Mount St Helens approximately 95 miles southwest of Ellensburg
- Mount Adams approximately 70 miles southwest of Ellensburg.

Mount Hood constitutes a low hazard because of distance, direction of prevailing winds, and evidence that its previous ash eruptions were confined to its immediate vicinity.

Ash Falls

Ash falls, also called "tephra," are from explosive eruptions that blast fragments of rock and ash into the air. Large fragments fall to the ground close to the volcano. Small fragments and ash can travel thousands of miles downwind and rise thousands of feet into the air. In some cases, ash can harm the human respiratory system. Heavy ash fall can create darkness. Ash can clog waterways and machinery, cause electrical short circuits, and drift into roadways, railways and runways. Ash harms mechanical and electronic equipment and can cause jet engines on aircraft to stall. The weight of ash, particularly when it becomes water saturated, can cause structural collapse. Ash carried by winds can be a hazard to machinery and transportation systems for months after an eruption.

The most serious tephra hazard in the region is from Mount St. Helens, the most prolific producer of tephra in the Cascades during the past few thousand years. Figure 17-2 provides estimates of the annual probability of tephra fall of 10 centimeters (about 4 inches) or greater affecting the region from all volcanoes. Probability zones extend farther to the east of the range than to the west because prevailing winds are from the west most of the time.

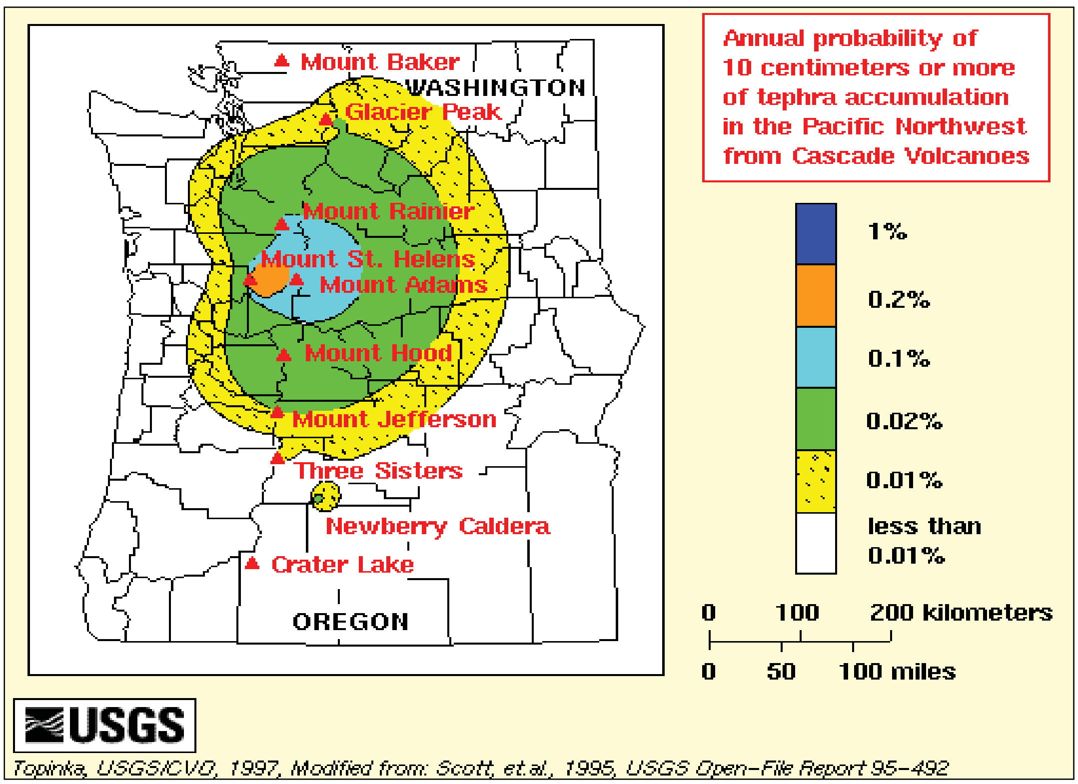


Figure 13-2. Probability of Tephra Accumulation in Pacific Northwest

13.2.3 Frequency

Many Cascade volcanoes have erupted in the recent past and will be active again in the foreseeable future. Given an average rate of one or two eruptions per century during the past 12,000 years, these disasters are not part of our everyday experience; however, in the past hundred years, California's Lassen Peak and Washington's Mount St. Helens have erupted with terrifying results. The U.S. Geological Survey classifies Glacier Peak, Mt. Adams, Mt. Baker, Mt. Hood, Mt. St. Helens, and Mt. Rainier as potentially active volcanoes in Washington State. Mt. St. Helens is by far the most active volcano in the Cascades, with four major explosive eruptions in the last 515 years.

13.2.4 Severity

The explosive disintegration of Mount St. Helens' north flank in 1980 vividly demonstrated the power that Cascade volcanoes can unleash. A 1-inch deep layer of ash weighs an average of 10 pounds per square foot, causing danger of structural collapse. Ash is harsh, acidic and gritty, and it has a sulfuric odor. Ash may also carry a high static charge for up to two days after being ejected from a volcano. When an ash cloud combines with rain, sulfur dioxide in the cloud combines with the rain water to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose, and throat.

In an assessment published in April 2005, the U.S. Geological Survey rated the threat to civil and military aviation, life, and property posed by Mount St. Helens, Mount Rainier, Mount Baker and Glacier Peak to be "very high," the highest classification. The report rated the threat posed by Mount Adams as "high."

13.2.5 Warning Time

Constant monitoring of all active volcanoes means that there will be more than adequate time for evacuation before an event. Since 1980, Mount St. Helens has settled into a pattern of intermittent, moderate and generally non-explosive activity, and the severity of tephra, explosions, and lava flows have diminished. All episodes, except for one very small event in 1984, have been successfully predicted several days to three weeks in advance. However, scientists remain uncertain as to whether the volcano's current cycle of explosivity ended with the 1980 explosion. The possibility of further large-scale events continues for the foreseeable future.

13.3 SECONDARY HAZARDS

The secondary hazards associated with volcanic eruptions are mud flows and landslides.

13.4 CLIMATE CHANGE IMPACTS

Large-scale volcanic eruptions can reduce the amount of solar radiation reaching the Earth's surface, lowering temperatures in the lower atmosphere and changing atmospheric circulation patterns. The massive outpouring of gases and ash can influence climate patterns for years. Sulfuric gases convert to sub-micron droplets containing about 75 percent sulfuric acid. These particles can linger three to four years in the stratosphere. Volcanic clouds absorb terrestrial radiation and scatter a significant amount of incoming solar radiation, an effect that can last from two to three years following a volcanic eruption.

13.5 EXPOSURE AND VULNERABILITY

According to the Washington State Enhanced Hazard Mitigation Plan, Kittitas County has exposure to ash fall from any of the active volcanos in the region. The plan estimates that Kittitas County has a 1 in 1,000 chance of receiving 10 centimeters (4 inches) of ash fall each year.

13.5.1 Population

The whole population of Kittitas County is exposed to the effects of a tephra. The populations most vulnerable to the effects of a tephra are the elderly, the very young and those already experiencing ear, nose and throat problems. Homeless people, who may lack adequate shelter, are also vulnerable to the effects of a tephra fall, although Whitman County has few, if any, homeless people who would not be able to find adequate shelter or assistance during an event.

13.5.2 Property

All of the property and infrastructure exposed to nature in the county is exposed to the effects of a tephra fall. Vulnerable property includes equipment and machinery left out in the open, such as combines, whose parts can become clogged by the fine dust. Since Kittitas County receives snow every year, and roofs are built to withstand snow loads, most roofs are not vulnerable and would be able to withstand the potential load of ash. Infrastructure, such as drainage systems, is potentially vulnerable to the effects of a tephra fall, since the fine ash can clog pipes and culverts. This may be more of a problem if an eruption occurs during winter or early spring when precipitation is highest and floods are most likely.

To estimate the loss potential for this hazard, a qualitative approach was used, based on recommendations from FEMA guidelines on state and local mitigation planning. Loss estimation tools such as HAZUS-MH currently do not have the ability to analyze impacts from volcano hazards. For this study, it was decided to use 0.1 percent as the loss ratio for the volcano hazard. Assessed valuations provided by the Kittitas County assessor were the basis for these estimations. The results are summarized in Table 13-2.

TABLE 13-2.
ASH FALL (TEPHRA) LOSS ESTIMATION

	Assessed Value	Estimated Loss Potential @ 0.1% Damage
Cle Elum	$630,479,103	$630,479
Ellensburg	$2,218,994,244	$2,218,994
Kittitas	$125,383,922	$125,384
Roslyn	$293,096,242	$293,096
South Cle Elum	$85,339,152	$85,339
Unincorporated	$5,001,535,372	$5,001,535
Total	**$8,354,828,036**	**$8,354,828**

13.5.3 Critical Facilities

All transportation routes are exposed to tephra accumulation, which could create hazardous driving conditions on roads and highways and hinder evacuations and response. Machinery and equipment using these transportation routes would also be vulnerable. Visibility in the short aftermath of an eruption would also be problematic.

13.5.4 Environment

The environment is highly exposed to the effects of a volcanic eruption. Even if the related ash fall from a volcanic eruption were to fall elsewhere, it could still be spread throughout the county by the surrounding rivers and streams. A volcanic blast would expose the local environment to many effects such as lower air quality, and many other elements that could harm local vegetation and water quality. The sulfuric acid contained in volcanic ash could be very damaging to area vegetation, waters, wildlife and air quality.

13.6 FUTURE TRENDS IN DEVELOPMENT

All future development within the planning area will be susceptible to the potential impacts from volcanic eruptions within the region. While this potential impact on the built environment is not considered to be significant, the economic impact on industries that rely on machinery and equipment such as agriculture or civil engineering projects could be significant. Since the extent and location of this hazard is difficult to gauge because it is dependent upon many variables, the ability to institute land use recommendations based on potential impacts of this hazard is limited. While the impacts of volcanic hazards are sufficient to warrant risk assessment for emergency management purposes, the impacts are not considered to be sufficient to dictate land use decisions.

13.7 SCENARIO

Any eruption of Washington's five Cascade Range volcanoes would likely produce significant amounts of ash fall that could impact the planning area. This impact is totally dependent upon the prevailing wind direction during and after the event. No one in the planning area would likely be injured or killed from these events, but businesses and non-essential government would be closed until the cloud passes. People and animals without shelter would be affected. Structures would be safe, but private property left out in the open, such as farm equipment, might be damaged by the fine ash dust. Clean-up from such an event could be costly, depending upon the magnitude of the event.

13.8 ISSUES

Since volcanic episodes have been fairly predictable in the recent past, there is not much concern about loss of life, but there is concern about loss of property and infrastructure and severe environmental impacts.

CHAPTER 14.
WILDFIRE

14.1 GENERAL BACKGROUND

The wildfire season in Washington usually begins in early July and ends with precipitation in late September, but wildfires have occurred in every month of the year. Drought, snow pack, and local weather conditions can affect the length of the fire season. How a fire behaves primarily depends on the following:

- **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 trees that are diseased, dying, or dead present special hazards. 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**—Strong, dry winds in late summer and early fall produce extreme fire conditions. Wind events can persist up to 48 hours, with wind speed reaching 60 miles per hour; these winds generally reach peak velocities during the night and early morning.
- **Thunderstorm activity**—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.
- **Terrain**—Topography influences the amount and moisture of fuel; the impact of weather conditions; barriers to fire spread, such as highways and lakes; and land elevation and slope. Fire spreads uphill more easily than downhill, and the steeper the slope, the faster the fire travels. Fires travel in the direction of the ambient wind, which usually flows uphill. A wildfire is also able to preheat the fuel further up the hill because the smoke and heat are rising in that direction which, in turn, increases the fire's speed.
- **Time of Day**—A fire's peak burning period generally is between 1 p.m. and 6 p.m.

People start most wildfires through arson, recreational fires that get out of control, smoker carelessness, debris burning, or children playing with fire. From 1992 to 2001, on average, people caused more than 500 wildfires each year on state-owned or protected lands, compared to 135 fires caused by lightning.

DEFINITIONS

Conflagration—A fire that grows beyond its original source area to engulf adjoining regions. Wind, extremely dry or hazardous weather conditions, excessive fuel buildup and explosions are usually the elements behind a wildfire conflagration.

Firestorm—A fire that expands to cover a large area, often more than a square mile. A firestorm usually occurs when many individual fires grow together into one. The involved area becomes so hot that all combustible materials ignite, even if they are not exposed to direct flame. Temperatures may exceed 1000°C. Hot gases rise over the fire zone, drawing winds in from all sides at velocities as high as 50 miles per hour. Firestorms seldom spread because of the inward direction of the winds, but there is no known way of stopping them. Within the area of the fire, lethal concentrations of carbon monoxide are present; combined with the intense heat, this poses a serious life threat to responding fire forces. In very large events, the rising column of heated air and combustion gases carries enough particulate matter into the upper atmosphere to cause cloud nucleation, creating a locally intense thunderstorm and the hazard of lightning strikes.

Interface Area—An area susceptible to wildfires and where wildland vegetation and urban or suburban development occur together. An example would be smaller urban areas and dispersed rural housing in forested areas.

Wildfire—Fires that result in uncontrolled destruction of forests, brush, field crops, grasslands, and real and personal property in non-urban areas. Because of their distance from firefighting resources, they can be difficult to contain and can cause a great deal of destruction.

Still, wildfires started by lightning burn more state-protected acreage than any other cause, an average of 10,866 acres annually; human-caused fires burn an average of 4,404 state-protected acres each year. 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.

14.2 HAZARD PROFILE

14.2.1 Physical Conditions

Fuels

Fuels that contribute to wildfires in Kittitas County range from sagebrush/grass to various types of conifers in the upper county. Fire exclusion and lack of thinning have resulted in dense stands of vegetation that act as ladder fuels. In the lower elevations, sagebrush, grass and weed areas provide fuel for wildfire spread and increased intensity. Drought, combined with these vegetation types, provides additional dead vegetation to fuel future wildfires. Other fuels are slash from logging and clearing for development. Homes in the wildland urban interface (WUI) are also fuel.

Weather

High temperatures in Kittitas County during wildfire season dry out fuel sources, allowing fuels to ignite and burn faster. Low humidity and lack of precipitation also increase the chance of wildfire ignition. The dry windy weather of Kittitas County can cause wildfires to grow quickly and can carry firebrands a mile or more from the original fire. Drought conditions must be taken into consideration, because drying vegetation can ignite and burn more easily.

Insect Damage

Mortality caused by the western pine beetle may be increasing over historical levels. With more small Ponderosa pine present, moisture competition is high, which results in small stands that are of poor vigor. This can cause an increase of beetle infestation. Once the infestation begins in the small trees, they often attack large healthy Ponderosa pine still present in the stand. Western pine beetle is now the most common tree-killing beetle in second growth Ponderosa pine stands on the Wenatchee National Forest. Pole and small saw timber-sized trees, especially those in dense stands, are also affected. These trees are important for future replacement of the older Ponderosa pine removed by past harvesting.

Douglas fir beetle attacks have also become more frequent. Trees defoliated by the western spruce budworm are especially susceptible to attack by this insect. Some of the most serious damage occurs in riparian areas, putting these sensitive ecosystems at increased risk to future fires because an attack by certain insects can leave large patches of dead trees which dry out and will more easily ignite (Mason Community Countywide Fire Protection Plan, 2005).

14.2.2 Wildland Urban Interface

Wildland urban interface areas are areas that lack adequate fire flow and areas outside a fire district. In heavily timbered mountainous regions or sparsely populated areas, each jurisdiction designates additional WUI areas. As more development extends deeper into these regions, the risk of wildfire interacting with these residences increases. A WUI analysis conducted by the National Fire Protection Association for Kittitas County suggested that 33 percent of the region is classified as “high risk” for wildfire. Parcel delineation activity from 2001-2006 showed that approximately 60 percent of new parcels fall within the high-risk WUI areas (McColl, 2007).

14.2.3 Past Events

Kittitas County has a rich fire history, but according to the Washington State Enhanced Hazard Mitigation Plan, the county has received no state or federal disaster declarations for wildfire since 1950. Figure 14-1 and Figure 14-2 summarize wildfires that occurred from 1972 through 2008 on lands in the county protected by the Washington Department of Natural Resources.

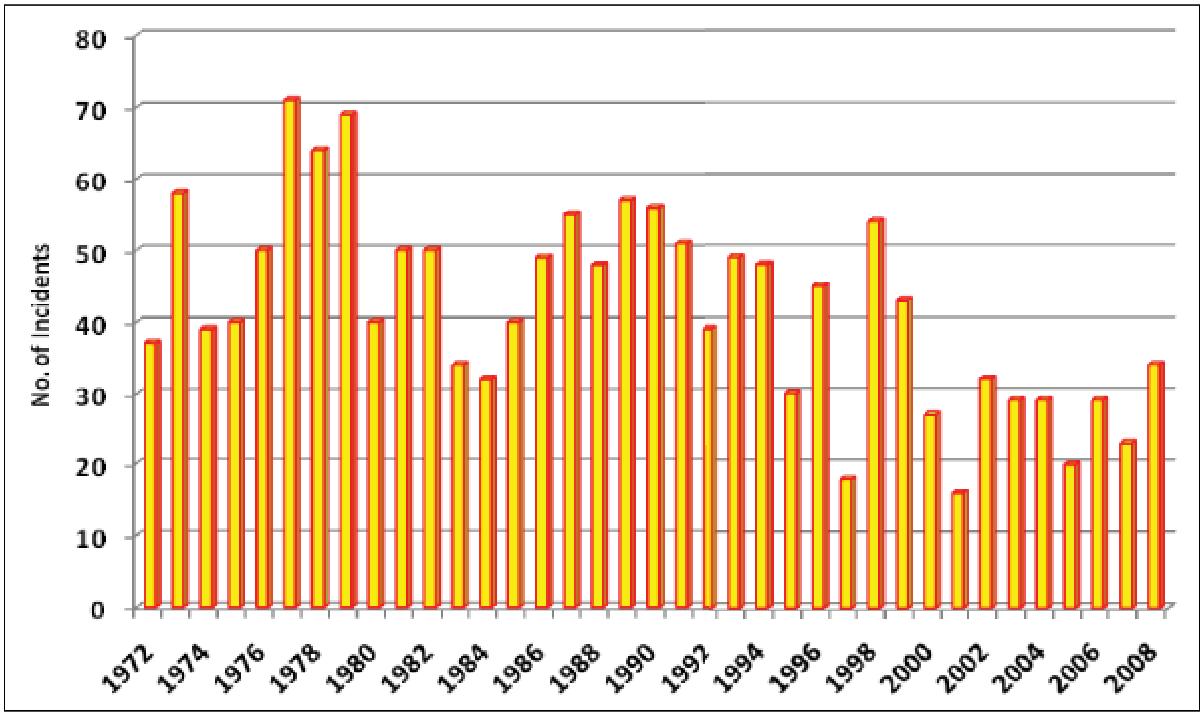


Figure 14-1. Wildfire Incidents in Kittitas County, 1972-2008

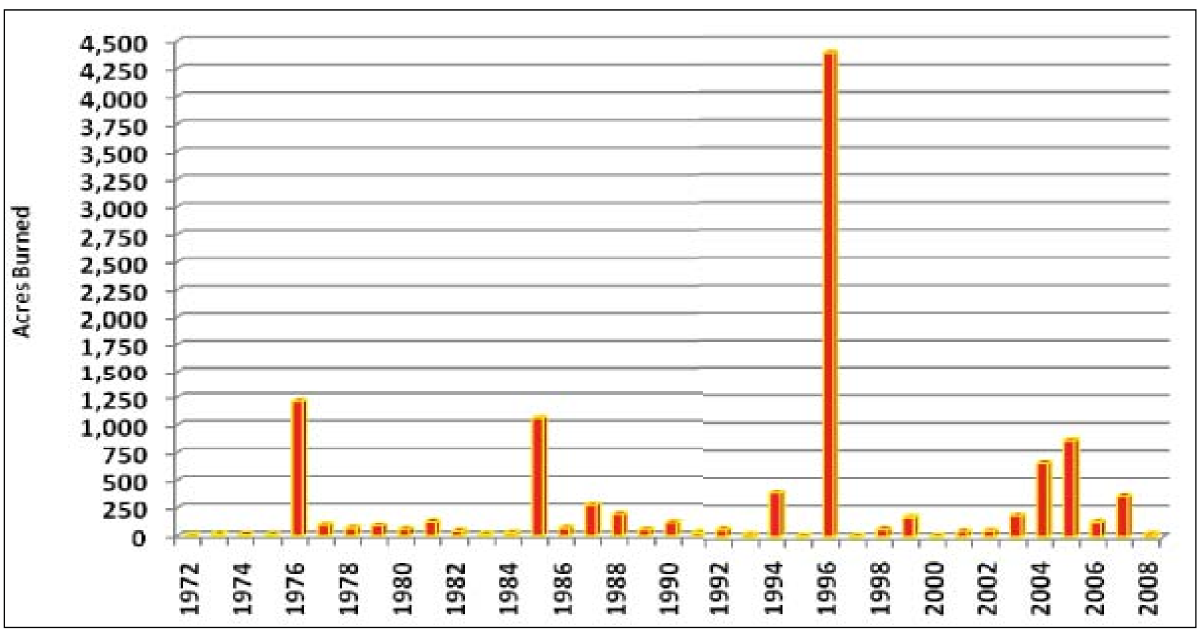


Figure 14-2. Total Acres Burned Annually by Wildfire in Kittitas County, 1972 – 2008

14.2.4 Location

Two types of mapping produced by the Washington Department of Natural Resources have been used to identify the location of the wildfire hazard: wildfire hazard area mapping and fire regime mapping.

Wildfire Hazard Area Mapping

Map 14-1 shows wildfire hazard areas, based on data from the National Fire Protection Association risk assessment (NFPA 299). The NFPA 299 hazard ranking process scores the risk and vulnerability of a planning area by looking at the following components:

- Subdivision design (ingress, egress, road width, road condition, fire service access, signage)
- Vegetation
- Topography
- Other rating factors (weather, history, building separation)
- Roofing material
- Building condition
- Available fire protection (water supply, response time, fire protection systems)
- Utilities.

Planning areas are ranked as a low, moderate, high or extreme hazard areas, based on their score. Wildfire analysis was done using WUI data created by the Department of Natural Resources, which analyzed areas with population densities of at least 20 people per square mile.

Fire Regime Mapping

Map 14-2 shows fire regimes in Kittitas County. Five fire regimes are classified based on average number of years between fires and the severity (amount of replacement) of the fire on the dominant overstory vegetation:

- 0- to 35-year frequency and low (surface fires most common) to mixed severity (less than 75 percent of the dominant overstory vegetation replaced)
- 0- to 35-year frequency and high (stand replacement) severity (greater than 75 percent of the dominant overstory vegetation replaced)
- 35- to >100-year frequency and mixed severity
- 35- to >100-year frequency and high (stand replacement) severity
- >200-year frequency and high (stand replacement) severity.

14.2.5 Frequency

Natural fire rotation (NFR) is defined as the number of years necessary for fires to burn over an area equal to that of the study area. NFR is calculated from the historical record of fires by dividing the length of the record period in years by the percentage of total area burned during that period. Since 1990, Kittitas County has seen an average of 36 wildfires per year, totaling about 500 acres burned each year. This yields an NFR for Kittitas County of 2,571 years. According to the national Landfire database prepared by the U.S. Departments of Interior and Agriculture, the average burn recurrence interval for the planning area is 65 years. This represents the average period between fires under a presumed historical fire regime.

14.2.6 Severity

Potential losses from wildfire include human life, structures and other improvements, and natural resources. There are no recorded incidents of loss of life from wildfires in Kittitas County. Given the immediate response times to reported fires, the likelihood of injuries and casualties is minimal. Smoke and air pollution from wildfires can be a health hazard, especially for sensitive populations including children, the elderly and those with respiratory and cardiovascular diseases. Wildfire may also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke. In addition, wildfire can lead to ancillary impacts such as landslides in steep ravine areas and flooding due to the impacts of silt in local watersheds.

14.2.7 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.

If a fire does break out and spread rapidly, residents may need to evacuate within days or hours. A fire's peak burning period generally is between 1 p.m. and 6 p.m. Once a fire has started, fire alerting is reasonably rapid in most cases. The rapid spread of cellular and two-way radio communications in recent years has further contributed to a significant improvement in warning time.

14.3 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.

14.4 CLIMATE CHANGE IMPACTS

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.

14.5 EXPOSURE

14.5.1 Population

Population could not be examined directly by wildfire regime zones because census blocks do not coincide with the zones. However, population was estimated using the residential building count in each zone and applying the census value of 2.32 persons per household for Kittitas County. The results are shown in Table 14-1.

**TABLE 14-1.
POPULATION ESTIMATES WITHIN FIRE REGIME ZONES**

	0- to 35-Year, Low/Mixed Severity		0- to 35-Year, Stand Replacement		All Other Wildfire Regimes	
	Residential Buildings	Population	Residential Buildings	Population	Residential Buildings	Population
Cle Elum	430	998	459	1,065	0	0
Ellensburg	0	0	4,595	10,660	0	0
Kittitas	0	0	440	1,021	0	0
Roslyn	607	1,408	0	0	0	0
South Cle Elum	255	592	0	0	0	0
Unincorporated	4,364	10,124	4,990	11,577	638	1,480
Total	**5,656**	**13,122**	**10,484**	**24,323**	**638**	**1,480**

14.5.2 Property

Property damage from wildfires can be severe and can significantly alter entire communities. The number and value of homes in the various fire regime zones within the planning area are summarized in Table 14-2 through Table 14-4. Table 14-5 shows the general zoning of parcels exposed to the wildfire hazard in the unincorporated portions of the county.

**TABLE 14-2.
PLANNING AREA STRUCTURES EXPOSED TO 0- TO 35-YEAR,
LOW/MIXED SEVERITY FIRE REGIME**

Jurisdiction	Buildings Exposed	Assessed Value Structure	Assessed Value Contents	Assessed Value Total	% of AV
Cle Elum	501	$132,103,392	$113,991,564	**$246,094,957**	39.0%
Ellensburg	0	0	0	**0**	0.0%
Kittitas	0	0	0	**0**	0.0%
Roslyn	705	$159,134,400	$133,961,841	**$293,096,242**	100.0%
South Cle Elum	270	$47,341,998	$37,997,154	**$85,339,152**	100.0%
Unincorporated	4,483	$1,410,319,813	$1,129,311,513	**$2,539,631,326**	51.1%
Total	**5,959**	**$1,748,899,604**	**$1,415,262,073**	**$3,164,161,677**	**38.0%**

**TABLE 14-3.
PLANNING AREA STRUCTURES EXPOSED TO 0- TO 35-YEAR,
STAND REPLACEMENT FIRE REGIME**

Jurisdiction	Buildings Exposed	Assessed Value Structure	Assessed Value Contents	Assessed Value Total	% of AV
Cle Elum	790	$195,523,610	$188,860,536	**$384,384,146**	61.0%
Ellensburg	5,437	$1,183,099,939	$1,035,894,305	**$2,218,994,244**	100.0%
Kittitas	514	$67,904,817	$57,479,105	**$125,383,922**	100.0%
Roslyn	0	0	0	**0**	0.0%
South Cle Elum	0	0	0	**0**	0.0%
Unincorporated	5,163	$1,167,383,547	$898,551,042	**$2,065,934,589**	41.1%
Total	**11,904**	**$2,613,911,914**	**$2,180,784,988**	**$4,794,696,902**	**57.6%**

**TABLE 14-4.
PLANNING AREA STRUCTURES EXPOSED TO ALL OTHER FIRE REGIMES**

Jurisdiction	Buildings Exposed	Assessed Value Structure	Assessed Value Contents	Assessed Value Total	% of AV
Cle Elum	0	0	0	**0**	0.00%
Ellensburg	0	0	0	**0**	0.00%
Kittitas	0	0	0	**0**	0.00%
Roslyn	0	0	0	**0**	0.00%
South Cle Elum	0	0	0	**0**	0.00%
Unincorporated	710	$217,114,715	$178,854,742	**$395,969,457**	8.0%
Total	**710**	**$217,114,715**	**$178,854,742**	**$395,969,457**	**4.8%**

**TABLE 14-5.
GENERAL ZONING WITHIN THE WILDFIRE REGIMES (UNINCORPORATED COUNTY)**

	Low Severity (0 – 35 years)		Stand Replacement (0 – 35 years)		All Other Wildfire Regimes	
Zoning	Area (acres)	% of total	Area (acres)	% of total	Area (acres)	% of total
Agriculture	45,153	3.07%	279,520	18.98%	145,724	9.90%
Commercial	349	0.02%	209	0.01%	284	0.02%
Commercial Forest	468,845	31.84%	22,812	1.55%	234,262	15.91%
Flooded	0	0.00%	0	0.00%	791	0.05%
Forest & Range	55,387	3.76%	114,668	7.79%	29,936	2.03%
Historic	17	0.00%	0	0.00%	0	0.00%
Industrial	107	0.01%	2,096	0.14%	9	0.00%
Master Planned Resort	4,953	0.34%	1,253	0.09%	0	0.00%
Planned Unit Development	910	0.06%	160	0.01%	237	0.02%
Public	20	0.00%	0	0.00%	0	0.00%
Residential	20,181	1.37%	7,970	0.54%	2,710	0.18%
Right of Way	11,078	0.75%	10,983	0.75%	5,200	0.35%
Wind Farm Overlay	3,723	0.25%	4,791	0.33%	0	0.00%
Total	**610,722**	**42%**	**444,462**	**30%**	**419,153**	**28%**

14.5.3 Critical Facilities and Infrastructure

Table 14-6 identifies critical facilities exposed to the wildfire hazard in the county. During a wildfire event, these materials 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 they could leak into surrounding areas, saturating soils and seeping into surface waters, and have a disastrous effect on the environment.

In the event of wildfire, there would likely be little damage to the majority of infrastructure. Most road and railroads would be without damage except in the worst scenarios. Power lines are the most at risk to wildfire because most are made of wood and susceptible to burning. In the event of a wildfire, pipelines could provide a source of fuel and lead to a catastrophic explosion.

14.5.4 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.

**TABLE 14-6.
CRITICAL FACILITIES EXPOSED TO WILDFIRE REGIMES**

	Low Severity (0 – 35 years)	Stand Replacement (0 – 35 years)	All Other Wildfire Regimes
Medical and Health Services	4	19	0
Government Function	4	27	0
Protective Function	24	34	9
Schools	5	11	0
Other Critical Function	10	4	1
Bridges	83	138	15
Water	15	19	3
Wastewater	2	3	1
Power	1	9	12
Communications	1	8	0
Total	**149**	**272**	**41**

- 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.

Many ecosystems are adapted to historical patterns of fire occurrence. These patterns, called “fire regimes,” include temporal attributes (e.g., frequency and seasonality), spatial attributes (e.g., size and spatial complexity), and magnitude attributes (e.g., intensity and severity), each of which have ranges of natural variability. Ecosystem stability is threatened when any of the attributes for a given fire regime diverge from its range of natural variability.

14.6 VULNERABILITY

Structures, above-ground infrastructure, critical facilities and natural environments are all vulnerable to the wildfire hazard. There is currently no validated damage function available to support wildfire mitigation planning. Except as discussed in this section, vulnerable populations, property, infrastructure and environment are assumed to be the same as described in the section on exposure.

14.6.1 Population

There are no recorded incidents of loss of life from wildfires within the planning area. Given the immediate response times to reported fires, the likelihood of injuries and casualties is minimal; therefore, injuries and casualties were not estimated for the wildfire hazard.

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. 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 may also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke.

14.6.2 Property

Loss estimations for the wildfire hazard are not based on damage functions, because no such damage functions have been generated. Instead, loss estimates were developed representing 10 percent, 30 percent and 50 percent of the assessed value of exposed structures. This allows emergency managers to select a range of economic impact based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 14-7 lists the loss estimates for the general building stock for jurisdictions that have an exposure to the wildfire hazard.

TABLE 14-7.
LOSS ESTIMATES FOR BUILDINGS EXPOSED TO WILDFIRE HAZARD

		Estimated Loss Potential		
	Assessed Value[a]	10% Damage	30% Damage	50% Damage
Cle Elum	$630,479,103	$63,047,910	$189,143,731	$315,239,551
Ellensburg	$2,218,994,244	$221,899,424	$665,698,273	$1,109,497,122
Kittitas	$125,383,922	$12,538,392	$37,615,177	$62,691,961
Roslyn	$293,096,242	$29,309,624	$87,928,873	$146,548,121
South Cle Elum	$85,339,152	$8,533,915	$25,601,746	$42,669,576
Unincorporated	$5,001,535,372	$500,153,537	$1,500,460,612	$2,500,767,686
Total	**$8,354,828,036**	**$835,482,804**	**$2,506,448,411**	**$4,177,414,018**

a. Sum of assessed value totals from Table 14-2, Table 14-3 and Table 14-4

14.6.3 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. Power lines are the most at risk from wildfire because most poles are made of wood and susceptible to burning. Fires can create conditions that block or prevent access and can isolate residents and emergency service providers. Wildfire typically does not have a major direct impact on bridges, but it can create conditions in which bridges are obstructed. Many bridges in areas of high to moderate fire risk are important because they provide the only ingress and egress to large areas and in some cases to isolated neighborhoods.

14.7 FUTURE TRENDS IN DEVELOPMENT

The highly urbanized portions of the planning area have little or no wildfire risk exposure. Urbanization tends to alter the natural fire regime, and can create the potential for the expansion of urbanized areas into wildland areas. The expansion of the wildland urban interface can be managed with strong land use and building codes. The planning area is well equipped with these tools and this planning process has asked each planning partner to assess its capabilities with regards to the tools. As Kittitas County experiences future growth, it is anticipated that the exposure to this hazard will remain as assessed or even decrease over time due to these capabilities.

14.8 SCENARIO

A major conflagration in Kittitas County might begin with a wet spring, adding to fuels already present on the forest floor. Flashy fuels would build throughout the spring. The summer could see the onset of insect infestation. A dry summer could follow the wet spring, exacerbated by dry hot winds. Carelessness with combustible materials or a tossed lit cigarette, or a sudden lighting storm could trigger a multitude of small isolated fires.

The embers from these smaller fires could be carried miles by hot, dry winds. The deposition zone for these embers would be deep in the forests and interface zones. Fires that start in flat areas move slower, but wind still pushes them. It is not unusual for a wildfire pushed by wind to burn the ground fuel and later climb into the crown and reverse its track. This is one of many ways that fires can escape containment, typically during periods when response capabilities are overwhelmed. These new small fires would most likely merge. Suppression resources would be redirected from protecting the natural resources to saving more remote subdivisions.

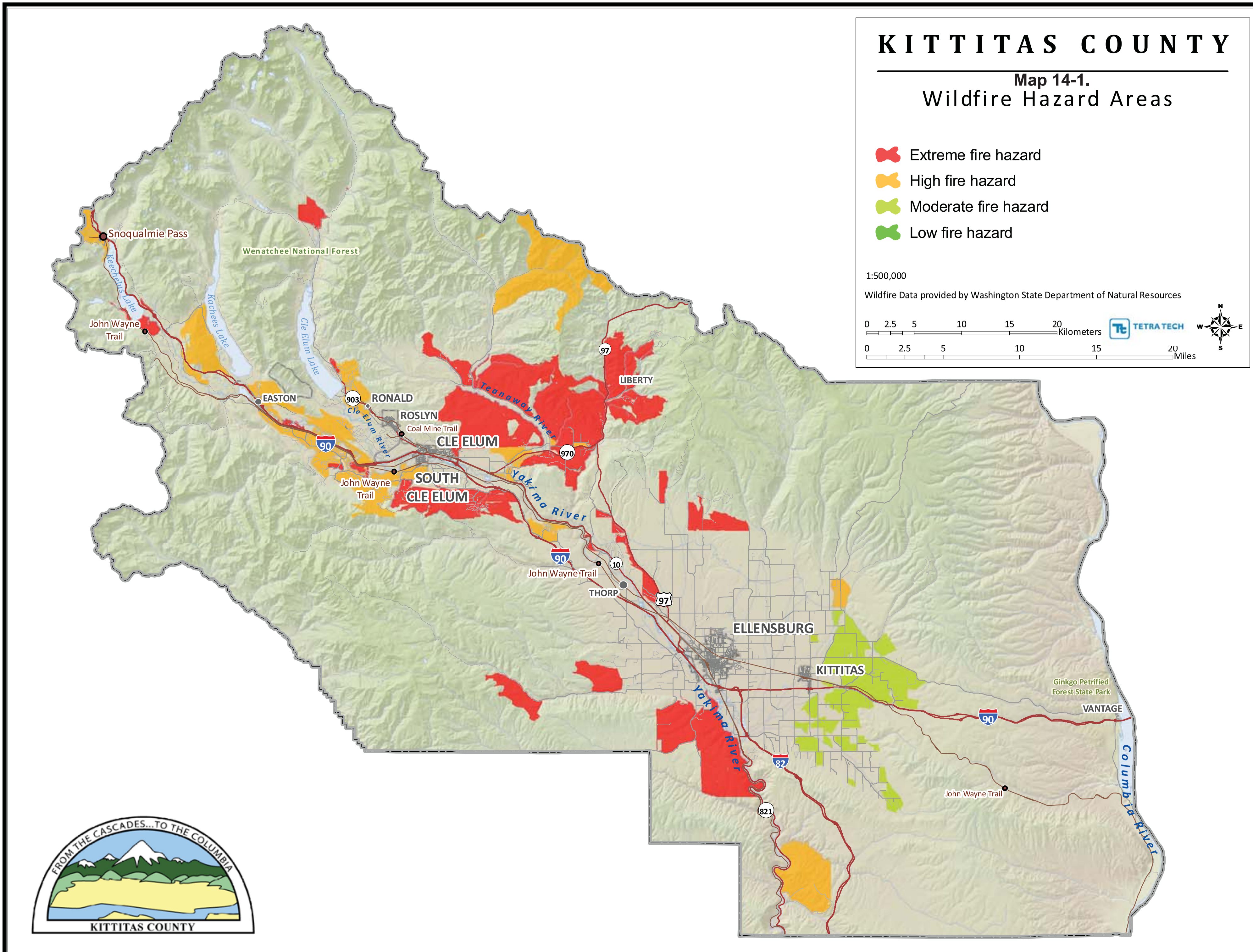
The worst-case scenario would include an active fire season throughout the American west, spreading resources thin. Firefighting teams would be exhausted or unavailable. Many federal assets would be responding to other fires that started earlier in the season. While local fire districts would be extremely 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.

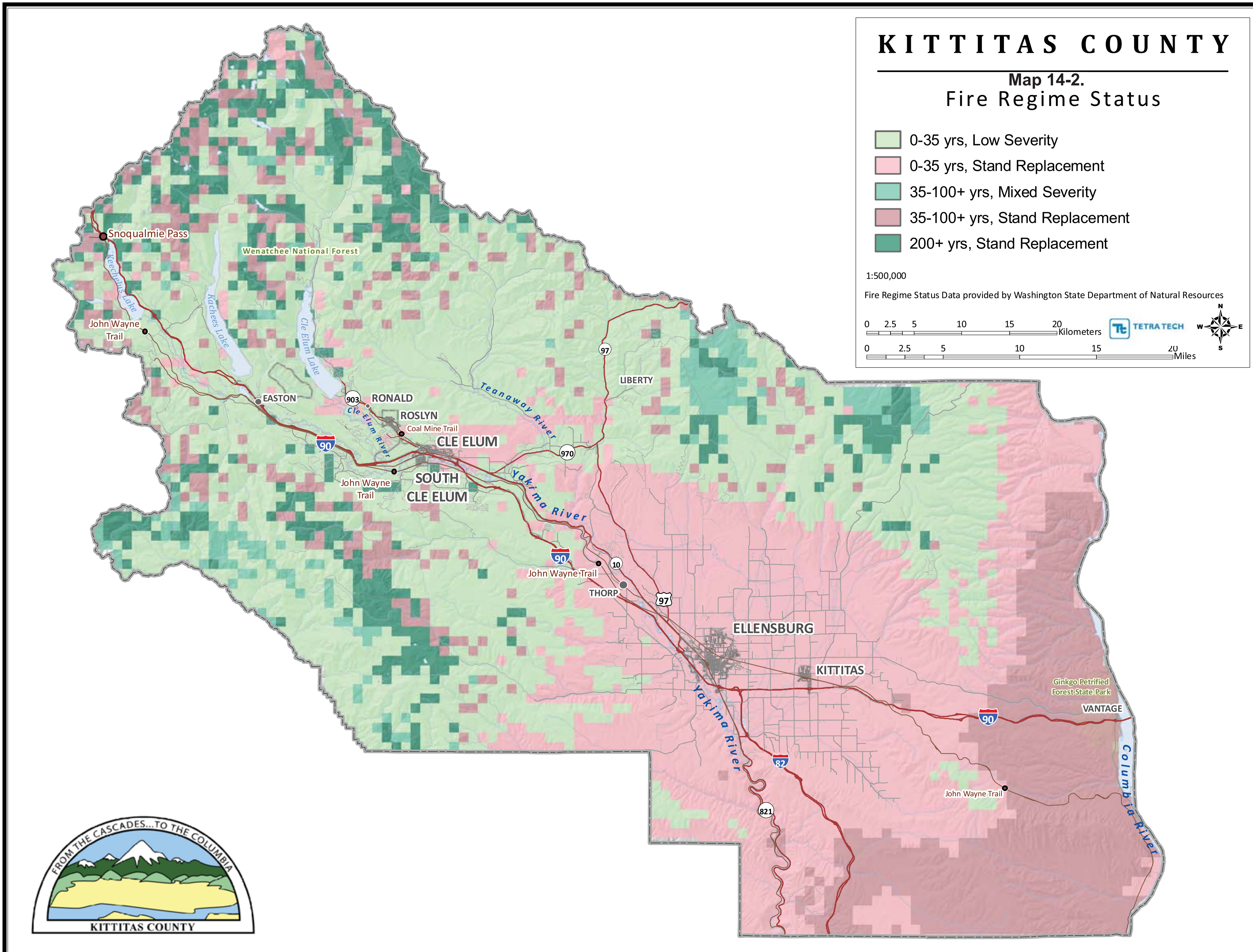
To further complicate the problem, heavy rains could follow, causing flooding and landslides and releasing tons of sediment into rivers, permanently changing floodplains and damaging sensitive habitat and riparian areas. Such a fire followed by rain could release millions of cubic yards of sediment into streams for years, creating new floodplains and changing existing ones. With the forests removed from the watershed, stream flows could easily double. Floods 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 floodplain elevations would increase.

14.9 ISSUES

The major issues for wildfire 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 could affect the wildfire hazard.
- Future growth into interface areas should continue to be managed.
- Area fire districts need to continue to train on wildland-urban interface events.
- Vegetation management activities. This would include enhancement through expansion of the target areas as well as additional resources.
- Regional consistency of higher building code standards such as residential sprinkler requirements and prohibitive combustible roof standards.
- Fire department water supply in high risk wildfire areas.
- Expand certifications and qualifications for fire department personnel. Ensure that all firefighters are trained in basic wildfire behavior, basic fire weather, and that all company officers and chief level officers are trained in the wildland command and strike team leader level.


KITTITAS COUNTY
Map 14-1.
Wildfire Hazard Areas
Extreme fire hazard
High fire hazard
Moderate fire hazard
Low fire hazard
1:500,000
Wildfire Data provided by Washington State Department of Natural Resources
0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles
TETRA TECH
N
S
E
W
Snoqualmie Pass
Wenatchee National Forest
Keechelus Lake
Kachees Lake
Cle Elum Lake
John Wayne Trail
EASTON
RONALD
ROSLYN
Coal Mine Trail
CLE ELUM
SOUTH CLE ELUM
Cle Elum River
Teanaway River
Yakima River
LIBERTY
THORP
ELLENSBURG
KITTITAS
Ginkgo Petrified Forest State Park
VANTAGE
Columbia River
97
903
970
90
10
82
821
FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY



KITTITAS COUNTY
Map 14-2.
Fire Regime Status
0-35 yrs, Low Severity
0-35 yrs, Stand Replacement
35-100+ yrs, Mixed Severity
35-100+ yrs, Stand Replacement
200+ yrs, Stand Replacement
1:500,000
Fire Regime Status Data provided by Washington State Department of Natural Resources
0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles
TETRA TECH
Snoqualmie Pass
Wenatchee National Forest
Keechelus Lake
Kachees Lake
Cle Elum Lake
John Wayne Trail
EASTON
RONALD
ROSLYN
Coal Mine Trail
CLE ELUM
SOUTH CLE ELUM
Cle Elum River
Teanaway River
Yakima River
LIBERTY
THORP
ELLENSBURG
KITTITAS
Ginkgo Petrified Forest State Park
VANTAGE
Columbia River
FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY

CHAPTER 15.
PLANNING AREA RISK RANKING

A risk ranking was performed for the hazards of concern described in this plan. This risk ranking assesses the probability of each hazard's occurrence as well as its likely impact on the people, property, and economy of the planning area. The risk ranking was conducted via facilitated brainstorming sessions with the steering committee. Estimates of risk were generated with data from HAZUS-MH using methodologies promoted by FEMA. The results are used in establishing mitigation priorities.

15.1 PROBABILITY OF OCCURRENCE

The probability of occurrence of a hazard is indicated by a probability factor based on likelihood of annual occurrence:

- High—Hazard event is likely to occur within 25 years (Probability Factor = 3)
- Medium—Hazard event is likely to occur within 100 years (Probability Factor =2)
- Low—Hazard event is not likely to occur within 100 years (Probability Factor =1)
- No exposure—There is no probability of occurrence (Probability Factor = 0)

The assessment of hazard frequency is generally based on past hazard events in the area. Table 15-1 summarizes the probability assessment for each hazard of concern for this plan.

TABLE 15-1.
PROBABILITY OF HAZARDS

Hazard Event	Probability (high, medium, low)	Probability Factor
Avalanche	High	3
Dam Failure	Low	1
Drought	High	3
Earthquake	High	3
Flood	High	3
Landslide	High	3
Severe Weather	High	3
Volcano	Low	1
Wildfire	High	3

15.2 IMPACT

Hazard impacts were assessed in three categories: impacts on people, impacts on property and impacts on the local economy. Numerical impact factors were assigned as follows:

- **People**—Values were assigned based on the percentage of the total ***population exposed*** to the hazard event. The degree of impact on individuals will vary and is not measurable, so the calculation assumes for simplicity and consistency that all people exposed to a hazard because they live in a hazard zone will be equally impacted when a hazard event occurs. It should be noted that planners can use an element of subjectivity when assigning values for impacts on people. Impact factors were assigned as follows:

  - High—50 percent or more of the population is exposed to a hazard (Impact Factor = 3)
  - Medium—25 percent to 49 percent of the population is exposed to a hazard (Impact Factor = 2)
  - Low—25 percent or less of the population is exposed to the hazard (Impact Factor = 1)
  - No impact—None of the population is exposed to a hazard (Impact Factor = 0)

- **Property**—Values were assigned based on the percentage of the total ***property value exposed*** to the hazard event:
  - High—30 percent or more of the total assessed property value is exposed to a hazard (Impact Factor = 3)
  - Medium—15 percent to 29 percent of the total assessed property value is exposed to a hazard (Impact Factor = 2)
  - Low—14 percent or less of the total assessed property value is exposed to the hazard (Impact Factor = 1)
  - No impact—None of the total assessed property value is exposed to a hazard (Impact Factor = 0)
- **Economy**—Values were assigned based on the percentage of the total ***property value vulnerable*** to the hazard event. Values represent estimates of the loss from a major event of each hazard in comparison to the total assessed value of the property exposed to the hazard. For some hazards, such as wildfire, landslide and severe weather, vulnerability was considered to be the same as exposure due to the lack of loss estimation tools specific to those hazards. Loss estimates separate from the exposure estimates were generated for the earthquake and flood hazards using HAZUS-MH.
  - High—Estimated loss from the hazard is 20 percent or more of the total assessed property value (Impact Factor = 3)
  - Medium—Estimated loss from the hazard is 10 percent to 19 percent of the total assessed property value (Impact Factor = 2)
  - Low—Estimated loss from the hazard is 9 percent or less of the total assessed property value (Impact Factor = 1)
  - No impact—No loss is estimated from the hazard (Impact Factor = 0)

The impacts of each hazard category were assigned a weighting factor to reflect the significance of the impact. These weighting factors are consistent with those typically used for measuring the benefits of hazard mitigation actions: impact on people was given a weighting factor of 3; impact on property was given a weighting factor of 2; and impact on the operations was given a weighting factor of 1.

Table 15-2, Table 15-3 and Table 15-4 summarize the impacts for each hazard.

**TABLE 15-2.
IMPACT ON PEOPLE FROM HAZARDS**

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (3)
Avalanche	Low	1	(3x1) = 3
Dam Failure	Low	1	(3x1) = 3
Drought	None	0	(3x0) = 0
Earthquake	High	3	(3x3) = 9
Flood	Medium	2	(3x2) = 6
Landslide	Low	1	(3x1) = 3
Severe Weather	High	3	(3x3) = 9
Volcano	High	3	(3x3) = 9
Wildfire	Low	1	(3x1) = 3

**TABLE 15-3.
IMPACT ON PROPERTY FROM HAZARDS**

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (2)
Avalanche	Low	1	(1x2) = 2
Dam Failure	Medium	2	(2x2) = 4
Drought	No Impact	0	(0x2) = 0
Earthquake	High	3	(3x2) = 6
Flood	Medium	2	(2x2) = 4
Landslide	Low	1	(1x2) = 2
Severe Weather	High	3	(3x2) = 6
Volcano	Low	1	(1x2) = 2
Wildfire	Low	1	(1x2) = 2

**TABLE 15-4.
IMPACT ON ECONOMY FROM HAZARDS**

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (1)
Avalanche	Low	1	(1x1) = 1
Dam Failure	Low	1	(1x1) = 1
Drought	High	3	(3x1) = 3
Earthquake	Low	1	(1x1) = 1
Flood	Low	1	(1x1) = 1
Landslide	Low	1	(1x1) = 1
Severe Weather	Medium	2	(2x1) = 2
Volcano	Low	1	(1x1) = 1
Wildfire	Low	1	(1x1) = 1

15.3 RISK RATING AND RANKING

The risk rating for each hazard was determined by multiplying the probability factor by the sum of the weighted impact factors for people, property and operations, as summarized in Table 15-5.

Based on these ratings, a priority of high, medium or low was assigned to each hazard. The hazards ranked as being of highest concern are earthquake and severe weather. Hazards ranked as being of medium concern are landslide, flood and wildfire. The hazards ranked as being of lowest concern are drought and dam failure. Table 15-6 shows the hazard risk ranking.

**TABLE 15-5.
HAZARD RISK RATING**

Hazard Event	Probability Factor	Sum of Weighted Impact Factors	Total (Probability x Impact)
Avalanche	3	(3+2+1) = 6	3x6 = 18
Dam Failure	1	(3+4+1) = 8	1x8 = 8
Drought	3	(0+0+3) = 3	3x3 = 9
Earthquake	3	(9+6+1) = 16	3x16 = 48
Flood	3	(6+4+1) = 11	3x11 =33
Landslide	3	(3+2+1) = 6	3x6 = 18
Severe Weather	3	(9+6+2) = 17	3x17 = 51
Volcano	1	(9+2+1) = 12	1x12 = 12
Wildfire	3	(3+2+1) = 6	3x6 = 18

**TABLE 15-6.
HAZARD RISK RANKING**

Hazard Ranking	Hazard Event	Category
1	Severe Weather	High
2	Earthquake	High
3	Flood	High
4	Avalanche	Medium
4	Landslide	Medium
4	Wildfire	Medium
5	Volcano	Low
8	Drought	Low
9	Dam Failure	Low