CHAPTER 10.
FLOOD

10.1 GENERAL BACKGROUND

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

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.

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.

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.

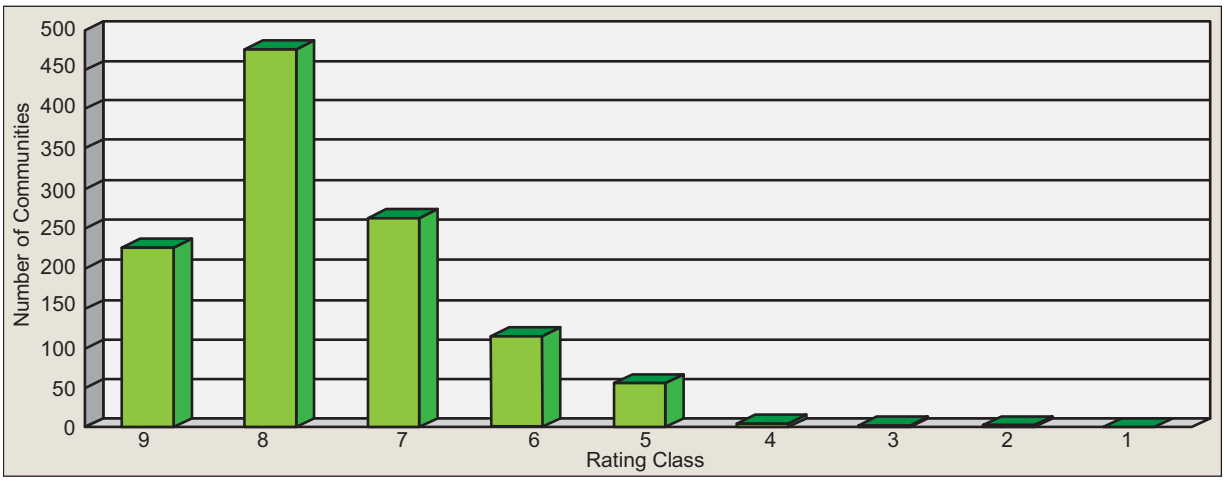


Figure 10-1. CRS Communities by Class Nationwide as of May 1, 2010

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

Source/Location	Discharge (cubic feet/second)			
	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

Source/Location	Discharge (cubic feet/second)			
	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.

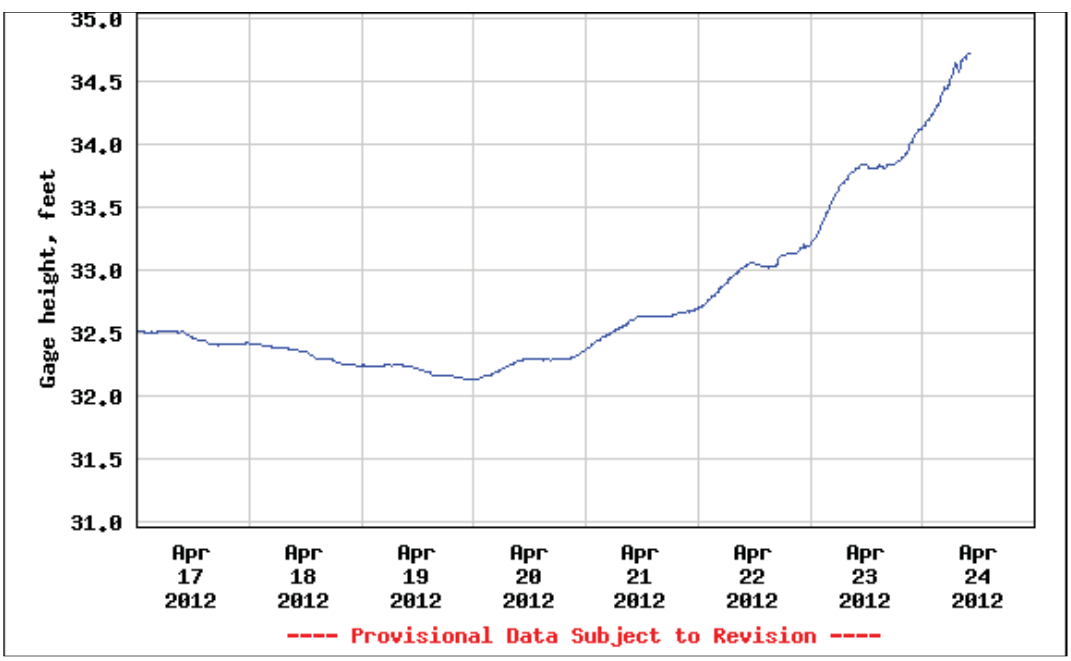


Figure 10-3. Yakima River Hydrograph at Umtanum (USGS Station 12484500)

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
	Structure	Contents	**Total**	Assessed Value
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
	Structural	Contents	**Total**	Assessed Value
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
	Structural	Contents	**Total**	Assessed Value
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

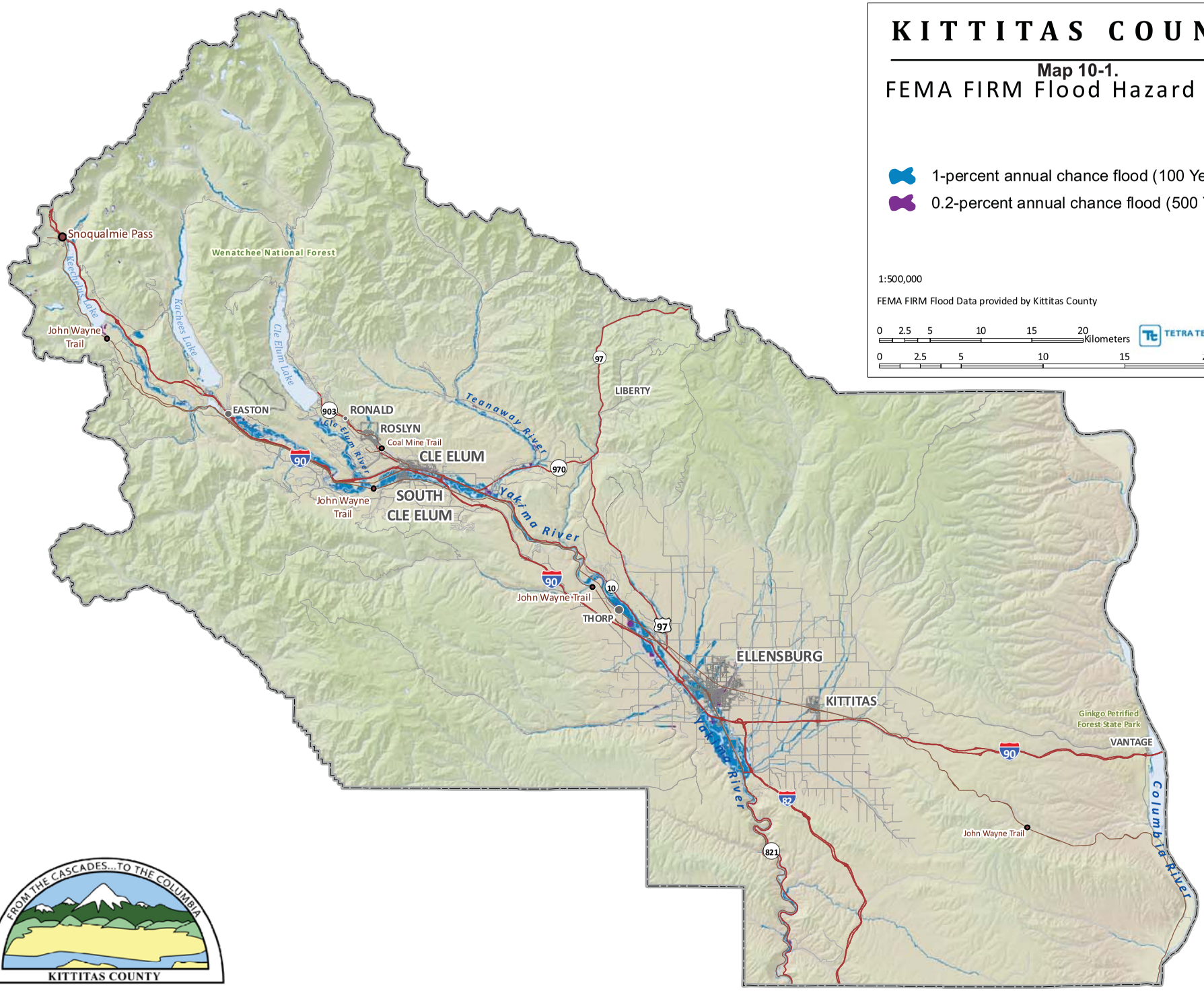
The planning team has identified the following flood-related issues relevant to the planning area:

- 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



FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY

KITTITAS COUNTY

Map 10-2.
Repetitive Loss Areas

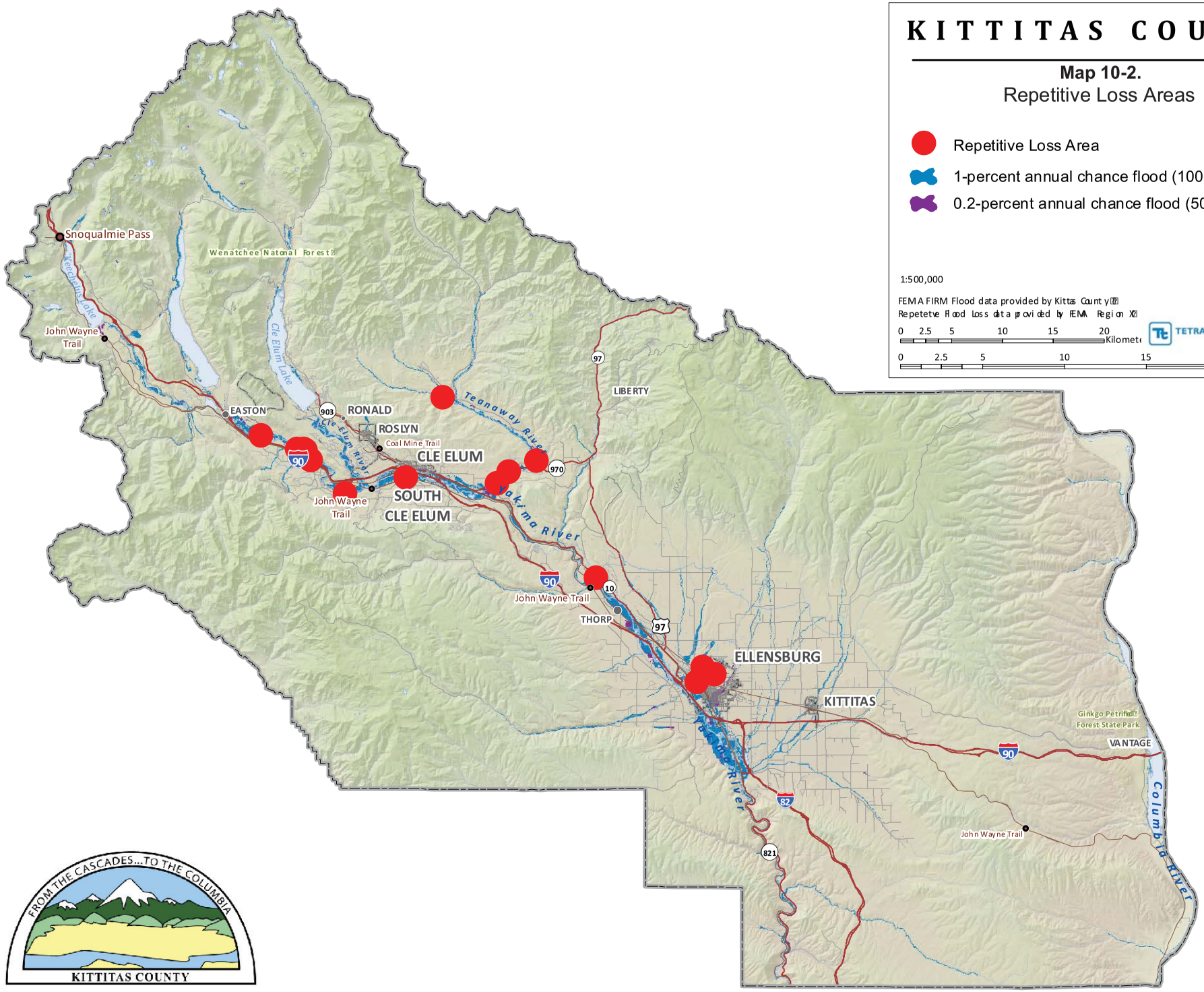
Repetitive Loss Area
1-percent annual chance flood (100 Year)
0.2-percent annual chance flood (500 Year)

1:500,000

FEMA FIRM Flood data provided by Kittitas County
Repetetive 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



FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY

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.

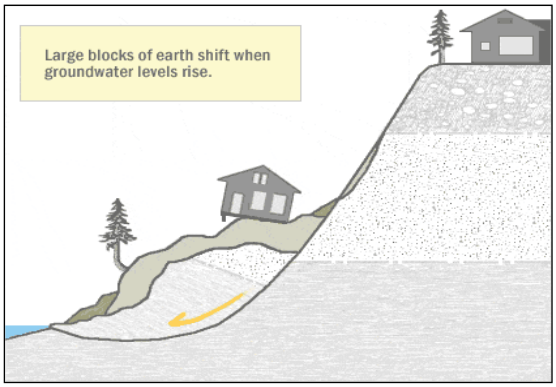


Figure 11-1. Deep Seated Slide

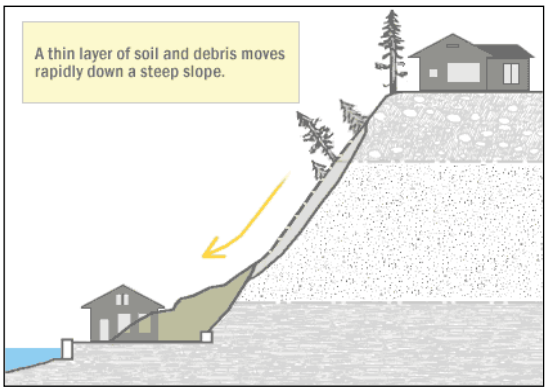


Figure 11-2. Shallow Colluvial Slide

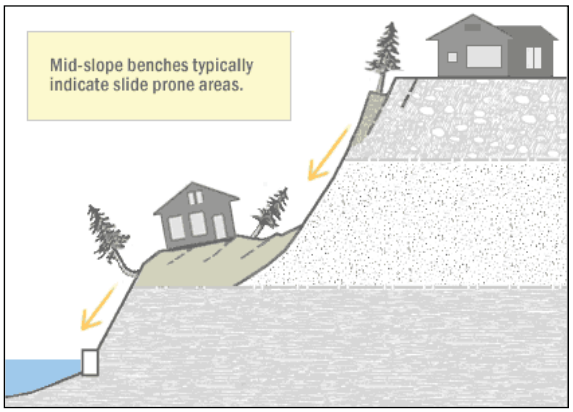


Figure 11-3. Bench Slide

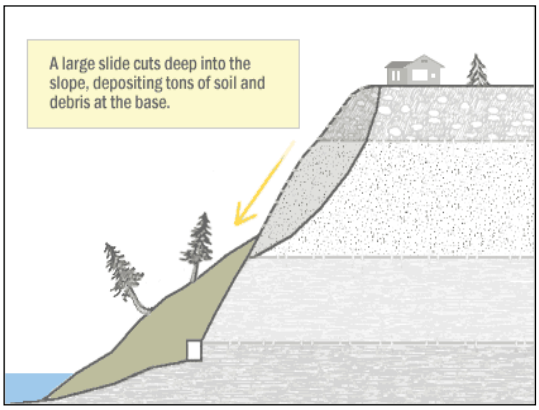


Figure 11-4. Large Slide

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			% of AV
		Structure	Contents	**Total**	
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

Jurisdiction	Building Count	Assessed Value	Estimated Loss Potential		
			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

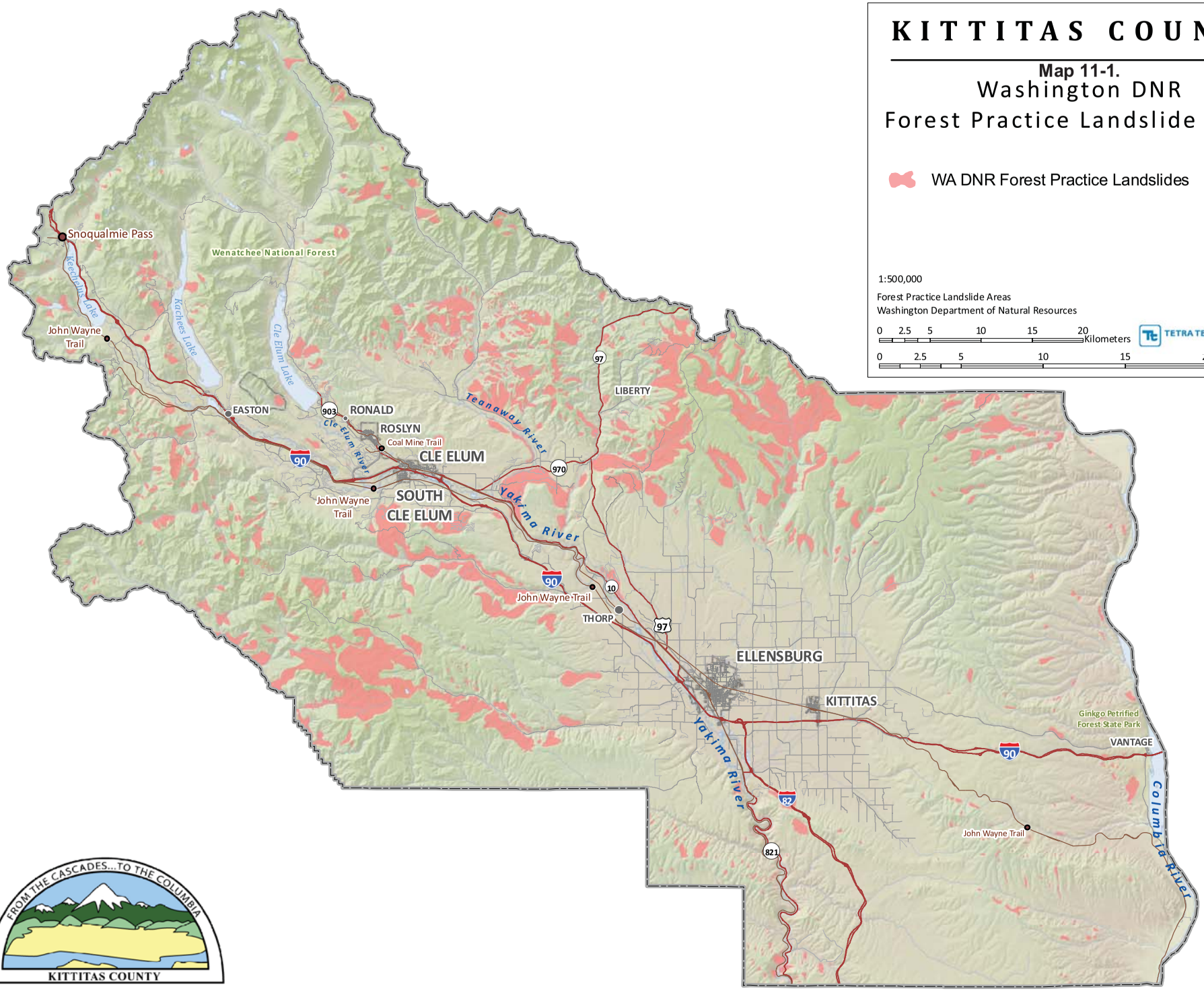
Map 11-1.
Washington DNR
Forest Practice Landslide Areas

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

TETRA TECH



FROM THE CASCADES...TO THE COLUMBIA
KITTITAS COUNTY

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.

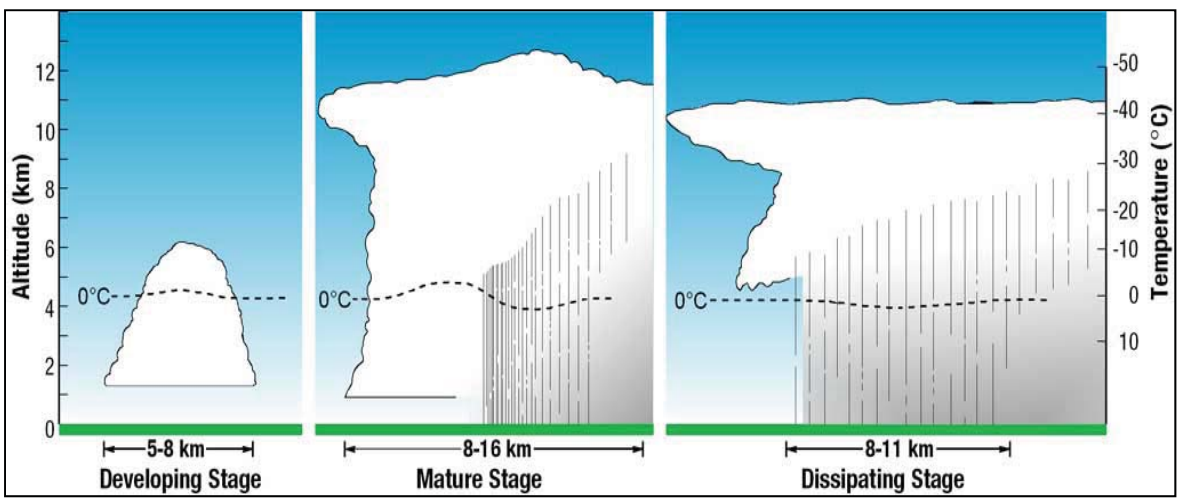


Figure 12-1. The Thunderstorm Life Cycle

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.

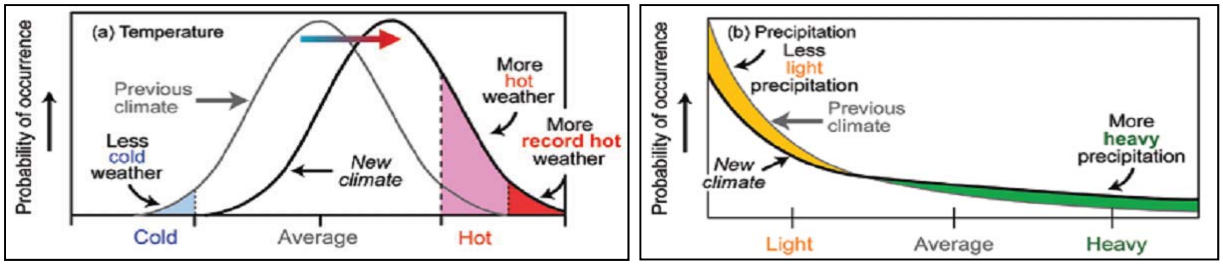


Figure 12-2. Severe Weather Probabilities in Warmer Climates

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

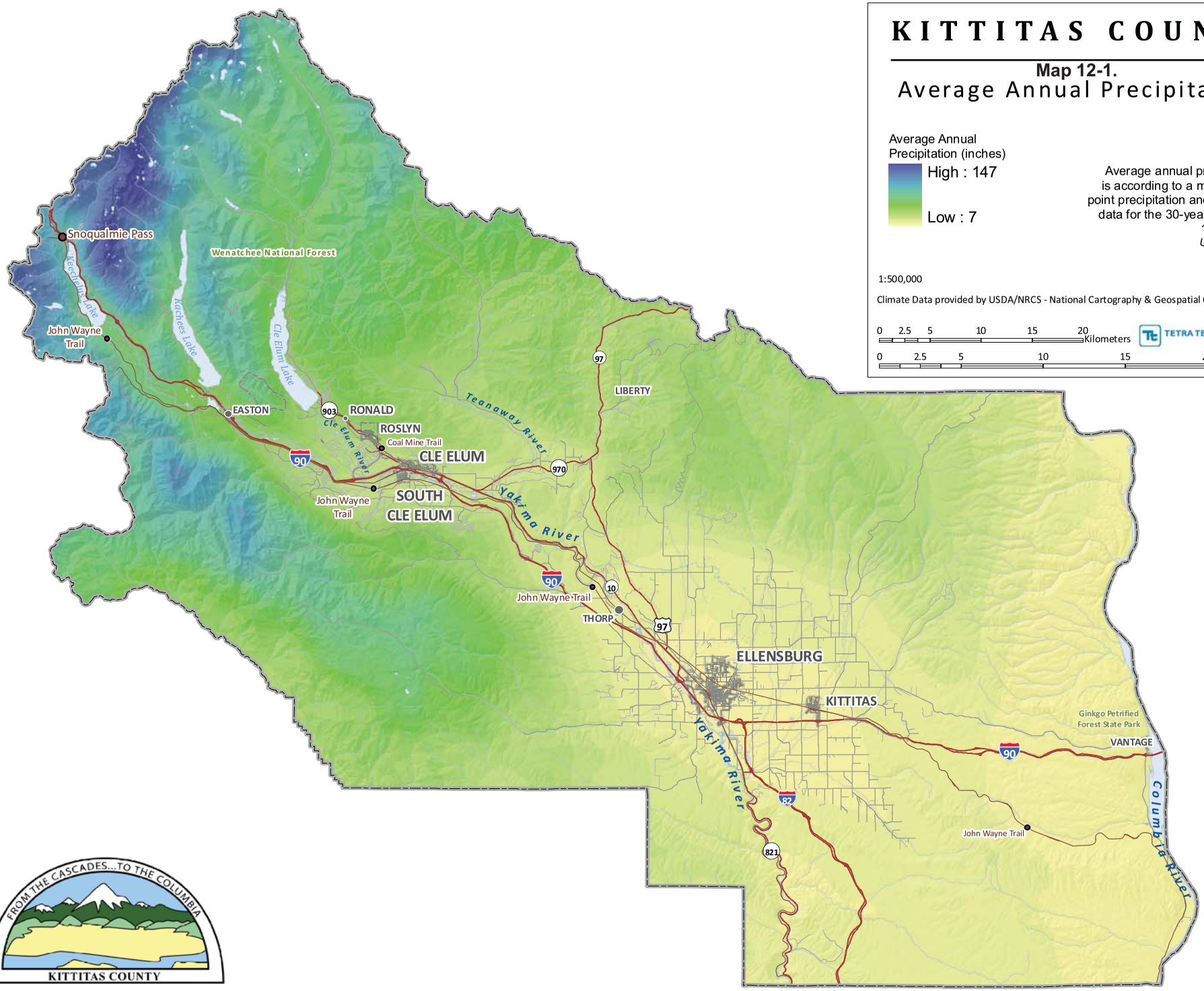
1:500,000

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)

High : 91

Low : 59

Average Maximum 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

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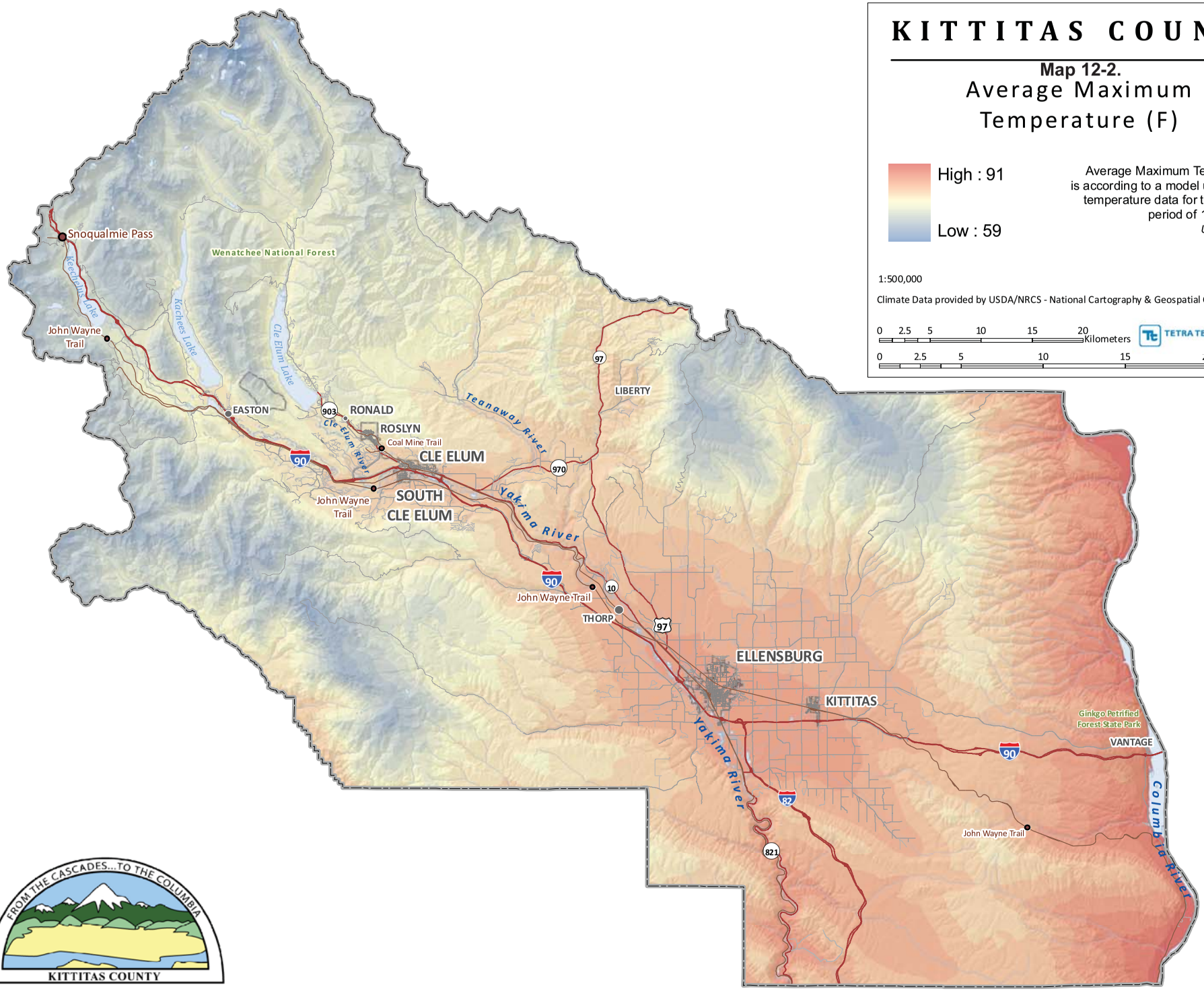

FROM THE CASCADES...TO THE COLUMBIA

KITTITAS COUNTY

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

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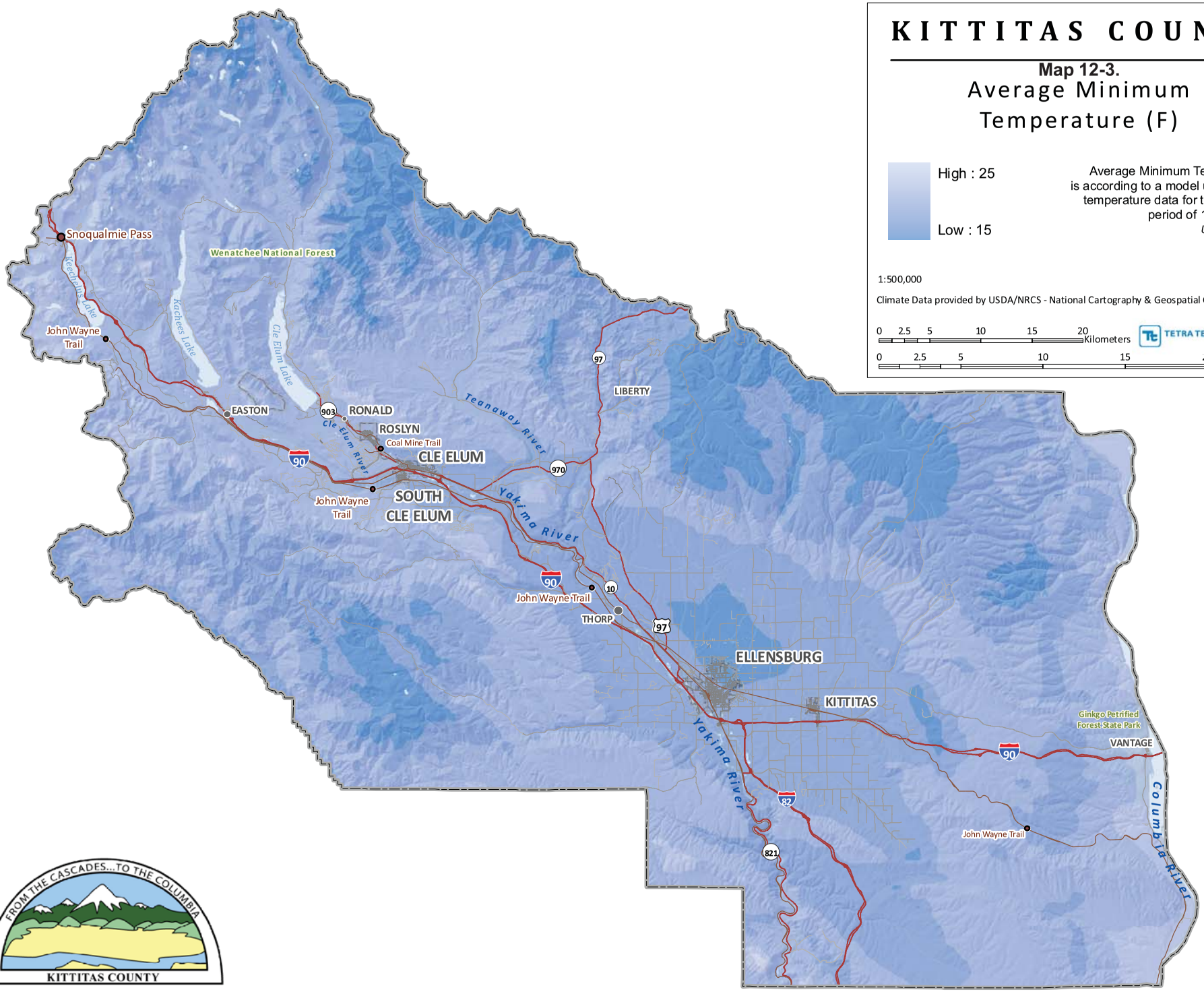

FROM THE CASCADES...TO THE COLUMBIA

KITTITAS COUNTY

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

0 2.5 5 10 15 20 Kilometers

0 2.5 5 10 15 20 Miles

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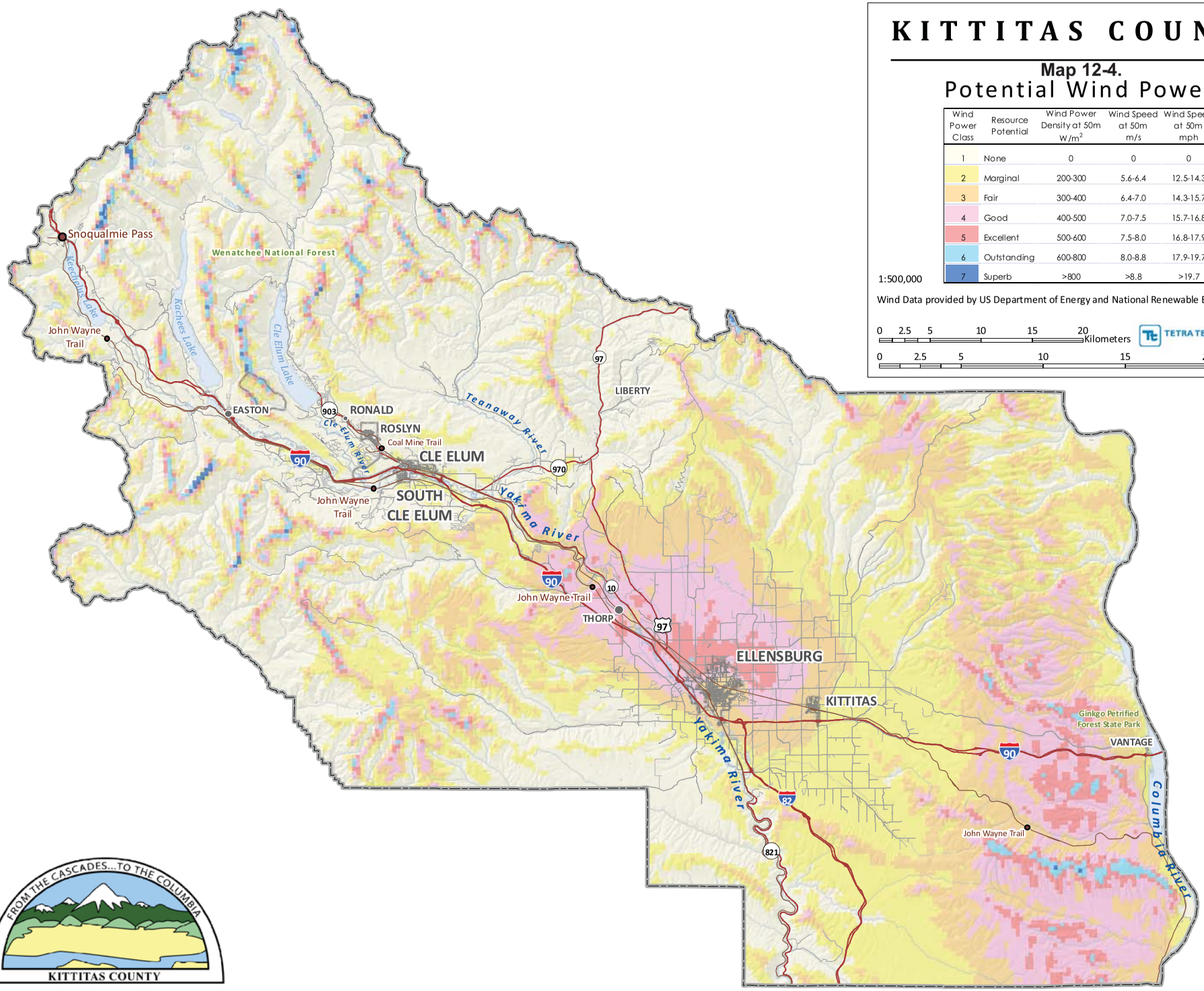


FROM THE CASCADES...TO THE COLUMBIA

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

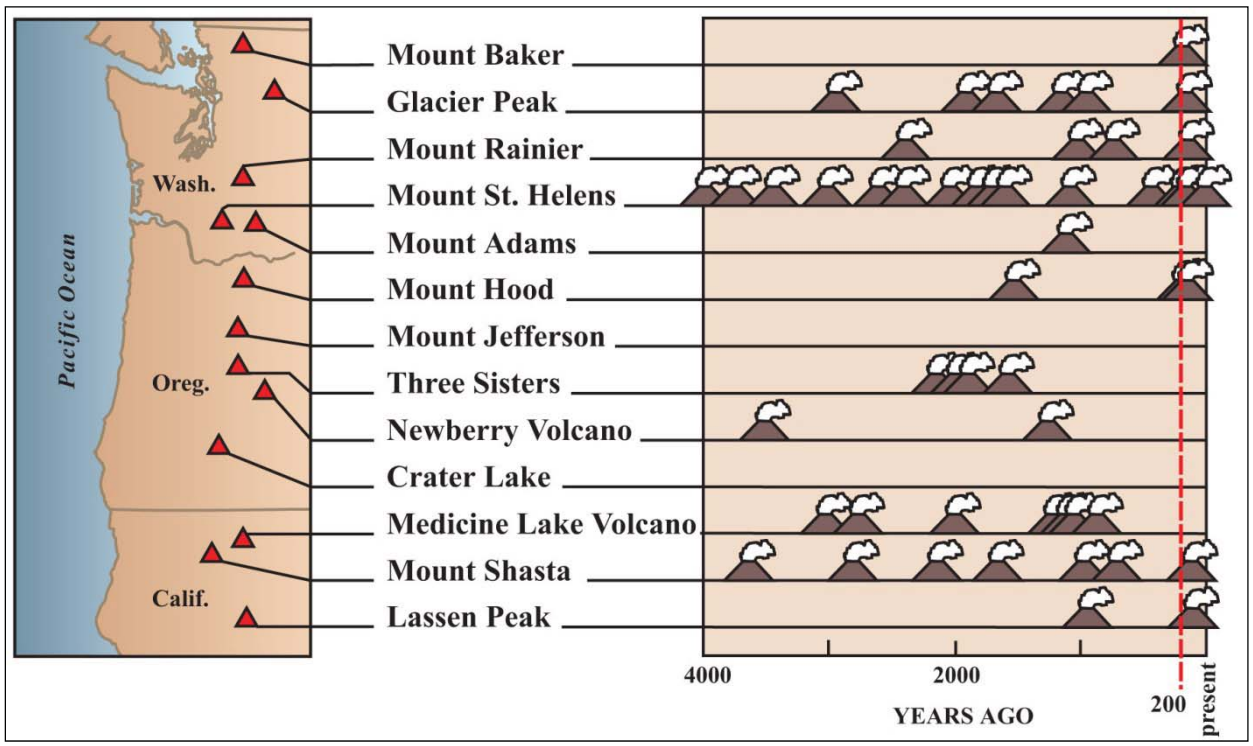


Figure 13-1. Past Eruptions in the Cascade Range

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

- Glacier Peak approximately 80 miles north-northwest of Ellensburg
- Mount Rainier 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.

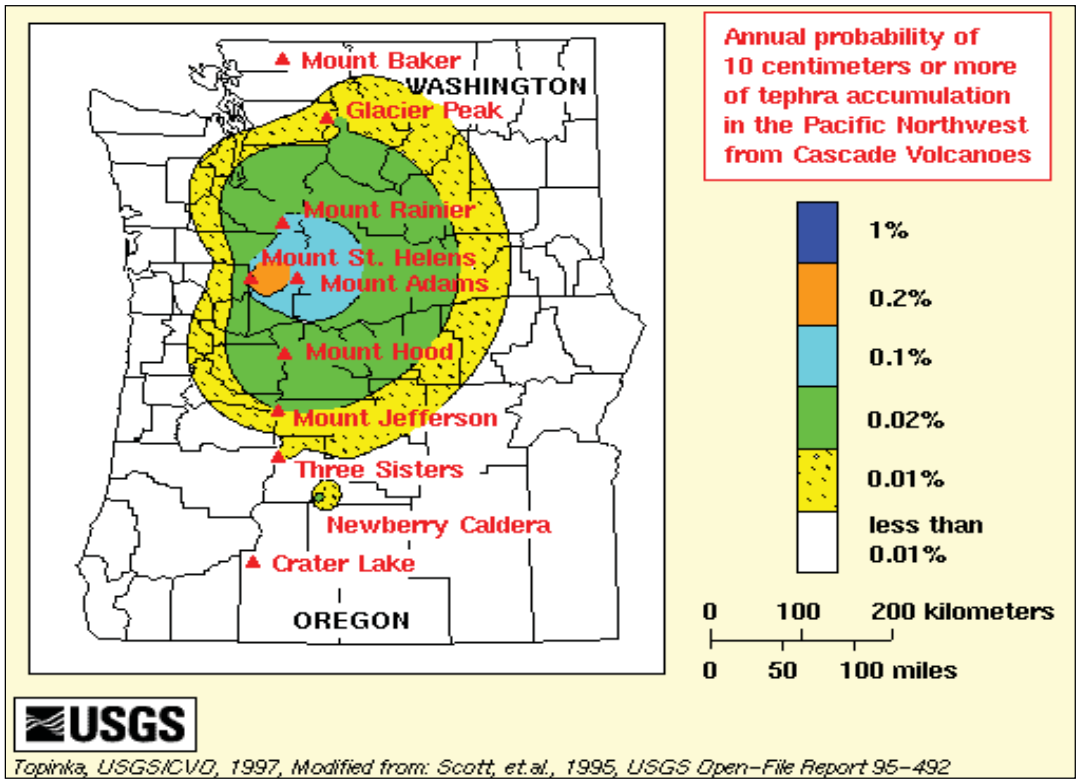


Figure 13-2. Probability of Tephra Accumulation in Pacific Northwest

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.

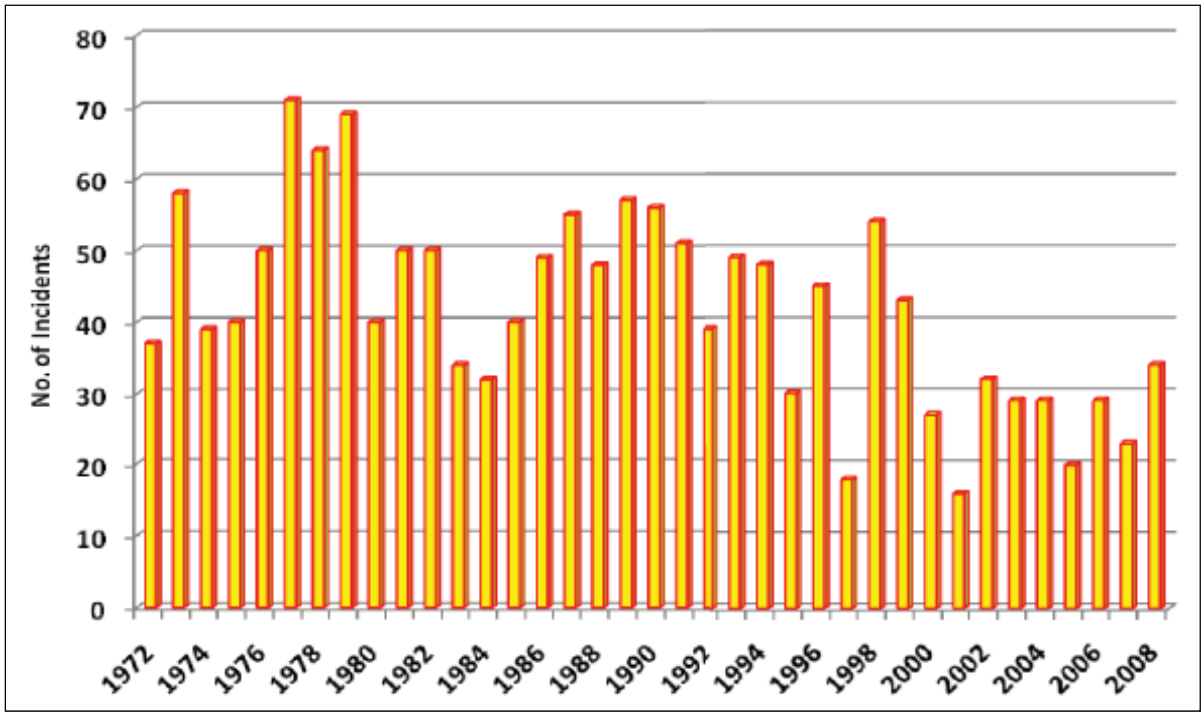


Figure 14-1. Wildfire Incidents in Kittitas County, 1972-2008

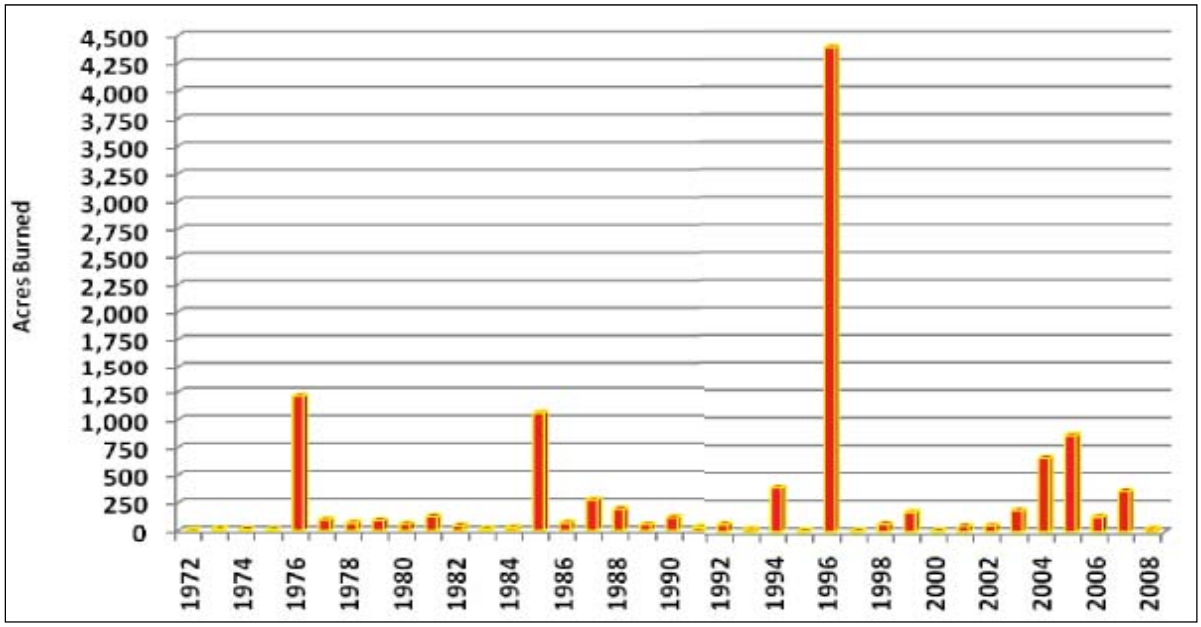


Figure 14-2. Total Acres Burned Annually by Wildfire in Kittitas County, 1972 – 2008

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			% of AV
		Structure	Contents	**Total**	
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			% of AV
		Structure	Contents	**Total**	
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			% of AV
		Structure	Contents	**Total**	
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.

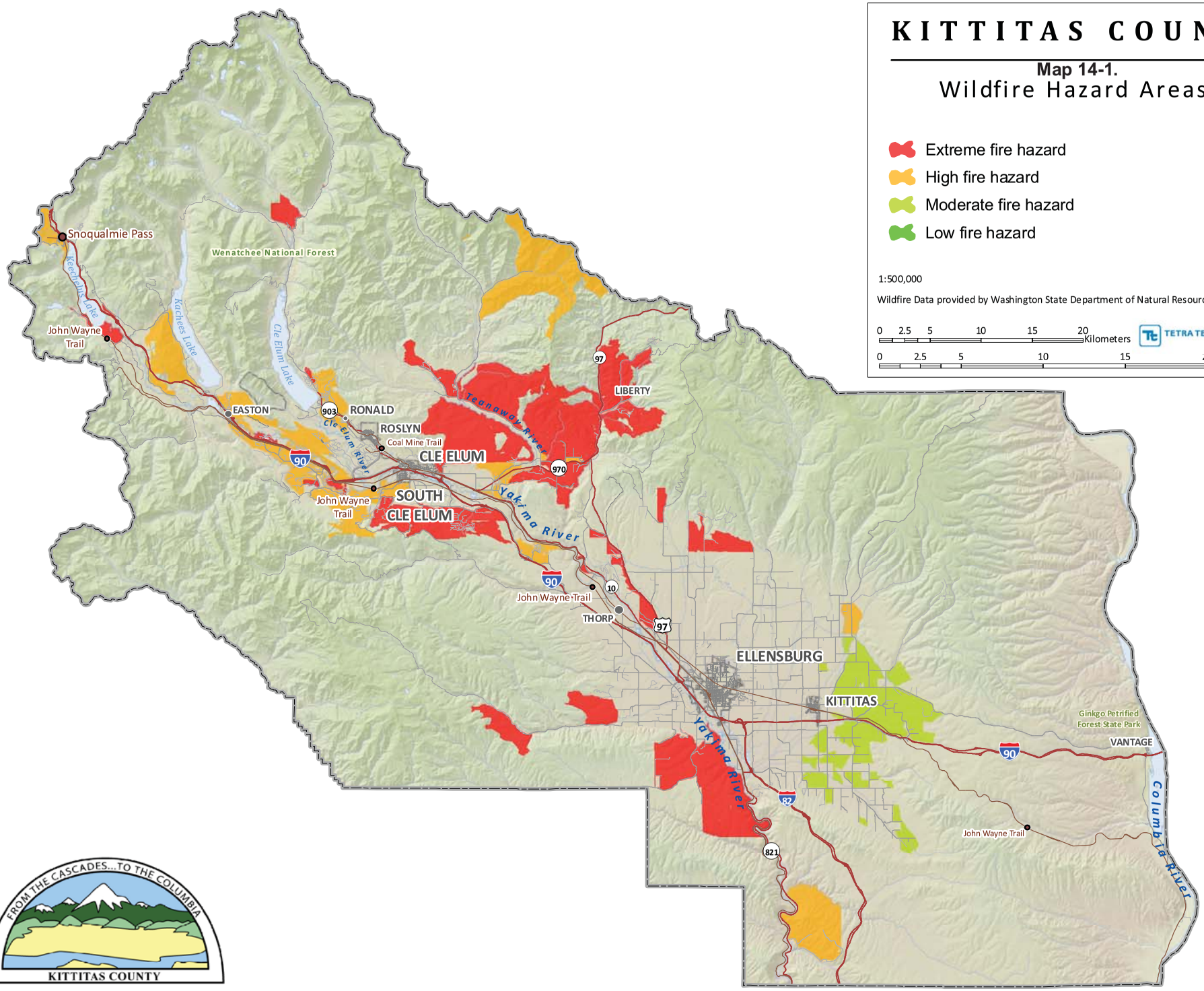
14.9 ISSUES

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



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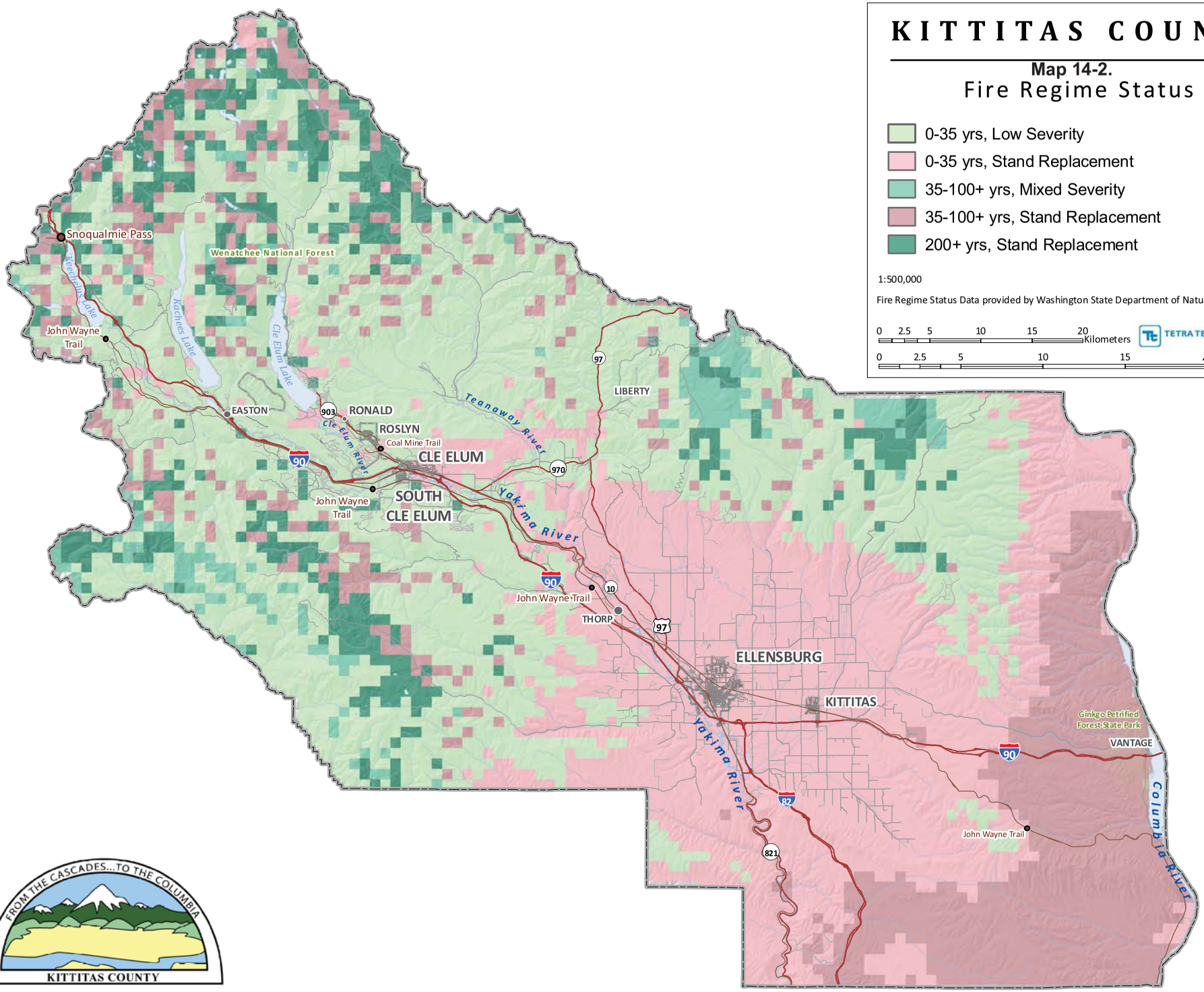
KITTITAS COUNTY
Map 14-2.
Fire Regime Status
0-35 yrs, Low Severity
0-35 yrs, Stand Replacement
35-100+ yrs, Mixed Severity
35-100+ yrs, Stand Replacement
200+ yrs, Stand Replacement
1:500,000
Fire Regime Status Data provided by Washington State Department of Natural Resources
0 2.5 5 10 15 20 Kilometers
0 2.5 5 10 15 20 Miles
TETRA TECH
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
90
903
970
97
10
82
821
FROM THE CASCADES...TO THE COLUMBIA
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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