Avalanche

Avalanche	Frequency	50+ yrs	10-50 yrs	1-10 yrs	Annually
	People	<1,000	1,000-10,000	10,000-50,000	50,000+
	Economy	1% GDP	1-2% GDP	2-3% GDP	3%+ GDP
	Environment	<10%	10-15%	15%-20%	20%+
	Property	<$100M	$100M-$500M	$500M-$1B	$1B+
	Hazard scale	< Low to High >			

Risk Level

- Frequency – Avalanches occur annually in Washington.
- People – National and international statistics show that there is the potential for significant loss of life from an avalanche.
- Economy – An incident is unlikely to cause the loss of 1% of the State GDP.
- Environment – An incident is unlikely to cause the loss of 10% of a single species or habitat.
- Property – An incident is unlikely to cause $100 million in damage.

Summary

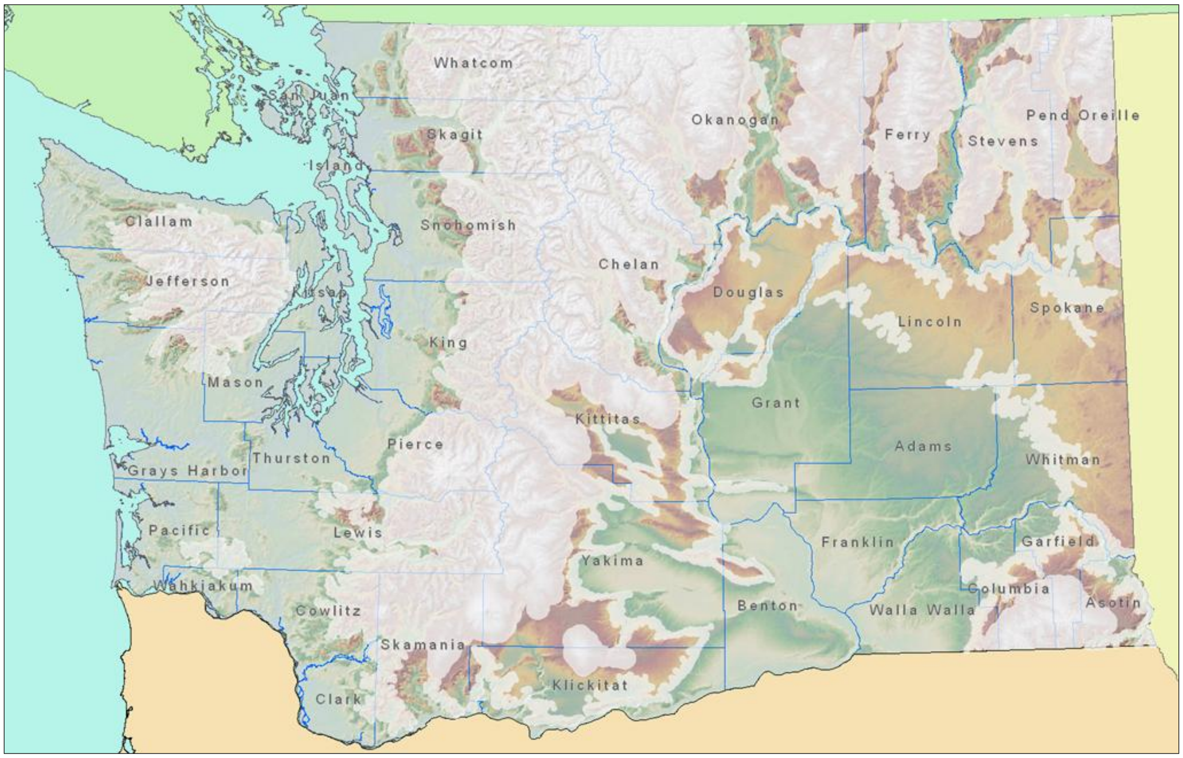
- The hazard – An avalanche occurs when a layer of snow loses its grip on a slope and slides downhill. Avalanches typically occur from November until early summer in all mountain areas, but year-round in high alpine areas. They primarily pose danger to people in areas where there is no avalanche control, and to continued movement of people and freight over the state's mountain highway passes.

- Previous occurrences – Avalanches occur frequently each year and kill one to two people annually in the Northwest (about 25-35 deaths annually in the U.S.). *Avalanches have killed more people in Washington than any other hazard during the past century*. In 90 percent of avalanche fatalities, the weight of the victim or someone in the victim's party triggers the slide.

- Probability of future events – Avalanches occur regularly every year in mountain areas. Many weather and terrain factors determine actual avalanche danger. Avalanches along two key mountain highway passes are limited due to ongoing mitigation to control slides during winter months.

- Jurisdictions at greatest risk – Twelve counties in which the Cascade, Olympic, Blue or Selkirk Mountains are found.

- Special note – This profile will not attempt to estimate potential losses to state facilities due to avalanche. Very few are in avalanche hazard zones, and other hazards pose a greater threat to people and the built environment than avalanches and thus, are more important to address. However, this hazard profile will identify a number of state highways that experience closure due to avalanches during the winter months.

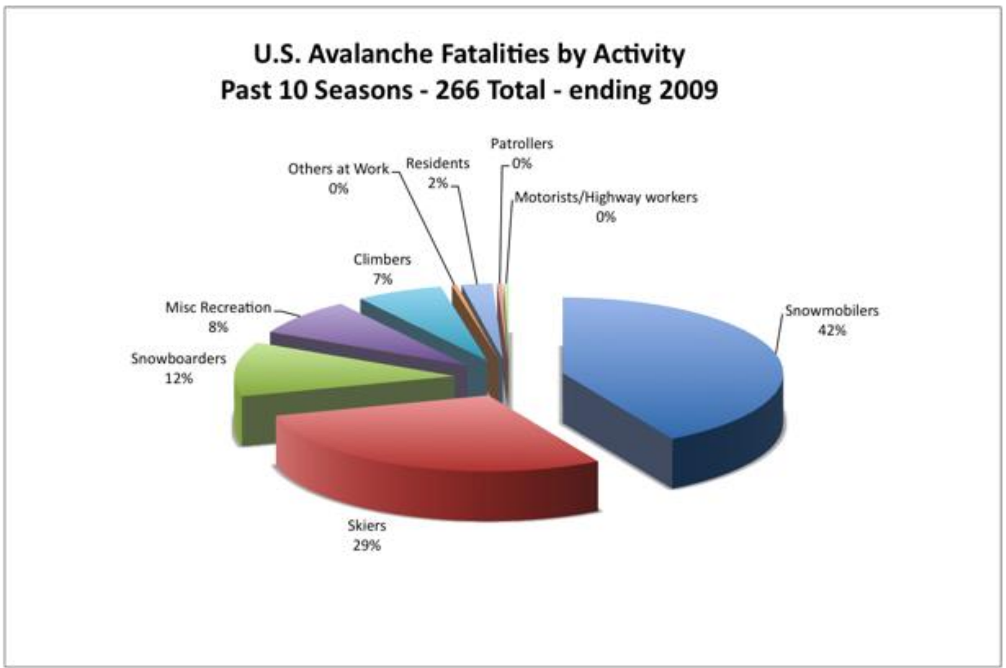


Washington State Avalanche Hazard Areas: White areas on the map indicate that those areas are at least 2,000 feet in elevation and most likely to be prone to avalanches. Avalanches can and do occur outside of these areas during unusual conditions.

The Hazard[1,2,3,4, 5]

An avalanche is an often-rapid downhill motion of the snow pack or portion of the snow pack. Some wet snow or slush-flow avalanches may travel quite slowly. This motion may be natural or artificially induced, and controlled or uncontrolled in terms of time, place, and severity. An avalanche occurs when a layer of snow loses its grip on a slope and slides downhill. Avalanches have killed more than 190 people in the past century in Washington State, exceeding deaths from any other natural hazard. The nation's worst avalanche disasters occurred in 1910 when massive avalanches hit two trains stopped on the west side of Stevens Pass; at least 96 people were killed. Avalanches kill one to two people, on average, every year in Washington, although many more are involved in avalanche accidents that do not result in fatalities. Since 1985, avalanches have killed 56 people in Washington State (through March 14, 2012).

Most current avalanche victims are participating in recreational activities in the backcountry where there is no avalanche control. Only one-tenth of one percent of avalanche fatalities occurs on open runs at ski areas or on highways.



Source: USDA Forest Service Utah Avalanche Center. (Accessed August 10, 2009)
Available at: http://utahavalanchecenter.org/education/faq

Avalanches occur in four mountain ranges in the state – the Cascade Range, which divides the state east and west, the Olympic Mountains in northwest Washington, the Blue Mountains in southeast Washington, and the Selkirk Mountains in northeast Washington. The avalanche season begins in November and continues until early summer for all mountain areas of the state. In the high alpine areas of the Cascades and Olympics, the avalanche season continues year-round.

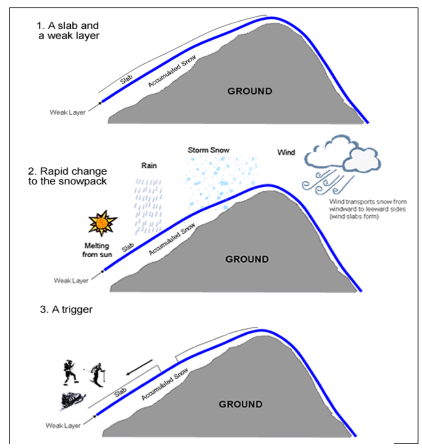
There are two types of avalanches, loose and slab, and two types of slab avalanches, soft and hard. Avalanches can be either dry or wet. Although the most dangerous avalanche is the slab avalanche, loose slides can and do produce injury and death.

Loose avalanches occur when grains of snow cannot hold onto a slope and begin sliding downhill, picking up more snow and fanning out in an inverted V. Slab avalanches occur when a cohesive mass of snow breaks away from the slope all at once. Most slides in the Northwest are slab avalanches.

Avalanches occur for one of two basic reasons:

1) Either the load on a slope increases faster than snow strength; or
2) Snow strength decreases.

Slab avalanches occur when the stresses on a slab overcome the slab's attachment strength to the snow layer below. A decrease in strength is produced through warming, melting snow, or rain. Decreased strength within the existing snowpack may also result from strong temperature gradients and associated vapor transfer that produces recrystallization within the existing snow matrix. An increase in stress may be produced by the weight of additional snowfall, or a skier or a snowmobile. Dry slab avalanches can travel 60 to 80 miles per hour or more, reaching these speeds within five seconds after the fracture; they account for most avalanche fatalities. Wet slab avalanches occur when warming temperatures or rain increase the creep rate of the surface snow, putting additional forces on the slab's attachment to the layer below. When water percolating through the top slab weakens the layer and dissolves its bond with a lower layer, it decreases the ability of the weaker, lower layer to hold on to the top slab, as well as decreases the slab's strength. In 90 percent of avalanche fatalities, the weight of the victim or someone in the victim's party triggers the slide. An avalanche is like a dinner plate sliding off a table; a slab of snow shatters like a pane of glass with the victim in the middle.



Error! Reference source not found. Ingredients for a Slab Avalanche

Factors That Affect Avalanche Danger[6]

A number of weather, terrain and snowpack factors determine avalanche danger:

Weather:

- Storms – A large percentage of all snow avalanches occur during and shortly after storms.
- Rate of snowfall – Snow falling at a rate of one inch or more per hour rapidly increases avalanche danger.

- Temperature – Storms starting with low temperatures and dry snow, followed by rising temperatures and wetter snow, are more likely to cause avalanches than storms that start warm and then cool with snowfall.
- Wet snow – Rainstorms or spring weather with warm, moist winds and cloudy nights can warm the snow cover resulting in wet snow avalanches. Wet snow avalanches are more likely on sun-exposed terrain (south-facing slopes) and under exposed rocks or cliffs.
- Wind is the most common cause of avalanches. Wind can deposit snow 10 times faster than snow falling from storms. Wind erodes snow from the upwind side of obstacles and deposits snow on the downwind (lee) side. This is called "wind loading".

Terrain:

- Ground cover – Large rocks, trees and heavy shrubs help anchor snow, but also create stress concentrations between anchored and unanchored snow.
- Slope profile – Dangerous slab avalanches are more likely to occur on convex slopes that produce stress concentrations within surface snow due to varying creep rates.
- Slope aspect – Leeward slopes are dangerous because windblown snow adds depth and creates dense slabs. South facing slopes are more dangerous in the springtime due to increasing solar effects.
- Slope steepness – Snow avalanches are most common on slopes of 30 to 45 degrees.

Snowpack:

- *Snow texture*—the feel, appearance, or consistency of the snow determined by the shape, size and attachment of snow grains that comprise the particular snow layer. Also the inter-granular relationship— the overall feel of a snow layer, specifically the relative quantities of the different types and sizes of snow particles in a particular layer, and the size, shape and arrangement of grains as seen with a hand lens. A layer of small grained moist snow has a distinctly different texture—much more cohesive and able to make snowballs—than well faceted snow that falls apart in one's hands and exhibits very little internal cohesion.
- *Snow layering* – The snowpack is composed of ground-parallel layers that accumulate over the winter. Each layer contains ice grains that are representative of the distinct meteorological conditions during which the snow formed and was deposited. Once deposited, a snow layer continues to evolve under the influence of the meteorological conditions that prevail after deposition.
- *Snow bonding*—in the absence of strong temperature gradients within a dry snowpack, this is the normally stabilizing or "rounding" process whereby individual snow grains or layers come into contact and gradually strengthen the ice skeleton or snow layer(s) through sintering or the formation of ice "necks" between the grains. This sintering process results from shape or size driven vapor pressure differences between or within grains or layers and involves preferential transfer of water vapor and subsequent vapor deposition. The associated redistribution of water vapor results in inter-granular attachments or bonds between grains through an expanding ice matrix, and typically

> results in gradual strengthening of the surrounding snowpack structure. However, it must be noted that in the presence of strong temperature gradients within or between snow layers, a different metamorphic process in the snow cover can occur which is known as faceting—a process that results in new crystal growth and/or recrystallization of existing snow grains, often producing general weakening of the snow structure. Faceting is characterized by strong (often local) temperature gradients in the snow pack and resulting strong vapor pressure gradients that move mass from warmer grains (higher vapor pressure) to colder grains (lower vapor pressure). As the process evolves and more mass is transferred, faceting snow loses existing grain bonds, forms new grains, and in general becomes more disaggregated and sugary (hence the related term "sugar snow"). In observations and tests, the hardness of a faceting snow layer decreases with time and it becomes easier to penetrate and pull individual faceted grains out of a snow pit wall.

Avalanche forecasting and control is a regular winter expense. The Washington State Department of Transportation's annual budget for removing snow and ice and for avalanche control for the highways that cross the Cascade Mountains is about $38 million. Additionally, the transportation department, ski areas, State Parks and Recreation Commission, US Forest Service, National Weather Service, National Park Service, and other agencies, help fund the Northwest Weather and Avalanche Center, which provides daily forecasts throughout the avalanche season for those involved with highway avalanche control and for recreationalists. In FY 2011 the avalanche center received approximately $603,984 in direct funding and in-kind contributions for its operations.[7]

During the avalanche season, the Northwest Weather and Avalanche Center issues twice daily mountain weather forecasts and daily (or more often) avalanche forecasts as well as special statements and avalanche warnings during times of significantly increased avalanche danger. Additionally, the NWAC maintains and manages a comprehensive network of remote mountain weather stations (see www.nwac.us/weatherdata/map/) that provide hourly weather data to users and cooperators alike.

The informational chart below details the current 2010 version of the US Danger Scale utilized by the NWAC when issuing their warnings.

North American
Public Avalanche Danger Scale

Danger Level		Current Conditions	Know Before You Go
5 Extreme	4 5	**Canadian Avalanche Bulletins** www.avalanche.ca	Does your group have the skills, knowledge and training to travel in avalanche terrain?
4 High	4 5	**American Avalanche Advisories** www.avalanche.org	Are you carrying transceivers, shovels and probes? Can you self-rescue? Do you have a plan?
3 Considerable	3		Do you know the emergency number?
2 Moderate	2	Parks Canada Parcs Canada canadianavalanchecentre	Have you checked the current avalanche bulletin and weather forecast ?
1 Low	1	caic	Have you checked out with someone? Do you have any other route options?

You control your own risk.

North American Public Avalanche Danger Scale

Avalanche danger is determined by the likelihood, size and distribution of avalanches.

Danger Level		Travel Advice	Likelihood of Avalanches	Avalanche Size and Distribution
5 Extreme	4 5	Avoid all avalanche terrain.	Natural and human-triggered avalanches certain.	Large to very large avalanches in many areas.
4 High	4 5	Very dangerous avalanche conditions. Travel in avalanche terrain not recommended.	Natural avalanches likely; human-triggered avalanches very likely.	Large avalanches in many areas; or very large avalanches in specific areas.
3 Considerable	3	Dangerous avalanche conditions. Careful snowpack evaluation, cautious route-finding and conservative decision-making essential.	Natural avalanches possible; human-triggered avalanches likely.	Small avalanches in many areas; or large avalanches in specific areas; or very large avalanches in isolated areas.
2 Moderate	2	Heightened avalanche conditions on specific terrain features. Evaluate snow and terrain carefully; identify features of concern.	Natural avalanches unlikely; human-triggered avalanches possible.	Small avalanches in specific areas; or large avalanches in isolated areas.
1 Low	1	Generally safe avalanche conditions. Watch for unstable snow on isolated terrain features.	Natural and human-triggered avalanches unlikely.	Small avalanches in isolated areas or extreme terrain.

Safe backcountry travel requires training and experience. You control your own risk by choosing where, when and how you travel.

Avalanche Mitigation

The Washington State Department of Transportation conducts active winter time avalanche control or mitigation on two of the state's mountain highway passes: Stevens Pass on U.S. Route 2 and Snoqualmie Pass on Interstate 90. This means avalanches are triggered intentionally on slopes above the roadways in a controlled environment to minimize traffic disruption and promote public safety. It also conducts passive avalanche control through elevated roadways so avalanches can pass under highways, over snow sheds over highways, into catchment basins to stop avalanche flow, and into diversion dams and berms to keep snow off highways. In addition to these controls the WSDOT closes three passes in winter because avalanches are so prevalent that control measures would be too costly and hazardous.[8] These passes are Chinook Pass (elevation 5,430') that connects Enumclaw and Yakima, Cayuse Pass (elevation 4,675') that connects Chinook and White Pass along the east slope of the Cascades, and Rainy/Washington Passes (elevations 4,855' and 5,500') along the North Cascades Highway, which connects the Skagit Valley to eastern Washington. This portion of the North Cascades Highway holds the distinction of being among the top areas in the United States for most avalanche chutes per mile of highway. Some areas of this highway have five avalanche paths in a mile of roadway.[9] Specific times of the winter when these passes close vary from year to year and are based on snow accumulation, personnel, avalanche risk, and a variety of other factors. Opening for the passes varies as well, although the target date for their opening is May 1 to coincide with the beginning of fishing season.

Use of explosives to prematurely trigger avalanche on Chinook Pass

Avalanche control is a winter-long task on the two primary travel corridors in Washington that must remain open all year long. The more heavily impacted corridors are Interstate 90 -Snoqualmie Pass (elevation 3,022'); the primary East-West corridor serving the Seattle-Tacoma-Olympia area and US Highway 2 - Stevens Pass (elevation 4,061') connecting Everett and Wenatchee. Snoqualmie Pass is the only interstate highway link in Washington through the Cascades. It averages 450 inches of snowfall each winter and has traffic volumes of over 32,000 vehicles a day, including 8,000 trucks. Interstate 90 is closed an average of eighty hours per year due to avalanches.[10] It is estimated that a two-hour closure of Snoqualmie pass costs the state's economy over $1 million.10

Snow shed over Interstate 90 Westbound

Intermittent winter time avalanche control is also used by WSDOT along US-12 (White Pass) when conditions warrant, however, an avalanche control program for US 12 does not exist at this time. Occasional closures due to avalanche danger have occurred. Avalanche control is also done during spring time re-opening of SR 410 (Chinook and Cayuse Passes) and SR 20 (Washington Pass).

Transportation Corridor Avalanche Control[11] [12]

Snow slides are a fact of life in the Cascade Mountains. WSDOT avalanche control technicians work to reduce the potential hazard using all available experience and tools. This means operating a comprehensive program to control when and how to bring down unstable snow. Each winter, WSDOT stations specially trained avalanche control teams at Hyak, near the I-90 Snoqualmie Pass summit and at Berne Camp, near the US 2 Stevens Pass summit. The teams work to reduce the avalanche hazard as well as the number and duration of highway closures. Active avalanche control is when crews intentionally trigger an avalanche. To do this, WSDOT stops traffic and triggers the avalanche. Avalanche control must be done during heavy snowfall. However, to be most effective, active control work is done just as the snow is becoming unstable; but before it slides. Whenever possible, the control work is scheduled outside of peak traffic hours.

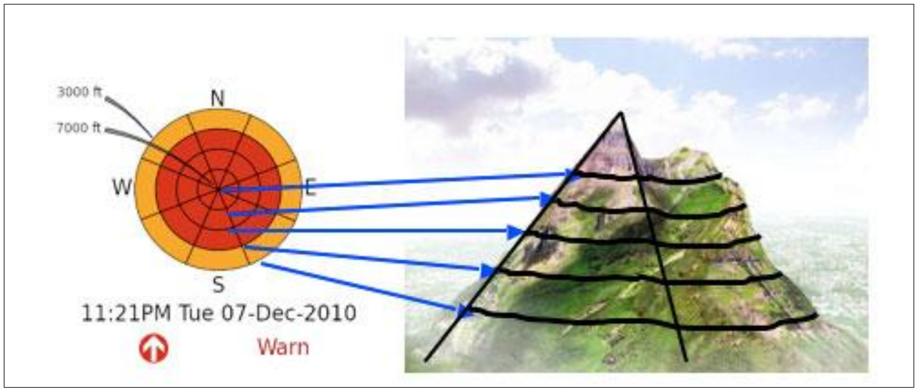
When an avalanche hazard develops, WSDOT uses artillery or explosives to trigger the avalanche. These are various methods of delivery depending on the topography and accessibility to the avalanche path. Explosives are placed by hand, cable-pulley bomb trams, or with surplus military weapons. In addition to active avalanche control, WSDOT also uses passive control methods to control snow slides. These include snow sheds over the highway; elevated roadways so avalanches pass under them, or with catchment basins to stop the avalanche before snow reaches the highway. WSDOT also uses diversion dams and snow berms to keep the snow off the highway.

WSDOT avalanche control activity affects more than travelers. Backcountry recreation has become very popular. From the US 2/Stevens Pass Ski Area, skiers and snowboarders can access backcountry areas and potentially venture into the highway avalanche zones. WSDOT posts warning signs at the top of the ski area and in key locations, but are sometimes ignored. Besides risking injury, skiers and snowboarders sometimes trigger avalanches. They also create a hazard for themselves and others by hitchhiking back to the summit. When vehicles stop to give hitchhikers a ride, it creates a traffic hazard. The Washington State Patrol petitioned WSDOT to post the avalanche zones from milepost 58 to 66 to prohibit hitchhiking and WSP troopers vigorously enforce this ban. Skiers and snowboarders face similar personal hazards at two Snoqualmie Pass ski areas when they ignore signs and venture outside ski area boundaries.

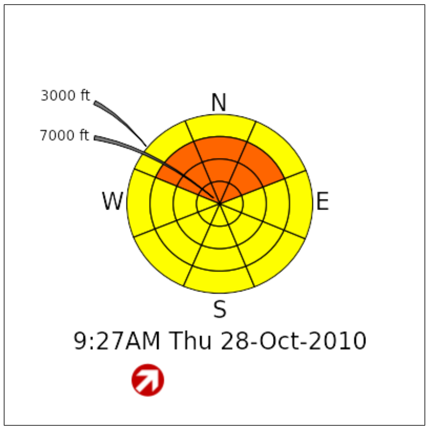
Recreational Activity Avalanche Control

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

The Avalanche Danger Rose represents the highest danger level(s) expected for the indicated area (by elevation and aspect) *for the daylight hours*. The danger trend arrow (lower left part of rose graphic) indicates the most significant (highest impact) avalanche danger change expected *for the daylight hours*, ranging from strongly increasing (arrow pointing up) to strongly decreasing (arrow pointing down). Although the danger rose figures only indicate the greatest danger for the particular region for the daylight hours, danger trends for overnight hours are discussed in the text product. The danger rose can be visualized as a conical mountain within the forecast area that is divided into elevation rings and aspect slices as shown in the example. The first sample rose shown below with the mountain indicates an avalanche warning along with a strongly increasing danger trend and high danger above 4000 feet.



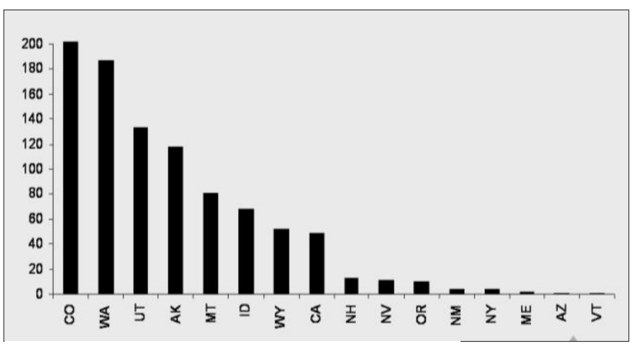
The second sample rose shown below indicates two danger levels between 3000 ft (the outermost ring) and 7000 ft (the innermost ring). The danger is moderate in yellow and considerable in orange and indicates the following danger description: *Considerable avalanche danger on northwest through northeast exposures above 4000 feet, otherwise moderate avalanche danger below 7000 feet. The slightly upward angled arrow in the left lower part of the figure indicates the most significant danger trend is for a slight danger increase during the day.*




Aerial Photo of 1970 Yungay, Peru Avalanche

Previous Occurrences

As shown, Washington ranks second behind Colorado in fatalities from avalanches with 187 from 1950 to 2006.[13] In the United States since the year 2000, there have been an average 200 people reported caught in avalanches each winter: 90 were partly buried or buried, 32 were injured, and 28 were fatalities. United States property losses due to avalanches in this same period ranged from a low of $30,000 to a high of $2 million. The largest accident in Washington involving an avalanche, known as the Wellington Disaster, occurred in 1910 when two trains near Stevens Pass were swept off the tracks killing 96 passengers on board. Although there is not any recorded history of a catastrophic disaster in this state from an avalanche, the potential for this hazard to cause massive destruction exists. A recent disaster from an avalanche took 50,000 lives in Iran in 1990 burying many villages in its path. The inhabitants of Yungay, Peru experienced a similar fate in 1970 when an earthquake triggered an avalanche on the slopes of Nevado de Huascarán sending millions of tons of snow into the valley below (Figure 1-4). The city and its 20,000 inhabitants were buried under 100 million cubic yards of snow, mud and rubble. Only 92 people survived.[14]



Avalanche Fatalities by State 1950-2006

Thousands of avalanches occur in the mountains of Washington every winter. Hundreds of these incidents can affect travel over the mountain pass highways, and all present the potential for accidents, delays, and fatalities to the citizens of the State. Current mitigation strategies in place lessen the potential for impact by this hazard. However, the possibility still exists for avalanches to affect the people, economy, environment, and property of Washington.

Selected Avalanches in Washington State – 1910 to Present[15]

Date	Location	Casualties
1910	Stevens Pass	Two trains swept off their tracks, 96 dead
1939	Mount Baker	6 dead
1958	Silver Creek	4 buried
1962	Granite Mountain	2 dead
1962	Stevens Pass	2 buried
1971	Yodelin	4 dead, several buried
1974	Source Lake	2 dead
1975	Mount St. Helens	5 dead
1981	Mount Rainier	19 dead, 18 injured
1988	Mount Rainier	3 dead
1992	Mount Rainier	2 dead
1994	Mission Ridge	1 dead
1996	Index	3 dead
1996-1997	Snoqualmie Pass	Hundreds of travelers stranded after repeated avalanches closed Interstate 90 during the holidays
1998	Drop Creek	Snowmobile buried, 1 dead
1998	Mount Rainier	1 climber dead, several climbers injured
1998	Mount Baker	1 dead
1999	Mount Baker	1 snow boarder and 1 skier dead
2000	Crystal Mountain	1 dead
2001	Twin Lakes	2 dead
2001	Mount Baker	1 dead
2001	Lake Ann	1 dead
2002	Crystal Mountain	1 dead
2003	Snoqualmie Pass	1 snowshoer dead
2003	Mount Baker	1 snowshoer dead, 2 snowshoers injured
2003	Navajo Peak	1 snowmobiler dead
2004	Mount Baker	1 snowboarder dead
2004	Mount Rainier	2 climbers dead
2005	Snoqualmie Pass	1 skier dead
2005	Mount Baker	2 snowboarders buried – found alive by beacon (2 separate incidents/days)
2006	Mount Baker	1 skier dead
2006	Tiffany Mountain	1 snowmobiler dead

2006	Mount Hood	3 skiers buried
2007	Edit Ck Basin, Mt Rainier National Park, WA	2 snowshoers totally buried, found by probing under ~6-10 ft of snow
2007	Union Creek, south-central WA Cascades, northeast of Crystal Mt, WA	3 snowboarders dead. Group departed on weekend trip on 11/30/2007. Reported missing on 12/2/07. Subsequent searches on ground and air found no evidence of any of the group. Official search abandoned 12/8/07. Final Search and Recovery effort concluded late June, 2008 when the three missing snowboarders were found buried in avalanche debris in Union Creek.
2007	Northway at Crystal Mt Resort, WA	Two ski patrollers caught, 1 totally buried, 1 mostly buried and able to self extricate--found and rescued partner; south-central Washington Cascades at Crystal Mountain Resort, WA
2007	Snoqualmie Pass	2 hikers killed; 1 additional buried, injured & self rescued
2007	Mount Rainier	1 skier dead
2008	Rockford, WA	1 resident caught, buried and killed by roof avalanche while shoveling walk and clearing roof
2008	Tatie Peak, near Harts Pass, northern WA Cascades	1 snowmobiler dead
2008	Kahler Glen, north-central WA Cascades near Lake Wenatchee	A large natural avalanche released during the late afternoon of February 7, impacting and mostly destroying a home in the Kahler Glen development just above and west of the Kahler Glen Golf Course
2008	Lake Twenty-two trail near Mt. Pilchuck, north-central WA Cascades	8 hikers descending Lake Twenty-Two Trail; 4 in party were caught by avalanche. Slide partially buried one; totally buried three. Three were found by spot probing and survived; 1 not recovered until later by rescue team died.
2008	Excelsior Pass below Church Mtn, northern WA Cascades	5 snowmobilers high marking in the Excelsior Pass area triggered a large 5-7 ft deep slab. The avalanche caught five, partly burying one, totally burying and killing two. Victims reportedly found by beacon and probing under three and six feet of snow.
2009	Hogsback Mtn, south-central WA Cascades	One skier caught and completely buried under ~2.5 ft of snow. Found by partner's beacon and recovered within about 10 minutes.
2010	Morning Star Peak, north-central WA Cascades	One hiker/climber caught, partially buried and killed; dog recovered alive
2011	Hooky Bowl on Trout Ck drainage, near Mt Cashmere, east slopes central WA Cascades	1 BC skier in a group of 5 triggered and caught by slide, carried through trees and fatally injured. Found deceased on the surface by party members.
2011	Backside of Cowboy Mtn toward Tunnel Ck, west of Stevens Pass Ski Area, north central WA Cascades	Snowboarder triggered and caught by wet loose slide, swept into tree band and fatally injured. Found quickly by party members but failed to respond to CPR
2012	Tunnel Creek draining west of Stevens Pass Mountain Resort, north-central WA Cascades	Four skiers triggered and caught by 2-3 foot slab while skiing the Tunnel Creek back country off Cowboy Mountain to the SSW of the ski area. Three buried and killed (combination of trauma and suffocation), one survived with air bag deployed.

2012	WAC Bluff area, east of Alpental Ski Area, central WA Cascades, WA	Three snowboarders entered the 80s chute in the back country to the east of Alpental Ski Area, triggering a slide. The slide caught two, one of whom was able to self arrest. The other boarder was carried over a steep cliff chute and died from trauma.

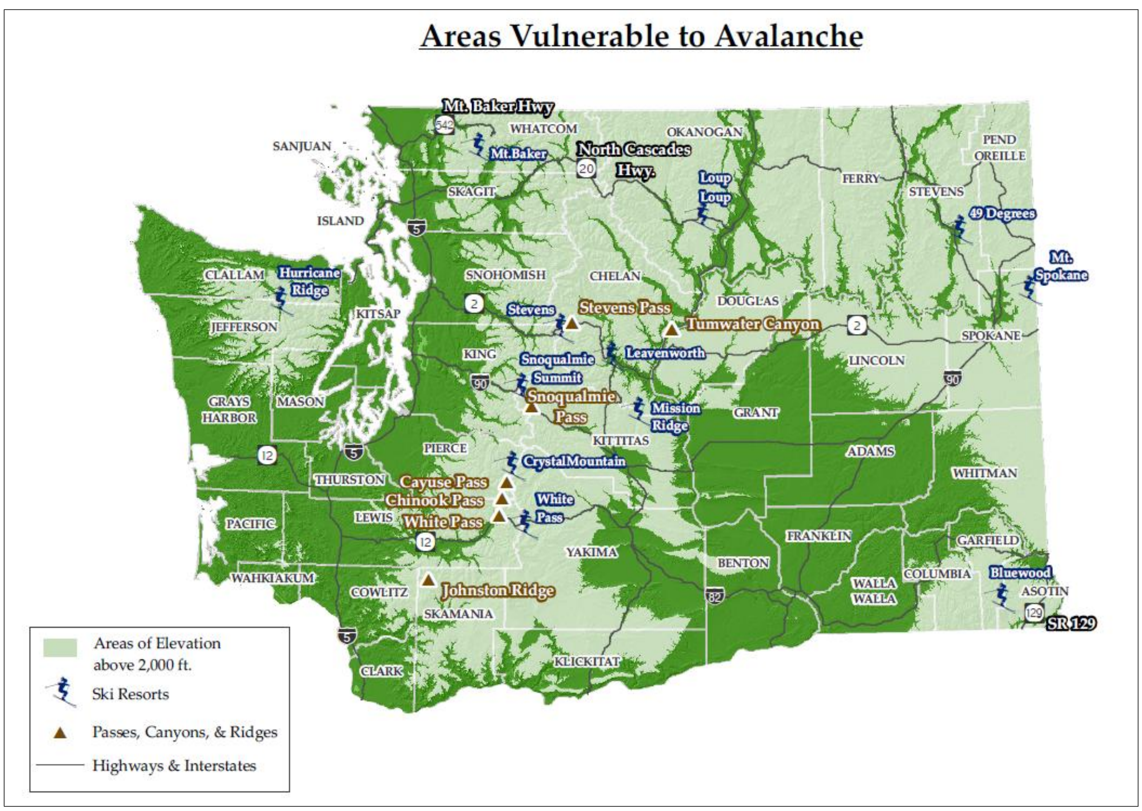
Probability of Future Events

Avalanches occur regularly every year in mountain areas. Many weather, snowpack and terrain factors determine actual avalanche danger. Avalanches along two key mountain highway passes are limited due to ongoing mitigation to control slides during winter months. Nonetheless, those highways do get closed regularly for control work and cleanup. Recreation activity in backcountry areas results in countless avalanches and a few deaths each year.

Jurisdictions Most Vulnerable to Avalanches

Based on the location of key transportation routes and recreational areas threatened by avalanche, parts of the following counties are most vulnerable to avalanche:

Asotin	**Chelan**	**Ferry**	**Garfield**	**King**	**Kittitas**	**Klickitat**	**Lewis**
Okanogan	**Pend Oreille**	**Pierce**	**Skagit**	**Skamania**	**Snohomish**	**Whatcom**	**Yakima**



Transportation routes threatened by avalanche[16,17,18.]

Highway closures due to avalanche can have a significant economic impact on the state. Economists estimate that closing Interstate 90 over Snoqualmie Pass has an economic cost to the state of between $500-750,000 per hour for stalled shipping, lost perishables, and rerouting. During the winter of 1996-97, there were 276 hours of closure of I-90 over Snoqualmie Pass, 70 percent related to avalanche control and avalanche safety closures; these closures were more than in any other year in recent times. The closures cost the state's economy an estimated $144 million (in 2002 dollars).

The Washington Department of Transportation spends considerable effort each winter keeping the following mountain passes open and free from avalanches:

- King County – Snoqualmie Pass I-90, Stevens Pass US 2.
- Kittitas County – Snoqualmie Pass I-90, Blewett Pass US 97.
- Chelan County – Stevens Pass and Tumwater Canyon US 2.

Passes closed all winter with spring openings that have residual avalanche hazard after they are open are:

- Pierce, Yakima Counties – Chinook Pass SR 410, Cayuse Pass SR 123.
- Skagit, Okanogan Counties – North Cascades Highway SR 20.

Mountain passes and highways that pose avalanche problems or that have the potential for problems in the worst conditions are:

- Lewis and Yakima Counties – White Pass US 12.
- Skagit County – Diablo Canyon SR 20.
- Skamania County – Johnston Ridge, SR 504.
- Asotin County – SR 129 south of Anatone.
- Whatcom County – SR 542 to the Mount Baker Ski Area.

Recreation areas threatened by avalanche[19]

With better equipment allowing more people to explore further into the wilderness, areas threatened by avalanche are those accessible by skiers, snowshoers, snowboarders, climbers, hikers and snowmobilers outside developed ski resorts in the mountains of Washington. This includes the areas that people can reach via Sno-Parks (parking lots cleared of snow) in Asotin, Chelan, Ferry, Garfield, King, Kittitas, Klickitat, Lewis, Okanogan, Pend Oreille, Pierce, Skagit, Skamania, Snohomish, Whatcom, and Yakima counties; Hurricane Ride in Olympic National Park (Clallam County) is another area providing easy access to avalanche-prone terrain (see map generally depicting areas at-risk to avalanche below).

State Agency Structures at Risk

State Agency Structures At Risk			
Number and Function of Buildings	**No. of Affected Staff / Visitors / Residents**	**Approx. Value of Owned Structures**	**Approx. Value of Contents**
Total at-risk buildings: 0	0	0	0
However, WSDOT has identified a number of state highways as being at risk to avalanche: 1. Asotin County – SR 129 south of Anatone. 2. Chelan County – Stevens Pass and Tumwater Canyon US 2. 3. King County – Snoqualmie Pass I-90, Stevens Pass US 2. 4. Kittitas County – Snoqualmie Pass I-90, Blewett Pass US 97. 5. Lewis and Yakima Counties – White Pass US 12 and SR 410. 6. Pierce County – Chinook Pass SR 410, Cayuse Pass SR 123. 7. Skagit County – North Cascades Highway SR 20. 8. Skamania County – Johnston Ridge, SR 504. 9. Whatcom County – SR 542 to the Mount Baker Ski Area.			
Total at-risk critical facilities: 0	0	0	0
Four state highways considered emphasis corridors because of their importance to movement of people and freight have been identified as being at risk to avalanche: 1. U.S. Highway 2 2. U.S. Highway 12 3. Interstate 90 4. U.S. Highway 97			

Potential Climate Change Impacts[20,21,22,23]

With the advent of climate change coming into worldwide focus; it is necessary to take into account the potential effects this emerging climate crisis may have on the dangers associated with avalanches. The research done so far indicates the potential for avalanches to become more frequent and deadly, as global warming effects the melting of permafrost, the permanent frozen layer of snow that gives our mountains and peaks their distinctive look. Already, the melting of permafrost can be blamed on several recent Alpine disasters, including the avalanches which killed more than 50 people at the Austrian resort of Galtur in 1999.[24]

According to a 2005 Governor's report prepared by the Climate Impacts Group titled *Uncertain Future: Climate Change and its Effects on Puget Sound*, from "paleoclimatological evidence, we know that over the history of the earth high levels of greenhouse gas concentrations have correlated with, and to a large extent caused, significant warming to occur, with impacts generated on a global scale." While the report also indicates that the "ultimate impact of climate change on any individual species or ecosystem cannot be predicted with precision," there is no doubt that Washington's climate has demonstrated change.

In July 2007, the Climate Impacts Group launched an unprecedented assessment of climate change impacts on Washington State. *The Washington Climate Change Impacts Assessment* (WACCIA) involved developing updated climate change scenarios for Washington State and using these scenarios to assess the impacts of climate change on the following sectors: agriculture, coasts, energy, forests, human health, hydrology and water resources, salmon, and urban stormwater infrastructure. The assessment was funded by the Washington State Legislature through House Bill 1303.

In 2009, the Washington State Legislature approved the *State Agency Climate Leadership Act* Senate Bill 5560. The Act committed state agencies to lead by example in reducing their greenhouse gas (GHG) emissions to: 15 percent below 2005 levels by 2020; 36 percent below 2005 by 2035; and 57.5 percent below 2005 levels (or 70 percent below the expected state government emissions that year, whichever amount is greater.). The Act, codified in RCW 70.235.050-070, directed agencies to annually measure their greenhouse gas emissions, estimate future emissions, track actions taken to reduce emissions, and develop a strategy to meet the reduction targets. Starting in 2012 and every two years thereafter, each state agency is required to report to Washington State Department of Ecology the actions taken to meet the emission reduction targets under the strategy for the preceding biennium.

Recognizing Washington's vulnerability to climate impacts, the Legislature and Governor Chris Gregoire directed state agencies to develop an integrated climate change response strategy to help state, tribal and local governments, public and private organizations, businesses and individuals prepare. The state Departments of Agriculture, Commerce, Ecology, Fish and Wildlife, Health, Natural Resources and Transportation worked with a broad range of interested parties to develop recommendations that form the basis for a report by the Department of Ecology: *Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy*.

Over the next 50 - 100 years, the potential exists for significant climate change impacts on Washington's coastal communities, forests, fisheries, agriculture, human health, and natural disasters. These impacts could potentially include increased annual temperatures, rising sea level, increased sea surface temperatures, more intense storms, and changes in precipitation patterns. Therefore, climate change has the potential to impact the occurrence and intensity of natural disasters, potentially leading to additional loss of life and significant economic losses. Recognizing the global, regional, and local implications of climate change, Washington State has shown great leadership in addressing mitigation through the reduction of greenhouse gases.

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