SUB-SECTION 4G.5

PUYALLUP TRIBE ALL HAZARD MITIGATION PLAN
VOLCANIC HAZARD[1]

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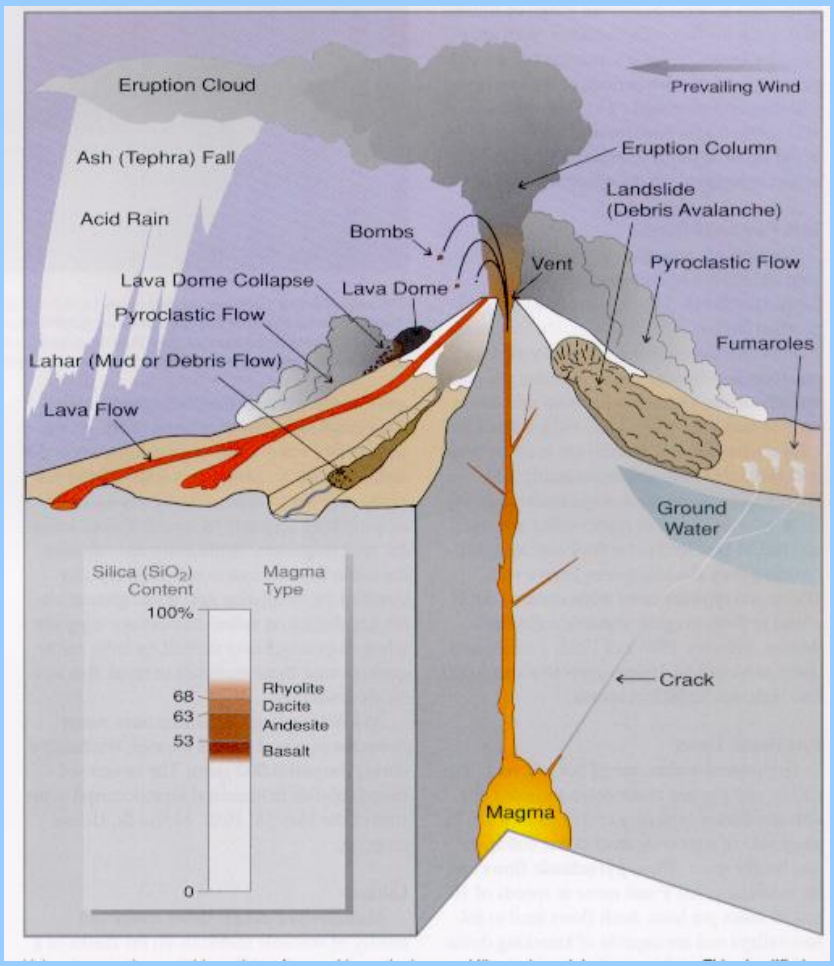
Identification Description

Definition[2]

A volcano is a vent in the earth's crust through which molten rock (lava), rock fragments, gases, and/or ash can be ejected from the earth's interior (see Figure 4.5-1). Volcanic hazards in the region include all hazards associated with individual volcanoes in the Cascade Mountain Range. This includes tephra, landslides, lahars, pyroclastic flows, lava, and acid rain, see Figure 4.5-1.

Figure 4.5-1 Volcanic Hazards[3]



Volcanoes have a number of hazards that have to be considered in any mitigation plan. Many of these will only affect areas close to the volcano, but others like lahars and tephra, can cause damage many miles away.

Figure 4.5-2 Debris flow at Tahoma Creek, July 26, 1988

Debris Flows

Debris flows of glacial ice and rock debris may be set in motion by explosions, earthquakes, and heat-induced melting of ice and snow, or the sudden release of water held within a glacier called a glacial outburst flood. A debris flow is a type of landslide that moves at high speeds; see Figure 4.5-2 Debris flow at Tahoma Creek, July 26, 1988.[4] The best recent examples of this are the small debris flows that come off the mountain every few years. The October 2-3, 1947 glacial outburst flood was the largest debris flow since Mt. Rainier National Park was established[5]. Most debris flows at Mt. Rainier are confined to areas either within the park or in a few instances extending to areas just outside the park boundary.

Lahars

Also called mudflows, lahars are a specific type of debris flow associated with volcanoes. They are dense mixtures of water-saturated debris that move down-valley, looking and behaving much like flowing concrete. They involve much greater quantities of material than do the normal debris flows and can cover many square miles of valley bottom with mud and other debris many meters deep, see Figure 4.5-3.[6] A contractor examines a large Douglas fir stump, which had been buried 20 feet below the valley floor in Orting after the Electron lahar. Over 60 postglacial (since the last ice age) lahars have been identified as coming from Mt. Rainier.[7]

4.5-3 Douglas Fir Stump – Electron Lahar Deposit in Orting

Lahars come in two types, called cohesive and non-cohesive lahars.[8] Cohesive lahars consist of debris with at least three to five percent clay content. The clay content in a cohesive lahar allows the lahar to resist losing material and transforming from a lahar to a hyper-concentrated stream flow. As such, a cohesive lahar will tend to maintain its integrity as a flow, constant in texture and coherent as a mass over greater distances than does a non-cohesive flow.

Non-cohesive lahars contain less than three to five percent clay, usually around one percent. These lahars tend to be more granular and consist of relatively unaltered volcaniclastic debris. As the flow moves away from the volcano, it tends to deposit material, become diluted and eventually become a hyper-concentrated flow. Essentially the fluid within the flow outruns the sediment, leaving it behind as deposits of rock, gravel, sand, etc.

Toxic Gases

Pockets or clouds of toxic gases may develop on or near both active and inactive volcanoes. Their chemical poisons can cause internal and external burns, or asphyxiation through oxygen starvation. Carbon dioxide, an example of an asphyxiant, is heavier than air and when given off by a volcano can collect in low-lying areas. Carbon dioxide has been collected within the summit caves of Mt. Rainier and a small area of release near Longmire has collected in small depressions in the past and proven hazardous to mice and insects. Other gases that may be present include sulfur compounds, carbon monoxide, chlorine, fluorine, boron, ammonia and various other compounds. With the exception of inside the summit caves these generally are dissipated rapidly by wind.[9]

Figure 4.5-4 Landslide from Little Tahoma Peak covering Emmons Glacier

Landslide

Landslides from the sides of the volcano may be large or small, but all can have effects on valleys down stream. Small landslides are common on Mt. Rainier. Large landslides occur occasionally; the last large one was from Little Tahoma Peak, a subsidiary peak on the side of Mt. Rainier in 1963; see Figure 4.5-4.[10] Depending on the size of the slide and the consistency and temperature of the material, some of them may transform into lahars.

Magmatic Volcanic Hazards

Volcanic Earthquakes

Often centered within or beneath the volcano, volcanic earthquakes are usually one of three kinds: pre-eruption earthquakes caused by explosions of steam or underground magma movements; eruption earthquakes caused by explosions and collapse of walls inside the volcano, and post-eruption earthquakes caused by the retreat of magma, interior structural collapse and landslides of material from the crater walls and sides of developing domes.

Lava flows

Lava flows are masses of hot, partially molten to molten rock that flow down slope, generally following valleys. Lava flows from the Cascade volcanoes tend to be short and slow moving due to their high viscosity. The viscosity of lava flows is more dependent on the chemical composition of the material rather than the temperature. Mt. Rainier lava flows have high silica content and tend to be more viscous than do those with low silica content. As such they tend to stay close to the volcano rather than extending down valleys long distances. Many of the Mt. Rainier lava flows in prehistoric times tended to flow down valleys, frequently beside glaciers. These flows now form many of the ridges that surround Mt. Rainier.

Tephra

Tephra is the general term now used by volcanologists for airborne volcanic ejecta of any size. Table 4.5-1 identifies tephra types and related sizes.

Table 4.5-1 Tephra Types and Sizes

Tephra Types and Sizes[11]	
Fine Ash	<1/16 mm
Coarse ash	1/16 mm – 2 mm
Lapilli	2 – 64 mm
Blocks and Bombs	>64 mm

Pyroclastic Flows and Surges

Pyroclastic flows and surges can occur during explosive eruptions. Pyroclastic flows are avalanches of hot ash, rock fragments, and gas that move at high speeds down the sides of a volcano during explosive eruptions or when the edge of a thick, viscous lava flow or dome breaks apart or collapses. Such flows can be as hot as 800 degrees Celsius, and are capable of burning and destroying everything in their paths. Pyroclastic surges are more energetic and thus less restricted by topography.

Lateral blasts

Lateral blasts are explosive events in which energy is directed horizontally instead of vertically from a volcano. These blasts are gas-charged, hot mixtures of rock and ash that are expelled at speeds up to 650 mph. Lateral blasts vary in size, but large ones are fairly rare.

Profile

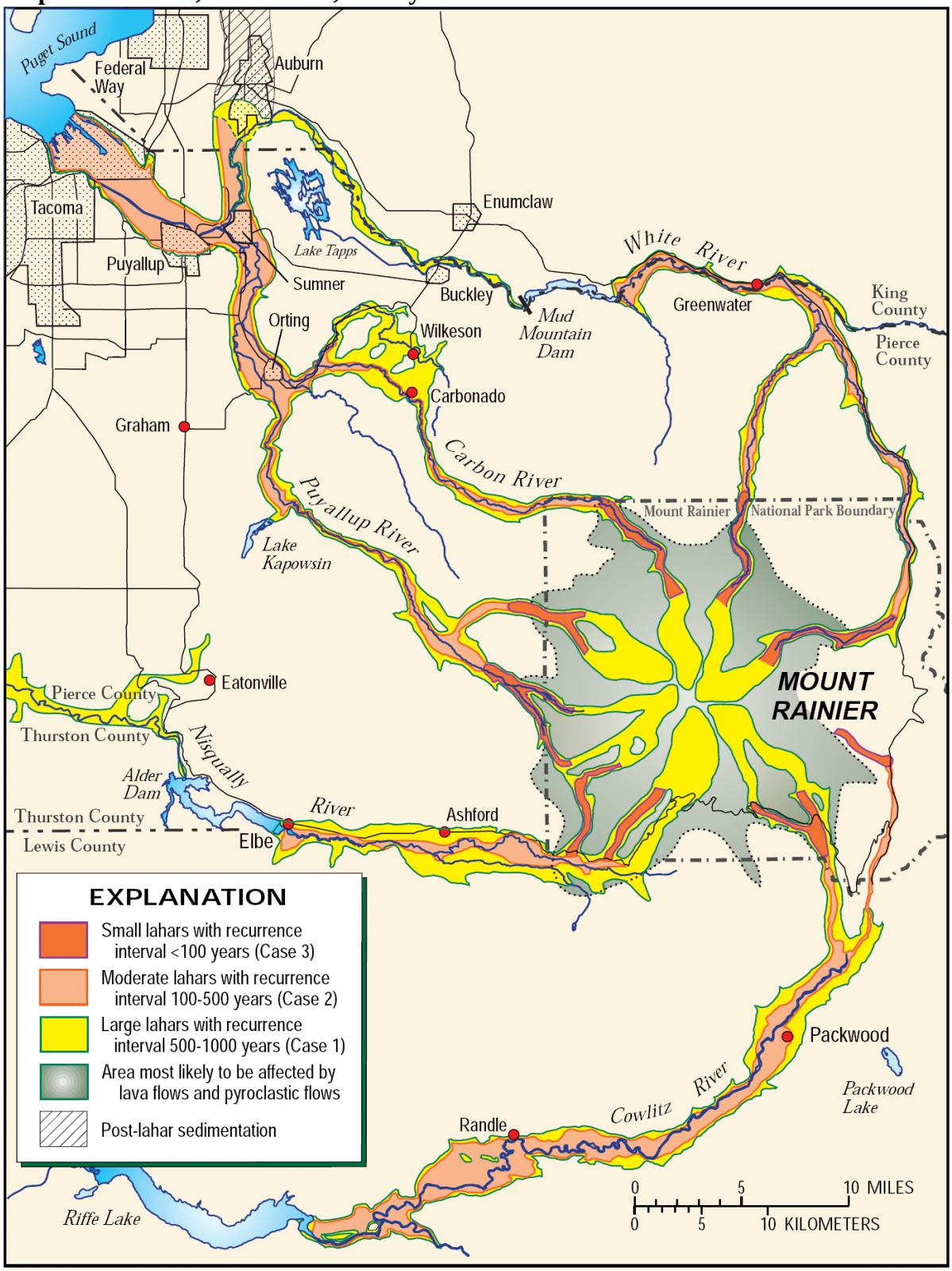
Location and Extent[12]

All of Pierce County is directly and indirectly affected by volcanic hazards. Map 4.5-1 shows the lahar, pyroclastic flow and lava hazard areas in Pierce County and Map 4.5-2 shows the potential for tephra distribution.

As illustrated on the first map, the lahar hazard covers a great deal of the County as each of the major river valleys comprises a portion of the lahar run out zone. USGS volcanologists and Washington Department of Natural Resources (DNR) geologists identify Mt. Rainier as being in an active eruptive window. From the magnitude of past events, they surmise that the consequences of a lahar or debris flow down the populated river valleys will be catastrophic and could potentially result in a tremendous loss of life and property. Over 150,000 inhabitants of the river valleys work and reside on the deposits of prehistoric and historic debris flows.

The area covered by a Case I or Case II lahar (See page 7.) will include some of the larger population centers, as well as major transportation routes, both rail and road. These areas include the industrial and economic base for the County - the Port of Tacoma. Even though much of the County will not be directly impacted by a lahar, it affects all of Pierce County, through transportation changes, population redistribution, infrastructure damage, loss of income and tax base, etc.

Map 4.5-1 Lahars, Lava Flows, and Pyroclastic Hazards of Mt. Rainier[13]



Lahars are categorized by both cohesiveness and size. According to best available science, Case M, I, II, and III lahars are outlined below by their recurrence intervals:[14]

- **Case M Lahars—**the largest lahar to occur in the past 10,000 years is the Osceola Mudflow. It formed about 5,600 years ago when a massive debris avalanche of weak, chemically altered rock transformed into a lahar. Osceola deposits cover an area of about 212 square miles in the Puget Sound lowland, extending at least as far as Kent and to Commencement Bay in Tacoma. The communities of Orting, Buckley, Sumner, Puyallup, Enumclaw, and Auburn are wholly or partly located on top of deposits of the Osceola Mudflow. This lahar is at least 10 times larger than any other known lahar from Mount Rainier. Geologists believe flows of this magnitude occur far less frequently than once every 1,000 years.

- **Case I Lahars**—cohesive lahars originate as enormous avalanches of weak, chemically altered rock from the volcano. They can occur with or without eruptive activity. Most Case I flows have reached some part of the Puget Sound lowland. The Electron Mudflow reached the lowland about 600 years ago along the Puyallup River. Its deposits at Orting are as much as 18 feet thick and contain remnants of an old-growth forest. Average recurrence rate for Case I lahars on Mt. Rainier is about 500 to 1,000 years.

- **Case II Lahars**—Usually relatively large non-cohesive lahars, most commonly are caused by melting of snow and glacier ice by hot rock fragments during eruption, but which can also have a non-eruptive origin. More than a dozen lahars of this type have occurred in the past 6,000 years. A few have reached the Puget Sound lowland, including the National Lahar, which occurred about 2,000 years ago. It inundated the Nisqually River valley to depths of 30 to 120 feet and flowed all the way to Puget Sound. About 1,200 years ago, another lahar filled valleys of both forks of the White River to depths of 60 to 90 feet, and flowed 60 miles to Auburn. The average time interval between Case II lahars from Mt. Rainier is near the lower end of the 100 to 500 year range.

- **Case III Lahars**—this class of flows includes small debris avalanches as well as debris flows triggered by sudden, unpredictable release of water stored by glaciers. These debris flows are largely restricted to the slopes of the volcano, rarely moving beyond the National Park boundary; since 1926, outburst floods destroyed or damaged bridges, roads, and national park visitor facilities on about 10 occasions. Glacial outburst floods are unrelated to volcanic activity and typically coincide with periods of unusually high temperatures or unusually heavy rain in summer or early autumn. About three dozen such flows occurred during the 20th century. Case III lahars occur at an average time interval at Mt. Rainier of about 1 to 100 year

Table 4.5-2 Estimated Lahar Travel Times for Lahars 10^7 to10^8 Cubic Meters in Volume (Approaching a Case I Lahar in Size)[15] is based on information from geologists at the Cascade Volcano Observatory. It gives a more detailed overview of the lahar hazard from Mt. Rainier. Dr. Tom Pierson of the Cascade Volcano Observatory, at the request of Pierce County, developed some travel time estimates for the various rivers leading from the volcano. For the Puyallup and Carbon they are based on the time it takes for the lahar to travel from the point where the lahars are recognized by the monitors that are part of the lahar warning system in those valleys. Because they have no lahar warning system, estimates on the White and Nisqually Rivers are from the actual release of material from the volcano's edifice.

Table 4.5-2 Estimated Lahar Travel Times for Lahars 10^7 to10^8 Cubic Meters in Volume

River Basin	Estimated Travel Time in hours
Carbon River	
Carbonado	0.2
Wilkeson	0.3
Orting	0.7
Puyallup River	
Orting	0.7
Sumner	1.1
Puyallup	1.3
Commencement Bay	1.8
Nisqually River*	
Alder Lake	1.0
La Grande	1.5
Haggedorn Road & 526th St	2.0
White River**	
Greenwater	< 1
Mud Mt. Dam overtopping	ca. 2

Travel times on the Puyallup and Carbon Rivers are from Dr. Pierson and are based on the time it would take for the lahar to travel from the lahar recognition points, These are monitors that will pick up a seismic signal from the lahar and broadcast it to the State and County. Travel times on the Nisqually and White Rivers are from the Pierce County cartography work of Karen Truman.

*The Nisqually River lahar entering Alder and La Grande Lakes will displace the water column, pushing it over their tops, therefore travel times downstream from the dams will more closely follow the time patterns of a catastrophic flood.

**The White River has the Mud Mountain Flood Control Dam on it that can work very well at containing a Case II lahar and most of a Case I lahar. This is why all times below the dam are assumed to be 2 hours or greater. It is dependent on the amount of water behind the dam. It is empty most of the year.

New studies show that the process of hydrothermal alteration is unevenly weakening the inside of Mt. Rainier. This is a process whereby the interior portions of the mountain are being chemically altered by contact with hot, acidic water. This makes the slopes more susceptible for failure, increasing both the possibility and size of lahars. The slopes above the Puyallup River drainage are weaker than those above other river drainages originating from Mt. Rainier. The potential risk is compounded by the fact that more people live and work in this river valley than other Mt. Rainier drainage areas.

The other volcanic hazard that might directly affect the County is the potential for tephra, from an eruption, to cover portions of the County. Mt. Rainier has a long history of tephra eruptions. Early lava flows that may precede the development of Mt. Rainier appear to date from no earlier than 2.9 million years ago.

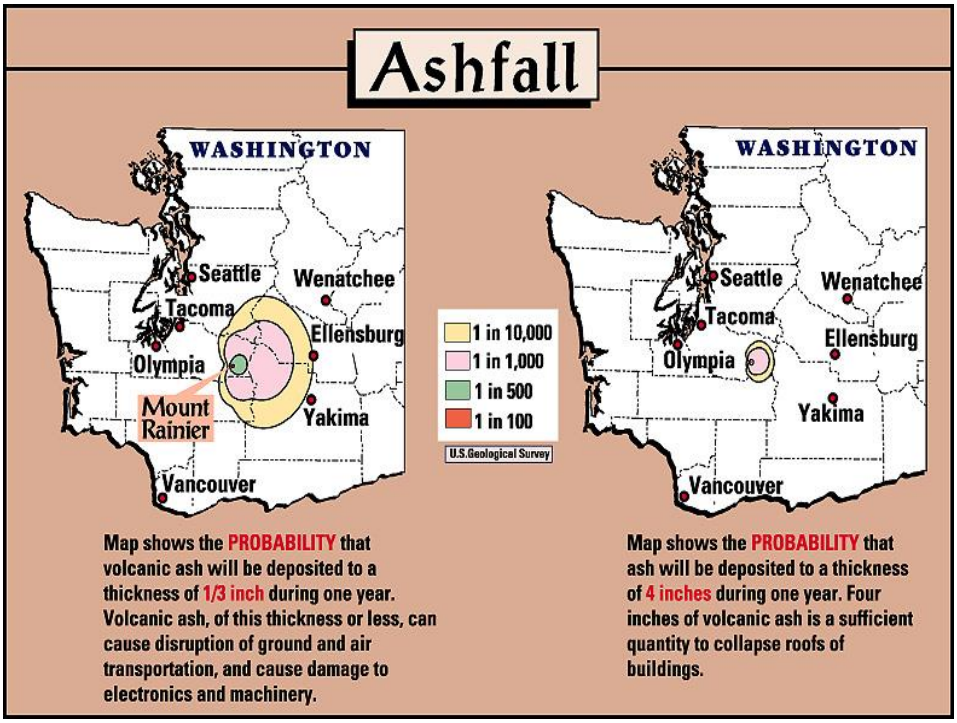
The volcanic cone built up gradually from a sequence of flows that were apparently frequent. Chemical composition of many of the flows shows them to be composed of andesite, with some marginally dacite.[16] Given this type of rock combined with the evidence of tephra and breccia, it appears that many of Rainier's eruptions distributed ash over significant areas. An extremely large deposit appears in the record somewhere between 30,000 and 100,000 years ago. This

eruption was apparently on the scale of the Mt. St. Helens eruption of 1980 and it is estimated that the volume of ash erupted was around 1 km^3.There have been no further eruptions of this size in Holocene times. The potential then for an actual deposition of ash itself from Mt. Rainier is relatively small over much of the County, see Map 4.5-2[17] which includes the probability of a major tephra eruption from the volcano impacting County.

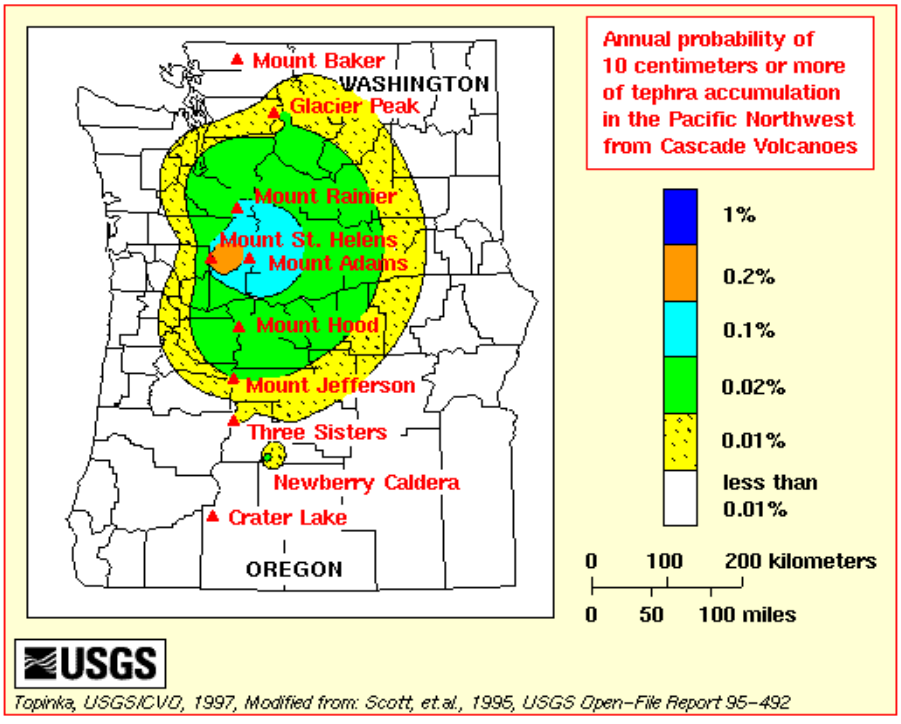
Another possibility is that Pierce County could be affected by tephra from other volcanoes in the Cascade chain. This probability, while possible, is also very small; see Map 4.5-3.[18] Besides Mt. Rainier, Mt. St. Helens has the highest probability of distributing ash across Pierce County. For any of the volcanoes to do so, including Mt. Rainier, the wind needs to be coming from the right direction.

Throughout the Pacific Northwest, most of the normal wind patterns tend to blow from south, southwest, or west. This takes the tephra away from the populated areas of the County. It should be noted that during the 1980 eruptions of Mt. St. Helens, most of Pierce County received some ash, although never a great quantity.

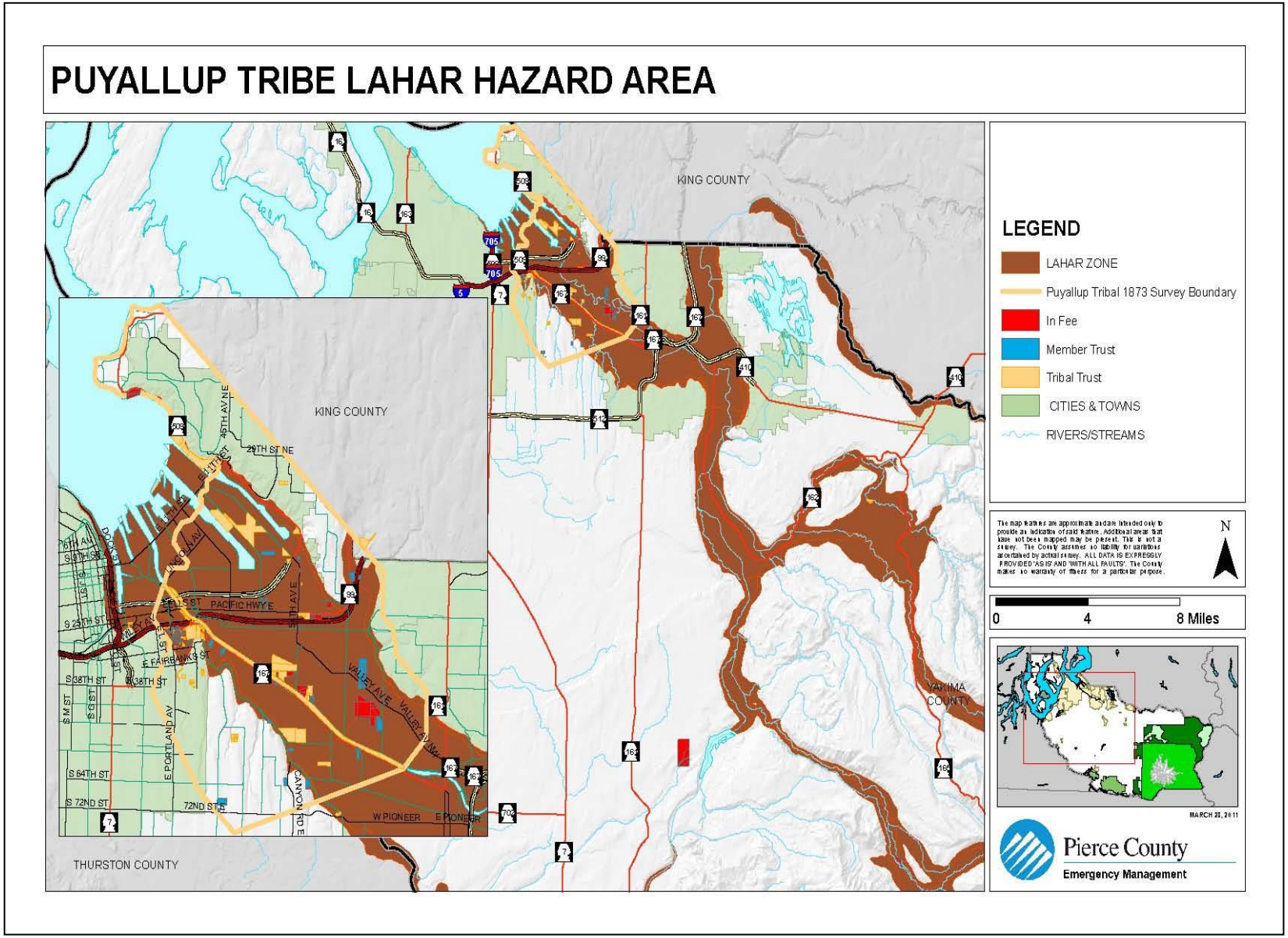
Map 4.5-2 Ashfall Probability from Mt. Rainier



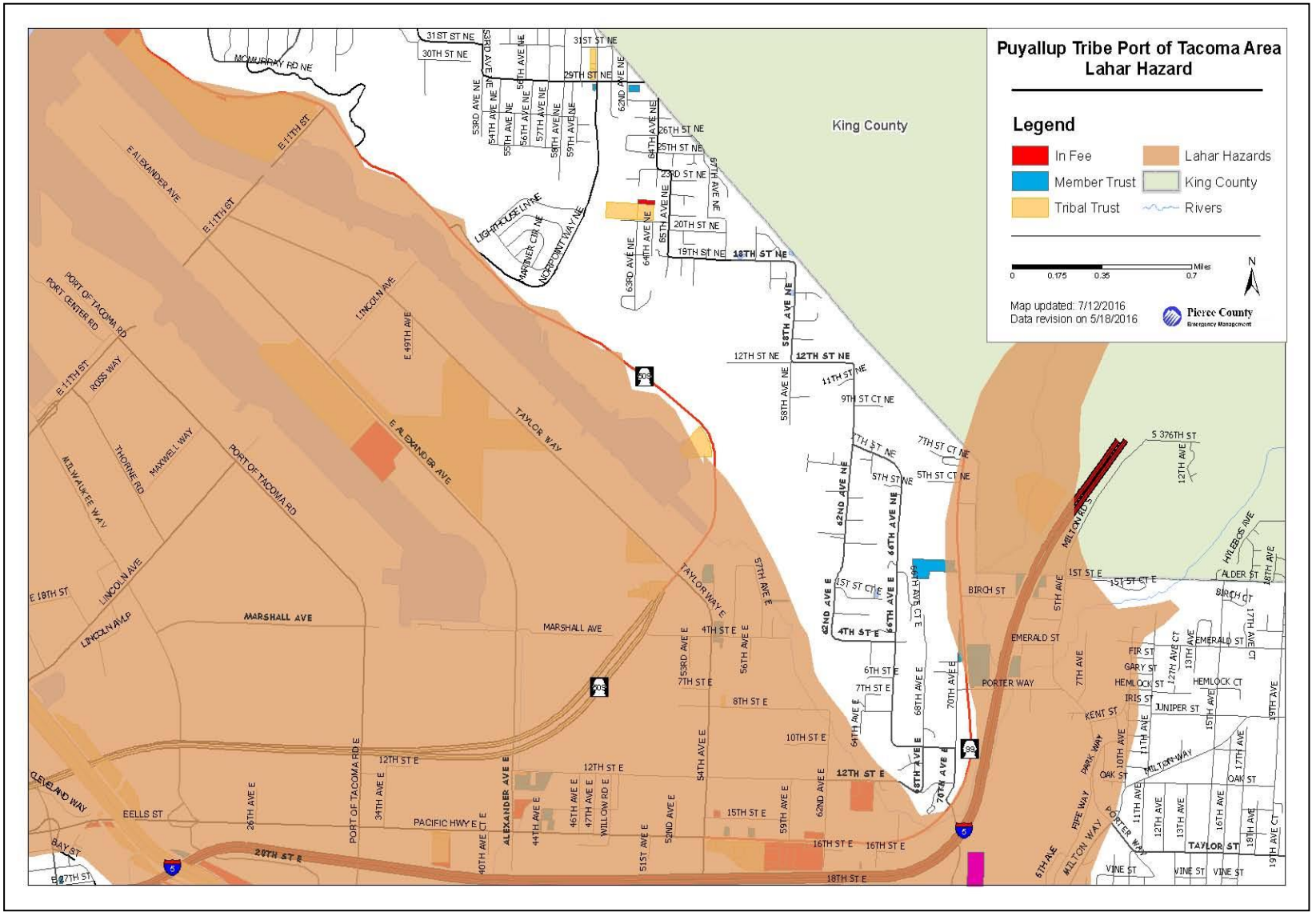
Map 4.5-3 Annual Probability of 10 Centimeters or more of Tephra Accumulation in the Pacific Northwest



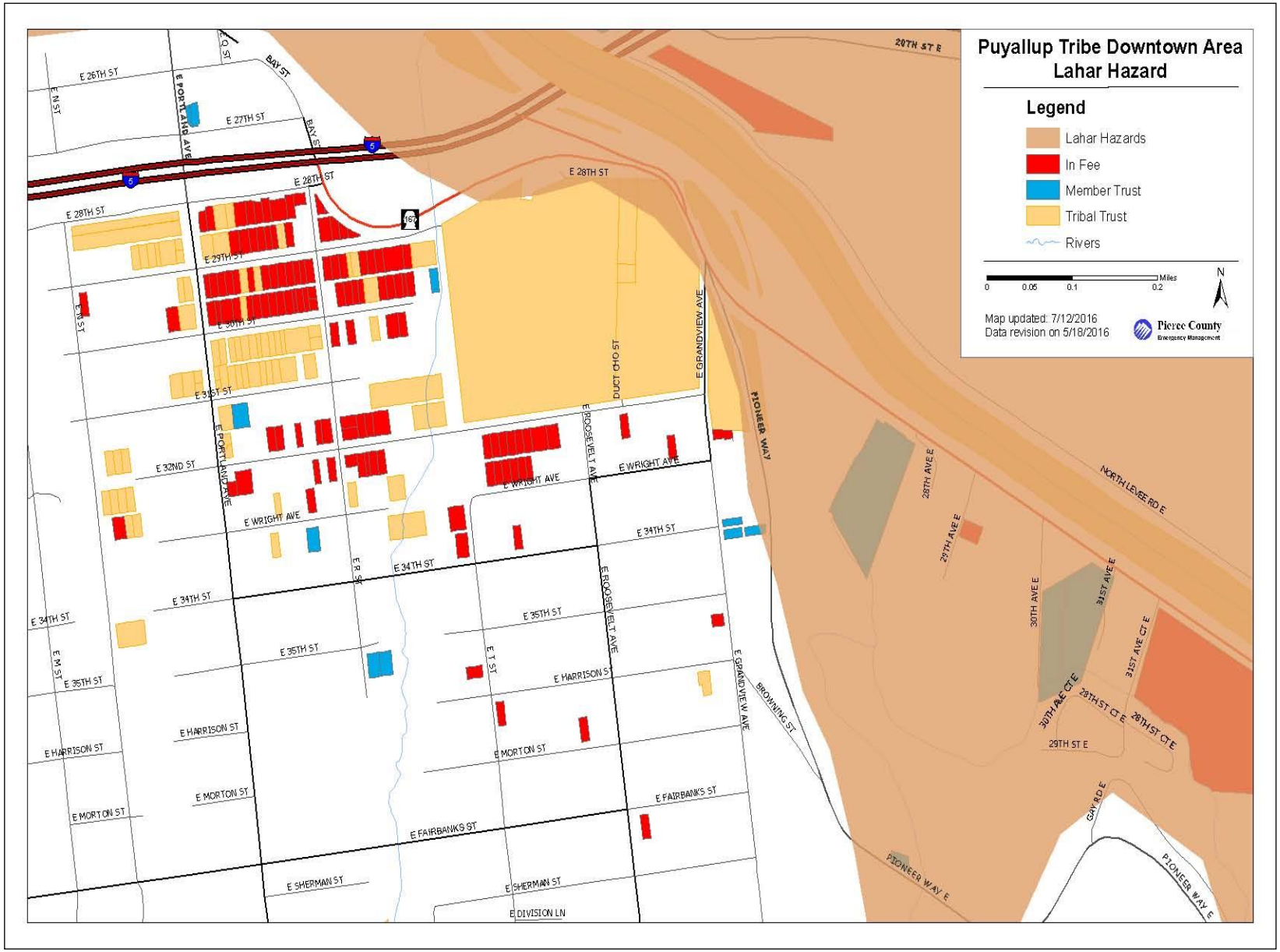
Map 4.5-4 Puyallup Tribe of Indians Lahar Hazard Area



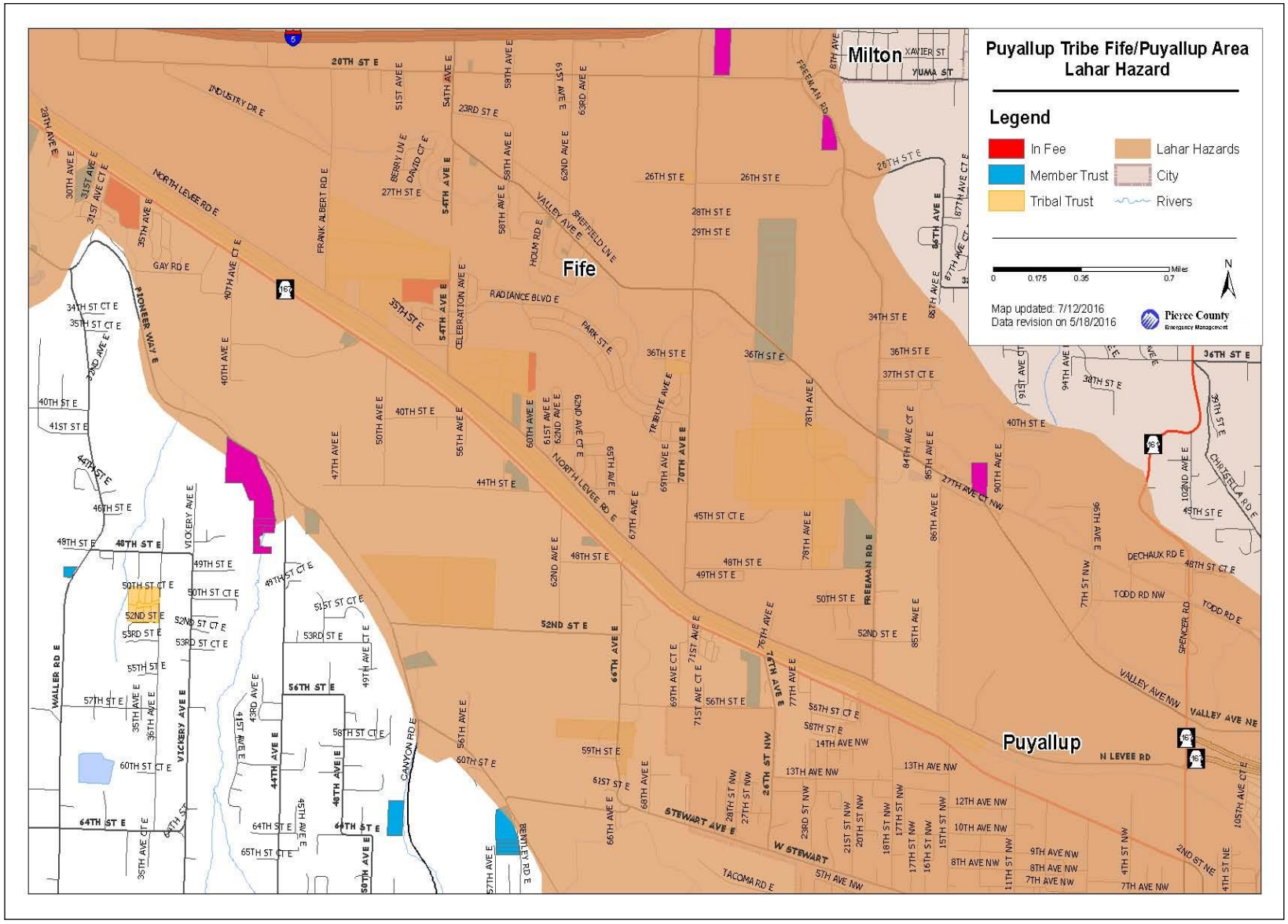
Map 4.5-5 Puyallup Tribe of Indians Port of Tacoma Lahar Hazard Area



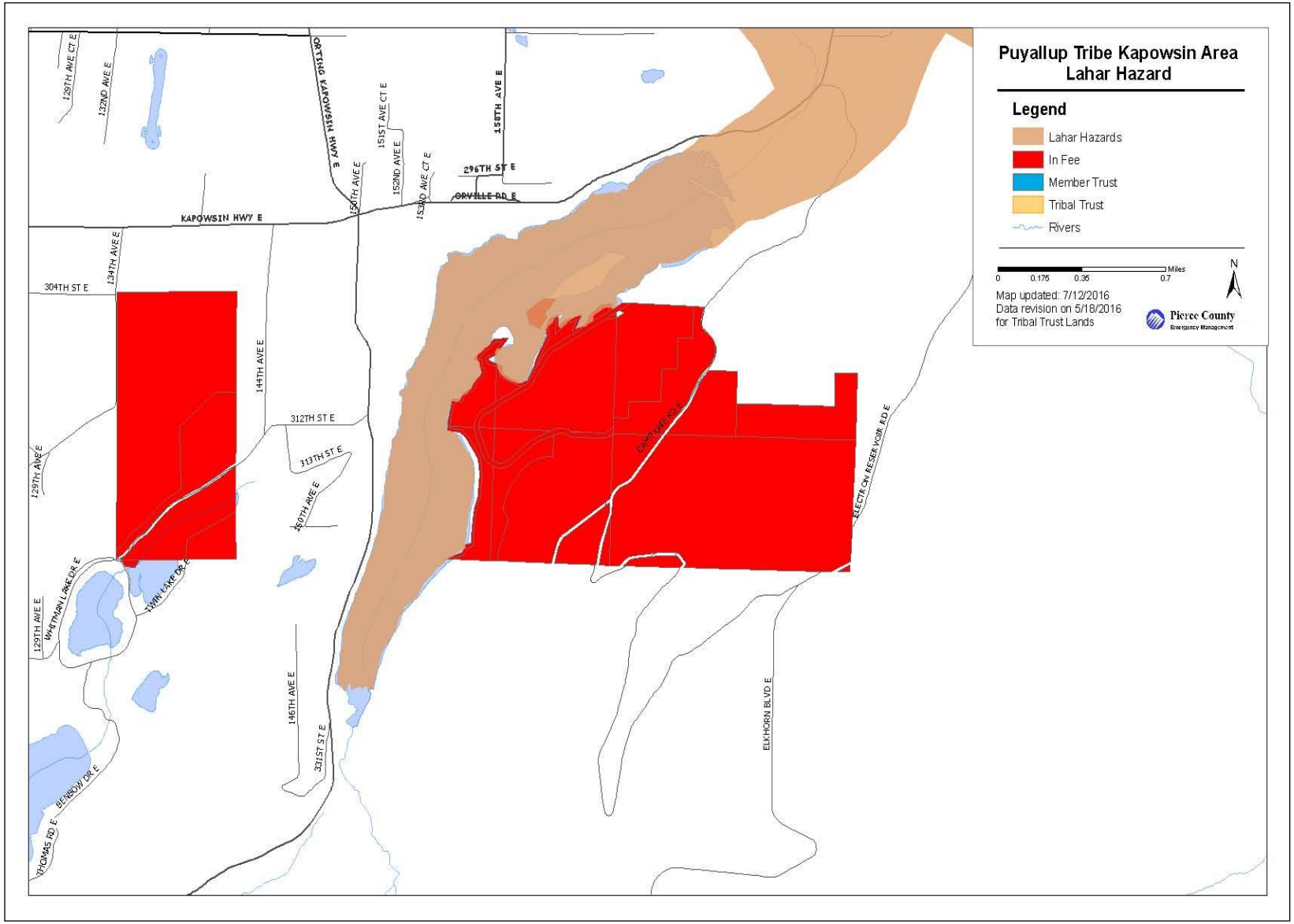
Map 4.5-6 Puyallup Tribe of Indians Downtown Lahar Hazard Area



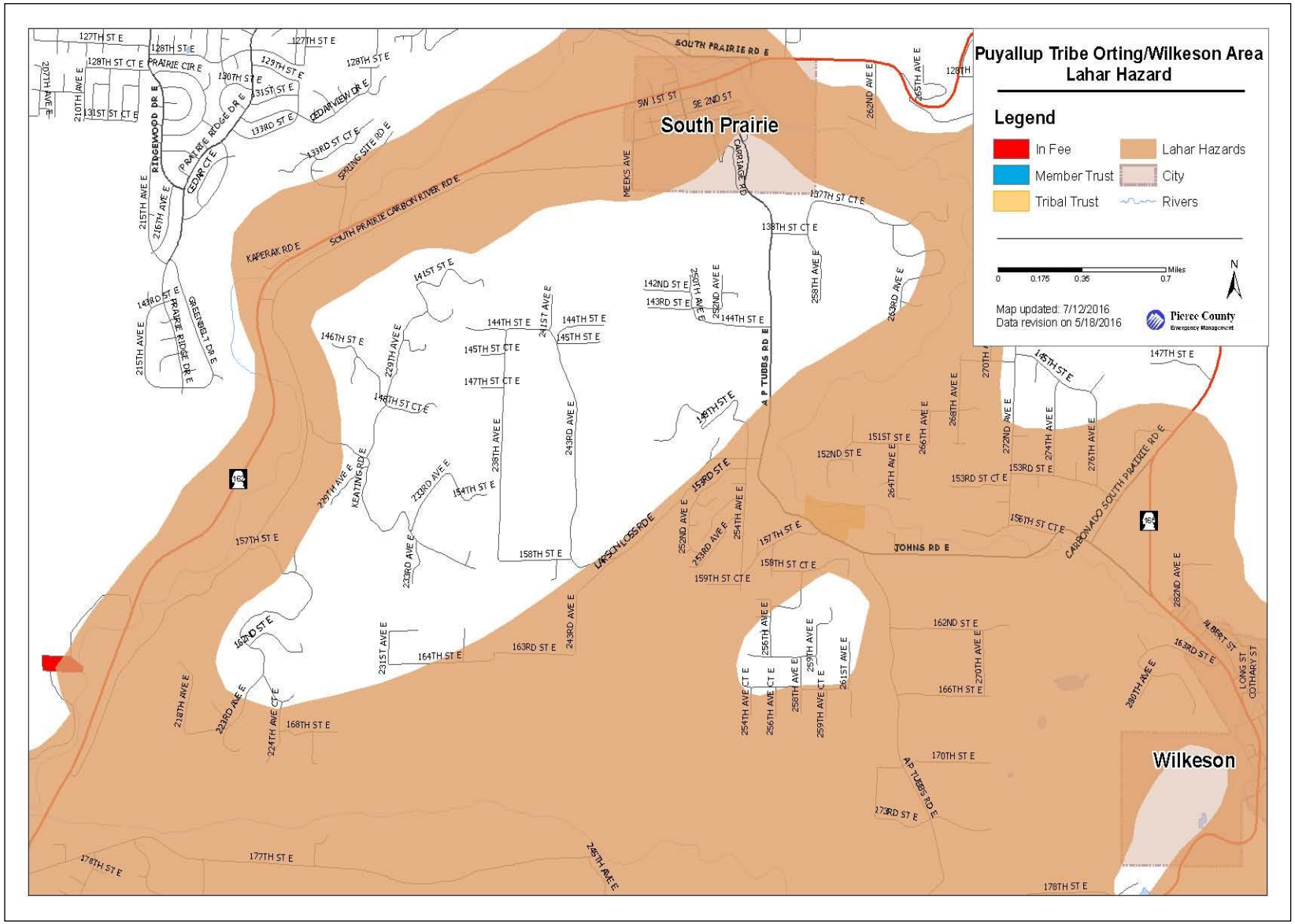
Map 4.5-7 Puyallup Tribe of Indians Fife/Puyallup Lahar Hazard Area



Map 4.5-8 Puyallup Tribe of Indians Kapowsin Lahar Hazard Area



Map 4.5-9 Puyallup Tribe of Indians Orting/Wilkeson Lahar Hazard Area



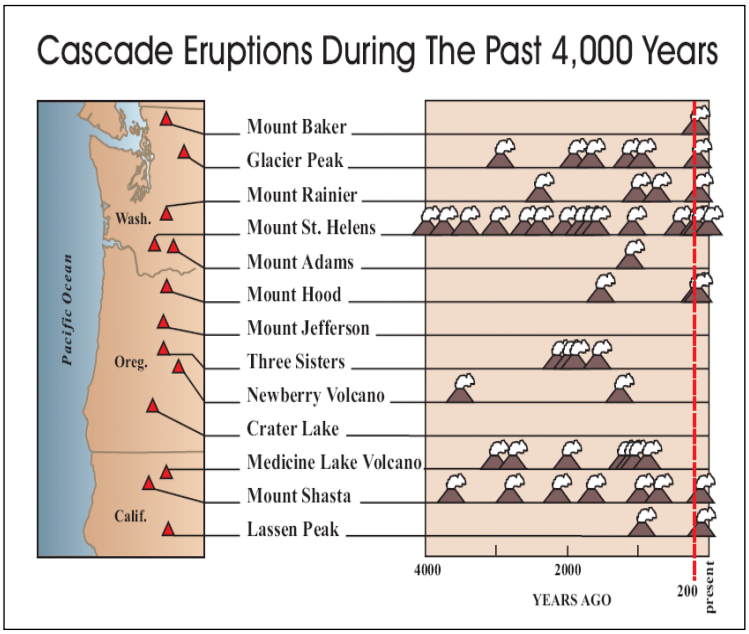
Planning Area

The volcano hazard impacts 100% of the Planning Area. Tephra directly affects the entire the planning area and lahars directly affect the Puyallup River Valley. Lahars also impact those areas that are not in the lahar path because of the impact on resources, displaced populations, transportation routes, etc. Map 4.5-4 shows the lahar hazard areas for the entire Planning Area and Map 4.5-5 through Map 4.5-9 are scaled down to show specific Tribal parcel lands at risk for lahar flows. This detail will allow for specific mitigation planning efforts. The portions of the Planning Area located on the plateau are not directly affected by the lahar. Those parts of the Planning Area whose elevation is out of the inundation zone will, however, be impacted by secondary impacts resulting from the lahar, such as evacuations of valley populations, and impacts to natural resources. A much further in depth discussion outlining the Planning Area's vulnerability to the volcanic hazards is discussed under the Vulnerability Section.

The Occurrences

Figure 4.5-5 Cascade Eruptions gives a good idea of how frequently the Cascade volcanoes have erupted in relation to each other.[19] As can be seen, while Mt. St. Helens has been the most active over the past 4,000 years, many other volcanoes, albeit not all of them, have also been active during this period, including Mt. Rainier. While the chart does cover many of the volcanoes in the Cascades, it is not inclusive. It ignores the British Columbia volcanoes like Mount Garibaldi and Meager Mountain. The area of the Cascade Range with the most volcanoes is Oregon. In addition to those listed on the chart, Oregon has a number of others that could erupt and deposit ash throughout the Pacific Northwest. They include, amongst others, Mount Bachelor, Broken Top, Belknap, Mount McLoughlin, Mount Bailey, Diamond Peak and Mount Thielsen.

Figure 4.5-5 Cascade Eruptions



During the past 10,000 years there have been 11 identified tephra eruptions, from Mt. Rainier, ranging in size from 0.001 to 0.3 km^3.[20] See Table 4.5-3, Mt. Rainier Identified Tephras from the last 10,000 years.[21] Notice that none of them begins to come close to the magnitude of ash deposited from the Mt. Saint Helens eruption of 1980.[22] The St. Helens eruption of 1980 deposited approximately 1.01 cubic kilometers of material or a little over three times the amount from the largest Rainier eruption shown on the table.

As can also be seen from the table the last eruption putting out tephra was around 150 years ago. Mt. Rainier however, had a few small eruptions throughout the 1800s. The record[23] shows minor eruptions about 1820(?), 1841 through 1843(?), 1854 (?), 1879 and 1882.

Table 4.5-4 provides a list of past occurrences of debris flows on the various river valleys in Pierce County.

Table 4.5-3 Mt. Rainier Identified Tephra, last 10,000 Years

Holocene Tephras from Mount Rainier			
Layer	Age (radiocarbon years B.P.	Predominant Materials	Volume (in millions of cubic meters)
X	+/- 150 (from tree rings)	Pumice	1
C	2200	Pumice, scoria, lithic fragments	300
B	>4000	Scoria, lithic fragments	5
H	>5000	Pumice, lithic fragments	1
F	5000	Lithic fragments, pumice, crystals, clay	25
S	5200	Lithic fragments	20
N	5500	Lithic fragments, pumice	2
D	6000	Scoria, lithic fragments	75
L	6400	Pumice	50
A	6500	Pumice, lithic fragments	5
R	>8750	Pumice, lithic fragments	25

USGS Topinka, USGS/CVO, 1997, Modified from: Swanson, et al., 1989, AGU FieldTrip Guidebook T106, taken from Mullineaux, 1974

Table 4.5-4 Pierce County River Valley Debris Flow History

PUYALLUP RIVER DEBRIS FLOW HISTORY		
TYPE OF FLOW	**AGE OR DATE**	**AREA REACHED**
Electron Mudflow	530-550 BP*	Puget Sound Lowland, possibly to Puget Sound
Lahar	~ 1000 BP*	Puget Sound Lowland
Round Pass Mudflow	~2,600 BP*	Probably to the Puget Sound Lowland
Lahar runout	< 3400 BP*	Puget Sound Lowland
"Pre-Y" Lahar	< 3500 BP*	Puget Sound Lowland
Lahar runout	>3500 BP*	Puget Sound Lowland
NISQUALLY RIVER DEBRIS FLOW HISTORY		
TYPE OF FLOW	**AGE OR DATE**	**AREA REACHED**
Kautz Glacier/Van Trump Creek Debris Flows	August 2001	Near the Park boundary
Outburst flow on Kautz Creek	1947 AD	Below confluence with Nisqually River
Tahoma Lahar	Post 1480 AD	Below the confluence of Tahoma Creek & the Nisqually River
Lahar runout	< 2500 BP*	At least to Elbe
Lahar runout	< 2500 BP*	At least to Elbe
National Lahar	~ 2200 BP*	Puget Sound
Round Pass Mudflow	~ 2,600 BP*	At least to National
Lahar runout	< 3400 BP*	At least to Ashford
Large lahar runout	< 3400 BP*	Probably to Puget Sound Lowland
Paradise Lahar	4,500-5,000 BP*	At least to Elbe
WHITE RIVER (INCLUDING WEST FORK) DEBRIS FLOW HISTORY		
TYPE OF FLOW	**AGE OR DATE**	**AREA REACHED**
Debris Avalanche	1963	Within 1 km of the White River Campground
Gravel-rich flow	~ 1550 AD	At least to Mud Mountain Reservoir
At least one lahar	> 1480 AD	At least 5-10 miles outside of Park boundary
Lahar in West Fork	< 2200 BP*	At least to confluence of forks
Lahar (TBD)	< 2200 BP*	Probably to Puget Sound
Many lahars	< 2200 BP*	Probably to Puget Sound
At least 5 lahars	< 4500 BP*	Probably to edge of Puget Sound Lowland
Osceola Mudflow	~ 5000 BP*	Puget Sound Lowland
Greenwater Lahar	~ 5000 BP*	Puget Sound Lowland

CARBON RIVER DEBRIS FLOW HISTORY		
TYPE OF FLOW	**AGE OR DATE**	**AREA REACHED**
Lahar runout	Post 1480 AD	At least 5 km below end of glacier
Lahar runout	Pre 1480 AD	8-10 km beyond end of glacier
*Carbon 14 years before present, working from a base line of 1950		

Recurrence Rate

While Mt. Rainier had a few small steam or very small tephra eruptions during the 1800s, these were not eruptions to cause concern. The same can be said about the small mudflows down Tahoma Creek over the past 40 years, or even the larger Kautz mudflow of 1947. The geologic history of the volcano, as shown in the above tables, shows 11 volcanic tephra eruptions over the past 9,000 years. In addition, the history of lahars in the valleys shows their time frames to be variable with some long periods, occasionally over 1,000 years, between them. Research from USGS scientists and others points to an annual probability of 1 in 500 to 1,000 for a significant landslide driven lahar. In addition, the "(A)nnual probability of eruption-triggered lahars is basically the same as the eruption probability because most eruptions will create lahars of some magnitude –1 in 100 to 500, but probably more toward the 500 end."[24] Taking all this into consideration, it is estimated the recurrence rate for damaging volcanic activity, be it a damaging tephra eruption or a lahar coming down a valley, to be a 500 to 1,000 year occurrence.

Impacts

Impacts discussed here will cover ashfall or tephra, pyroclastic flows and lahar damage. Unless stated otherwise, lahar damage will be based on the potential for a Case I lahar traveling down the various valleys from Mt. Rainier. It will be assumed that general impacts are the same across the four main valleys (Carbon, Puyallup, Nisqually, and White) unless stated otherwise. Impacts from a lahar descending the Cowlitz River, the other river with its headwaters on Mt. Rainier and located partially in Pierce County, will have no direct effect on the County once it has exited the Park into Lewis County. There will be no further discussion of it.

Most of the impacts from a lahar will be determined by the volume of the lahar and which valley or valleys it descends. Next is whether there is a recognizable sequence of volcanic events leading up to its initiation. Whether it is a spontaneous lahar or the result of other developing volcanic convulsions leading to, or part of, an eruption will have a major impact on the response and the recovery. Other contributing factors include the time of day, time of year, and the clay consistency of the mud.

For the purposes of this section we will assume an Electron size and type flow and for most impacts look at the difference between the two basic scenarios of an eruption or magmatic triggered lahar and a spontaneous lahar.

Health and Safety of Persons in the Affected Area at the Time of the Incident

Tephra

As mentioned above most of the tephra or ash from a volcanic eruption of Mt. Rainier should leave western Washington and be deposited east of the Cascades. However the wind patterns may not always blow in that direction. If not, then ash could be deposited over portions of Pierce County. If so, a number of problems will arise.

Thick depositions of ash can collapse buildings. This is especially true if it is raining. A one-inch layer of ash weighs between five and ten pounds per square foot. This weight can increase dramatically with rain, because ash will hold the water. The weight can increase to 10 to 15 lbs per square foot, leading to collapse in some cases.[25] Persons inside those buildings have a significant chance of being killed or at least injured by the collapsing structure.

Persons located in areas with falling ash can experience eye, nose and throat problems. Patients with bronchitis, emphysema and asthma are at even greater risk. Breathing similar material in mines and quarries by workers can lead to silicosis over many years. Short term breathing of small quantities of ash particles is not known to cause long-term problems. The decrease in visibility and increase in darkness in those areas heavily impacted by the tephra will disrupt outdoor activities and in some cases cause psychological distress.

Thin ash layers can make roads slick leading to an increase in accidents. It can also clog up air intake systems for automobiles and destroy the engine rendering the car useless for evacuation if necessary.

Pyroclastic Flows

Pyroclastic flows by their nature will cause extensive death and injury to people in the areas inundated by them. In Pierce County, this is restricted to those in close proximity to the volcano. Park service personnel and tourists in the impacted area will have a very low chance of survival; however pyroclastic flows will not extend very far beyond the boundaries of Mt. Rainier National Park. Any citizens or park personnel in the vicinity of a pyroclastic flow will experience the devastating impact and heat created by the flowing hot ash and rock with the usual result being death, or if surviving, then major burns and or partial asphyxiation.

Lahars

A lahar coming down one or more valleys from Mt. Rainier has the potential to cause the highest number of fatalities and casualties of any hazard treated in this risk assessment. The difference in the impact on the population will be highly dependent on whether the lahar was a result of increasing volcanic activity or is due to the spontaneous collapse of a portion of the mountain.

Lahars can be devastating in their consequences. The lahar that inundated the town of Armero in Columbia on November 13, 1985 was relatively small compared to some of the ones that have descended Mt. Rainier. The lahar, from the volcano Nevado del Ruiz, killed over 23,000 people

and injured about 5,000 people.[26] In this case the main wave of mud that demolished the town ranged in depth from 6.5 to 16 feet. There could be a similar percentage of injured and killed in a lahar from Mt. Rainier. The method of destruction, burying entire communities in a flow of dense mud does not allow most people caught in it a chance of survival.

Magmatic or Eruption Triggered Lahar

The normal situation for lahars from most volcanoes is for there to be some warning that a lahar is possible due to an increase in volcanic activity. With a lahar that begins when the volcano enters an eruptive stage, there will usually be many hours, if not days or weeks of increasing volcanic unrest. During this time, the citizens that live in the valley areas surrounding the mountain will be put on a high alert that a lahar is possible. Memories of Mt. St. Helens and the lahar from it should inspire people in the valleys close to the volcano to prepare to evacuate or even self evacuate early in the eruption process. The more distant from the volcano they live or work, the less preparation there will be overall, even for those who are directly in the path.

As the situation deteriorates, monitoring of the volcano will increase. Any needed warnings from the State, the County, or the Cascades Volcano Observatory will be broadcast to inform and warn residents in the potential paths to prepare for and evacuate, if able, well before any lahar is created. Having a percentage of the people leave the valleys early allows a quicker evacuation when it becomes necessary.

Much of the response for an early evacuation will depend on the perceived security of property left behind. If local government does not provide adequate security, many people will not leave their property behind, but will rather gamble that they can get out in time if necessary. For those who did leave early, the perception that there is a lack of security for their property will bring them back. The other factor that will bring people back is if the volcano does not erupt or send down a lahar over time. People's patience will rapidly wear thin and they will want to move back home.

Overall though, having knowledge ahead of time that the volcano is coming back to life and that a lahar could happen at any time will allow many people to get themselves and many of their belongings out of harms way before the mud arrives. This could save many lives and a great deal of personal belongings and property.

Spontaneous Lahar

A spontaneous lahar is most likely to happen due to the collapse of a portion of the headwall above the Puyallup Glacier on the west flank of Mt. Rainier. The Mt. Rainier Lahar Warning System composed of sensors to detect the lahar, and radio transmitters to send that information back to Pierce County and Washington State warning points is in place to help prevent a lahar coming down either the Puyallup or Carbon Rivers from taking the communities by surprise.

Having a warning system in place does not mean that everyone will be able to evacuate the valley bottoms in time. The short time between the warning and the inundation of homes, schools, roads and businesses will not allow the entire population to escape. In the upper valley south of the confluence of the Puyallup and Carbon Rivers there could be many fatalities.

A large spontaneous lahar in either the White or Nisqually Rivers would also create an instant problem. Neither of these valleys has a lahar warning system. Having no warning system in either of those valleys, citizens living, working, or recreating close to the mountain in the upper valleys may have only the sound of the lahar coming down the valley to warn them. This would not allow enough time for many of those people to evacuate. Once it has become known to response agencies that a lahar is descending either of these valleys they will be able to put out a notification that might reach people further downstream to allow evacuation. This would be accomplished through use of a telephone notification system that is able to send an informational phone call to each phone in the respective valleys. At the same time an Emergency Alert System message can go out over radio, TV, and all hazard radio addressing the need to evacuate the valleys.

The one good point about both of these valleys is that they have dams. If either is empty, as is Mud Mt. Dam most of the year, or low, as Alder Dam frequently is, they could contain much of a large lahar thereby lessening the damage and casualties further downstream.

Health and Safety of Personnel Responding to the Incident

Tephra

As pointed out above, thick depositions of tephra can collapse buildings, especially if it is raining. Persons inside those buildings have a significant chance of being killed or at least injured by the collapsing structure.

Responders may wind up working for long periods of time in areas with ash. The problems of eye, nose and throat irritation could impact their ability to work in those conditions. It is not known if this has long-term, negative health consequences.

Personnel responding to incidents will find that thin ash layers can make roads slick leading to an increase in accidents. Emergency equipment will break and ash can clog up air intake systems and destroy engines for rescue vehicles like helicopters, fixed wing aircraft and automobiles. This is not just a maintenance problem. It could lead to crashes of response vehicles.

Pyroclastic Flows

Any responders in the vicinity of a pyroclastic flow will experience the same devastating impact and heat that citizens would, with the same results, probable death, or major burns and/or partial asphyxiation. Those responders attempting a rescue or body recovery will potentially be working in a hot environment, with lots of ash and the potential for further pyroclastic flows that could engulf their position.

Lahars

Because of the enormity of the event, initial response to a lahar will be limited to saving response resources and assisting citizens to get to high ground, all while attempting to keep themselves safe. What will be a problem for the safety and health of responders is that the lahar will leave citizens stranded at various places throughout the valley. They could be on buildings that did not

collapse or in trees that were not knocked down or highway overpasses. Essentially, people could be on any structure, tall enough to be above the mud and strong enough to survive being inundated by it. Since the mud will in many cases be too deep to drive or walk through directly, helicopter rescues might be necessary. This has all the dangers inherent in that type of operation. In addition hazardous chemicals and sewage will contaminate some areas rendering them hazardous to anyone working there. There is also the possibility of more mud flows inundating the valley floor. A contributing factor is rain. Rain could pick up more of the material left in the higher parts of the valley and transport it down to the lower valley and deposit it as a new layer on the earlier flow.

During the initial build up to an eruption, when the Cascade Volcanoes Observatory warns about an upcoming event and warns citizens that they might want to evacuate, all local police forces will be put in the position of controlling access to those areas deemed hazardous. This could include both the Nisqually and Puyallup Valleys. Irate citizens, demanding access to their properties could create hazardous situations for these forces. There could be attempts to push through barricades, threats to officers or others staffing those barricades, or even if the area is shut down for a long period of time, riots.

After a major lahar responders from public works and utilities will not be able to do any initial work in the lahar zone to restore the damaged area. The lahar will totally block access to the area and will have taken out the utilities and roads; in effect the entire surface infrastructure. Utilities that were underground to begin with, like pipelines, may be buried under the mud but may still be operational. As the mud solidifies over time, public works and utility providers may be able to work back out into the devastated areas. As they do so they will have to be aware of any hazards that might still be in the environment.

Magmatic or Eruption Triggered Lahar

With the knowledge that the volcano is threatening to erupt, first responders will be able to move critical equipment to high ground well ahead of time. Since the public will know what is happening as the volcano awakens and, in some cases, self evacuate ahead of time, the problems relating to a spontaneous mass evacuation will diminish. Barricades and police services will be in position ahead of time to conduct evacuees rapidly out of the valleys should a lahar start. Close monitoring of the mountain should give the warning points quicker notification when a lahar does begin. The number of people needing assistance should decrease. This should decrease the number of technical rescues that will need to be done once the lahar has finished moving through the valleys. Problems could be compounded if there is a lot of tephra due to the eruption at the same time.

Spontaneous Lahar

With a spontaneous lahar, any responders in the affected valleys will be in the same position as other citizens. They will have to get themselves and any vital equipment to high ground as quickly as possible. In those areas some distance away from the volcano, like Fife and Puyallup, there should be enough time for a few first responders to assist with the evacuations of some citizens. In those areas closer to the volcano like Orting, that will be out of the question. It is possible that when a spontaneous lahar sets off the volcanic warning system or one is heard

coming down either the White or Nisqually rivers that the ensuing panic could by itself injure, kill or trap in the lahar zone, those who would normally respond.

Continuity of Operations

Tephra

Small tephra explosions should not have an effect on the continuity of operations for jurisdictions or agencies in the County unless the wind patterns are perfect for dropping it directly on their service area.

Large tephra eruptions are different. Due to the amount of material dropped on an area, operations can be strained. Damage to communications equipment, roofs of buildings collapsing, roads closed, etc. can all limit the ability of an agency to maintain day-to-day operations. If the volcano has a large tephra eruption and conditions are right to deposit the ash across portions of Pierce County, there could be difficulty finding alternate facilities, getting staff to work and having necessary equipment in operational shape.

However, the probability that this will be the case is relatively low. As mentioned above, Mt. Rainier's eruptions tend to have low quantities of tephra and when an eruption does occur the normal wind directions over Pierce County should distribute it to eastern Washington. While possible, it is unlikely that tephra, by itself, will dramatically alter or limit the continuity of operations for agencies within Pierce County.

Pyroclastic Flows

Pyroclastic flows, by themselves, should not have any affect on the continuity of operations for jurisdictions throughout the County. Rather, the effects will come from their impact on the glaciers and snow fields located on the mountain. Their melting, from the hot rock, ash and gas flowing across their surface, could create massive lahars in the valleys below.

Lahars

Any major lahar coming down one or more of the valleys radiating from Mt. Rainier will dramatically alter the continuity of operations for local jurisdictions. However, depending on the level of preparedness and whether a lahar is the result of the buildup of volcanic activity or of a spontaneous sector collapse the continuity of operations for a jurisdiction or agency could be very different.

Magmatic or Eruption Triggered Lahar

Lahars triggered by a buildup and release of volcanic energy will have a lead in time, ranging from hours to weeks, for jurisdictions and agencies to prepare for the likelihood that a lahar may be forthcoming. Those entities with infrastructure in the path of the flow will be able to find alternate work sites and move at least some equipment to high ground out of the path. For those entities that are only partially within the lahar path this should work well. Even if the lahar does take out some of their infrastructure and property they should still be able to maintain an operational posture, albeit reduced, for the rest of their jurisdiction or clients.

For those entities entirely, or nearly entirely, within confines of the flow, things will probably be different. Even if they were able to initially remove equipment from the valley floor and protect all staff, normal day-to-day operations will be non-existent. With no citizens no tax base, no offices, no infrastructure and no community, there is no continuity of operations.

Spontaneous Lahar

For spontaneous lahars the impacts to the valleys, while identical, could have a different impact on the agencies and jurisdictions located there. Those that have operations located in the valley that are unable to get an alternate site from which to operate will have all the problems of those jurisdictions and agencies who have a warning but also many others. In addition they may lose records, staff and equipment when the lahar overwhelms the valley. The possibility of maintaining operational continuity in this scenario is impossible.

Those that have their operations run from outside the lahar inundation zone should be able to maintain operational continuity, albeit in a possibility reduced capacity.

Delivery of Services

Delivery of services will be nonexistent in those areas of the County that are deeply buried by a lahar. With no homes, no businesses, and no infrastructure, there will not even be a reason to attempt delivery of services into the impacted area. Delivery of services into other areas will depend directly on the infrastructure that is left after the lahar has inundated the valley, combined with how much of the jurisdictions' or agencies' resources have been salvaged. If the lahar has destroyed one or more of the exits from Pierce County across the Puyallup and or Nisqually Rivers, then the ability to receive outside assistance will be delayed possibility for days. Re-supply of equipment, equipment parts, food, or any of the necessities of life will be difficult.

A lahar inundating the Puyallup Valley will cut the eastern part of the County from the rest. Bonney Lake, Buckley, Cascadia, the East Hill of Sumner and others would have to go through King County for assistance. Delivery of services to those areas from local agencies within these areas would go on, although some might be reduced.

There can however be some differences between the delivery of services after a magmatic generated lahar and a spontaneous lahar.

Magmatic or Eruption Triggered Lahar

Just as with the continuity of operations, the disruption to the delivery of services would be reduced with an eruption generated lahar. The ability to get supplies stockpiled ahead of time, get equipment out of the lahar zone, set up sheltering system for thousands of people and develop immediate contingency plans will all assist with the delivery of services to those areas not destroyed by the lahar.

Spontaneous Lahar

A worst case scenario would include a lahar that begins with a sector collapse on the west side of the mountain above the headwaters of the Puyallup River. Such a lahar could partially overtop

the ridge separating the Puyallup River and Tahoma Creek that empties into the Nisqually River. This could cause delivery of services to be compromised in both watersheds.

All the problems that exist with an eruption triggered lahar are also inherent with a spontaneous lahar. In addition delivery of services to citizens will be even more compromised in the case of a spontaneous lahar because local agencies and jurisdictions will not have the lead up time to evacuate equipment, records, and supplies from the valley bottom. Those that normally have their equipment, supplies and records or backup copies, out of the impacted area will be able to respond with at least some service delivery to those areas not directly impacted by the lahar.

Property, Facilities, and Infrastructure

Any Mt. Rainier major event, whether eruptive related or from a spontaneous lahar, will have a major impact on the property, facilities and infrastructure of jurisdictions and agencies within the confines of Pierce County as well as surrounding counties.

Tephra[27]

Tephra can collapse roofs, destroy engines, make roads slippery, clog both water and air filtration systems, kill crops, clog drains, and short out electrical systems. All these can and will affect jurisdictions and their ability to operate on a day to day basis. Depending on the depth and distribution pattern of the ash, individual agencies or jurisdictions will be more or less impacted by it. With more than one cm of ash having the ability to disrupt traffic by closing down roads combined with the other damage listed above, it could take weeks for the local agencies and jurisdictions to get their individual infrastructures back to normal.

Pyroclastic Flows

Pyroclastic flows by themselves, should only affect the infrastructure of the National Park. Any effects outside the park will be the result of their impact on the snow and ice resident on the volcano, melting it and initiating a lahar that could cause damage to facilities, property and local infrastructure.

Lahars

Lahars are the primary force that will damage the infrastructure, property, and facilities. They will flatten buildings, destroy equipment, bury roads, take out power lines, and destroy sewer pumping systems. A major lahar coming down any of the river systems from Mount Rainier will damage, destroy or bury all facilities, property and infrastructure that are above ground in the impacted area. Only those areas on the periphery or where the flow weakens, thins out and reduces in speed and volume will have any chance of survival.

Current buried pipes, power lines, etc. should not be damaged directly; although where they rise to the surface they can be damaged. However, having a sewer line buried under an extra 15 feet of mud in a community that no longer exists is essentially worthless. In areas where the lahar is shallow, many of these underground utilities may be able to be rehabilitated.

The extent of damage will be directly correlated with the quantity of debris the volcano coughs up. Smaller lahars will not cover as much territory as the larger lahar would and will cause less damage to those areas they do cover. This can be seen graphically on Map V-1. Here the Case 1 lahars are inclusive of all the territory also contained in Case 2 lahars and in addition all the area highlighted in yellow.

Magmatic or Eruption Triggered Lahar

With a magmatic triggered lahar there will be time to evacuate records, supplies, and equipment from the lahar's path. How much of the material will actually be evacuated depends on the length of time between when the volcano awakens and finally sends a lahar down valley. This could be from a few hours to many days or weeks. The more time allowed the more that can be saved.

Spontaneous Lahar

With a spontaneous lahar, there will be very little that jurisdictions can do to protect their facilities, property or infrastructure located in its path. Those with resources further away from the volcano will have a little time once the warning has been disseminated, but it may be too little to make a major difference. Those agencies and jurisdictions will essentially have little or no time to evacuate anything of value. That which was not protected prior to the initiation of the lahar may be damaged or gone.

Environment

Environmental impacts will be dramatic and in some cases long lasting.

Tephra

Small tephra eruptions will have limited environmental impacts. Large tephra eruptions could have dramatic impacts on the environment or ecology of large areas around Mt. Rainier. Because under normal circumstances the prevailing wind patterns will blow much of the tephra to the east impacting the upper White River and much of eastern Washington. In this scenario, plants and animals in the White River valley could suffocate under the ashfall.

Tephra damage[28] will partly depend on the size of the particles. Large pieces, one to two inches or greater in diameter, can be very damaging. However, lethal impact from falling tephra is likely only in the immediate vicinity of the volcano, generally within about six miles of the vent. Animals not protected in this area could be severely injured or killed by the large particles. Further away the finer grains begin to fall and can cause respiratory and eye irritation to animals, burying plants and robbing the animals of their natural food supply. Ash washed down by the rain will tend to add to the rest of the silt in the rivers and some of it will settle out downstream possibly affecting the fish resources, including salmon that return up the various rivers.

A large tephra eruption that blows in other than an easterly direction could cause extensive, long-term environmental damage to much of the County. Having the same types of damage mentioned above but spread over much of the County could cause environmental impacts that may take years to recover from.

Pyroclastic Flows

Pyroclastic flows by their very nature destroy everything in their path. They will burn the forest, kill the wildlife and plants and boil the water in the rivers and lakes they enter. This destruction will mostly be localized within Mt. Rainier National Park although the hot water in the streams and rivers could cause fish kills for miles downstream. They could cause damage outside the national park by starting wildfires in the park that could spread outside the park, or initiating enough rapid melting from glaciers that lahars are created spreading damage for miles outside the park.

Lahars

Lahars are the primary damaging factor associated with Mt. Rainier. Lahars descending the valley will destroy and bury any and all plants and animals in their path. They can destroy forested areas and they will silt up rivers and change their channels. They will add pollutants or hazardous chemicals to the environment by the damage they do to manmade structures, vehicles, sewage treatment facilities, etc. The addition of mud to the valley bottom by winter rains bringing down more debris from upstream will continue to cause problems for the environment possibly for a few years after the initial mudflow. They may totally destroy salmon habitat, and the valley ecology in the areas they cover.

Those that reach Puget Sound could cover the near shore environment with silt and possibility partially fill in Commencement Bay, and/or cover the shallow Nisqually delta and mud flats creating a new surface and killing the creatures that currently make it home.

A new environmental balance will eventually be formed as plants and animals re-inhabit the area covered by the mud. While it may take years for nature to repair the damage, it will eventually reclaim those areas damaged by the lahar.

Economic and Financial Condition

Economic and financial affects will be of two parts. First is the damage to property, buildings, inventories and equipment. Second is the loss of revenue due to the inability to get supplies through the damaged area, the loss of markets, the decrease in population and, in some cases, the loss of infrastructure to support the area economically.

Tephra

The damage to individual businesses, homes, and equipment could cause major financial losses for individuals and businesses throughout Pierce County, but only if the wind does not blow the ash to the east. If the wind does blow to the east as expected, then areas in the White River Valley will be the ones affected. In this case, the Crystal Mountain ski area, and the homes between it and the Greenwater area could be heavily damaged. The Greenwater businesses and the Fire Department could all have structural building damage and the damage to vehicle engines may prevent owners from evacuating to a safer area.

Pyroclastic Flows

There should be little or no economic or financial effects directly from any pyroclastic flows except to the National Park and those businesses located directly adjacent to the park boundaries. However, the secondary damage from either the lahars or the forest fires started by the pyroclastic flows could cause major economic problems depending on their size and the community's level of preparedness for them.

Forest fires started from the volcano will initially affect Federal land in the National Park and on USFS land. Secondly, the fires could spread to Washington State DNR lands and could affect the communities in the Nisqually Valley above Alder Lake; the Greenwater area in the White River Valley; the towns of Carbonado and Wilkeson in the Carbon River drainage; and to homes in the upper Puyallup. It must be remembered that all these communities, except for some in the upper Nisqually, are further away from the volcano than the geologic record shows pyroclastic flows to travel.

Lahars

Lahars have the potential to be the major destroyer of economic viability within Pierce County. Any major lahar coming down one of the valleys from Mt. Rainier will destroy the homes, businesses and much of the infrastructure within whichever valley it descends. Closer to the mountain, like in Ashford or Elbe, some of it will be related to the tourist trade, or other wilderness operations. Citizens there maintain their restaurants and shops along the mountain highway, work in the National Park, or in many cases work for logging corporations, any or all of which may be out of business because of a lahar.

In other cases like the cities of Puyallup, Sumner and Orting, there are thriving communities that have been located on the valley floor for over 100 years, that have flourishing downtowns and whose citizens are involved in the full range of occupations that any city or bedroom community has in Washington. Many of them work in King County or the City of Tacoma. Many of them have their own businesses in town. There are schools, medical clinics, libraries, fire stations, and the Puyallup Fair Grounds. Any lahar that inundates these areas will be destroying vibrant communities that have taken over a century to grow to their current size.

Those portions of these communities on the valley floor, which includes most of Puyallup, almost all of Sumner and all of Orting could be destroyed totally with no viable way to regain their economic base. It is not a question of rebuilding a few destroyed buildings as it would be after an earthquake. With a lahar there may be no houses, no businesses and no infrastructure to begin the rebuilding process. The result will be that there will be no population base for an economic revival. People will have left the area. There will be no tax base for the cities to begin their rebuilding process. With many feet of mud in the valley, and the threat of further flooding and lahars, it will be awhile until people begin the rebuilding process.

Magmatic or Eruption Triggered Lahar

As the developing threat from the volcano is recognized by the scientists and they begin to warn the public there will be some time for some people and business to move some of their belongings, records and goods to higher ground. However no matter how much they are able to

save this way, the economic recovery will be long and hard. With the destruction of homes and the physical structures of the businesses in the valley, people will have no option except to leave the area and find homes and work elsewhere.

Spontaneous Lahar

With a spontaneous lahar almost no community in the way of the lahar will have the ability to adequately protect its assets. This is the worst case scenario. There could be a total loss of homes and businesses in the impacted area. With buildings, equipment, records, inventories, and community infrastructure gone, no business in the lahar zone will be able to restart immediately. Even attempting to reestablish their business at a different location, outside the inundation zone, will, in many cases, fall short. With the exodus by many members of the community, numerous businesses will have little incentive to even attempt rebuilding in the valley.

Public Confidence in the Jurisdiction's Governance

The reputation of an agency or jurisdiction as well as the public's confidence in it will depend to a great extent on the amount of planning and preparation that was done in anticipation of the eventual event. This, combined with the open distribution of information to the public regarding what is happening, could happen, and will happen during a volcanic event will greatly boost the public's confidence in the agencies and jurisdictions effected by it.

False alarms, alarmist pontificating, or confusion on what needs to be done will only lower the public's perception of the entity. Premature warnings of impending danger, especially if leading to what is seen as unnecessary evacuation, will only weaken any entity's authority.

Mt. Rainier is a big enough problem that good faith efforts put forth by the agencies and jurisdictions will reap a good response from the public. Incompetence, will however, show through and will destroy any reputation that the entity had before.

Tephra

Good information regarding what needs to be done to prevent or limit damage to property and individuals will allow homeowners, businesses, and other local organizations to prepare for and limit the damage from tephra. Any additional programs to assist them in alleviating the problem, such as a community program to clean the ash off roofs, will help.

Pyroclastic Flows

Since there will be little or no direct damage from pyroclastic flows to agencies or jurisdictions within Pierce County there should be little or no resulting loss of confidence from any pyroclastic flow that descends Mt. Rainier.

Lahars

If an agency or jurisdiction produces good information ahead of time regarding what needs to be done to prepare for a lahar, how to evacuate, upon receiving a credible lahar warning, limits false alarms, and then puts out credible warnings, the confidence of the public will be largely

maintained. If, on the other hand, false alarms become the norm, sirens do not work, and there is confusion as to what people are supposed to do, the entity's reputation will suffer. Any confidence the public has in that entity will be lost.

Another factor affecting the eventual reputation is the ability to get infrastructure back up and running as soon as possible. The fact that some areas will be unavailable, perhaps for years, will take awhile for the public to accept. Even the visual clue of square miles of mud will not prevent some people from complaining that local, state and federal agencies are not doing enough to help them return to their pre-lahar state.

Magmatic or Eruption Triggered Lahar

A lahar triggered by an eruption will allow the local agencies more time to prepare for the eventual destruction associated with it. They will have time to move resources, set up assistance centers, evacuate people if necessary, and be seen as leading the response, not just being reactive to the circumstances. In this case, those agencies and jurisdictions seen as preparing for the potential lahar will maintain credibility with the public. Where this could break down is if an evacuation is ordered based on the best geological evidence the scientists can provide and the mountain does not produce a lahar. In this case, there could be citizen unrest as they want to get back to their homes with the resulting loss of support for the actions of the local entity.

Spontaneous Lahar

In the case of a spontaneous lahar, the timely warning of an approaching lahar in the Puyallup Valley should help in the maintenance of the local entity's reputation. Even with some loss of life, if the warning system operates as it is designed and all jurisdictions follow the Mt. Rainier Volcanic Hazards Response Plan, confidence in the jurisdictions will remain intact.

This will not be the case if, without a warning a spontaneous lahar descends either the Nisqually or the White River Valleys and impacts homes and businesses. In this situation, there would be many questions about why no warning system was regarded as necessary on the Nisqually or White River sides of the mountain and the reputation of government would be adversely affected. The short time frame from when a spontaneous lahar is initiated to when it begins to impact citizens in the Nisqually or White River Valleys does not allow enough time to put out an EAS or telephone ringdown message to citizens in those valleys close to the mountain. Those further downstream may be able to be reached in time to allow evacuation.

Vulnerability to Planning Area

The degree of hazard vulnerability is dependent on numerous variables. Those variables include but are not limited to as stated before: the type and size of the event; time of day; amount of warning time; size of population in harm's way; special needs populations (physically or mentally impaired); weather conditions; transportation availability; emergency response capabilities, and; type of warning methods.

The potential hazards posed by Mount Rainier have led to its inclusion as one of sixteen volcanoes worldwide to be designated Decade Volcanoes. The Decade Volcano initiative is part

of a United Nations program aimed at better utilizing science and emergency management to reduce the severity of natural disasters. The Decade Volcanoes are the focus of coordinated earth-science studies and land-use planning to learn the best ways to reduce the risks to life and property from volcano-related hazards.

The Planning Team determined that the Planning Area has a medium vulnerability to the volcanic hazard. Although the probability of recurrence is low, a lahar is a high consequence event that would kill people and destroy buildings, infrastructure and cultural and sacred sites as well as natural resources. Mt. Rainier's location within the County and its proximity to population centers help elevate this vulnerability. The Planning Area is known to have experienced debris flow, heavy ashfall, or blast effects from past volcanic activity, and the effects of these are described above.

Many of the Tribe's structures and served population are located in lahar inundation path. In the event of a lahar, the Tribe's response would include evacuation and accommodation of potentially thousands of permanently displaced people. A lahar would also destroy resources and have high direct and indirect economic impact. A lahar would cause numerous fatalities, destroy many properties, destroy resources and have high direct and indirect economic impact. According to Map 4.5-1, the estimate lahar travel time for the Reservation's southern boundary is just over 80 minutes following the automated warning.

In the entire Planning Area, over 18,000 acres are vulnerable to the volcanic tephra hazard. The total damage to the planning Area could equal approximately $8 billion (the assessed value of all parcels in the Planning Area.)

A more detailed vulnerability assessment by the Planning Team showed that approximately 8,826 acres (56.6% of the Planning Area) are located in volcanic lahar inundation zones making those acres even more vulnerable to the volcanic hazard. The total estimated losses to these parcels would be $4.2 billion.

For Tribal Trust parcels located in the Planning Area, all 485 parcels are vulnerable to the volcanic tephra hazard. The total estimated losses to these parcels would equal $3 million.

Of the 485 Tribal Trust parcels in the Planning Area, 185 parcels (38.1%) are located in volcanic lahar inundation zones. The total estimated losses to these parcels would equal $252 million.

Figure 4.5-6 Mt. Rainier

Lahar flows

Lahar flows can overwhelm roads and railroad tracks, destroy bridges and other public and private property, kill both wildlife and the people caught in the path, and destroy forest and other agricultural products grown. In addition, a lahar flow can destroy the rivers' fish, which may take years to restock, if ever. With the potential of lahars containing cohesive clays, damage can occur up to100 km downstream (with Mt. Rainier, this would be all the way to Puget Sound). As per the Land Settlement Agreement, the Tribe owns the bed of the Puyallup River within the Reservation boundary. Further the Tribes extensive commitment to salmon habitat and populations leads to the Tribes unique vulnerability to this hazard.

Lahars that do not have the mass or force to reach anywhere near the Reservation can still have a large negative impact on both the Puyallup River and the resources associated with it. Currently, there is more than 20 times as much ice locked up in the glaciers of Mt. Rainier than that which existed on Mount St. Helens prior to the 1980 eruption. In the 1980 eruption, this ice melted almost instantaneously.[29] A water volume of that magnitude melting instantaneously and funneling down the Puyallup Valley would have a catastrophic effect on the Tribe's fisheries and commerce.

A large-scale eruption of Mt. Rainier has the potential to alter the region's topography, population centers, and economic foundation for years and possibly decades. A Case I lahar could destroy much of the reservation as well as natural resource areas further upriver and much, if not all, of the port-industrial area of Commencement Bay. Portions of the deepwater Port, would remain clogged with material for some time.

The amount of debris that could fill the valley in the neighborhood of Sumner could be enough to block the White River, backing up water into the City of Auburn. The lahar deposits could remain soft and muddy for weeks, either drastically inhibiting transportation and cleanup or making it impossible. Loss of transportation would have a negative impact upon the Tribe's business interests. Therefore mitigating the loss of transportation routes is necessary for the Tribe's long-term economic sustainability.

In addition there is the possibility of continued smaller mudflows. Some of these will occur as rain continues to wash mud from the upper valley, where some of it settled out during the initial flow, into the lower Puyallup Valley. Some will come from the damming of side streams and rivers, which would then form new channels, and in some cases lakes that would, as they filled up, eventually either break through or overtop the mud damming them, thus creating new floods in the valley. All of these would exacerbate the problem of cleanup and recovery. The actual recovery time for some areas might be counted in years rather than weeks or months.

Tephra

Under normal wind conditions, the deposition of tephra should travel to the northeast, affecting the upper White River basin and much of eastern Washington rather than the populated areas of Pierce County. For the full effects of a tephra eruption to be felt in Pierce County, Mt. Rainier would have to erupt at the same time of a southeast wind. This would deposit the majority of ash in western Washington, especially in the populated areas of Pierce County.[30]

Depending on the size of the eruption, weather, and time of year, the ash could do any number of the following to the Planning Area: clog drainage channels; cause electrical short circuits; drift onto roadways and rail lines causing accidents; collapse roofs of houses and other buildings; cause skin and eye irritation to the general population and/or respiratory distress to the aged, the infirm, the very young, or those who with already decreased respiratory flow; clog engines and air filters, and; create acid rain, which may effect water supplies, strip paint, burn foliage, corrode machinery, and age fabric.[31]

Resource Directory

Regional

- **Pierce County Department of Emergency Management**
  http://www.co.pierce.wa.us/PC/Abtus/ourorg/dem/abtusdem.htm
- **Mt. Rainier National Park**
  http://www.nps.gov/mora/
  http://www.mount.rainier.national-park.com/
- **Mt. Rainier Seismicity Information**
  http://www.geophys.washington.edu/SEIS/PNSN/RAINIER/rainier.html
- **Pacific Northwest Seismograph Network**
  http://www.geophys.washington.edu/SEIS/PNSN/INFO_GENERAL/volcanoes.html
- **USGS Cascade Volcano Observatory**
  http://vulcan.wr.usgs.gov
- **USGS Lahar Warning System: Mt. Rainier**
  http://volcanoes.usgs.gov/About/Highlights/RainierPilot/Pilot_highlight.html
- **Washington State Department of Natural Resources**
  http://www.wa.gov/redirDNR/splash.html

National

- **Alaska Volcano Observatory**
  http://www.avo.alaska.edu/avo4/products/hazard.htm
- **Smithsonian Institution Global Volcanism Program**
  http://www.nmnh.si.edu/gvp
- **USGS Volcano Themes**
  http://www.usgs.gov/themes/volcano.html
- **Volcano Hazard Maps**
  http://volcanoes.usgs.gov

Endnotes

[1] Background and specific information for entire Pierce County Volcano Section provided through consultation with volcanic hazard expert, Tim Walsh, Washington State Department of Natural Resources.
[2] Modified from PC HIVA (DRAFT), Volcano Section, September 5, 2002, p. 1. http://www.co.pierce.wa.us/pc/abtus/ourorg/dem/EMDiv/HIVA/VOLCANIC.pdf
[3] US Geological Survey Cascade Volcano Observatory
[4] Debris flow at Tahoma Creek, July 26, 1988.,USGS Photo Archives, Photo by G.G. Parker, July 26, 1988, http://vulcan.wr.usgs.gov/Volcanoes/Rainier/images.html
[5] Walder and Driedger, 1993, Volcano Fact Sheet: Glacier-generated debris flows at Mount Rainier: USGS Open-File Report 93-124
[6] Ibid, Pringle and Scott.
[7] Pringle, Patrick and Scott Kevin, Postglacial Influence of Volcanism on the Landscape and Environmental History of the Puget Lowland, Washington: A Review of Geologic Literature and Recent Discoveries, with Emphasis on the Landscape Disturbances Associated with Lahar, Lahar Runouts, and associated Flooding, p.10
[8] Scott, K.M., Vallance, J.W., Pringle, P.T., Sedimentology, Behavior, and Hazards of Debris Flows at Mount Rainier, Washington, U.S. Geological Survey, U.S. Geological Survey Professional Paper 1547, U.S. GPO, 1995 PP7-8x.
[9] Hobblett, R.P. et al, Report: volcano Hazards from Mount Rainier, Washington, Revised 1998, U.S. Geological Survey Open-File Report 98-428 accessed at http://vulcan.wr.usgs.gov/Volcanoes/Rainier/Hazards/OFR98-428/OFR98-428.html
[10] Rockfall Avalanche, Mt. Rainer, Washington**,** Results of the 1963 rockfall avalanche of volcanic debris on Little Tahoma, Mt. Rainer, Washington. There were no witnesses to the event., Geologic Hazards Photos Volume 3 Landslides, Tsunamis, and Volcanoes, http://www.ngdc.noaa.gov/seg/cdroms/geohazards_v3/document/647006.htm
[11] www.nsm.buffalo.edu/courses/gly433/Pyroclast.pdf
[12] Walder and Driedger, p. 2.
[13] Hazard zones for lahars, lava flows and pyroclastic flows from Mount Rainier (Hoblitt and others, 1998: US Geological Survey Open file Report 98-428, accessed at http://vulcan.wr.usgs.gov/Volcanoes/Rainier/Publications/FS065-97/FS065-97_map.pdf
[14] K.M. Scott, P.T. Pringle, and J.W. Vallance, Sedimentology, Behavior, and hazards of Debris Flows at Mount Rainier, Washington, U.S. Geological Survey, Open File Report 90-385, P.80-84
[15] T.C. Pierson, Estimated Lahar Travel Times for Lahars 107 to 108 Cubic Meters in Volume (Approaching a 'Case 1' Lahar in Magnitude) in the Puyallup River Valley, Mount Rainier, and Estimated Lahar Travel Times for Lahars 107 to 108 Cubic Meters in Volume (Approaching a 'Case 1' Lahar in Magnitude) in the Carbon River Valley, Mount Rainier, Revised October 11, 2001, U.S. Department of the Interior, U.S. Geological Survey.
[16] Swanson, D.A. et al. Excerpt from Cenozoic volcanism in the Cascade Range and the Columbia Plateau, Southern Washington and Northern Oregon: AGU field Trip Guidebook T106, July 3-8 1989 as quoted in an excerpt at http://vulcan.wr.usgs.gov/Volcanoes/PacificNW/AGU-T106/rainier.html
[17] USGS, http://vulcan.wr.usgs.gov/Volcanoes/Rainier/Outreach/rainier_posters.html
[18] W.E. Scott, R.M. Iverson, J.W. Vallance, and W. Hildreth, Volcano Hazards in the Mount Adams Region, Washington: U.S. Geological Survey Open-File Report 95-492 1995, accessed at: http://vulcan.wr.usgs.gov/Volcanoes/Cascades/Hazards/ash_accumulation_10cm.html
[19] http://vulcan.wr.usgs.gov/Volcanoes/Cascades/EruptiveHistory/cascades_eruptions_4000yrs.pdf
[20] Mt. Rainier, Active Cascade Volcano, National Research Council, National Academy Press, Washington DC, 1994, pps.42-43.
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[22] Lyn Topinka, Mount St. Helens: A General Slide Set GS9, http://vulcan.wr.usgs.gov/Volcanoes/MSH/SlideSet/ljt_slideset.html
[23] Description: Mount Rainier Volcano, USGS Cascade Volcano Observatory, http://vulcan.wr.usgs.gov/Volcanoes/Rainier/description_rainier.html
[24] Email correspondence from William E. Scott, USGS geologist, David A. Johnston, Cascade Volcano Observatory, 2/26/08.
[25] Volcanic Ash: How to be Prepared for an ashfall, USGS, and Washington Military Department, Emergency Management Division pamphlet, June 2003

[26] Deadly Lahars from Nevado del Ruiz, USGS Volcano Hazards Program, Colombia, November 13, 1985, http://volcanoes.usgs.gov/Hazards/What/Lahars/RuizLahars.html
[27] Materials in this section on tephra are from the Cascades Volcano Observatory website http://vulcan.wr.usgs.gov/Hazards/NRC_Definitions/tephra.html
[28] Much of this section is taken from Volcanic-Hazard Zonation for Mount St. Helens, Washington 1995, by Edward Wolfe and Thomas Pierson, USGS Open-File Report 95-497.

[29] *Ibid*, p. 5, 6.
[30] *Ibid*, p. 5, 6.
[31] *Ibid*, p. 5, 6.