

## 7.0 VOLCANIC HAZARDS:

### 7.1 Overview

The Cascade Mountain Range, which runs from British Columbia into northern California, contains more than a dozen major volcanoes and hundreds of smaller volcanic features. In the past 200 years, seven of the volcanoes in the Cascade Range have erupted, including four in Washington State: Mount Baker, Glacier Peak, and Mount Rainier, and Mount St. Helens. Over the past 4,000 years (a geologically short time period), the most active volcano in the Cascades has been Mount St. Helens with about 14 eruptions.

Many other volcanoes in the Cascades are deemed active or potentially active. The Smithsonian Institution's Global Volcanism Project<sup>1</sup> lists seven active volcanoes in Washington. These volcanoes are listed below, along with Mount Hood in Oregon, which is close enough to Washington to potentially affect parts of Washington.

**Table 7.1**  
**Active Volcanoes in Washington<sup>1</sup>**

| Volcano             | Type             | Last Eruption |
|---------------------|------------------|---------------|
| Mount Baker         | Stratovolcano    | 1880          |
| Glacier Peak        | Stratovolcano    | 1700 ± 100    |
| Mount Rainier       | Stratovolcano    | 1894 (?)      |
| Mount Adams         | Stratovolcano    | 950 AD (?)    |
| Mount St. Helens    | Stratovolcano    | 1980 - 2008   |
| West Crater         | Volcanic Field   | 5750 BC (?)   |
| Indian Heaven       | Shield Volcanoes | 6250 ± 100 BC |
| Mount Hood (Oregon) | Stratovolcano    | 1866          |

The numerous volcanoes of the Cascades differ markedly in their geological characteristics. The largest volcanoes are generally what geologists call composite or stratovolcanoes, which have steep slopes because they are built mostly by flows of viscous lava. Shield volcanoes have gentle slopes because they are built mostly by flows of more fluid, low viscosity lavas. Volcanic fields are areas where volcanic activity occurs or large areas from numerous vents, fissures and cinder cones.

The current USGS ranking of threat potential for the eight volcanoes shown above is shown in the following table: six of the eight volcanoes are ranked as having high to very high threat potential.

**Table 7.2  
USGS Volcano Threat Potential<sup>2</sup>**

| <b>Volcano</b>      | <b>USGS Threat Potential<sup>a</sup></b> |
|---------------------|--|
| Mount Baker         | High to Very High                        |
| Glacier Peak        | High to Very High                        |
| Mount Rainier       | High to Very High                        |
| Mount Adams         | High to Very High                        |
| Mount St. Helens    | High to Very High                        |
| West Crater         | Low to Very Low                          |
| Indian Heaven       | Low to Very Low                          |
| Mount Hood (Oregon) | High to Very High                        |

<sup>a</sup> Qualitative ranking based on rate of volcanic activity, explosiveness, and consequences.

Detailed information about specific volcanoes may be found on the following websites.

**Table 7.3  
Volcano Websites**

| <b>Institution</b>  | <b>Website</b>  |
|---|---|
| United States Geological Survey (USGS)  | <a href="http://www.usgs.gov">www.usgs.gov</a>                    |
| USGS Cascades Volcano Observatory   | <a href="http://vulcan.wr.usgs.gov">http://vulcan.wr.usgs.gov</a> |
| Smithsonian Institution (Global Volcanism Project)  | <a href="http://www.volcano.si.edu">www.volcano.si.edu</a>        |
| Washington State Department of Natural Resources<br>(see: Geology and Earth Resources Division) | <a href="http://www.dnr.wa.gov">www.dnr.wa.gov</a>                |

Further information about volcanic hazards in Washington State, including references to USGS publications about each active volcano are included in Chapter 9 of the Washington State K-12 Facilities Hazard Mitigation Plan.

## 7.2 Volcanic Hazard Types

Volcanic eruptions often involve several distinct types of hazards to people and property, as well evidenced by the Mount St. Helens eruption. Major volcanic hazards include: lava flows, blast effects, pyroclastic flows, landslides or debris flows, ash falls, and lahars.

### Proximal Volcanic Hazards (Effects Near a Volcano)

**Lava flows** are eruptions of molten rock. Lava flows for the major Cascades volcanoes tend to be thick and viscous, forming large steep cones and typically affecting only those areas near the eruption vent. However, lava flows from the smaller volcanoes in volcanic fields tend to be less viscous flows that spread out over wider areas. Lava flows obviously destroy everything in their path.

**Blast effects** may occur with violent eruptions, such as Mount St. Helens in 1980. Most volcanic blasts are largely upwards. However, the Mount St. Helens blast was lateral, with impacts up to 17 miles from the volcano. Similar or larger blast zones are possible in future eruptions of any of the major Cascades volcanoes.

**Pyroclastic flows** are high-speed avalanches of hot ash, rock fragments and gases. Pyroclastic flows can be as hot as 1500 °F and move downslope at 100 to 150 miles per hour. Pyroclastic flows are extremely deadly for anyone caught in their path.

**Landslides or debris flows** are the rapid downslope movement of rocky material, snow and/or ice. Volcano landslides can range from small movements of loose debris to massive collapses of the entire summit or sides of a volcano. Landslides on volcanic slopes may be triggered by eruptions or by earthquakes or simply by heavy rainfall.

### Distal Volcanic Hazards (Effects at Considerable Distances from a Volcano)

**Lahars** or mudflows are common during eruptions of volcanoes with heavy loading of ice and snow. These flows of mud, rock and water can rush down channels at 20 to 40 miles an hour and can extend for more than 50 miles. Large lahars may be hundreds of yards wide, tens of yards deep and capable of carrying large boulders more than 30 feet in diameter. In most cases, inundation by a lahar will result in complete destruction of buildings.

**Ash falls** result when explosive eruptions blast rock fragments into the air. Such blasts may include tephra (solid and molten rock fragments). The largest rock fragments (sometimes called “bombs”) generally fall

within two miles of the eruption vent. Smaller ash fragments (less than about 0.1”) typically rise into the area forming a huge eruption column. In very large eruptions, ash falls may total many feet in depth near the vent and extend for hundreds or even thousands of miles downwind.

### **7.3 Volcanic Hazards for K-12 Facilities**

There are only a few K-12 facilities located within the proximal volcanic hazard zones, as defined above. However, there many K-12 facilities at risk from lahars and all campuses have at least some risk from ash falls.

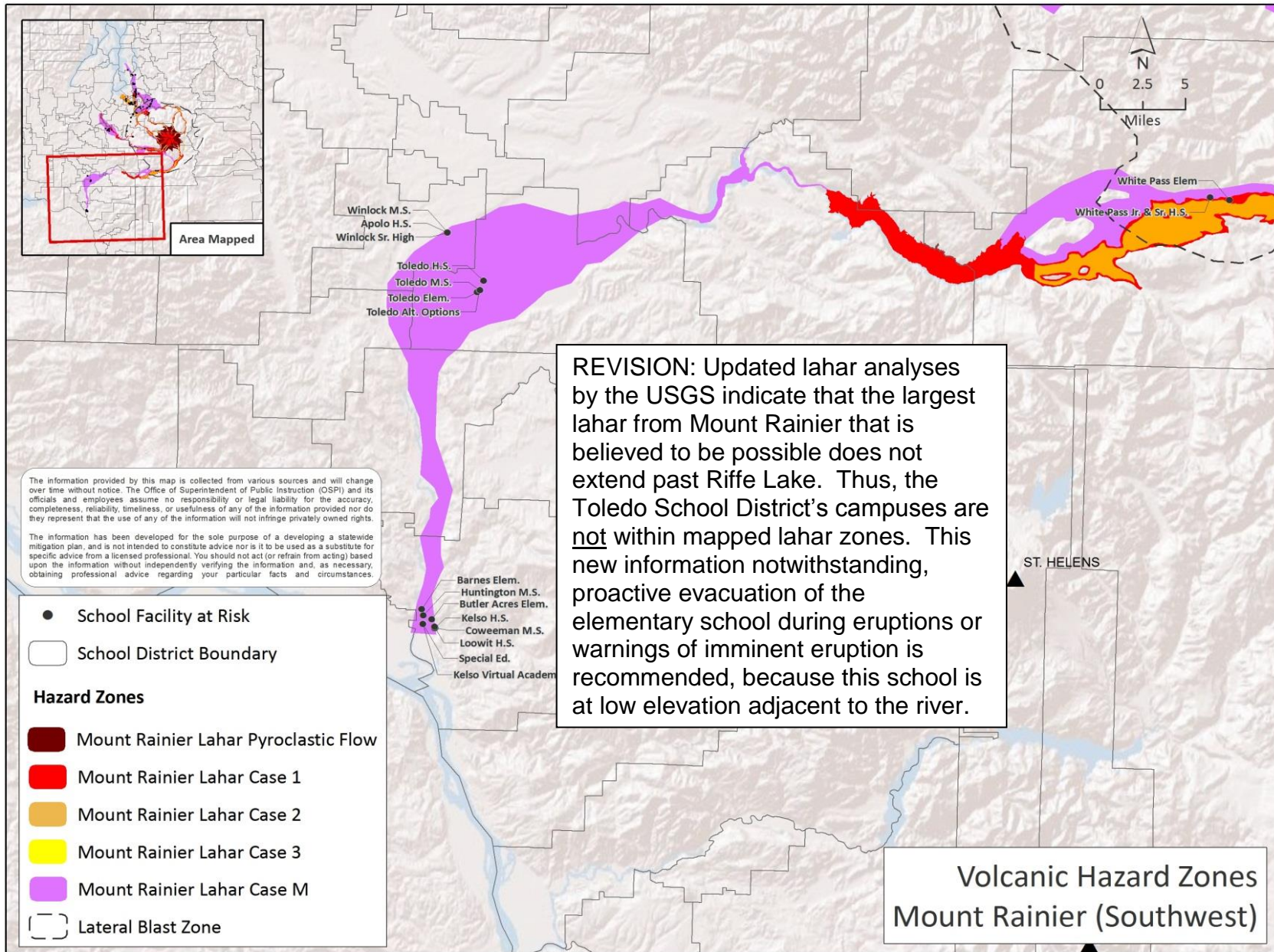
Lahars are often initiated when volcanic activity rapidly melts snow and ice at high elevations on a volcano. Volcanic ash and debris constitutes part of the load carried by lahars, but as lahars flow downslope they pick up additional debris loads from eroding sediments and vegetation. Large lahars may be up to hundreds of yards wide and tens of yards deep and capable of carrying large boulders more than 30 feet in diameter.

When a lahar occurs, evacuation to safe locations well outside of the anticipated lahar inundation zone must be completed before arrival of the lahar at a facility’s location. Buildings inundated by lahar flows are generally totally destroyed and may be deeply buried under many feet of deposited debris.

**Lahars pose an extreme life safety threat for K-12 campuses within lahar inundation zones.**

The United States Geological Survey’s volcanic hazard map showing the Toledo School District’s facilities within mapped volcanic hazard zones is shown on the following page.

**Figure 7.1**  
**USGS Volcanic Hazard Zones for the TOLEDO School District**



The USGS probabilistic ash fall maps are shown in Figure 7.2 on the following page. The maps show the probabilities of 1 centimeter (0.4 inch) or more of ash and 10 centimeters (4 inches) or more of ash over a 30-year time period. The probabilistic ash fall contours are dominated by Mount St. Helens because this volcano is the most active volcano in the Cascades. The probabilistic ash fall contours are higher eastwards from Mount St. Helens and the other volcanoes because the prevailing winds are from the west.

For any volcanic eruption generating ash, the thickness of ash accumulations decreases with distance from the volcano. Thus, locations nearest to Mount St. Helen or to the other volcanoes will receive the highest ash accumulations. Depending on which volcano erupts, the volume of volcanic ash ejected by an eruption and on prevailing wind directions at the time of eruption, the thicknesses of ash falls will vary markedly with location. However, ash falls may affect a significant number of K-12 facilities in Washington.

In extreme ash fall events, accumulation depths may reach several feet or more with the potential for building collapses from the ash load. None of the volcanoes in the Cascades are believed capable of generating such extreme volumes of ash. However, many roofs cannot support more than a few inches of wet ash. Extreme ash thicknesses are not necessary for building roofs to collapse.

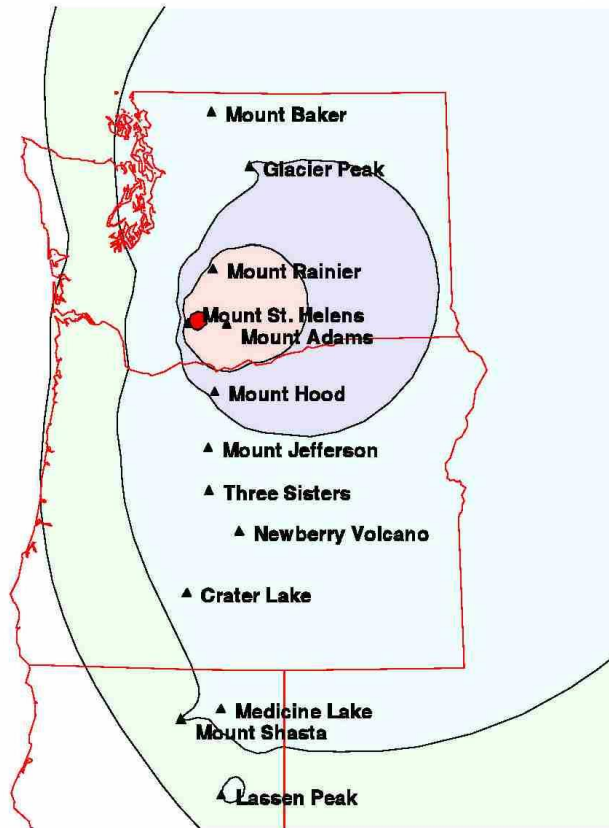
Most ash fall events impacting K-12 facilities are likely to be relatively minor with an inch or less of ash likely. However, even minor amounts of ash fall can result in significant impacts. The impacts of ash falls on K-12 facilities include health effects and several other disruptive effects such as:

- a) The inability of some schools to evacuate due to a combination of the disruption of vehicular traffic and health concerns that may preclude people being outside during heavy ash falls. In this case, shelter in place may be necessary, possibly for up to several days.
- b) Respiratory problems for at-risk populations such as young children, people with respiratory problems and the elderly,
- c) Clogging of filters and possible severe damage to vehicle engines, furnaces, heat pumps, air conditioners, commercial and public building combined HVAC systems (heating, ventilation and air conditioning) and other engines and mechanical equipment,
- d) Clean-up and ash removal from roofs, gutters, sidewalks, roads vehicles, HVAC systems and ductwork, engines and mechanical equipment,
- e) Impacts on public water supplies drawn from surface waters, including degradation of water quality (high turbidity) and increased maintenance requirements at water treatment plants,
- f) Possible electric power outages from ash-induced short circuits in distribution lines, transmission lines and substations, and
- g) Disruptions of vehicular and air traffic.

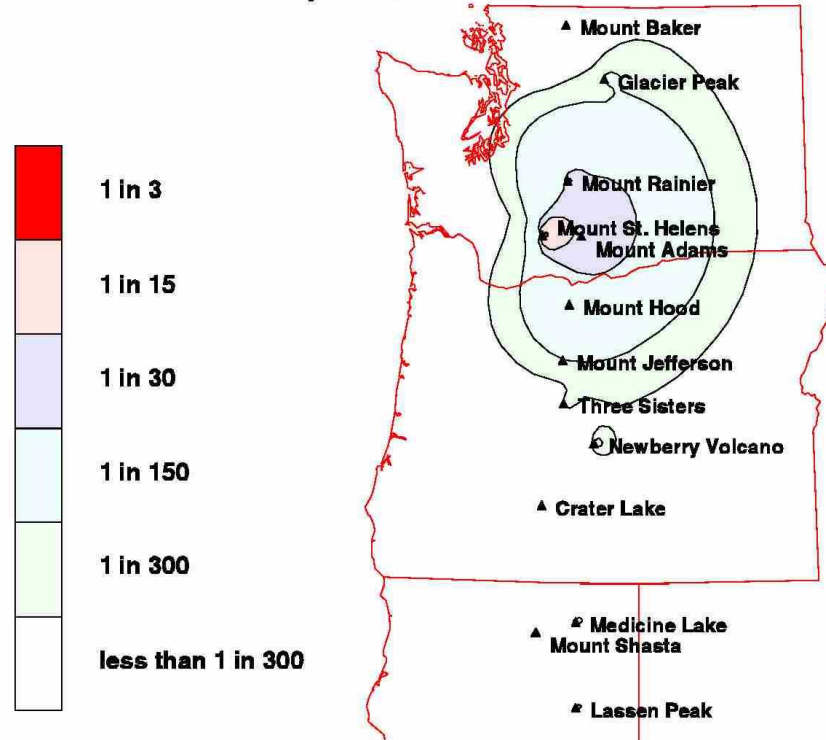


Figure 7.2  
USGS Ash Fall Probabilistic Maps<sup>3</sup>

Map showing 30-year probability of accumulation of 1 centimeter (0.4 inch) or more of tephra from eruptions of volcanoes in the Cascade Range.



Map showing 30-year probability of accumulation of 10 centimeters (4 inches) or more of tephra from eruptions of volcanoes in the Cascade Range.



The term “tephra” used on the above USGS maps includes volcanic ash, dust, cinders and other ejecta from an erupting volcano.

## 7.4 Volcanic Hazard and Risk Assessment

The potential impacts of future volcanic events on the Toledo District are varies markedly from campus to campus. The following campuses are within or near mapped lahar zones or volcanic blast zones: insert list. The potential impacts for these campuses include deaths and injuries, damage to buildings and contents (including complete destruction in severe events), disruption of educational services, and displacement costs for temporary quarters if some buildings have enough damage to require moving out while repairs are made.

The potential impacts of future volcanic ash fall events are substantially less severe than those noted above, but all of the district's campus may be affected by ash falls. The potential impacts include health effects and disruptive effects as summarized on Page 7-6 (check page number).

Note of the district's campuses have been affected by lahars or volcanic blasts, but all campuses were affected by volcanic ash from the 1980 eruption of Mount St. Helens.

For a given campus, the level of volcanic hazard and risk depends on several factors, including:

- Is the campus in or near a mapped volcanic hazard zone?
- If so, what are the estimated return periods for volcanic events that would affect the campus?
- How far from the campus is a safe area well outside of the hazard zone?
- How long would it take students and staff to reach the safe area?
- Can people reach the safe area in the anticipated time between awareness of an approaching lahar (or other volcanic event) and the arrival of the lahar at the campus?

The campus-level summary report for volcanic hazard and risk for the Toledo School District is shown in Table 7.4 on the following page.

There are important caveats regarding the interpretation of the results shown in Table 7.4:

1. Warning times for a lahar approaching a given campus will always be much shorter than the lahar travel time. With a lahar warning system, the estimated time between the initiation of a lahar and the issuance of a warning is about 30 minutes and it may take longer for the warning to reach a given campus.
2. Absent a warning system or other notification that a lahar has been initiated, the only warning of an approaching lahar would be a loud rumbling accompanied by a roaring sound similar to a locomotive or jet. The time



interval between hearing an approaching lahar and lahar arrival may be only five to ten minutes, or even less.

3. The distance to the peak of a volcano is the straight line distance. The actual distance along valleys will be longer.
4. The lahar travel time estimates are rough estimates based on a typical flow velocity for lahars of 25 miles per hour. Actual travel times may be significantly shorter or longer than these estimates, depending on slopes and other channel characteristics.
5. The life safety risk levels are based on the volcanic hazard level with adjustments for travel times in three ranges: less than 15 minutes, 15 to 30 minutes and more than 30 minutes.

**Table 7.4  
Campus-Level Hazard and Risk Summary: Volcanic Hazards**

| <b>Volcanic Campus-Level Hazard and Risk Report</b> |                |                                 |                                 |                              |                                 |                              |                                |                              |  |                               |                                     |
|---|----------------|---------------------------------|---------------------------------|------------------------------|---------------------------------|------------------------------|--------------------------------|------------------------------|--|-------------------------------|-------------------------------------|
| <b>Campus</b>                                       | <b>Volcano</b> | <b>Distance to Peak (Miles)</b> | <b>Lahar Travel Time (Mins)</b> | <b>Volcanic Hazard Zones</b> | <b>Governing Volcanic Event</b> | <b>Return Period (Years)</b> | <b>Probability in 50 Years</b> | <b>Volcanic Hazard Level</b> | <b>Travel Time to Safe Area (Mins)</b> | <b>Life Safety Risk Level</b> | <b>Evaluate Mitigation (Yes/No)</b> |
| <b>TOLEDO SCHOOL DISTRICT</b>                       |                |                                 |                                 |                              |                                 |                              |                                |                              |  |                               |                                     |
| Cowlitz Prairie Academy                             | Mount Rainier  | 59.12                           | 142                             | None                         | None                            | N/A                          | N/A                            | Very Low                     | N/A                                    | Very Low                      | No                                  |
| District Offices                                    | Mount Rainier  | 59.09                           | 142                             | None                         | None                            | N/A                          | N/A                            | Very Low                     | N/A                                    | Very Low                      | No                                  |
| Toledo Elementary School                            | Mount Rainier  | 59.32                           | 142                             | None                         | None                            | N/A                          | N/A                            | Low                          | N/A                                    | Low                           | Yes                                 |
| Toledo High School                                  | Mount Rainier  | 58.74                           | 141                             | None                         | None                            | N/A                          | N/A                            | Very Low                     | N/A                                    | Very Low                      | No                                  |
| Toledo Middle School                                | Mount Rainier  | 59.12                           | 142                             | None                         | None                            | N/A                          | N/A                            | Very Low                     | N/A                                    | Very Low                      | No                                  |

NOTE: the table above has been edited from the version in ICOS, to incorporate district-specific differences that couldn't be made directly in ICOS.

As noted in the text box in Figure 7.1, revised analysis by the United States Geological Survey indicates that the largest lahar from Mount Rainier that is believed to be possible does not extend past Riffe Lake. Thus, the Toledo School District's campuses are not within mapped lahar zones. This new information notwithstanding, proactive evacuation of the elementary school to the middle school or high school during eruptions or warnings of imminent eruption is recommended, because this school is at low elevation adjacent to the river. There is a remote possibility that a Mount Rainier eruption could cause a large flood event if upstream dams fail. In addition, all of the district's campuses might be subject to volcanic ash from Mount Rainier.

## 7.5 Volcano Monitoring and Volcano Activity Alerts

The USGS monitors volcanic activity in the Cascade Range via networks of seismic sensors (which can detect earthquakes related to magma movements) as well as very accurate ground surface measurements. The USGS also has a volcanic warning and notification system with several levels of alert as a potential eruption becomes more likely and more imminent.

**Figure 7.3**  
**Volcanic Alert Levels for People on the Ground<sup>4</sup>**

| Alert Term      | Description  |
|-----------------|--|
| <b>NORMAL</b>   | Volcano is in typical background, noneruptive state or, after a change from a higher level, volcanic activity has ceased and volcano has returned to noneruptive background state.   |
| <b>ADVISORY</b> | Volcano is exhibiting signs of elevated unrest above known background level or, after a change from a higher level, volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase. |
| <b>WATCH</b>    | Volcano is exhibited heightened or escalating unrest with increased potential of eruption, timeframe uncertain, or eruption is underway but poses limited hazards.   |
| <b>WARNING</b>  | Hazardous eruption is imminent, underway or suspected.   |

There is an important caveat on volcanic alerts: in most cases, volcanoes show signs of increasing activity before an eruption occurs. However, this is not always the case. For example, a volcanic eruption may occur without warning if a volcano suffers an extremely large landslide which releases pressure and results in an essentially immediate eruption.

The seismic monitoring systems summarized above cannot predict lahars or determine that a given event has produced a lahar. A USGS-designed lahar warning system in the Carbon River and Puyallup River valleys is operated by Pierce County. Mount Rainier poses the highest level of lahar risk because of the combination of the estimated frequency of lahars and the very large population within its mapped lahar zones. None of the other Cascade volcanoes have lahar warning systems.

The operation of the USGS lahar warning system is described in the following quotation from the USGS website:<sup>5</sup>

*"An automated system detects lahar flows by using a network of*

*small sensors called acoustic flow monitors (AFMs) embedded underground to measure ground vibrations made by passing lahars. Computer base stations located in the Washington State Emergency Operations Center (EOC) continuously analyze signals from the field stations. Upon detection of a lahar, the computer alerts local 24-hour emergency monitoring and notification centers, who initiate the warning component of the system. Warning messages would trigger immediate, preplanned emergency-response actions.*

***Know how to respond to a lahar warning.***

*Residents, employees, and visitors in lahar-hazard areas will be notified of an approaching lahar through multiple channels of communication. Many schools and other public and commercial facilities will receive notice directly from the EOC, television and radio stations, as well as NOAA Weather Radio, will broadcast warnings on the Emergency Alert System. A system of All Hazard Alert Broadcast (AHAB) sirens in cities and towns from Orting to the Port of Tacoma will provide evacuation alerts regarding the lahar and protective measures. Check with local officials to find out what is available in your community, school, or workplace.*

*Once people in the Puyallup and Carbon River valleys receive a lahar warning, they need to respond effectively. Pierce County and the State of Washington agencies have developed an evacuation plan with marked evacuation routes to aid residents and visitors. Parts of some communities rely on evacuation by foot to high ground, especially in areas where highways may become clogged with traffic.*

*In at-risk areas too remote to receive notification by one of the above methods, it is necessary to be aware of the natural warning signs of an approaching lahar—ground rumbling accompanied by a roaring sound similar to a jet or locomotive. Moving to high ground immediately is the recommended course of action.”*

Most volcanic eruptive events have precursor activity for days, weeks or months before an eruption. However, the exact time of an eruption cannot be predicted. It is also possible that some eruptions may have no precursor activity and thus no warning. For example, a major collapse of a volcanic peak could trigger a volcanic eruption without warning. This possibility appears higher for Mount Rainier than for other volcanoes in Washington because of the steep slopes and unstable rock on this peak.

Some hazard events closely analogous to volcanic hazard events, including landslides, debris avalanches or debris flows may occur in valleys below

volcanoes without volcanic activity, with events triggered by earthquakes or heavy rain.

## **7.6 Volcanic Hazard Mitigation Measures**

There are no physical measures that are practical from either an engineering perspective or an economic perspective to prevent lahars, lateral blasts, lava flows, pyroclastic flows or ash falls from affecting a campus.

The most effective mitigation measures to reduce life safety risks from volcanic events for campuses located within or near mapped volcanic hazard zones include the following:

1. Awareness. Ensure that staff and students are aware of lahar and other volcanic hazards.
2. Emergency Planning. Develop and practice an effective emergency evacuation plan, with designated evacuation methods, evacuation routes and pre-determined safe haven gathering locations. Given the high likelihood that the warning time will be very short, designated safe haven locations should be the location reachable in the shortest possible time.
3. For locations where there are impediments to the most rapid evacuation, such as a river without a nearby bridge, improving access by constructing a pedestrian bridge or other measures would reduce life safety risks from lahars.
4. Develop contingency plans and decision-making criteria for district actions when a volcano is showing signs of increased activities. For high risk campuses, it is essential to define criteria for which the risk is deemed high enough to warrant pro-active evacuation of a campus before volcanic activity.
5. Whenever possible, avoid building new facilities in or near mapped lahar zones or other volcanic hazard zones.

The Toledo School District's mitigation Action Items for volcanic hazards are shown in Table 7.4 on the following page.

**Table 7.4  
TOLEDO School District: Volcanic Hazard Mitigation Action Items**

| Hazard  | Action Item  | Timeline | Responsible Party | Plan Goals Addressed |                    |                            |                                 |
|---|--|----------|-------------------|----------------------|--------------------|----------------------------|---------------------------------|
|   |  |          |                   | Life Safety          | Protect Facilities | Enhance Emergency Planning | Enhance Awareness and Education |
| <b>Volcanic Hazards Mitigation Action Items</b> |  |          |                   |                      |                    |                            |                                 |
| Short-Term #1                                   | Include volcanic ash events in the District's emergency operations plan.   | 1 Year   | Supt.             | X                    |                    | X                          | X                               |
| Short-Term #2                                   | Develop an emergency evacuation plan for the Elementary School if Mount Rainier erupts or the USGS issues a warning that an eruption appears imminent. | 1 Year   | Supt.             | X                    |                    | X                          | X                               |
| Short-Term #4                                   | Update public education, emergency notification procedures and emergency planning for volcanic events, especially ash fall events.                     | 1 Year   | Supt.             | X                    |                    | X                          | X                               |
| Long-Term #1                                    |  |          |                   |                      |                    |                            |                                 |
| Long-Term #2                                    |  |          |                   |                      |                    |                            |                                 |

The funding source for the above action items is District funds.

Draft action items edited 11/17/2015. District to review and edit as desired and delete any blank rows.

## 7.7 References

1. Smithsonian Institution, Global Volcanism Project:  
<http://volcano.si.edu/world/region/.cfm?rnum=1201>
2. United States Geological Survey, Volcanic Hazards Program:  
<http://volcanoes.usgs.gov/observatories/cvo/>
3. United States Geological Survey, Volcano Hazards in the Mount Hood Region, Oregon -- Scott, et.al., 1997, USGS Open-File Report 97-88.
4. United States Geological Survey:  
<http://volcanoes/usgs.gov/activity/alertsystem/index.php>
5. United States Geological Survey:  
[http://volcanoes/usgs.gov/volcanoes/mount\\_rainier\\_monitoring\\_98.html](http://volcanoes/usgs.gov/volcanoes/mount_rainier_monitoring_98.html)