SEISMIC MONITORING IN MOUNT RAINIER NATIONAL PARK: ASSESSING THE POTENTIAL FOR GEOLOGIC AND VOLCANIC EVENTS

PUBLIC REVIEW DRAFT
ENVIRONMENTAL ASSESSMENT

April 6, 1998
May 18, 1998
May 27, 1998
May 28, 1998

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Figure 1: Location: Mount Rainier National Park

I. INTRODUCTION

Mount Rainier National Park encompasses 235,612 acres on the west side of the Cascade Range, about 100 kilometers (50 miles) southeast of the Seattle-Tacoma metropolitan area. The park was established in 1899 to "provide for the preservation from injury or spoilation of all timber, mineral deposits, natural curiosities, or wonders within said park, and their retention in their natural condition. . . for the benefit and enjoyment of the people. . ." (Mount Rainier National Park Act 1899) **(Figure 1: Location: Mount Rainier National Park**).

This Draft Environmental Assessment is prepared to satisfy the requirements of the National Environmental Policy Act (NEPA) (1969), as amended. This Act requires the documentation and evaluation of potential impacts resulting from federal actions involving lands under federal jurisdiction. This Environmental Assessment discloses the potential environmental consequences of implementing the National Park Service (NPS) proposed action and other reasonable alternatives.

II. PURPOSE

Mount Rainier is a volcano. The potential for geologic and volcanic hazards has been known for decades (Crandell 1969 *et al.*). Recently, a host of media presentations, public awareness information presentations and publications have been widely distributed most as a result of the U.S. Geological Survey (USGS) Cascades Volcano Observatory (CVO) and the National Park Service's greater involvement with the USGS. (*See Reference section and Appendix A for a list of some of these.*) These presentations and publications have been the result of increasingly focussed study and attention on the potential geologic and/or volcanic hazards posed by Mount Rainier. As late as 1990, when designated a Decade Volcano by the United Nations, Mount Rainier was still rather poorly understood. Although still not well-understood, Mount Rainier is now known to be of greater potential hazard than previously believed. Geologic and/or volcanic hazards, such as devastating mudflows much larger than the one generated by Mount St. Helens, may occur with little or no warning and could affect residents of the whole of the Puget Sound lowlands, including communities as distant as Auburn. Other volcanic effects have worldwide consequences. As a result the U.S. Geological Survey Cascades Volcano Observatory has developed a series of Public Information Fact Sheets and Public Awareness Presentations developed along the theme: A Volcano in Your Backyard. These are widely presented at county fairs, libraries and schools. The CVO is currently developing an educational curriculum for middle school students.

Some of the most recent publications include the following:

- ***Mount Rainier: Perilous Beauty* – a video presentation which showcases the potential hazards from the volcano and which has aired several times on the Public Broadcasting System (PBS);**

- **A joint U.S. Geological Survey/Mount Rainier National Park exhibit on geologic and volcanic hazards at the Sunrise Developed Area within the park.**

- **a National Geographic Magazine (April 1998) article which focuses on catastrophic seismic events in the Pacific Northwest, including the potential at Mount Rainier;**

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Seismic stations are one of the principle and most effective means of monitoring hazardous activity and studying subsurface volcanic structure and processes (Scott 1998). The seismic network in the vicinity of Mount Rainier has led to great changes in understanding of its structure and potential hazards.

Mount Rainier Decade Volcano

When the United Nations designated the 1990s as the International Decade for Natural Disaster Reduction, the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) took on the responsibility of coordinating focused study on a series of geologically active volcanoes in populated regions -- termed "Decade Volcanoes." Mount Rainier was selected as a Decade Volcano because of its extensive, but poorly studied geological and historical record of activity and because the volcano is situated in a densely populated region. A population of more than 2.5 million people resides in the vicinity of the Mountain, and more than 100,000 people live on mudflow deposits that originated from the Mountain. (National Research Council 1994). **Mount Rainier poses additional hazards from lava flows, ash eruptions, avalanches and catastrophic mudflows, which could be caused by rapid melting of its extensive cover of snow and ice during a volcanic eruption or by debris avalanches which may or may not be related to an eruption and which may cause catastrophic loss of life and property at any time** (Hoblitt *et al.* 1995, Sisson 1995, Walder and Driedger 1995, *et al.*).

> Major edifice failures, glacier outburst floods, and lahars could occur in the absence of volcanic eruptions because of the inherent instability of the volcanic edifice. Mount Rainier is a high volcano . . . that contains about 140 cubic kilometers of structurally weak and locally altered rock capped by about 4.4 cubic kilometers of snow and ice, all of which stand near the angle of repose. Ground shaking during an earthquake, or ground deformation due to intrusion of magma into the edifice, could cause the gravitational failure of a large sector of the volcano, producing catastrophic avalanches and debris flows and possibly triggering an eruption (National Research Council 1994).

Mount Rainier Seismology

Mount Rainier is considered the second most seismically active volcano in the Cascade Range north of California (National Research Council 1994). **A network of seismic stations within and surrounding the park have recorded tectonic earthquakes, volcanic earthquakes, glacial outburst floods, mudflows, avalanches and rockfalls. Each of these events produces a distinctive seismic "signature," which helps scientists to understand where an event occurred, what caused it and whether it is a continuing hazard.** The network has particularly enabled more detailed investigation of an area of tectonic activity along the western perimeter of the park known as the Mount Rainier seismic zone **(Figure 2: Mount Rainier Seismic Zone). A well-placed array of seismic stations is the most essential tool available to scientists and park managers seeking information about potential hazards from Mount Rainier (Scott and Driedger 1998).**

Recent research (Moran 1997) shows that seismic waves are slowed significantly as they pass beneath Mount Rainier, indicating that heated rock exists beneath the volcano at depths between 4-15 kilometers (2.5 to 9.3 miles). Moran (1997) used the Pacific Northwest Seismic Network (PNSN) **(Figure 3: Pacific Northwest Seismic Network)** to study the internal structure of Mount Rainier. In this study, he placed a temporary seismic station on Shriner Peak, which was in place for approximately two years. He also placed several temporary seismic stations that remained in place for only a few days to a few weeks near Ohanapecosh and along the Westside Road. Although the relationship of the current earthquake activity just below the summit to possible magmatic sources deeper within the volcano is not well understood, Moran's research enabled seismologists a greater understanding of the deeper internal structure of the volcano, particularly giving a better picture of the deeper velocity structure of earthquakes waves, that is, how fast the waves are moving through the volcano. Earthquakes beneath Mount Rainier occur at depths of 5 km (3 miles) or less below the surface; away from the mountain they occur at depths of 10-20 km (6.2 to 12.4 miles) below the surface.

The proper interpretation of the shallow edifice earthquakes depends on an accurate knowledge of their depth. Unfortunately, the present distribution of seismic stations is not adequate to determine the depths of the shallow edifice quakes very accurately (Moran 1997, National Research Council 1994). Several potential causes of the edifice earthquakes have been postulated: 1) that they are tectonically induced (caused by movement of the earth's crustal plates); 2) that they are volcanically induced (a) caused by volumetric forces associated with active magmatic intrusion (magma moving up in the volcano), or (b) caused by volumetric or thermal forces associated with cooling magma and hydrothermal circulation; or 3) that they are gravitationally induced (a) caused by progressive disintegration of the volcano due to the extensive amount of hydrothermally-altered rock, or (b) caused by the gravitational forces related to the loading or weight of the edifice. These hypotheses are called: 1) the tectonic hypothesis, 2a) the magmatic hypothesis, 2b) the hydrothermal hypothesis, 3a) the disintegration hypothesis, and 3b) the loading hypothesis (Moran 1997).

If the seismic activity is caused by tectonic forces, the hazard posed by the volcano would not appear to be any more predictable than is tectonic or earthquake activity elsewhere. If the seismic activity is caused by volcanic forces, with magma moving upward in the volcano, the threat of an eruption could be more imminent than previously believed. If, however, the seismic activity is being caused by gravitational forces, owing to the known unstable nature of the peak, then the volcano could be at risk of producing large debris avalanches and debris flows. If either of the last two situations is the case, the threat posed by Mount Rainier is greater than previously believed. The most likely cause for these earthquakes, however, is thought to be forces associated with rising hot, gas-rich fluids – the hydrothermal hypothesis (Moran 1997).

"Evidence for a possible systematic mislocation of the earthquakes, indicates that more work needs to be done to delineate the exact depth range in which these events are occurring before any firm conclusions can be reached about the process(es) responsible for these earthquakes" (Moran 1997).

Although most research projects recommended by the Decade Volcano program are conducted with no or minimal placement of temporary monitoring equipment, some require the placement of temporary structures, such as seismometers, to aid in the continued understanding of volcanic hazards. Because of the inability of a recent study (Moran 1997) to adequately interpret the depths and causes of earthquakes within the edifice, Dr. Steve Malone, a seismologist at the University of Washington Geophysics Program, proposed, in a June 1997 letter to the Superintendent, to place a seismic station in the summit area on Mount Rainier. **According to the research proposal submitted by Dr. Malone, a summit area seismic station will help seismologists to achieve two important goals: 1) to accurately locate earthquakes within the edifice; and 2) to obtain a clearer understanding of the velocity structure of the upper part of the edifice. This information is needed to better identify the causes of earthquakes in the volcano and to detect conditions that might herald hazardous events such as eruptions or large landslides, both of which could generate mudflows that would severely affect areas far downstream from the volcano.**

Although preliminary support was expressed for the summit area seismic station, proposed by Dr. Malone, the request was eventually put on hold pending further environmental analysis of the action. As mentioned, the request was made to build on the revealing study by Moran (1997). Also, as mentioned, that study was unable to determine either a cause or an accurate location for the shallow earthquakes occurring beneath the summit. Such information would give a better indication of the hazard posed by Mount Rainier to the surrounding population. If the seismic activity is occurring higher in the volcanic edifice than assumed, then the likelihood of a hazardous event happening may be greater than previously believed.

Role of Mount Rainier National Park

An understanding of the hazards associated with Mount Rainier is essential if the National Park Service is to honor its commitment and **innate** obligation as a public service agency to the citizens of the Puget Sound Region. The National Park Service desires to provide the most accurate and appropriate information regarding the volcanic hazards associated with Mount Rainier to ensure the safety of park visitors and area residents (Management Policies 1988). The National Park Service was an active participant in the development of the National Research Council's science plan (1994) and has formally acknowledged its role in studying and mitigating hazards associated with the volcano.

Mount Rainier Volcanic Hazards Planning Group

In 199_, the park initiated a broad-based hazards planning group comprised of federal, state and local agencies in an effort to provide emergency preparedness

Figure 2: Mount Rainier Seismic Zone and Earthquakes in Cross Section

Figure 3: Pacific Northwest Seismic Network

systems and mitigation plans for the five Washington state counties that border Mount Rainier National Park. The ongoing planning process involves assessing the potential effects of a disaster originating down one or more of Mount Rainier's river valleys. Among the agencies that have been contacted or have participated in this effort are: the U.S. Geological Survey, U.S. Forest Service, U.S. Army (Fort Lewis); departments of emergency services and/or sheriff departments from the following counties: King, Pierce and Lewis; police departments; fire departments and/or school districts from the cities of Puyallup, Orting, Ashford, Buckley, Enumclaw, Tacoma, Sumner, and ______; the University of Washington Geophysics Program, the Washington Office of Emergency Management, Federal Emergency Management Agency (FEMA), and congressional representatives. The U.S. Geological Survey, the University of Washington and the coordinated Mount Rainier Volcanic Hazards Planning Group above have all recommended additional seismic studies to assess potential earthquake-generated hazards, including eruptions and debris flows. **The primary concern of this planning group is responding to a catastrophic event from Mount Rainier, in terms of its effect on communities (most of the cities listed above) downstream on the wide plains created by previous mudflows originating from the volcano. As a result, much of the research focus of this group has been targeted on the placement of acoustic flow monitors and _________ on the major rivers, such as the Puyallup and the Carbon, where the greatest number of people would be threatened. Because fewer persons live in the Nisqually River valley and because the inhabitants are closer to the volcano (and therefore may not receive warning in time) less emphasis has been placed. These meters have been used successfully in other parts of the world. The logistics of such a warning system, what format it would take, how emergency response personnel would be notified and how the system could be tested are the primary concerns being addressed. A plan is expected by fall 1998.**

III. NEED

A well-designed and maintained seismic network at Mount Rainier is of paramount importance for park emergency staff and for state, county and city emergency managers, all of who are responsible for the safety of hundreds of thousands of people who live, work and commute daily in volcanic hazard zones within and downstream from Mount Rainier. This network is also important for scientists seeking a better understanding of the volcano's earthquakes, structure and hazard potential. The five seismic stations currently located within the park are part of this seismic monitoring network and have been extremely valuable in assessing geologic events, such as rockfalls, at Mount Rainier. The seismic monitoring network is one of many tools being used by scientists to better understand the hazards posed by Mount Rainier. Other tools include technologically advanced geologic mapping, using satellite imagery and field surveys, as well as comparison of the characteristics of Mount Rainier to other active volcanoes.

The need for additional seismic stations has been clearly stated by the National Research Council (1994). A summit area seismic station, however, would mean placing a structure in designated wilderness, where only one percent of park visitors have the skill or opportunity to visit. Clearly, wilderness implications and park management geohazards implications must be considered in deciding, as an attempt to better define the location and possible cause of seismic activity in the volcano, whether to place even a small seismic station in the summit area on Mount Rainier. The placement of a temporary (not to exceed two years) seismic station on the summit of Mount Rainier could represent an intrusion into the experience of solitude and could affect the wilderness visitor experience. The decision not to place a summit area seismic station could mean that the NPS may abrogate its responsibility as a public service agency to effectively administer Mount Rainier National Park, to the extent that it has an obligation to understand the hazards of the land it manages when those hazards might threaten an array of people not associated with the direct management of the park. **If a major geologic or volcanic event were to occur that could threaten areas in and outside of the park, the National Park Service would, however, work closely with the USGS, emergency organizations and others to facilitate the deployment of necessary equipment needed to assess and mitigate or limit, if possible, the consequences of such an occurrence on life and property. If there is a way to facilitate research that will lead to a better understanding of the volcano's hazards *before* a catastrophic event occurs then Mount Rainier National Park must assess the research proposal in relationship to the National Park Service mission and wilderness issues.** These concerns are the subject of this environmental assessment. An attempt is made to identify National Park Service, wilderness and Mount Rainier National Park policy to fully disclose the implications of making either decision.

IV. OBJECTIVES

The principle objective of the University of Washington proposed study would be to determine more accurately the location and probable cause of the continued seismic activity. **Additional objectives of the University are to provide public information and education; to encourage basic scientific research through student training; and to provide public service, potentially through geologic hazards warning derived from this project.** The objectives of this environmental assessment are additionally to evaluate the current placement of seismometers in Mount Rainier National Park.

The primary purpose for seismic monitoring of Mount Rainier is as part of an ongoing process to detect precursors to volcanic activity such as the movement of magma beneath or within the edifice that could signal an imminent volcanic eruption. Seismic monitoring is also used to detect the movement of glaciers or of the edifice itself, which could trigger glacial outburst floods, rockfalls, slope failures, and debris flows (National Research Council 1994).

V. ALTERNATIVES

<u>Alternative A: No Action</u>

Under this Alternative, the seismic stations currently in operation on Mount Rainier would remain. Agreements for the use of the seismic stations currently in wilderness would be extended until such time as they no longer provide information that fulfills the purpose for their establishment. Agreements for the other (non-wilderness) seismic stations would be extended indefinitely, as long as the National Park Service and the University of Washington or the U.S. Geological Survey want to maintain them.

There are currently five seismic stations in Mount Rainier National Park, including one which is displayed for interpretive purposes in the Jackson Visitor Center at Paradise and which shows visitors a recent (usually ongoing) record of seismic activity. The seismic stations are located at Longmire, Mount Fremont, Emerald Ridge, Camp Schurman and Camp Muir and are part of the Pacific Northwest Seismic Network. Of these, only the ones at Mount Fremont and Emerald Ridge are located in wilderness. The Mount Fremont, Camp Schurman, Camp Muir and Emerald Ridge seismometers are operated under agreements with the University of Washington; the other (Longmire) is operated under an agreement with the U.S. Geological Survey. An additional temporary seismometer was located near the Shriner Peak Lookout 1778 meters (5,834 feet) from 1995-1996 during the period of Dr. Moran's study. In addition, five other temporary seismic stations were used by Moran (1997) (during a nine-day period in 1994) who used a total of 18 seismic stations both within and outside of Mount Rainier National Park to complete his doctoral research.

The Longmire seismograph was **one of the first seismic stations located in the Pacific Northwest** and is, of course, the oldest station in the park (Malone 1998). The first Paradise station was established in 1958, originally in the Paradise Meadow area. **The station location was eventually moved to Longmire (in the administrative housing area) to remove surficial (non-seismic) impacts from the continual foot traffic in the Paradise meadows and to reduce the potential for vandalism.** A phone cable connects this seismic station to the Jackson Visitor Center, where a helicorder demonstrates seismic activity on a visible recorder for park visitors. **The Longmire seismic station is a Worldwide Standard unit.**

The Mount Fremont seismic station is located down-slope from the Mount Fremont Lookout in the Sunrise area of the park. Perhaps due to its excellent maintenance, good calibration or luck, this seismic station provides some of the best information in the state for the Pacific Northwest Seismic Network (Malone 1998). It was placed there in the 1970s as the U.S. Geological Survey began to actively monitor volcanoes.

The Emerald Ridge seismic station is the only one located on the west side of Mount Rainier within the park boundary. Its position has been essential in interpreting Mount Rainier seismic events. This station was placed after after a series of devastating glacial outburst floods occurred on Tahoma Creek. Like its counterparts, this seismic station is an attempt to better detect seismic events. **Like the Mount Fremont seismic station, the Emerald Ridge station is snuggled in a clump of trees.**

The Camp Schurman seismometer was installed in 1989 under a 5-year term Memorandum of Agreement with the University of Washington. Due the location of Camp Schurman (surrounded by designated wilderness) the park requested and the University complied with minimum tool provisions in its installation. A solar panel and antenna were mounted on a pre-existing hut. The batteries and radio transmitter are inside the hut. The seismometer and voltage-controlled oscillator are outside the hut and are connected to the equipment inside and on the hut via a two-conductor wire that lies under the scree adjacent to the hut. After minimum tool analysis, a helicopter was used to ferry materials to Camp Schurman in June 1989. The Camp Schurman seismic station is difficult to maintain due to winter access limitations.

Table 1

Location and Elevation	Installation Date	Partner	Agreement	Equipment	Purpose
Longmire 2,760 feet Non-wilderness Located in L-508	1958	U.S. Geological Survey: Branch of Earthquake and Geomagnetic Information (Denver, CO)	Interagency Agreement renewed in 1988 and 1993. Also issued a Special Use Permit 1987-1988 and from 1982-1987 and 1972-1982 for reimbursement of electricity costs. Term of Agreement is not specified but 60 days notice must be given for termination by either party.	L-508 containing seismometer and associated equipment	First station in Pacific Northwest Collect baseline seismic data for Mount Rainier and the northwest
Mount Fremont (Sunrise) 2,195 meters (7,200 feet) **Wilderness**	1972, renewed 1989 Expired 1994	University of Washington	Memorandum of Understanding (Special Use Permit 1983-1988)	10' x 10' subsurface sensor, aerial mast antenna (20'), small solar panel, batteries (2.0 ' x 3.0' x 1.0' box)	Provide accurate data concerning seismic activity within and around Mount Rainier
Emerald Ridge (Westside Road) 1,798 meters (5,900 feet) **Wilderness**	1989	University of Washington	Research and Collecting Permit		Study debris flows, outburst floods from Tahoma Creek Only seismic station on west side of park

Camp Schurman (White River) 2,865 meters (9,400 feet) Non-wilderness	1989	University of Washington	Memorandum of Understanding	Seismometer (buried) plus cable and materials stored in a steel box similar to those associated with other seismic stations	To record ice movements and earthquakes near the summit. At the time it was placed, it was the highest station (the one at Camp Muir cam four years later).
Camp Muir (Paradise) 3,048 meters (10,000 feet) Non-wilderness	1993 (Capitalized on MORA designation as Decade Volcano by IAVCEI)	University of Washington	Research and Collecting Permit	Cylindrical seismometer 3" x 6" buried 18" deep. Short cable to voltage controlled oscillator and radio transmitter housed in small steel box (3.0' x 2.0' x 1.5'). Antenna and solar panel on Butler Hut.	To better investigate the tectonic earthquakes near the summit and to considerably improve ability to detect and locate another class of seismic signals known as "low-frequency icequakes."

The Camp Muir seismometer is located on the side of the climbing hut in Camp Muir. It was installed in 1993 to improve the ability to monitor and locate seismic events and to enhance depth determination of summit and near-summit earthquakes. **This station is subject to the severest weather conditions, particularly strong winds.** Maintenance here is difficult due to the susceptibility of the station to breaks in data.

These seismic stations have collectively shown that many of the seismic events that occur on the edifice of Mount Rainier are due to glacier movement, glacial outburst floods, and rain-triggered debris flows. Collectively, the stations have been valuable to an understanding of the structure of Mount Rainier. In the 1980s the seismic stations recorded several thousand events beneath or within the volcano. Of these, a few hundred were clearly earthquakes, the others were caused by the movement of glaciers or by rockfalls on the flanks of the mountain (National Research Council 1994). Since the publication of *Mount Rainier: Active Cascade Volcano*, seismologists have been able to determine the seismic signature differences among glacial movements, rockfalls, and earthquakes.

<u>Alternative B: Continue Seismic Monitoring but Allow No New Seismic Monitoring Equipment to Be Placed in Wilderness</u>

Under this Alternative, the established seismometers would remain as stated under Alternative A, but the park would not entertain research that placed additional seismic stations in wilderness in the park, including the seismic station proposed for the summit area. This alternative does not meet the goals of the National Park Service as stated in NPS Management Policies (1988) regarding safety. This Alternative, if chosen might limit the ability of the National Park Service to **interpret** a situation in which the volcano became suddenly far more active. **If, however, the volcano became suddenly more active, the justification for placing additional seismic stations would be greater.**

<u>Alternative C: Continue to Conduct Limited Seismic Monitoring, but Remove Seismic Stations from Wilderness</u>

Under this Alternative, the University of Washington would be asked to remove the seismic station currently located on Emerald Ridge at their earliest convenience. The removal of the Mount Fremont seismic station would be immediate, since the agreement for it expired in 1994. The park or these institutions would then conduct site rehabilitation if necessary according to the terms of the agreements under which these seismic stations were installed. This alternative, if chosen would be unfavorable to the continued seismic monitoring of Mount Rainier, if the Emerald Ridge station were not replaced because this station is the only station located on the west side of the volcano. The Mount Fremont station, as mentioned, is one of the best in the Pacific Northwest Seismic Network, in Washington, and its accuracy would be sorely missed (Malone 1998). The Emerald Ridge seismic station agreement has no termination agreement. **The removal of the Emerald Ridge and Mount Fremont seismic stations would severely undermine scientist's**

present ability to monitor rockfalls, mudflows, and other ongoing hazardous geological phenomena. Seismic station removal could also restrict the park's ability to enable public warning of geologically and volcanically hazardous areas by limiting scientist's and therefore the park's understanding of such events (Scott and Driedger 1998).

Alternative D: Continue to Conduct Seismic Monitoring Parkwide (Place Summit Area Seismic Station) and Re-evaluate Current Seismic Stations

In addition to the five seismic stations that would be retained as under Alternative A and B, the proposal to install a temporary (not to exceed two years) seismic station in the summit area (above 4,400 meters or 13,500 feet) of Mount Rainier, in a location selected as the most unobtrusive location by Mount Rainier National Park staff in consultation with the University of Washington Geophysics Laboratory (currently the north northwest rim of the west crater) would be approved. The proposed station would be installed, as stipulated by draft Research and Collecting Permit conditions, not to exceed two years and would be similar to the other seismic stations currently operating in the park (**Figure 4: Typical Seismic Station**). The batteries and other electronic materials would be housed in a "boulder-colored" box (color to be determined by NPS to blend with the environment). A small, television-sized antenna would be installed on a short (approximately one meter or 3.3 feet), well-braced pole. A small solar panel (located almost on the ground, but propped up at a 60-70 degree angle), to charge the battery would also be installed. Because the equipment would have to withstand severe weather conditions present on the summit, including high winds, all components would be placed within a 2 meter by 1.5 meter by 1.5 meter (6.5 feet x 5 feet by 5 feet) shelter, which would be burrowed into the crater rim, placed behind a large rock, or snuggled within rocks to aid in non-detection by climbers. The preferred site is as described but could be changed to reduce visibility of the structure (**Figure 5: Photo of Mount Rainier Summit Area**). **To place a seismic station in this area of the summit would require good coupling to surface rock outcrops, which may be difficult in this soft area of loose rock fragments (mostly fist-sized and smaller) in an unconsolidated ashy (sandy) to clay rich matrix. As a result, the leveling of a small area (approximately seven square feet) and the pouring of a small concrete pad may be necessary.** To be useful the seismic station must be located above 4,400 meters (13,500 feet) and should be on the western side of the volcano summit area. According to Dr. Malone, if the seismicity rate continues with the same frequency it has over the recent past, it might be possible to get enough information to operate the summit station for only one year. If, however, there is a months long interruption in the seismicity rate (as occurred during the study by Moran), a longer period would be necessary (Malone 1998).

Technology and minimum tool limitations mean that the installation site must have line-of-sight visibility between the summit and a radio receiver off the mountain to enable continuous transmission of the seismic signal to the University of Washington. If the information were instead to be transmitted directly overhead via satellite to the University of Washington, the satellite transmitted to would have to be a geostationary satellite to

Figure 4: Typical Seismic Station

Figure 5: Photo of Mount Rainier Summit Area

enable continuous transmission of data. To do so would require the use of a much larger summit installation, as have been installed in isolated places in Alaska **and Canada as permanent stations in the U.S. and Canadian National Seismograph Networks (USNSN and CNSN).** Transmitting information to a moving satellite, such as those used for weather monitoring would not be appropriate, albeit less obtrusive, due to the inability of these satellites to accept continuously transmitted data that is needed here. Transmission to a geostationary satellite would require an amplified power source, and **therefore a much larger structure to support the solar panels that would be needed. Furthermore, rather than a pole antenna,** which is part of the current proposal, this type of installation would require a large dish antenna [of approximately 2.5 meters (over eight feet)], to enable satellite transmission (Malone 1998).

Figure 2 shows Mount Rainier earthquakes in map view and in cross-section and indicates that earthquakes occur in two places: 1) in a cluster at depths of 0-3 kilometers (0-10,000 feet) below the summit, and 2) in a deeper linear zone along the western boundary of the park (the Mount Rainier seismic zone). In 1994, the National Research Council stated that the relationship between the Mount Rainier seismic zone and volcanic activity is unknown. This is still true. According to the National Research Council (1994), with the array of seismic stations then present (4) it was difficult to distinguish between surface seismic events caused by glacial movements on the edifice and shallow earthquakes beneath the mountain. As mentioned above, these shallow earthquakes, shallower than 914 meters (3,000 feet) could signal movement of magma, which might signal an impending eruption and/or volumetric and/or thermal forces associated with the magmatic and hydrothermal system, whereas an increase or change in surface seismic events could come before a glacial outburst flood or rockfall, either of which could produce a debris flow. **These events, however, are frequently preceded by deeper earthquakes.** The National Research Council (1994) stated "clearer distinction and more reliable detection of shallow earthquakes and surface seismic events could be made if two or three additional seismic stations were placed in operation on the upper slopes of the volcanic edifice, especially if these seismometers were three-component instruments capable of detecting ground motion with high resolution." **The seismic station, however, would be useful in detecting a better location (regardless of depth) for all earthquakes within the cone.**

The installation of a seismic station in the summit area on Mount Rainier would, therefore, improve knowledge about the locations and depths of volcano-tectonic earthquakes. It might also be effective in detecting and locating precursors to massive landslides, rock and icefalls from Mount Rainier, such as the 1989 rockfall from Russell Cliff which traveled four kilometers (2.5 miles) down the Winthrop Glacier, although this would not be its primary purpose. In addition, a summit area seismic station would help study the enigmatic, low frequency events thought to be associated with glacial movements high on the mountain (such as those caused by glacial outburst floods) and it would temporarily enhance the seismic monitoring network already present on the mountain (although these benefits are not part of its primary purpose).

The Decade Volcano plan called for an evaluation of the influence of seismic activity on edifice stability. It states that additional seismic stations and associated tomographic (internal structure) studies are needed on the volcano to improve resolution of low-velocity magma zones. The techniques which would be used in this Alternative have been useful at Mount St. Helens, where a high degree of subsurface detail was described with tomographic imaging, using local earthquakes recorded on a local seismic network, and in Alaska, as well as in other areas. An accurate seismic velocity model of Mount Rainier and the crustal rocks below it is essential to locate seismic events of all types accurately and to more definitively attempt to answer the question: 'Just how hazardous is Mount Rainier' and 'What types of hazards are the greatest?'

Alternatives Considered But Rejected

Cease Conducting Seismic Monitoring of Mount Rainier

This alternative neither meets the intent of the National Park Service to aid in research in the National Parks, nor the **public service**-intent of the National Park Service to provide visitors and nearby residents with appropriate geological hazards information. Because Mount Rainier is a volcano and volcanoes are inherently risky places, it is expected that some type of seismic monitoring will always take place. Seismic monitoring, particularly in non-wilderness areas, is a research activity that is both encouraged and appropriate in a national park.

VI. AFFECTED ENVIRONMENT and IMPACTS OF THE PROPOSED ALTERNATIVES

This section addresses the environment within Mount Rainier National Park that has a potential to be affected by the actions proposed in this assessment. Included here are the policy and management of the National Park Service as it pertains to the proposed action, the perceived effects of the proposed action on wilderness, a background history of geology and geologic and volcanic hazards, the setting of the five current seismic stations located within the park and the likely effects on recreational users of the proposed actions. Because there are no direct effects on wildlife, sensitive, threatened or endangered species, floodplains, wetlands and other similar resources, these are not discussed.

Wilderness

Following are National Park Service and Mount Rainier National Park policies as they relate to scientific experimentation and placement of monitoring equipment in national parks and in wilderness, as well as to the need to provide volcanic and geologic hazards safety information to park visitors and area residents.

<u>Management Policies</u>

Section 4:3: *Management Policies* (1988) recognizes that parks are useful as scientific laboratories and promulgates the use of a permit to enable activities that are consistent with NPS policies, but which might disturb resources or visitors, that require the waiver of any regulation or the collection of specimens. "Manipulative or destructive research activities generally will not be permitted within parks. Exceptions may be granted if the

impacts will be short-lived, the park is the only area where such research can be conducted, the value of the research is greater than the resource impacts, or the research is essential to provide information for resource management."

In Section 6:3, *Management Policies* (1988) states "Within a designated wilderness area, the preservation of wilderness character and resources while providing for the appropriate use is the primary management responsibility (other than activities related to the saving of human life)."

According to *Management Policies* (1988), one of the statutory purposes for wilderness includes scientific and educational use. Accordingly, "a research project may be conducted in wilderness if it meets all of the following requirements:

> The research activities are allowable under federal laws and regulations.
> There is no alternative to conducting the research in a wilderness area.
> The project will not adversely affect physical or biological resources, ecosystem processes or aesthetic values over an area or duration greater than necessary to meet research objectives.
> The project will not interfere with recreational, scenic, or conservation purposes of the wilderness over a broad area or long duration."

It further states

> "Hydrologic, hydrometeorologic, *seismographic,* and other research and monitoring devices may be installed and operated in wilderness only upon a finding that (1) the desired information is essential and cannot be obtained from a location outside of wilderness, and (2) the proposed device is the minimum tool necessary to accomplish the objective safely and successfully. Devices located in wilderness will be removed when determined to be no longer essential. All research activities and installation, servicing, and monitoring of research devices will be accomplished in compliance with NPS wilderness management policies and procedures contained in the park's wilderness management plan. Non-NPS research activities that might disturb resources or visitors or require the waiver of any regulations may be allowed only pursuant to the terms and conditions of a permit." (Section 6:7).

Another statement from *Management Policies* (1988) is pertinent to this proposal: "The saving of human life will take precedence over all other management actions. . .The park will work cooperatively with other federal, state, and local agencies, organizations, and individuals to carry out this responsibility. . .The National Park Service will strive to identify recognizable threats to the safety and health of persons and to the protection of property. . . The National Park Service recognizes that the environment being preserved is a visitor attraction but that it also may be potentially hazardous. . ." (Section 8:6-7).

<u>NPS-77: Natural Resources Management Guideline</u>
According to *NPS-77: Natural Resource Management Guideline* (1992):

> "The scientific value of Wilderness Areas derives from their undisturbed natural condition and from the wealth of biological diversity they contain. Usually they provide excellent benchmarks of environmental quality. Research is encouraged, provided it does not negatively impact the resource, intrude on the aesthetic, or conflict with the preservation of wilderness values. . ." (Section 4:10)

Mount Rainier National Park Wilderness Management Plan

The *Mount Rainier National Park Wilderness Management Plan* (1989) states:

> Research activities are permitted in accordance with 36 CFR. Research projects are permitted if they meet the following requirements: the project addresses an identified management need; addresses a stated Wilderness Management objective; there is no alternative to conducting the research in the Wilderness area; and the project will not adversely affect or interfere with natural resources, ecosystem processes, aesthetic values, or recreational or conservation purposes of the Wilderness over a broad area or long duration."
>
> "Research equipment and numerous study sites exist within the Wilderness: seismic monitoring stations; a weather station north of Chinook Pass on the park boundary; a Research Natural Area at Butter Creek; and several study sites marked with small metal stakes, tags or wooden markers."
>
> Monitoring devices for hydrological, seismic, hydrothermal or other purposes may be installed and operated in Wilderness only when park management has determined that the information is essential and cannot be obtained from a location outside of Wilderness and the proposed device is the "minimum tool" necessary to accomplish the study objective. Devices used for monitoring or research purposes are removed when they are no longer essential. All areas are restored to natural conditions at the completion of studies."

Mount Rainier National Park Resource Management Plan (1989/1998 Draft)

The Mount Rainier National Park Resource Management Plan contains the following project statements which relate to the need for additional information on volcanic hazards, including seismic monitoring: MORA-N-201.00 Geologic Resources Program; MORA-N-205.00 Investigate Factors Contributing to Volcanic Hazards; MORA-N-206.00 Assess Edifice Stability; MORA-N-207.00 Analyze Risks of Non-Cohesive Lahars; and MORA-N-208.00 Determine Eruptive History, Styles and Mechanisms of Volcano. Collectively, these project statements call for additional research on volcanic hazards, including additional monitoring.

Mount Rainier: Active Cascade Volcano (1994)

Appendix B in this book is a document prepared by the park which outlines procedures for conducting research in the park and states "Scientific research has long been an important part of the operation of national parks. (National) Park Service Management Policies direct that a program of natural and social science research be conducted in the parks to support National Park Service goals, and to assist park staff in carrying out the mission of the Service by providing accurate scientific information for planning, development and management of the parks. The National Park Service cooperates with research institutions and in recognition of the scientific value of parks as natural laboratories, investigators are encouraged to use the parks for scientific studies whenever such use is consistent with National Park Service policies."

National Park Service Director's Order #41 (DRAFT): Wilderness Preservation and Management (1998)

> The increase of scientific knowledge, even if it serves no immediate wilderness management purpose, may be an appropriate wilderness resource objective when it does not compromise wilderness resources and character. Research and other scientific use projects in wilderness must meet accepted protocols and standards, including those involving safety."
>
> Any research or scientific use in NPS wilderness which requires the use of motorized equipment, mechanical transport, or the need for an installation, must be integral to the understanding and protection of wilderness."

Summary

From the policy statements above, it is clear that research is an appropriate activity in national parks and that research in wilderness must meet several criteria. These criteria are listed above and entail justification that the park is the only place the project can be accomplished, that the information is needed for appropriate administration of the wilderness area, that there are no alternatives that would provide the information without conducting the activity in wilderness, that the equipment is the "minimum tool" needed for the research, and that the research questions are pertinent to the park. Finally, it is clear that the NPS and therefore Mount Rainier National Park has **an obligation** to provide for public, park visitor and employee safety above all else.

The following numbered items are delineated in the above policy and management requirements. Issues and impacts as they relate, primarily to the new action of placing additional seismic monitoring equipment in wilderness, are summarized below.

1. Need for Permit

In compliance with Section 4:3 of *Management Policies*, a Research and Collecting Permit or a Memorandum of Understanding would be developed to ensure tracking of this proposal if Alternative D were approved. The seismic stations currently located in wilderness already have either a Research and Collecting Permit (1) or a more formal Memorandum of Understanding (2) or Interagency Agreement (2).

2. Allowable Under Federal Laws and Regulations

The placement of seismic stations in wilderness or in national parks is an activity allowable under all federal laws and regulations, including National Park Service and Mount Rainier National Park policies.

3. No Alternative to Conducting the Research in a Wilderness Area

Because 97 percent of Mount Rainier National Park is designated Wilderness, there are few alternatives to placing monitoring equipment in non-wilderness areas. Where they exist, non-wilderness areas (Longmire, Camp Muir and Camp Schurman) have been used

Figure 6: Mount Rainier National Park Wilderness

for the placement of seismic stations. Other non-wilderness areas where research and monitoring equipment can be placed include the Paradise, Ohanapecosh, White River and Sunrise developed areas (**Figure 6: Mount Rainier National Park Wilderness**). Because the summit of Mount Rainier is designated wilderness and because the objectives of the proposal delineated in Alternative D call for placing a seismic station directly above the location where the earthquakes are occurring (at least above 4,400 meters or 13,500 feet) on the west side in the summit area of the volcano), there is not a non-wilderness option for conducting the proposed research. In addition, non-wilderness and other wilderness options have been previously evaluated (Moran 1997) for this research. It is because seismic stations at the current and non-wilderness locations were unable to determine accurate depths for the edifice earthquakes that this research proposes placing a summit area seismic station.

4. No adverse effect on physical or biological resources, ecosystem processes or aesthetic values over an area or duration greater than necessary to meet research objectives

Under Alternatives A, B and C, there would be no adverse impact on physical or biological resources, or ecosystem processes and aesthetic values.

Under Alternative D, there are neither adverse effects on physical or biological resources, ecosystem processes or aesthetic values, nor do the very minor effects that do exist affect an area greater than necessary to meet the research objectives. The proposal to place a self-contained box approximately 1.5 by 1.5 by 2.0 meters is also not considered to be an effect over a wide area. In addition, the summit area seismic station is proposed in Alternative D as a temporary installation of research and monitoring equipment that will be removed.

The implication of the effects of this proposal on aesthetic values is related primarily to the visibility of the new monitoring equipment placed under Alternative D. The principal investigator making the proposal has willingly desired to work closely with NPS officials, including climbers to ensure that the equipment is placed in the most sensitive way possible and in the least obtrusive location.

5. No interference with recreational, scenic or conservation purposes of the wilderness over a broad area or long duration

There has been no interference with the recreational or scenic purposes of wilderness from any of the seismic stations (Alternatives A and B) currently located in Mount Rainier National Park during their existence in wilderness (Emerald Ridge and Mount Fremont). Few persons have known of their existence; fewer still have located these monitors. **The current seismic stations, due to the need for managing the volcanic wilderness that is Mount Rainier National Park, do not interfere with the conservation purposes of wilderness**. Instead, they exist to better understand and manage that wilderness. In Alternative C, the removal of the wilderness seismic stations would ensure this. Similarly, because the summit area seismic station proposed in Alternative D is proposed as a temporary (not to exceed two years) structure, placed to address specific research objectives regarding the hazardous nature of the volcano, there is no indication to suspect that the structure will become permanent; therefore it will not have a long duration with respect to the conservation purposes (particularly the clause regarding no permanent structures) of the Mount Rainier National Park wilderness. **Appropriate language will be added to the research permit to ensure that the station is removed at the end of its approval period and that the area is restored to natural conditions. Because Mount Rainier is an active volcano, however, it is likely that additional research equipment will continue to be proposed and periodically to frequently approved in wilderness in Mount Rainier National Park. As needed, these proposals will be evaluated for their potential environmental, cultural and wilderness effects.**

6. Desired information essential and cannot be obtained from a location outside of wilderness

This condition has been partially addressed above in #3. The essential nature of the information that could be provided by the project proposed in Alternative D has also been addressed under section ***II. Need*** above. Without the information potentially provided by placement of a seismic station in the summit area, seismologists will continue to be unable to determine an accurate location for the shallow earthquakes that occur within the edifice. Without additional detailed information regarding the internal structure of the volcano, the scientific community and the National Park Service may be unable to fulfill their public service responsibility (dictated by NPS management policies and legal precedents) to obtain the best possible information about the high probability of geologic and volcanic hazards, originating from Mount Rainier. This is significant because information about the internal structure of the volcano may lead to a more accurate assessment of the potential for an eruption or a large sector collapse. In addition, because the events generated by Mount Rainier have the potential to affect the millions of persons who reside in the Puget Sound region and other areas near the volcano, the decision to continue to assess Mount Rainier geologic and volcanic hazards is even more significant.

7. Proposed device is the minimum tool necessary to accomplish the objective safely and successfully

The research proposals which have already had the effect of placing seismic stations in wilderness (Alternatives A, B and C) were analyzed using a "minimum tool" approach. The seismic station proposed for wilderness under Alternative D is also being assessed via this environmental assessment and the park's "minimum tool" process to determine if it is, in fact, the minimum tool necessary to accomplish the research objective safely and successfully.

This project may be conducted either with or without the use of a helicopter to ferry the seismic station to the summit area for initial placement. The use of a helicopter would enable project designers to create and build a stronger, more robust station, which has a high probability of successfully enduring the weather conditions on the summit. These conditions, however, are thought to be possibly less severe than maintaining a station at Camp Muir due to the difference in maintaining a station in a relatively snow-free area, albeit colder and less sheltered, than in maintaining a station where a huge snowfall is routinely present. If a helicopter were not used, there would be some concern that the equipment, because of the need to be designed to be carried in in chunks, would not be as robust and therefore would have a higher likelihood of not meeting the project objectives (Malone 1998). All monitoring and maintenance, however, would be accomplished by National Park Service and research staff on foot.

This environmental assessment discussed the potential for the equipment to be placed without direct line of sight view toward the University of Washington and to be transmitted via a geostationary satellite to the University. As mentioned, that kind of seismic station would be much larger than the one currently proposed, and certainly would not meet the minimum tool guidelines. A small, slightly or barely visible station is preferable to a large, widely visible station.

There are additional philosophical concerns related to the determination of a "minimum tool." At this time, based on current knowledge, this summit area seismic station is considered to be the minimum tool necessary to obtain a detailed and clear picture of the depth of earthquakes that occur within the volcano, and possibly to postulate a cause for these earthquakes. If there was a "more minimum tool," seismologists would propose it instead (Malone 1998). If placed **and successfully operated, there is an excellent chance** that the seismic station will meet the desired objective of greater understanding of the upper portion of the volcano (Malone 1998).

<u>8. Project addresses an identified management need</u>
Mount Rainier National Park has, on more then one occasion, indicated the need for additional research to determine the hazard from the volcano. Most recently, this management need has been identified in the General Management Plan process (1994 to present), in the Volcanic Hazards Planning Group (ongoing), in the Decade Volcano publication (1994), and in the park Resource Management Plan (1984 and current draft).

<u>9. Project addresses a stated Wilderness management objective and project is integral to the understanding and protection of wilderness</u>
One of the stated objectives of wilderness management is to enable the wilderness to be used as a research area to better understand non-wilderness areas and the wilderness area itself. Alternatives A, B and D fully meet this objective. Alternative C, because it proposes a cessation of seismic research in wilderness may not meet this objective.

Because the wilderness in this instance is a volcano, this project is integral to NPS understanding and protection of it, primarily due to the abundant potential hazards that have occurred and continue to occur as a result of the volcano's presence.

<u>10. Area restored to natural conditions at the completion of study</u>
Under the terms of park Memoranda of Understanding, Interagency Agreements and Research and Collecting Permits once research activities are completed, researchers and/or the National Park Service are required to restore affected areas to natural conditions. At the conclusion of the proposed project, if implemented as in Alternative D, University of Washington researchers would be required to remove all equipment from the wilderness

and to restore the area to natural conditions. The other seismic stations (already in place) also include this caveat.

Physical Resources

Geology

The landscape upon which Mount Rainier is built was formed from much older volcanic rocks that were squeezed, folded and metamorphosed, and then invaded by masses of granodioritic magma about 12 million years ago. The granodioritic (a kind of granite) rocks and the metamorphosed volcanic rocks were uplifted into mountains by continued squeezing and rivers, which cut into the rocks, exposing them to the surface. Eruptions of new magma began near one million years ago. By 500,000 years ago, Mount Rainier had attained a height similar to today and was flanked by large lava flows that radiated from the volcano for distances of up to 25 kilometers (Sisson and Lanphere 1995, 1997). Over the ensuing 500,000 years the volcano has repeatedly shed its upper portions, both by flank collapses and by rapid glacial erosion. It has rebuilt itself through eruptions of lava and pyroclastic flows.

The most recent of these cycles of destruction and regeneration began about 5,600 years ago when the summit and northeast slope of Mount Rainier slid away down the main and west forks of the White River to form the Osceola mudflow, a wave of muddy rock debris a third again larger than the major avalanche produced by the collapse of Mount St. Helens on May 18, 1980. During the Osceola collapse, some mudflows descended the south flank of the volcano and formed deposits known as the Paradise lahar (Scott, Vallance and Pringle 1995; Vallance and Scott 1997). The Osceola collapse left an enormous horseshoe shaped crater, about 2 kilometers wide, open to the northeast. Eruptions of lava and pyroclastic flows began refilling this crater and formed the slopes that now floor the Emmons and Winthrop glaciers. By about 2,300 years ago, the newly-forming cone had reached or exceeded the height of the rear wall of the Osceola crater, and pyroclastic flows spilled over the back crater rim down the Puyallup drainage (Crandell 1971). A large eruption near this time blanketed the eastern slopes of the volcano with about 20 centimeters of pumice. Mount Rainier had probably regained its present height by about 1,000 years ago, which is when the last eruption or eruptions took place. The most recent eruption to have produced a recognizable deposit happened between 1820 and 1854 (Sigafoos and Hendricks 1972), but newspaper accounts report near-summit eruptions as recently as 1894, although these were too small to produce distinguishable volcanic deposits on the lower slopes of the volcano.

Flanks of the volcano have slid away more recently than the Osceola collapse and have formed large mudflows, notably at about 2,800 years ago and 550 years ago when the Round Pass and Electron mudflows were unleashed from an area of altered and weakened rocks in Sunset Amphitheater, high on Mount Rainier's west slope. Presently it is not known if there were concurrent eruptions that may have assisted in triggering these collapses.

GEOLOGIC HAZARDS

Mount Rainier has an extensive geologic and historic record of activity, including lava flows, ash eruptions, avalanches, and mudflows. The threat of mudflows is particularly acute due to the weakened array of rocks altered by hot acidic waters within the volcano and the presence of an extensive glacial cap. Earthquakes, although they may be associated with periodic volcanic activity, are also a threat in and of themselves. Mount Rainier erupted as recently as between 1820 and 1854 (pumice) and may have erupted as recently as 1894 (unverified ash and steam) and also erupted 1000-2000 years ago (lava). Since that time numerous large floods and debris flows have been generated on its slopes (National Academy of Sciences, 1994). The National Academy of Sciences (1994) has stated that "volcanic hazards or volcano related events that are likely to pose threats to persons or property include the following:

> *Volcanic eruptions*: The eruption of ash flows and tephra (ash or pumice).
> *Edifice failure*: The gravitational collapse of a portion of the volcano.
> *Glacial outburst floods*: The sudden release of meltwater from glaciers and snowpack or from glacier dammed lakes on the edifice.
> *Lahars or debris flows, and debris avalanches*: Gravitational movement of commonly water-saturated volcanic debris down the steep slopes of the volcano and into nearby valleys."

Debris flows, in terms of the potential effects and probability of occurrence, constitute the greatest volcanic hazard in the Cascade Range (Hoblitt *et al.* 1995). Debris flows consist of slurries of water and sediment (60 percent or more by volume) that look and behave much like flowing concrete. Debris flows are sometimes called mudflows or, when they originate on volcanoes, lahars (Hoblitt *et al.* 1995). The White River valley is the site of the most devastating mudflow Mount Rainier is known to have unleashed. The Osceola mudflow dates from about 5,600 years ago. It exhumed the northeast flank and summit of Mount Rainier and inundated the valleys of the White River and its West Fork, covering a total area of more than 195 square miles (Dragovitch, Pringle and Walsh 1994). The mudflow, estimated to contain more than 4.9 billion cubic yards of material, deposited a layer up to 30.5 meters (100 feet) thick and buried the areas where the towns of Enumclaw, Buckley, Orting, Puyallup, Sumner and Auburn are now located. A portion of the mountain also collapsed and formed the Paradise lahar. More recent and smaller collapses from the west flank of Mount Rainier produced the Round Pass mudflow (Nisqually and Puyallup Rivers: 2,800 years ago; more than 200 million cubic yards) and Electron mudflow (Puyallup River: 550 years ago; 340 million cubic yards) among others (Crandell 1971; Scott, Vallance and Pringle 1995). For comparison, Mud Mountain Dam (White River) has a capacity of approximately 170 million cubic yards and Alder Dam (Nisqually River) has a capacity of approximately 375 million cubic yards. An Electron-sized mudflow might be contained by Mud Mountain Dam, but because the Alder Reservoir is water-filled, an Electron-sized event could lead to dam failure with catastrophic results. Neither dam could influence an Osceola-sized mudflow. The Paradise lahar (4,500-5,000 years ago) inundated the Nisqually River Valley, at least to the National area. The National lahar (1,200-1,700 years ago) retained a significant amount of sediment downstream onto the Puget Sound lowland (below La Grande).

On December 14, 1963, the largest rockslides on Mount Rainier in historic time occurred on its east flank. Huge masses of rock fell in a series of avalanches from the steep side of Little Tahoma Peak (Crandell 1969). Altogether, about _____ **cubic meters** (4 billion cubic feet) of rock fell. Although most rock fell on the Emmons glacier, some traveled to within ___ **kilometers** (0.6 miles) of the White River Campground (Scott and Vallance 1994). These rockslides occurred on a clear day and were heard by U.S. Forest Service employees on ski patrol at Crystal Mountain.

Air Quality

If the proposed action to place a summit area seismic station as called for in Alternative D is to be accomplished via helicopter, there would be some very minor impacts to air quality from that helicopter use. There could also be some very minor air quality effects from helicopter use associated with restoration if Alternative C were implemented.

Biological Resources

Vegetation

There would be no new impacts to vegetation resulting from the additional placement of a seismic station in the summit area on Mount Rainier. In fact, there may be no vegetation at all in the selected site for the proposed Alternative D. Very minor impacts to vegetation could occur as a result of the need to maintain the current seismic stations in the park as called for in Alternative A (5), B (5), C (3) and D (6). Additional, potential improvements in vegetation could result from the restoration of seismic station sites in Alternative C.

Recreation Resources

Climbing

Climbing is a very popular visitor experience in Mount Rainier National Park. Glacier travel, ascending the summit of the volcano and other alpine and subalpine recreational activities are inherently a part of many visitors' experiences in the park. Approximately 10,000 persons attempted to climb Mount Rainier last year by a variety of routes. Of these, approximately half were successful. Last year was the first time 10,000 persons had been recorded as attempting the ascent and this number represents a trend of increasing attempts (over the past 30 years) to climb the volcano (Samora 1998).

Rainier Mountaineering, Inc. is the primary concessionaire leading guided climbs, primarily up the Muir corridor. Their success ratios are somewhat higher than those attempting to climb the mountain without a guide service. Last year, there were several Incidental Business Permits granted to lead summit climbs up the Emmons Glacier as well. That practice will continue through 1998. There are also many persons who attempt and succeed at summit climbs without a guide service.

The experience of having attained the summit of Mount Rainier on such a climb is comparable to that of reaching the summits of other high peaks, but is, in itself a unique experience. Mount Rainier is the highest of the Cascade volcanoes and its active hydrothermal activity on the summit is evident on such a climb. Many areas of the summit craters remain snow free throughout the year as a result of summit boiling temperatures (86 degrees Celsius) attained at or near the surface there. The significant component of hydrothermal clay in the cohesive lahars studied from Mount Rainier indicates that a hydrothermal system has been active within the edifice for at least 5,000 years (National Research Council 1994).

Visitor Experience

Wilderness Impacts

Alternative A and B, if implemented would continue to have extremely minor impacts on wilderness in that there would continue to be seismic stations located, unobtrusively, in park wilderness. Alternative C would have the least impact on wilderness in that a structure would be removed, however site restoration impacts would occur.

Alternative D has an impact on the character of wilderness in that a seismic station, not currently in wilderness, would be approved. Alternative D, however, would not result in a precedent in terms of placing monitoring equipment on the summit of Mount Rainier. Weather monitoring equipment was placed on the summit in the 1960s and again in the 1970s. The placement of the weather monitoring station, however, occurred outside of the context of wilderness. Mount Rainier Wilderness was designated by the Washington Parks Wilderness Act in 1988. The only current structure on the summit is a summit register and marker. There are, however, many park structures (most of them historic cabins, shelters and lookouts currently located in designated wilderness) which will likely continue to remain in wilderness for administration of the wilderness resource, the convenience of visitors, and in compliance with the provisions of the National Historic Preservation Act (1964, as amended). **In addition, the park regularly places snow poles to mark the safest route along the most frequently climbed course below and beyond Camp Muir. The Rainier Mountaineering Institute (RMI) and others also regularly to routinely use equipment, such as extendable ladders to assist climbers in the safe crossing of crevasses. This equipment is often left in place temporarily.**

Wilderness Aesthetics

Due to the relatively snow-free nature of the proposed location for the summit seismic station and the proximity of that area to very large boulders, a great deal of effort would be expended to make the seismic station as unobtrusive as possible. Seismologists, in general, due to a variety of factors, including the need to protect seismic equipment from vandalism and from odd fluctuations in surficial ground disturbance, as a rule, place seismic stations where they can be, to the greatest extent possible, undetected. This also has been characteristic of the seismic stations placed within Mount Rainier National Park by the U.S. Geological Survey and the University of Washington. Most of the park seismic stations, except for the drum on display in the Paradise Visitor Center, go undetected by most park visitors and employees.

If a seismic station is placed in the summit area, as proposed by Alternative D, an attempt will be made to “snuggle” it in adjacent to a large boulder, where it could also be anchored (Malone 1998). This location would likely preclude its visibility to most summit climbers.

In fact, the proposed location was chosen by Mount Rainier climbing staff to aid in its non-detection by climbers. The proposed location is off the major climbing routes out of climber traffic and is located in an area that remains relatively snow free and which has visibility to the north to enable transmission of a radio signal to the University of Washington.

Wilderness Solitude

Beyond the statutory designation, wilderness is very much in the eye of the beholder/user. It is based on their prior wilderness experience and therefore their expectations of the current wilderness experience (Jarvis 1997). There is indeed precedent for placing monitoring equipment both in wilderness in the park and for placing monitoring equipment on the summit of Mount Rainier. In the late 1960s and again in the early 1970s, as mentioned above, weather data collecting equipment was placed on the summit. In and around the edifice, throughout the park, a variety of research and monitoring equipment has been placed, temporarily to aid in a variety of studies of flora, fauna, air quality, geologic hazards, water flow, etc. **The very large number of climbers that attempt the summit each year also is responsible for the placement of safety equipment, such as snow poles to mark the safest route on glacial surfaces and extendable ladders to enable safer crossing of these crevasses. Although these poles are often a temporary measure until the route is clearer to climbers, even their placement likely has some affect on the perception of wilderness by climbers and others. Therefore, even an attempt to disguise the seismic station would not preclude the fact that the perception of wilderness by those aware of such a station in wilderness in Mount Rainier National Park may be affected.**

Wilderness Noise

If the use of a helicopter is approved for the transport of the seismic monitoring equipment to the summit in Alternative D, there would be a slight impact to park wilderness visitors during the duration of the helicopter flight to the summit and back (approximately 2 hours). Other Alternatives, including Alternative D if helicopter use is not approved, would have no impact on wilderness noise, because helicopters would not be used.

Cultural Resources

Prehistoric Resources

No archeological resources have been located in the vicinity of the existing seismic stations and there are unlikely to be archeological resources located on the summit. **It is generally believed that few native people visited the summit and those that did would have left few signs visible today due to the ever-changing nature of the volcano. Because a survey for prehistoric signs has not been accomplished, one will be done prior to any activity under the proposed project in Alternative D. The west rim of the west crater is generally snow-free due to hot activity below, and mostly consists of fist-size or smaller rocks in an ash and sand matrix, there is a possibility that there could be more recent signs of human activity from the numerous historic visits (mid to late 1800s and early 1900s) of early climbers. As a result, prior to the proposed installation of the seismic station proposed in Alternative D, an areal**

archeological survey would be conducted by a qualified archeologist climber. Collectively, the proposed alternatives would be managed to ensure no effect on archeological resources. If site restoration is necessary under the other Alternatives, it would occur upon additional archeological investigation. If during the proposed project implementation, archeological or historic resources were encountered, all work would cease until the find could be assessed by an archeologist.

Historic Resources

None of the current or proposed seismic station locations have been identified as cultural landscapes or historic resources. As mentioned above, the proposed area of installation will be surveyed for prehistoric and historic resources prior to implementation. There would be no effects on historic resources or cultural landscapes from any of the proposed alternatives.

National Historic Landmark District

None of the existing or proposed seismic station locations are within the NHL.

VII. CONSULTATION AND COORDINATION

This environmental assessment is available for a thirty-day public review period from June 1, 1998 to June 30, 1998. It will be mailed to a select list of persons and agencies who have expressed interest in Mount Rainier National Park proposed actions and events. Included among these will be organizations such as The Wilderness Society, the Sierra Club, The Mountaineers, etc. This document will also be posted on the National Park Service Wilderness Bulletin Board (internal review) and the park's website located at http://www.nps.gov/mora.html. Among the reviewers of this document have been National Park Service staff with wilderness and National Environmental Policy Act expertise, and U.S. Geological Survey staff from the Volcano Hazards Team and from the Cascades Volcano Observatory.

Comments on this environmental assessment should be directed to:
Superintendent
Mount Rainier National Park
Tahoma Woods, Star Route
Ashford, WA 98304.

Comments will be incorporated into a final document sent to reviewers. If substantial environmental impacts are not identified by reviewers, this environmental assessment will be used to prepare a Finding of No Significant Impact (FONSI) which will be sent to the Assistant Regional Director, Pacific West Field Area for final signature.

For additional information concerning this environmental assessment, please contact Chief, Natural and Cultural Resources, Dr. Gary Ahlstrand at (360) 569-2211, extension 3380. For additional copies of this document, please call Mount Rainier National Park at (360) 569-2211, extension 2301.

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