



## Volcanoes: Local hazard, global issue



### Module Overview

Middle school students are interested in volcanic eruptions because of their dramatic nature and because of the sensational destruction they can cause. The National Geography Standards expect students to understand how physical processes like plate tectonics shape and change patterns in the physical environment, how the characteristics of different environments both encourage and constrain human activities, and how natural hazards affect humans. Detecting change and tracking processes in Earth's systems is an important component of NASA research. This module allows students, like NASA scientists, to explore two ways that volcanoes affect Earth: by directly threatening people and the environments adjacent to them, and by ejecting aerosols into the atmosphere. Through three investigations, students explore issues of volcano hazards at different scales, from their local environment to the global effect of volcanic aerosols on climate and aircraft safety.

#### **Investigation 1: How close is safe? Buffer zone development**

This investigation provides an overview of the local effects of volcanism. Students categorize causes, effects, and responses to volcanic hazards. They observe the visible effects of Mount St. Helens' 1980 eruption over time. Based on these observations students identify a buffer zone to prevent development in dangerous locations.

#### **Investigation 2: Sensing volcanic effects from space**

The second investigation provides students with basic understanding about volcanoes and aerosols as well as skills in remote sensing. Students learn about volcanic aerosols and how to interpret satellite data. This investigation reinforces skills of comparison as students measure and graph satellite data to compare various satellite signals.

#### **Investigation 3: Tracking world aerosol hazards**

In this investigation, students are introduced to a global hazard of volcanic aerosols: aircraft damage. In small groups, students use satellite images to create time series of global aerosol hazards. By collecting and organizing data, students designate global locations with high aerosol dangers. Two methods of observation are used, and students compare the usefulness of each strategy.

### Geography Standards

#### *The World in Spatial Terms*

- **Standard 1:** How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective
- **Standard 3:** How to analyze the spatial organization of people, places, and environments on Earth's surface

#### *Physical Systems*

- **Standard 7:** The physical processes that shape the patterns of Earth's surface

#### *Environment and Society*

- **Standard 15:** How physical systems affect human systems

#### *Uses of Geography*

- **Standard 18:** How to apply geography to interpret the present and plan for the future

### Science Standards

#### *Unifying Concepts and Processes*

- Systems, order, and organization
- Constancy, change, and measurement

#### *Science as Inquiry*

- Abilities necessary to do scientific inquiry

#### *Life Science*

- Structure and function in living systems
- Populations and ecosystems

#### *Earth and Space Science*

- Structure of the Earth system

#### *Science and Technology*

- Understandings about science and technology

#### *Science in Personal and Social Perspectives*

- Natural hazards
- Risks and benefits
- Science and technology in society

## Connection to the Curriculum

This module can be used in geography and science classes to extend a study of volcanism and to practice skills in map interpretation, remote sensing, and problem solving. In addition, it provides students with real-world contexts in which to learn about ways humans learn to adapt to hazardous physical systems. This module also reinforces mathematical skills of estimation, graphing, and computation. Students apply many language arts skills through readings.

## Time

Investigation 1: Two 45-minute sessions

Investigation 2: Two 45-minute sessions

Investigation 3: Three 45-minute sessions

## Module Assessment

At the completion of the unit, students may be given the assignment of preparing a brief to an international organization in which they must address this statement:

Roughly 28 percent of Earth's surface and over half of its population are directly affected by volcanism. Volcanism has wide effects on world rainfall, temperature, and other atmospheric conditions. Summarize the potential effects of volcanism on the world population based on the material studied in this module. Suggest ways humans can prepare for and adapt to this dynamic aspect of Earth's physical system.

## Mathematics Standards

### *Number and Operation*

- Compute fluently and make reasonable estimates

### *Algebra*

- Understand patterns, relations, and functions
- Analyze change in various contexts

### *Measurement*

- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools and formulas to determine measurements

### *Data Analysis and Probability*

- Develop and evaluate inferences and predictions that are based on data

### *Problem Solving*

- Apply and adapt a variety of appropriate strategies to solve problems

### *Communication*

- Communicate mathematical thinking coherently and clearly to peers, teachers, and others

### *Connections*

- Recognize and apply mathematics in contexts outside of mathematics

### *Representation*

- Create and use representations to organize, record, and communicate mathematical ideas
- Use representations to model and interpret physical, social, and mathematical phenomena

## Technological Literacy Standards

### *Nature of Technology*

- **Standard 3:** Relationships among technologies and the connection between technology and other fields

### *Technology and Society*

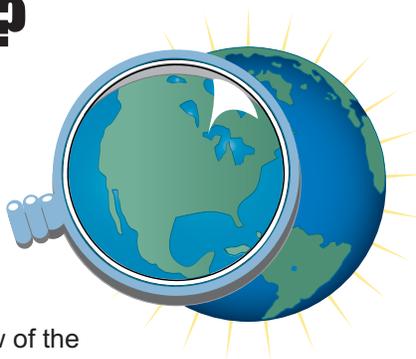
- **Standard 4:** The cultural, social, economic, and political effects of technology

### *Abilities for a Technological World*

- **Standard 13:** Assess the impact of products and systems



## How close is safe? Buffer zone development



### Investigation Overview

This investigation provides an overview of the local effects of volcanism. Students categorize causes, effects, and responses to volcanic hazards by focusing on the interdependence of all Earth systems. Using various remotely sensed images, students observe the visible effects of Mount St. Helens' 1980 eruption over time. Based on these observations students identify a buffer zone to designate safer locations for development.

Time required: Two 45-minute sessions

### Materials/Resources

Log 1, Briefing, and Log 2 (one copy per student)

One set of Cause and Effect Statements, cut into strips (per group)

Poster paper for categorization (per group)

Images needed (one copy per group)

Figure 1: Mount St. Helens, March 1980, before the eruption

Figure 2: Mount St. Helens, June 1980, after the eruption

Figure 3: Aerial photograph of 1980 damage to Mount St. Helens

Figure 4: Mount St. Helens in 1999

Figure 5: Mount St. Helens hazards map

Blank overhead transparency (one per group)

Five different colors of transparency markers

Ruler (one per group)

Masking tape

### Content Preview

Geographers conceptualize Earth in terms of physical systems (the lithosphere, the biosphere, the hydrosphere, and the atmosphere) and human systems that are unified in a single, highly interconnected system. Changes in one system lead to changes in other systems, with an impact on a variety of scales, from local to regional to global. Volcanoes provide an outstanding opportunity to highlight the relationships between human and physical systems and how humans deal with natural hazards.

### Geography Standards

#### **Standard 15: Environment and Society**

##### **How physical systems affect human systems**

- Analyze ways in which human systems develop in response to conditions in the physical environment.
- Describe the effect of natural hazards on human systems.

#### **Standard 7: Physical Systems**

##### **The physical processes that shape the patterns of Earth's surface**

- Predict the consequences of a specific physical process operating on Earth's surface.

#### **Standard 3: The World in Spatial Terms**

##### **How to analyze the spatial organization of people, places, and environments on Earth's surface**

- Analyze and explain distributions of physical and human phenomena with respect to spatial patterns, arrangements, and associations.

### Geography Skills

#### **Skill Set 4: Analyze Geographic Information**

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.
- Interpret and synthesize information obtained from a variety of sources.

#### **Skill Set 5: Answer Geographic Questions**

- Make generalizations and assess their validity.

**Classroom Procedures**

***Beginning the Investigation***

1. Explain that the purpose of the module is to investigate the effects of volcanoes. Geographers are vitally interested in learning about changes caused by volcanoes at different scales, from the local (immediately adjacent to volcanoes) to the global (world atmospheric conditions affected by volcanic eruptions). Give students time to discuss what they already know about volcanoes and their local-to-global effects.
2. Distribute **Log 1** and have students read the background and objectives. Distribute the **Briefing** and have students read the narrative account of Mount St. Helens' 1980 eruption. You may ask students to take turns reading this dramatic story in a "reader's theater."
3. NASA monitors volcanoes because of their significant effect on people and the environment. Introduce or review the following terms used to describe the environment in Earth-systems terms:
  - Hydrosphere: Earth system dealing with water (hydro-), including surface water systems (lakes, rivers, oceans) and frozen water (glaciers, polar ice caps) as well as water beneath the surface of Earth (aquifers, groundwater, etc.)
  - Lithosphere: Earth system dealing with land (soil, rocks, etc.)
  - Atmosphere: Earth system dealing with air
  - Biosphere: Earth system dealing with plant and animal life (flora and fauna)

Have students record definitions in the Log.

4. Divide the class into groups of 3-5 and distribute the Cause and Effect Statements, cut into strips, one set per group.

- Review the statements with students to make sure they understand the vocabulary.
- Ask students to organize the strips into three groups: Causes, Effects, and Human Responses. Some statements may require a fine distinction between "cause" and "effect"; develop working definitions as a class if necessary. (Suggested definitions: Cause—incidents that lead up to or are related to the actual eruption event. Effect—incidents that result from the actual eruption event).

- Students complete item 3 in the Log.
5. Using large sheets of poster paper and tape, have students classify the statements again, this time into more specific categories shown in **Log 2: Cause and effect organizer**. Be sure that all students understand the categories. Discuss the types of cues they would use to determine a statement's classification. For example, students should identify that statements dealing with the plant and animal life of the area would be placed under "Effects on the Biosphere."
    - Students record their categorizations on **Log 2**.

6. Ask selected groups to share their classifications with the class. If groups disagree about a statement's classification, allow them to explain their underlying thought process. Use points of disagreement to reinforce the concept that Earth systems function interdependently, so it is sometimes difficult to determine which "-sphere" is being affected.

7. Debrief this activity by highlighting that effects and consequences such as the ones listed require considerable lengths of recovery time after an eruption. How people prepare for and respond to volcanic eruptions is vital to the safety and productivity of an area. Explain that NASA images show the extent of damage after an eruption and provide data useful to lessen the human impacts of possible future eruptions.

***Developing the Investigation***

8. Distribute **Figure 1: Mount St. Helens, March 1980, before the eruption** to each group. Explain that this is a false color Landsat image, which means that the colors on the image are not the same as would appear to the human eye. In this image, vegetation is red.

Causes	Effects	Human Responses
Structure of the Volcano	Effects on... Lithosphere	Clean-Up Efforts
The Eruption Event	Hydrosphere	Responses to Environmental Hazards
	Biosphere	Monitoring Efforts
	Atmosphere	
	Human Activities	

9. Guide students in interpreting the image using the following questions:
- What would you look for to identify a river? (*Look for meanders or curves in a line.*)
  - How would you identify the location of the volcano's peak? (*Look for dark gray or black areas surrounded by little vegetation. These represent snow and glaciers that are on top of the volcano.*)
  - How would you find areas of vegetation? (*Look for red areas since this is a false color image and living vegetation is reddish.*)
  - Why might some areas of vegetation have straight boundaries? (*They are probably boundaries for agricultural land or some other managed landscape.*)
- Have students complete item 4 in the Log.
10. Ask students to review the Cause and Effect Statements they organized earlier in the investigation. Have them record in their log three things that they would expect to be able to observe in a false color image taken after an eruption. Allow students to discuss their predictions with the class. They should mention things like:
- less red color because much of the vegetation was killed by the blast
  - changes in the course of rivers or the development of new lakes as debris obstructed the flow of rivers
  - changes in the shape of the volcano due to landslides
11. Distribute a blank overhead transparency and transparency marker to each group. Instruct students to mark the corners of **Figure 1** on the transparency to aid in lining up other images later.
12. Ask students to locate the summit of the volcano (*in the lower left area of the image*) and then trace the extent of the volcano. Students should create a key at the bottom of the transparency for each color used throughout the investigation.
13. Explain the concept of a buffer. A buffer provides an area to absorb negative consequences of physical or human activities. For example, tree buffers can serve to protect a neighborhood from highway traffic and noise, while an uninhabited buffer area can protect people from some dangers of natural hazards.
- In a different colored transparency marker, ask students to sketch the area they think should be the buffer zone for safety around Mount St. Helens.
14. Distribute **Figure 2: Mount St. Helens, June 1980, after the eruption**.
- Instruct students to compare this figure to **Figure 1**.
  - Have students discuss their reactions to the changes from **Figure 1** to **Figure 2**. In what ways was the environment disturbed and disrupted by the eruption? In what ways was vegetation altered? The flow of rivers? Students should check to see the changes they predicted. Were their predictions accurate?
  - Have students measure the areal extent of the damage in four directions using a ruler and the scale of the image.
  - Have students place the transparency on **Figure 2**, lining up the corner marks.
  - In another color, have students trace the boundary of the extent of the disruption and devastation brought on by the eruption. Ask how effective their buffer would have been for this particular eruption.
15. Have students review the Cause and Effect Statements again to imagine what the area in this image would look like at ground level. Then, display **Figure 3: Aerial photograph of 1980 damage to Mount St. Helens** to illustrate what the land looked like after the eruption.
16. Ask students to formulate a hypothesis about the present environment around Mount St. Helens. What would it look like today? Using a new color transparency marker, have students draw in with dashed lines how much of the area they think probably still shows effects of the 1980 eruption today.
17. Distribute **Figure 4: Mount St. Helens in December 1999**. Students need to line this image up with the lower right corner of their transparency. Explain that instead of vegetation appearing red, in a true color image vegetation looks green like it does in the real world. Ask students to compare this image with the previous two. How has the local environment changed? Ensure that students notice the vegetation regrowth in some areas. Where has regrowth occurred, and where has it not? Have students look for patterns and explanations for the areas of regrowth. (*Explanations could include: The impact was more severe and lasting in the direction of the blast. The area directly adjacent to the volcano was slowest to grow vegetation. Areas along the river and surrounding Spirit Lake have begun to recover vegetation.*)

18. Using a different color marker, ask students to draw a second safe buffer zone around the volcano applying this new information. Students should record their justification for the boundary by stating which effects are being addressed by their new buffer zone.

### Concluding the Investigation

19. Compare the second buffer zone to the buffer they drew originally. Ask how many groups made their second buffer zone bigger.

Students may assume that the next eruption will affect the same area, which would not necessarily be the case. Ask what other information students or scientists would need to create a buffer zone that took this possibility into account.

20. Remind students that scientists are constantly monitoring changes with volcanoes, hoping that new information will help the area be safer and more prepared for potential eruptions. Using data from several different years allows people to make wiser decisions. If students changed their buffer zone, they understand the need to respond to additional information about dangers.
21. Circulate **Figure 5: Mount St. Helens hazards map** for students to compare their second buffer zone area with the hazard areas identified by the U.S. Geological Survey.

22. Ask students to review the Cause and Effect Statements they used in the beginning of the investigation. Have them identify which effects may have been less of a problem if there had been a sufficient buffer zone in place before the 1980 eruption of Mount St. Helens. Have students record their answers in their Log. Provide time for whole group discussion of the possible effects and limitations of buffer zones.

### Background

Volcanoes are dangerous, but they are also very important to humans. Volcanic eruptions contribute substantially to soil fertility. In the Andes, many people live on the flanks or at the foot of active composite volcanoes, largely because of the fertility of the volcanic deposits. The same is true in the Philippines where residents near active volcanoes like Mount Mayon and Mount Taal regularly move away during eruptions, only to move right back when the danger subsides. These two cases present good examples of how people learn to live and adapt to hazardous environments.

Mount St. Helens is one of many composite (stratovolcano) volcanoes in the Cascade Range of the Northwest United States. Mount St. Helens has been one of the most active volcanoes in the Pacific Northwest although before the eruption in May 1980, it had been dormant since 1857.

	Shield	Composite/ Stratovolcanoes	Cinder Cones
Formation/ Location	Massive fluid lava flows and slowly builds up a gently sloping volcanic shape.	Built from both explosive eruptions and quieter eruptions. Layers of tephra (ash, cinders, and other material blown into the air) alternate with layers of lava to create steep-sided, often symmetrical cones.	Made primarily from explosive eruptions of lava. Blown into the air, the erupting lava breaks apart into the small fragments known as cinders. The fallen cinders accumulate into a cone around the volcano's central vent (the "hole in the ground" from which the lava emerged).
Location	Primarily located along tectonic spreading centers or at "hot spots."	Stratovolcanoes are located primarily along tectonic subduction zones, where two plates slowly collide.	Not associated with any particular tectonic activity. Some are found near current tectonic boundaries, and others are near old boundaries.
Examples	Kilauea, Mauna Loa (Hawaii)	Mount Fuji (Japan), Mount St. Helens (Washington)	Sunset Crater (Arizona), Capulin Mountain (New Mexico)

More detailed information about the Cascade Range, Mount St. Helens, and the 1980 eruption can be found at the USGS/Cascade Volcano Observatory web site: <<http://vulcan.wr.usgs.gov/Volcanoes/MSH/framework.html>>

## Evaluation

### Statement Categorization

Following are suggested categorizations and justifications. Some statements are listed in more than one category to illustrate the multiple categorizations that may occur.

#### Causes

##### Structure of the Volcano

- Composite volcanoes erupt explosively. (*Statement describes Mount St. Helens' volcano type.*)
- Composite volcanoes are made of alternating layers of lava, ash, and other volcanic debris. (*This layering of debris from former eruptions gives the volcano its structure as well as providing considerable material to spew during an eruption.*)
- Magma contains high concentrations of gas that may cause an explosion that breaks magma into pumice and tiny ash particles. (*This statement describes magma behavior in a composite volcano.*)

##### The Eruption Event

- The mountain "awoke" with a series of steam explosions and bursts of ash. (*This was a cause leading to the effect of an enormous ash cloud that traveled the globe [10, 14] and the development of global ash monitoring stations [9].*)
- The mountain shook from a strong, magnitude 4.2 earthquake. (*This statement is associated with activity immediately preceding the eruption.*)
- The entire face of the mountain broke free and slid downward in a giant rock avalanche. (*Depending on the interpretation, this statement could apply to the conditions surrounding the eruption or an effect of the eruption on the lithosphere. Students could justify placement in either of these categories based on their distinction between a physical cause and effect.*)
- The lava contained dissolved water that exploded into superheated steam. (*This was a cause leading to the effect of an enormous ash cloud that traveled the globe [10, 14] and the development of global ash monitoring stations [9].*)

- Within hours of the blast, mixtures of gas, pumice, and ash swept down the north side of the volcano at speeds up to 160 kilometers/hour (100 miles per hour) and at temperatures of over 648° C (1200° F). (*While this mentions a timeline of "within hours of the blast," the speed and temperature of the materials caused many of the devastating effects listed.*)

#### Effects

##### Lithosphere

- Volcanic deposits literally reshaped the entire region around the mountain. (*The term deposits is key in this statement to suggest actions after the actual eruption.*)
- Enormous mudflows gushed down the mountain. (*Mudflows are made up of primarily materials from the lithosphere, but students may see this as an interaction between the lithosphere and the hydrosphere.*)
- A fan-shaped pumice plain developed to the north and directly in front of the crater. (*The deposition of the pumice reshaped the physical landscape in front of the crater.*)
- Layers of pyroclastic flow (pumice, ash, and gas) were deposited as thick as 20 meters (60 feet) deep along the north side of the volcano. (*Volcanic deposits, again, affecting the landscape.*)

##### Hydrosphere

- The Columbia River was closed to freighter traffic for several days to remove debris. (*The reference to freighter [shipping] traffic makes this statement fit better within effects on human activities than effects on the hydrosphere, but students may initially associate the river with the hydrosphere.*)
- A debris avalanche blocked the natural outlet of Spirit Lake. (*The natural circulation processes of Spirit Lake were affected.*)
- Several new lakes were formed by debris deposits, but these natural dams were unstable and could fail and flood the streams. (*Students should recognize that actions such as natural or artificial damming have consequences such as potential failures, which ultimately can add considerable stress to the rest of the river system.*)

##### Biosphere

- Thousands of deer, elk, bear, and other animals died. (*Fauna are all part of the biosphere.*)
- Almost 594 square kilometers of forest were destroyed. (*Flora are part of the biosphere.*)

17. Plant growth was severely slowed for years after the eruption. *(The soil must have time to recover for the plant life to return. At first, though, only very short hardy plants will be able to survive.)*
23. Trees were stripped from the hillsides as far as 10 kilometers from the volcano. *(The blast literally tore many trees out of the ground.)*
24. Around the edges of the blowdown zone, trees were killed simply by the intense heat of the blast. These trees are called Standing Dead. *(Beyond the area where trees were torn out of the ground, trees were singed and killed. The Standing Dead resembled deciduous trees during the winter, except that they were not just dormant.)*

#### Atmosphere

10. Tiny ash particles were thrust 24 kilometers into the sky and continued for about nine hours. *(Material was being added to the atmosphere.)*
14. Small ash particles reached the eastern United States within three days of the blast and circled the globe within two weeks. *(This statement illustrates the global extent of the atmospheric impact. Material from an eruption in the United States traveled around the globe in less than two weeks.)*

#### Human Activities

6. Shipping channels were blocked. *(Students may place this statement in either the hydrosphere or in human activities. This statement speaks more directly to the human activities on the river rather than effects on the hydrology of the area, so it is better categorized here.)*
11. Many communities and agricultural areas were affected by falling ash. Machinery and crops were damaged. *(The emphasis on agriculture and technology focuses this statement on the effects on human activities.)*
12. A small airplane narrowly avoided disaster when the pilot put the plane into a steep dive to gain speed and turned south, away from the ash cloud. *(This statement refers to human activities in the atmosphere but is better categorized as an effect on human activities.)*
22. The Columbia River was closed to freighter traffic for several days to remove debris. *(The reference to freighter, shipping traffic makes this statement fit better within human activities than effects on the hydrosphere.)*

#### Human Responses

##### Clean-Up Efforts

25. From May to September 1980, the U.S. Army Corps of Engineers removed 32 million cubic meters of debris from the Cowling River. *(The Corps was working to free up shipping channels again.)*

##### Environmental Hazards

26. Levees and retaining structures were built to control sediment and debris deposits. This prevents deposits from clogging the rivers and hindering boat traffic or causing flooding downstream. *(While levees are designed to control floods and manage water resources, it is important for students to remember that these structures sometimes fail just as natural dams sometimes do [29]. Settling outside the floodplain is the safest way to minimize flood damage.)*
27. Flood gates were installed to prevent potential flooding of Spirit Lake caused by future volcanic activity. *(Efforts by humans to control natural environmental hazards.)*
30. A fish transport system was built to help fish get around the sediment-retention structure. This provided safe passage for salmon and steelhead returning from the sea. *(This system was an attempt to reconnect the migration path of fish that had been disrupted by human-built structures. Students should realize that human actions also have effects on the interactions of all the spheres, which should be minimized as much as possible.)*

##### Monitoring Efforts

9. A global network of Volcanic Ash Advisory Centers was created to observe volcanic eruptions in order to improve aircraft safety. *(The VAAC system was created to address the effects of worldwide volcanic ash hazards.)*
31. Scientists carefully watch the activity of magma under Mount St. Helens. Nonetheless, heat from the magma has led to avalanches (melting snow) and explosions of steam (heated water) without warning. *(Scientists monitor for changes that often lead up to volcanic eruptions to attempt to give some warning before the next one.)*
32. The U.S. Geological Survey and University of Washington are watching for volcanic activity of Mount St. Helens. Information on lahar (mud slides) and flood hazards is now collected by

the USGS and the National Weather Service who then issue warnings. (*This statement reflects the interagency concern with monitoring volcanic activity*).

### Suggested Key for Log 1

2. Hydrosphere: Earth system dealing with water  
Lithosphere: Earth system dealing with land  
Atmosphere: Earth system dealing with air  
Biosphere: Earth system dealing with plants and animals, flora and fauna
5. Responses will vary but might include: loss of vegetation, changes in shape of the volcano, changes in the course of the river, formation of additional lakes.
8. Observations will vary.
10. Student estimates will vary but should include reference to changes in the shape of the volcano, lack of trees, debris flow.
12. Students should observe that Figure 4 is true color; thus vegetation is green in this image rather than red.
13. Vegetation regrowth can be seen primarily to the northwest of the volcano. Directly north of the volcano is still gray because the area has not yet recovered.
14. Reasons may vary but should be evaluated for soundness of the reasoning. A sample answer: The area closest to the blast side of the volcano was most severely disrupted by the eruption as shown by loss of vegetation and other items, so it is taking the longest time to recover.
15. Student justifications will vary, but the response should include why they chose to make the new buffer zone larger or smaller than the previous one. Answers should also include consideration for the areas of regrowth. For example, areas that are green now were not "safe" during 1980, so establishing a buffer based only on Figures 1 or 4 would be misleading.
16. Student responses should illustrate reasoning and careful evaluation of the significant issues.
17. The paragraph should address both the importance

and limitations of buffer zones. On one hand, buffers protect humans and human activities from direct hazards. However, there are numerous effects of volcanic eruptions that a buffer cannot address such as effects on the various -spheres. By its nature, a buffer zone addresses natural hazards from a human perspective alone, although humans are not the only living things affected by natural hazards. This paragraph can also be evaluated for grammar and composition.

### Related NASA Resources

<http://volcano2.pgd.hawaii.edu/eos/> Earth Observation System Volcanology Homepage, provides comparative information on a variety of volcanoes under study. Includes eruption data as well as satellite and aerial images of each.

### Related Resources

<http://vulcan.wr.usgs.gov/Volcanoes/MSH/framework.html> Links to information about Mount St. Helens. Includes details of the 1980 eruption, maps and graphics of the Cascades Volcanoes, monitoring efforts, and more.

[http://vulcan.wr.usgs.gov/Volcanoes/MSH/May18/summary\\_may18\\_eruption.html](http://vulcan.wr.usgs.gov/Volcanoes/MSH/May18/summary_may18_eruption.html) Summary of the 1980 eruption event, including measurements and extent of damage

<http://volcano.und.nodak.edu/vwdocs/msh/msh.html> Mount Saint Helens Homepage

<http://edcwww.cr.usgs.gov/earthshots/slow/MtStHelens/MtStHelens> Landsat progression of images with additional pictures of selected sites

[http://volcano.und.nodak.edu/vwdocs/volc\\_images/img\\_st\\_helens\\_bw.html](http://volcano.und.nodak.edu/vwdocs/volc_images/img_st_helens_bw.html) Dramatic black and white picture of eruption and ash cloud

<http://www.avo.alaska.edu/avo3/atlas/atlindex.htm> Alaskan Volcano Observatory, outstanding images and text about all volcanoes in Alaska, the Aleutian Islands, and Kamchatka Peninsula. Regional and local maps. Images of volcanoes, their eruptions, and the effects on the nearby human populations

[http://volcano.und.nodak.edu/vwdocs/volc\\_images/volc\\_images.html](http://volcano.und.nodak.edu/vwdocs/volc_images/volc_images.html) Volcano World page with searchable world map. Students can search for volcanoes by region, country, name, etc. Provides useful information and images from a variety of sources.



## Module 1, Investigation 1: Cause and effect statements

1. Volcanic deposits literally reshaped the entire region around the mountain.
2. The mountain “awoke” with a series of steam explosions and bursts of ash.
3. The mountain shook from a strong, magnitude 4.2 earthquake.
4. The entire face of the mountain broke free and slid downward in a giant rock avalanche.
5. The lava contained dissolved water that exploded into superheated steam.
6. Shipping channels were blocked.
7. Thousands of deer, elk, bear, and other animals died.
8. Almost 594 square kilometers of forest were destroyed.
9. A global network of Volcanic Ash Advisory Centers was created to observe volcanic eruptions in order to improve aircraft safety.
10. Tiny ash particles were thrust 24 kilometers into the sky and were airborne for about nine hours.
11. Many communities and agricultural areas were affected by falling ash. Machinery and crops were damaged.

12. A small airplane narrowly avoided disaster when the pilot put the plane into a steep dive to gain speed and turned south, away from the cloud.

13. Enormous mudflows gushed down the mountain.

14. Small ash particles reached the eastern United States within three days of the blast and circled the globe within two weeks.

15. Composite volcanoes erupt explosively.

16. Composite volcanoes are made of alternating layers of lava, ash, and other volcanic debris.

17. Plant growth was severely slowed for years after the eruption.

18. Magma contains high concentrations of gas that may cause an explosion that breaks magma into pumice and tiny ash particles.

19. Within hours of the blast, mixtures of gas, pumice, and ash swept down the north side of the volcano at speeds up to 160 kilometers per hour (100 miles per hour) and at temperatures over 648° C (1200° F).

20. A fan-shaped pumice plain developed to the north and directly in front of the crater.

21. Layers of pyroclastic flow (pumice, ash, and gas) were deposited as thick as 20 meters deep along the north side of the volcano.

22. The Columbia River was closed to freighter traffic for several days to remove debris.

23. Trees were stripped from hillsides as far as 10 kilometers from the volcano.

24. Around the edges of the blowdown zone, trees were killed simply by the intense heat of the blast. These trees are called Standing Dead.
25. From May to September 1980, the U.S. Army Corps of Engineers removed 32 million cubic meters of debris from the Cowling River.
26. Levees and retaining structures were built to control sediment and debris deposits. This prevents deposits from clogging the rivers and hindering boat traffic or causing flooding downstream.
27. Flood gates were installed to prevent potential flooding of Spirit Lake caused by future volcanic activity.
28. A debris avalanche blocked the natural outlet of Spirit Lake.
29. Several new lakes were formed by debris deposits, but these natural dams were unstable and could fail and flood the streams.
30. A fish transport system was built to help fish get around the sediment-retention structure. This provided safe passage for salmon and steelhead returning from the sea.
31. Scientists carefully watch the activity of magma under Mount St. Helens. Nonetheless, heat from the magma has led to avalanches (melting snow) and explosions of steam (heated water) without warning.
32. The U.S. Geological Survey and University of Washington are watching for volcanic activity of Mount St. Helens. Information on lahar (mud slides) and flood hazards is now collected by the USGS and the National Weather Service who then issues warnings.



# Module 1, Investigation 1: Log 1

## How close is safe? Buffer zone development

### Background

Volcanoes are like good news, bad news jokes. The good news is that they offer humans benefits such as rich soil. The bad news is that they are very destructive when they erupt. Because of this contradiction between productivity and destruction, areas around volcanoes need to be evaluated for safety. Creating a safety zone around a volcano helps to minimize a volcano's effect on humans. Creating a safety or buffer zone, however, requires information about the extent of previous eruptions compared to human settlement patterns. In this investigation you use data at different scales to study the impact of volcanic eruptions on the environment and its inhabitants in order to establish a buffer zone.

**Objectives:** In this investigation, you

- categorize the causes and effects of volcanic eruptions and human responses to them,
- measure the extent of damage of the Mount St. Helens 1980 eruption, and
- analyze images of a volcano to suggest a settlement buffer zone.

### Procedures for the Investigation:

1. Read the account of the Mount St. Helens 1980 eruption.
2. Define the following elements of Earth's physical systems:

hydrosphere: \_\_\_\_\_

lithosphere: \_\_\_\_\_

atmosphere: \_\_\_\_\_

biosphere: \_\_\_\_\_

3. Categorizing causes, effects, and responses

Organize the Cause and Effect Statements into three categories. List the strip numbers under each category title.

Causes	Effects	Human Responses

Divide the strips into more specific categories using the headings on Log 2: Cause and effect organizer. Be prepared to explain your choices.



# Module 1, Investigation 1: Log 1

## How close is safe? Buffer zone development

4. Look at Figure 1. This is a false color image, which means the features in the figure do not have the same color as they do in real life. The volcano is in the lower left corner. In this image, the vegetation (plant life) appears reddish and the water appears dark blue or black. Locate the following.
- Mount St. Helens volcano
  - Spirit Lake
  - A river
  - Areas of vegetation

5. Go back to the Cause and Effect Statements that you organized earlier in this investigation. Write down three changes that you expect to observe in an image taken after an eruption.

1) \_\_\_\_\_

2) \_\_\_\_\_

3) \_\_\_\_\_

6. Place a transparency over Figure 1. Mark the corners of the image onto the transparency to line up the other images. With a transparency marker, outline the base of the volcano's cone. Create a key at the bottom of your transparency. Label the first colored line as **Volcano** on the key.

7. With a different color transparency pen, draw a line representing the nearest point to the volcano where you think people could safely build houses and businesses. This creates a buffer zone.

8. Look at Figure 2, another false color image of Mount St. Helens. This was taken *after* the 1980 eruption. Compare Figure 1 and Figure 2. Write down three changes that occurred.

1) \_\_\_\_\_

2) \_\_\_\_\_

3) \_\_\_\_\_

9. With another color transparency pen, trace the extent of the disruption caused by Mount St. Helens' 1980 eruption. Add this color to the key and label it **Damage**.

10. Think back to the Cause and Effect Statements. What would the area shown in this image look like from the ground?

11. Do you think the area has recovered to the way it was before the eruption in 1980? What is the extent of damage today? Sketch your predicted area on the transparency using dashed lines. Add the dashed line to your key and label it **Estimate for Today**.

\_\_\_\_\_

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# Module 1, Investigation 1: Log 1

## How close is safe? Buffer zone development

12. How is Figure 4 different from Figures 1 and 2?

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13. Where has the vegetation around the volcano begun to grow back? Where has it not?

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14. Write one reason why some of the areas have recovered from the 1980 blast while other areas still have not.

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15. With a different color transparency pen, draw a second buffer zone line based on all three images. Should the area be larger than your last prediction? How should you deal with the areas of regrowth and recovery? Record this color on your key and label it Buffer 2.

16. Review the Cause and Effect Statements from the beginning of the investigation. Which of these statements would be different if an effective buffer zone was in place before the 1980 eruption?

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# Module 1, Investigation 1: Briefing

## Narrative of Mount St. Helens 1980 eruption

### A Slumbering Volcanic Giant

Mount St. Helens was once one of the most beautiful mountains in the entire Cascade Range of the American Northwest. In 1805, William Clark in the Lewis and Clark expedition described Mount St. Helens as “perhaps the greatest pinnacle in America.”

The serenity of the mountain and its surroundings was misleading. One of the Indian names for Mount St. Helens was “fire mountain.” Local Indians were reluctant to approach the mountain despite the abundant game in the area.

To the experienced observer, the cone shape and composition of rocks on the mountain boldly proclaimed Mount St. Helens’ true nature—it was a volcano. Lava flows and multiple layers of ash (powdered volcanic rock) lay everywhere under the carpet of trees—abundant evidence of many prior eruptions. Volcanic deposits had reshaped the region around the mountain. Even beautiful Spirit Lake was a volcanic accident created by a giant mudflow that rolled down the mountain 3,000 years ago and backed up a stream.

Mount St. Helens was active between 1832 and 1857 during the early settlement of the area by Easterners. But the eruptions were small, and the mountain then “dozed off” for the next century. Small settlements became towns, and towns became cities like Portland and Seattle. These new neighbors of Mount St. Helens knew the mountain only as a sleeping giant. Its violent past was largely ignored.

### The Awakening

The quiet ended abruptly in March 1980, with a series of steam explosions and bursts of ash. The following story of the eruption of Mount St. Helens illustrates the potential dangers of an eruption from Mount Ranier—a volcano about 120 kilometers southwest of Seattle, Washington.

During the months following the initial outbursts, volcanologists and seismologists watched the mountain closely. Small earthquakes accompanied the bursts and indicated the movement of fresh lava into the heart of the mountain. Enormous cracks appeared in the summit and sides of the mountain,

and the entire northern face expanded outward some 137 meters. Locals perceived this initial activity as minor, so in spite of warnings and the designation of the mountain and its surroundings as a dangerous “Red Zone,” tourists flocked to the area to get a close view of the fireworks. Residents were strongly advised to move away, but some refused to go. Likewise, logging companies working in the area refused to shut down, claiming to “know the mountain.” Vulcanologists established several camps around the mountain to monitor its activity. Some of the camps had to be dangerously close to the mountain to provide the necessary data. The scientists who manned the camps in shifts knew they were at risk.

### The Main Eruption

On May 18, a quiet Sunday morning, a few observers were at their stations, watching Mount St. Helens. Tourists and loggers were also nearby. At 8:32 a.m. a small aircraft with two geologists aboard flew directly over the central cone.

Eleven seconds later, a strong earthquake shook Mount St. Helens. The whole north face of the mountain broke free and slid downward as a giant rock avalanche. In seconds, pressure in the mass of hot lava inside the mountain dropped; water that had been dissolved in the lava turned into superheated steam, fragmenting the lava into a fine powder ash. This mass of superheated steam and ash blasted upward and outward over the top of the avalanche, roaring to the north and west at speeds reaching hundreds of miles an hour. The pilot of the small aircraft narrowly avoided disaster by putting the “plane into a steep dive to gain speed” and turning sharply south, away from the expanding ash cloud.

Every living thing within about 16 kilometers of the volcano on the north side—tree or bush, human or animal, scientist or layman—was destroyed. Some of the people took a few quick pictures. Then, realizing their situation, most ran or tried to drive away from the approaching cloud of dust and steam. The near-supersonic blast of rock, ash, and hot gas engulfed the area with enough force to uproot trees. The temperature within the cloud reached 260°C (500°F), more than enough to start fires or burn exposed skin. The rock avalanche



# Module 1, Investigation 1: Briefing

## Narrative of Mount St. Helens 1980 eruption

roared over Spirit Lake and the valley of the North Fork of the Toutle River, burying them under layers of rock up to several hundred feet thick.

Moments after the rush of the avalanche and ash cloud, enormous mudflows—formed when glacial ice and snow that had capped the mountain were melted by the intense heat—surged down the mountain. Masses of mud poured down the nearby river valleys, sweeping away buildings, vehicles, trees, and bridges. One flow even blocked the shipping channel of the Columbia River, 88 kilometers downstream.

Millions of tons of fine ash were thrown high into the air and carried hundreds and thousands of miles downwind. These clouds, visible in satellite images, dropped several inches of ash over many communities and agricultural areas, ruining machines and crops.

### The Toll

To the nation, and especially to those living nearby, the May 18 eruption was apocalyptic. The crown and heart of a whole mountain had been blasted away, and the surrounding countryside devastated. The energy released by the eruption was estimated at 10 megatons, an explosion thousands of times stronger than an atomic bomb.

- Thousands of deer, elk, bear, and smaller animals perished—in addition to 57 humans.
- Over 593 square kilometers of forest were destroyed, including three billion board feet of timber estimated at \$400 million in value.
- Numerous buildings, bridges, roads, and machines were destroyed, and farms and communities up to 1,600 kilometers away were partially buried in ash.
- One hundred sixty-nine lakes and more than 4,800 kilometers of streams had either been marginally damaged or destroyed.
- Losses to property and crops were set at more than \$1.8 billion.

Yet, the impact on human life could have been much greater if the main eruption had occurred on a workday or if the blast had been directed southwest toward the Portland/Vancouver metropolitan area (just 72 kilometers away) or if the wind had been blowing toward the southwest.

As large and destructive as the May 18 eruption appeared, it was a relatively small eruption when seen in context. Thick deposits of older volcanic rock around Mount St. Helens attest to much larger eruptions in its past. Mount St. Helens is also only one of many volcanoes that dot the Cascade Range. All of these volcanoes grew in the same geologic setting. Some eruptions at other Cascade volcanoes have been truly huge, such as the explosion nearly 7,000 years ago—100 times larger than the May 18 eruption—that reduced Mount Mazama to Crater Lake. Eruptions ranging in size from the May 18 eruption to the Mazama blast could occur at any time at any of the Cascade volcanoes. For the metropolitan centers of Portland, Seattle-Tacoma, and San Francisco that have grown up among the Cascade volcanoes, this is a serious concern.

Source: *NASA's Classroom of the Future*. <http://www.cotf.edu/ete/modules/volcanoes/vnarrative1.html>

For an extended discussion of Mount St. Helens, see [http://vulcan.wr.usgs.gov/ljt\\_slideset.html](http://vulcan.wr.usgs.gov/ljt_slideset.html)



# Module 1, Investigation 1: Log 2

## Cause and effect organizer

<b>Causes</b>	<b>Effects</b>	<b>Human Responses</b>
Structure of the Volcano	Effects on the Lithosphere	Clean-Up Efforts
	Effects on the Hydrosphere	
	Effects on the Biosphere	Responses to Environmental Hazards
The Eruption Event	Effects on the Atmosphere	Monitoring Efforts
	Effects on Human Activities	



## **Module 1, Investigation 1: Figure 1**

### **Mount St. Helens, March 1980, before the eruption**



Infrared false color Landsat image of Mount St. Helens and the surrounding area in March 1980. The reddish areas are living vegetation.

Source: Landsat satellite <http://volcano.und.nodak.edu/vwdocs/msh/ov/ovs/ovssl.html>

## **Module 1, Investigation 1: Figure 2**

### **Mount St. Helens, June 1980, after the eruption**



Infrared false color Landsat image of Mount St. Helens and the surrounding areas in June 1980.

Orientation: NNE

Source: <http://volcano.und.nodak.edu/vwdocs/msh/ov/ovssl.html>



## **Module 1, Investigation 1: Figure 3**

### **Aerial photograph of 1980 damage to Mount St. Helens**



Mount St. Helens' 1980 eruption triggered massive debris flows down the north face of the volcano as seen in this photograph.

Source: Cascade Volcano Observatory by Thomas Casadevall [http://denali.gsfc.nasa.gov/research/volc2/volc\\_top.html](http://denali.gsfc.nasa.gov/research/volc2/volc_top.html)



## Module 1, Investigation 1: Figure 4

### Mount St. Helens in December 1999



True color Landsat image of Mount St. Helens in 1999. Some areas have yet to rebound from the 1980 eruption.

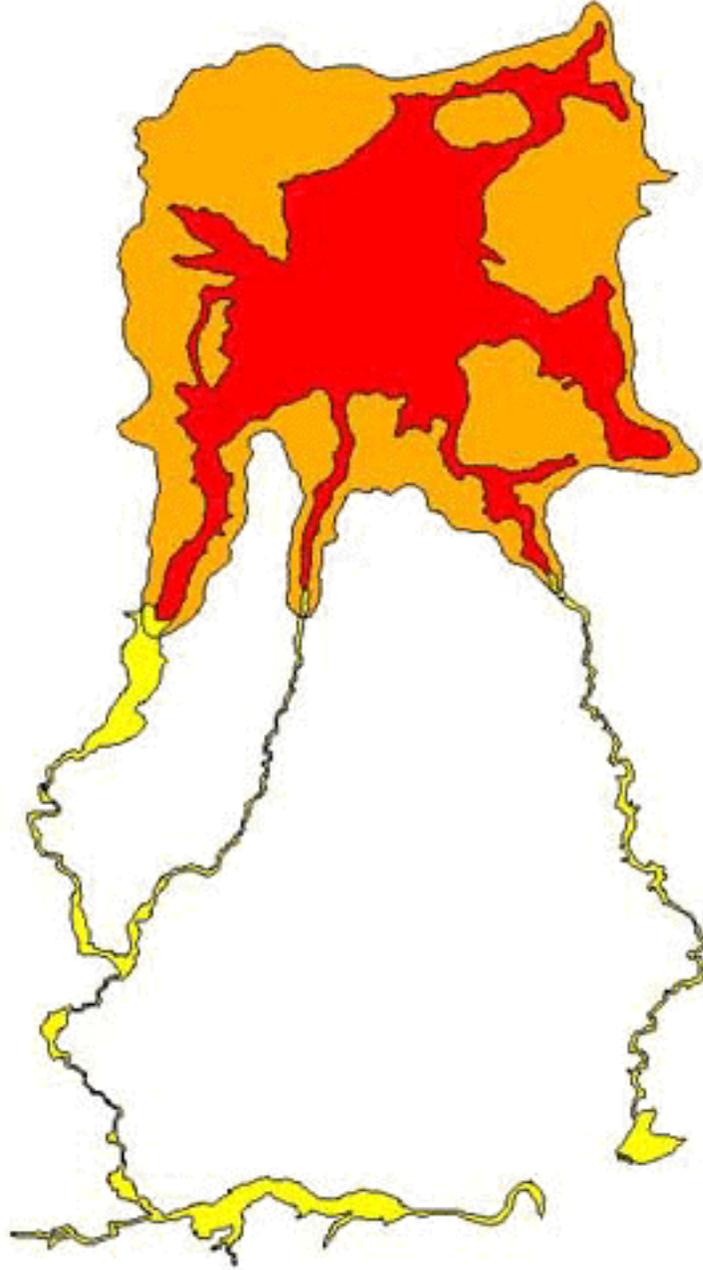
Key:    green = forest  
          white = snow and glaciers  
          grey = areas destroyed by 1980 debris flow which have not recovered

Orientation: NNE

Source: [http://volcano.und.nodak.edu/vwdocs/volc\\_images/img\\_st\\_helens.html](http://volcano.und.nodak.edu/vwdocs/volc_images/img_st_helens.html)

# Module 1, Investigation 1: Figure 5

## Mount St. Helens hazards map



### Hazard Zones



**Zone 1:** Vulnerable to high-density flows, including pyroclastic flows, lava flows, and parts of lahars



**Zone 2:** Area that could be overrun by low-density pyroclastic surges



**Zone 3:** Intermediate and lower reaches of valleys that could be inundated by lahars



Source: E. W. Wolfe and T. C. Pierson. 1995. Volcanic-Hazards Zonation for Mount St. Helens, Washington, 1995. USGS Open-File Report 95-497. <http://vulcan.wr.usgs.gov/Volcanoes/MSH/Hazards/OFR95-497/framework.html>