NATURAL HAZARDS LESSON PLAN

Are You Ready to Shake?

Theme

Earthquakes

Links to Overview Essays and Resources Needed for Student Research

http://oceanservice.noaa.gov/topics/coasts/assessment/
http://www.csc.noaa.gov/rvat/hazid.html

Subject Area

Earth Science/Physical Science

Grade Level

9-12

Focus Question

What can be done to reduce the vulnerability of coastal communities to the potential effects of earthquakes and their associated hazards?

Learning Objectives

- Students will explain the cause of earthquakes and tsunamis.
- Students will define and explain the terms "landslide," "liquefaction," "subsidence," and "secondary hazards."
- Students will define, compare and contrast the terms "risk" and "vulnerability."
- Students will describe potential mitigation activities for selected natural hazards.

Materials Needed

- Copies of "Are You Ready to Shake?" Worksheet, one copy for each student group
- (Optional) Computers with internet access; if students do not have access to the internet, download copies of materials cited under "Learning Procedure" and provide copies of these materials to each student group

Audio/Visual Materials Needed

None

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of 3-4 students

Maximum Number of Students

30

Key Words

Natural hazard
Risk
Vulnerability
Earthquake
Tsunami
Landslide
Liquefaction
Subsidence
Secondary hazard

Background Information

Almost half of the people living in the United States live near the coast. As the coastal population continues to grow, more people and property are threatened by natural hazards. Low-lying areas are particularly vulnerable, a fact that has been repeatedly underscored in recent years:

- In the summer of 2004, residents of Florida were battered by four major hurricanes within six weeks, resulting in billions of dollars' worth of damage;
- On December 26, 2004, the Sumatra-Andaman earthquake shook the Earth for nearly ten minutes; with an estimated magnitude of 9.15; a tsunami combined with the earthquake to kill more than 283,100 people, making it one of the deadliest disasters in modern history; and
- In August 2005, Hurricane Katrina wrought havoc on Gulf Coast communities in Alabama, Louisiana, and Mississippi.

These disasters emphasize the importance finding more effective ways to reduce the negative environmental, social, and economic impacts of natural hazards on coastal communities. To assist these efforts, NOAA's National Ocean Service provides essential information on natural hazards to government agencies and members of the general public concerned with lowering the risks associated with natural hazards. This information includes training, methods for assessing vulnerability to natural hazards, and tools that can be used to forecast threats such as floods and harmful algal blooms.

Ports and harbors are the focus of particular concern, because their location makes them vulnerable to a wide range of hazards. Moreover, if ports and harbors are built on fill material or soft natural material, or are surrounded by steep slopes, they are at risk of being damaged by earthquakes, tsunamis, and landslides. Earthquakes are associated with movement of the tectonic plates that make up the Earth's crust. The outer shell of the Earth (called the lithosphere) consists of about a dozen large plates of rock (called tectonic plates) that move several centimeters per year relative to each other. These plates consist of a crust about 5 km thick, and the upper 60 - 75 km of the Earth's mantle. The plates that make up the lithosphere move on a hot flowing mantle layer called the asthenosphere, which is several hundred kilometers thick. Heat within the asthenosphere creates convection currents (similar to the currents that can be seen if food coloring is added to a heated container of water). These convection currents cause the tectonic plates to move. Plates may slide horizontally past each other at transform plate boundaries. The motion of the plates rubbing against each other sets up huge stresses that can cause portions of the rock to break, resulting in earthquakes. Places where these breaks occur are called faults. A well-known example of a transform plate boundary is the San Andreas fault in California.

Where tectonic plates move apart (for example, along the mid-ocean ridge in the middle of the Atlantic Ocean) a rift is formed, which allows magma (molten rock) to escape from deep within the Earth and harden into solid rock known as basalt. Where tectonic plates come together, one plate may descend beneath the other in a process called subduction. This

process generates high temperatures and pressures that can lead to strong earthquakes and explosive volcanic eruptions, such as the Mount St. Helens eruption which resulted from subduction of the Juan de Fuca tectonic plate beneath the North American tectonic plate. The Sumatra-Andaman earthquake was caused by subduction of the India Plate beneath the Burma Plate.

In this lesson, students will investigate hazards associated with earthquakes, and some of the activities that can mitigate these hazards.

Learning Procedure

1.

To prepare for this lesson:

- Review information on the NOS Natural Hazards Assessment program (*http://oceanservice.noaa.gov/topics/coasts/assessment/*). You may also want to review information about formal Risk and Vulnerability Assessment (*http://www.csc.noaa.gov/rvat/hazid.html*), though this is a more involved process than students will use for this lesson.

- Make copies of the "Are You Ready to Shake?" Worksheet

- If students will not have internet access, download information from the Web sites referenced on the Worksheet.

2.

Briefly review the issue of coastal hazards. You may want to show some headlines and images from the 2004 Indian Ocean earthquake (your school or community library probably has back issues of weekly news magazines that could be used for this). Discuss the types of natural hazards that may pose a risk to coastal communities. The list should include hurricanes, floods, tsunamis, and earthquakes. Be sure students understand that increasing population in coastal communities means that an increasing number of people and their property are potentially threatened by these hazards.

3.

Tell students that this lesson will focus on hazards associated with earthquakes. Briefly review the relationship between earthquakes and movement of Earth's tectonic plates. Compare

and contrast hazards associated with hurricanes and those associated with earthquakes. One of the most striking differences is that specific earthquake events can happen with little or no warning, while hurricanes are rarely a surprise (though this has only been true since modern meteorological instruments and techniques have become available). On the other hand, the relationship between earthquakes and tectonic activity means that the relative risk of different geographic areas can be predicted fairly well.

Provide each student or student group with a copy of the "Are You Ready to Shake?" Worksheet, and say that their assignment is to do the research needed to prepare a written report that includes answers to questions on the Worksheet. Assign each group one of the following hazards for which they are to describe potential mitigation activities:

- earthquakes,
- tsunamis,
- landslides,
- liquefaction,
- subsidence, or
- secondary hazards.

4.

Discuss students' answers to Worksheet Step 1. The following points should be included:

- "Risk" is generally used as a measure of the likelihood of being exposed to a particular hazard. "Risk areas" are geographic regions that have a certain probability of being exposed to a given hazard. People and resources located within risk areas are considered to be "at risk" from this hazard.

- "Vulnerability" is a measure of the likelihood that people and/or resources will be negatively impacted by a given hazard. So, people living in a coastal community might all be at risk of being exposed to a hurricane, but their vulnerability to negative impacts could vary significantly depending upon the extent to which they were prepared to cope with this risk.

- An earthquake is a vibrating motion caused by an abrupt release of stress resulting from movement between Earth's tectonic plates.

- A crustal or shallow earthquake is caused by different relative motion between sections of a single tectonic plate, and occurs at depths of 10 to 25 kilometers.

- A deep earthquake results from movement within a single subducted plate at depths of 40 to 60 kilometers

- A subduction zone earthquake is caused by contact between two colliding tectonic plates.

- Liquefaction is a process in which vibrations (such as those caused by an earthquake) cause water-saturated soils to lose their strength and stiffness, and act as a jelly-like fluid.

- Earthquake intensity is a measure of an earthquake's damage to the surface and its effects on humans, and is measured on a scale called the Modified Mercalli Intensity Scale.

- Earthquake magnitude is a measure of an earthquake's wave amplitude and distance from the epicenter, and is measured on a scale called the Richter scale.

- Amplification is the increase in ground shaking during an earthquake due to factors such as earthquake magnitude, distance from the epicenter, and local geological conditions. River valleys and floodplains are susceptible to amplification, because loose sediments generally shake significantly more than dense bedrock. Increased liquefaction potential is also associated with increased risk of amplification.

- A tsunami is one or more huge waves caused by an earthquake, submarine earthquake, volcanic eruption, landslide, or other large-scale disturbance of the ocean floor.

- Ground failure results when soils lose their strength and stiffness because of liquification. Types of ground failure include:
  - Sandboils (formed when sediment with a high water content is blown to the surface);
  - Lateral spread (movement of large blocks of soil due to the liquefaction of underlying sediments);

  - Flow failure (blocks of intact soil riding on top of a layer of liquefied soil, typically on steep slopes); and
  - Loss of bearing strength (when liquefaction reduces the ability of soils to support the weight of buildings and other structures)

- A landslide is the downward and outward movement of rocks, dirt, or mud that form slopes. Landslides usually start on steep slopes and move downward by the force of gravity, accelerating to speeds of up to 35 miles per hour. Landslides can be classified by the type of material involved (e.g., mudslides, debris flows, rock falls, debris avalanches, debris slides, earth flows), as well as by the way in which they move. Slide movement is the downward movement of material along one or more surfaces. Flow movement is similar, but resembles the motion of fluids due to high water content in the soil. Lateral spreads occur in soils with a high potential for liquefaction (such as loose, sandy soils) and can occur on even very gentle slopes. Fall and topple movements occur when masses of rock or other material fall from cliffs or other steep slopes, and are commonly triggered by earthquakes.

- Subsidence takes place when the elevation of a land surface decreases due to the removal of subsurface support. For example, removal of water or extensive mining can cause soils to settle. Subsidence also can be caused by natural events such as earthquakes, soil compaction, and watering of fine soils deposited by wind (known as loess deposits).

- Secondary hazards are events that are triggered by an earthquake or seismic activity, such as dam failures, fires, spills of hazardous materials, and disruption of utility services. These events can worsen the effects of primary hazards and make response activities more difficult.

- Hazard Mitigation is "sustained action that reduces or eliminates long-term risk to people and property from natural hazards and their effects."

- Vulnerability reduction is a hazard mitigation technique that involves alterations to the natural or built environment

such as erosion control, windproofing, or elevating structures.

- Vulnerability avoidance is hazard mitigation achieved by limiting activities in high hazard areas.

5.

Have each group present mitigation options identified for their assigned hazard. Students should realize that while it is commonly assumed that "there is nothing we can do about earthquakes," the reality is that there are many things that can be done to reduce vulnerability to earthquakes and their associated hazards.

Options for mitigating earthquake hazards include:

- Eliminating conditions that may become hazardous during an earthquake (e.g., fasten shelves securely to walls, store breakable items in closed cabinets, hang heavy pictures and mirrors away from beds and places where people sit, repair deep cracks in ceilings and foundations;
- Locating safe places in which to shelter during an earthquake, such as under sturdy furniture indoors or in open places outdoors away from buildings, trees, utility lines, overpasses, or elevated expressways;
- Teaching all family members how and when to turn off gas, electricity, and water;
- Having appropriate disaster supplies on hand—many disaster preparedness authorities recommend that individuals and families should plan to be completely self-sufficient for at least three days following a disaster;
- Developing an emergency communications plan among family members, including a designated rendezvous point if family members are separated at the time of a disaster;
- Constructing buildings with earthquake-resistant features, for example:
  - without skylights or other openings that can weaken a roof
  - lightweight roofing materials to help keep the building's center of gravity low
  - without large ground floor openings in multiple-story buildings
  - without exterior brick or stone veneers that introduce

extra loads into the exterior walls
– slab-on-grade foundations with integral footing or crawl-space/basement foundations consisting of a continuous concrete or masonry wall system
– flexible supply lines and couplings on sprinkler systems and toilets
– bracing major appliances to walls and/or floors so that appliances will not overturn or shift in the event of an earthquake

Options for mitigating tsunami hazards include:
- Preparing maps that identify coastal population centers at risk of being inundated by tsunamis;
- Developing improved communications and warning systems;
- Improving building codes for new structures;
- Improving land use requirements for siting and relocating critical structures and facilities; and
- Establishing comprehensive programs for public education about tsunamis.

Options for mitigating landslide hazards include:
- Constructing debris dams, retaining walls, and drainage systems in landslide-prone areas;
- Avoiding landslide hazard areas by appropriate zoning and land-use regulations (more cost-effective over the long-term than "hard" solutions such as constructing debris dams and retaining walls).

Options for mitigating liquefaction hazards include:
- Avoid locating buildings and infrastructure in areas with high liquefaction potential;
- Require buildings to have foundations that will lessen impacts from liquefaction, such as foundations with sufficient flexibility to accommodate large ground deformations, flexible connections in utility lines, and deep foundation elements with large diameter support pilings and a flexible connection to the overlying foundation.
- Soil improvements that increase soil compactness and drainage capacity, such as soil compaction and inserting gravel or synthetic materials into soil to increase drainage capacity.

Options for mitigating subsidence hazards include:

- Mitigation options for liquefaction (see above); and
- Avoiding areas that have subsided in the past (advance prediction of new subsidence areas is difficult with current knowledge and technology).

Options for mitigating secondary hazards include:

- Appropriate construction codes for dams;
- Retrofitting older dams to meet current standards;
- Identifying downstream hazard potential in case of dam failure for areas where significant populations or infrastructure are at risk;
- Improving pipeline design and retrofitting pipelines to lessen breakage potential; and
- Reducing the vulnerability of railway hazardous material containers to rupture and puncture.

The Bridge Connection

http://www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Physics," then the "Waves" link at the top of the "Physics" page for links to information and activities related to tsunamis and earthquakes.

The Me Connection

Have students write a brief essay describing a personal disaster preparedness plan. If their own community is not susceptible to earthquakes or tsunamis, you may want to suggest more likely disaster scenarios (e.g., a wrecked train leaking hazardous chemicals; severe blizzard; flooding caused by unusually heavy rains).

Extensions

Have students prepare personal disaster preparedness plans, including provisions for 3-day self-sufficiency and communications/rendezvous plans with family members.

Resources

http://www.csc.noaa.gov/products/tsunamis/htm/cascadia/hazards.htm – The National Ocean Service "Protecting Our Ports and Harbors" Web site

http://earthquake.usgs.gov/ – The U.S. Geological Survey's Earthquake Hazards Program Web site

http://www.esri.com/hazards/ – Online Hazard Maps produced through a partnership between the Federal Emergency Management Agency and Environmental Systems Research Institute to assist in building disaster resistant communities across the country by sharing geographic knowledge about local hazards.

National Science Education Standards

Content Standard B: Physical Science
- Motions and forces

Content Standard D: Earth and Space Science
- Energy in the Earth system

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Personal and community health
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H2 – Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.

5D/H3 – Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

NATURAL HAZARDS WORKSHEET

Are You Ready to Shake?

This Worksheet is intended to help you find out more about hazards associated with earthquakes. All of the information needed to complete this Worksheet can be found at the National Ocean Service "Protecting Our Ports and Harbors" Web site (*http://www.csc.noaa.gov/products/tsunamis/htm/cascadia/hazards.htm*), and the U.S. Geological Survey's Earthquake Hazards Program Web site (*http://earthquake.usgs.gov/*)

1. Define:

- Risk

- Vulnerability

- Earthquake

- Crustal or shallow earthquake

- Deep earthquake

- Subduction zone earthquake

- Liquefaction

- Earthquake intensity

- Earthquake magnitude

- Amplification

- Tsunami

- Ground failure

- Landslide

- Subsidence

- Secondary hazards

- Hazard mitigation

- Vulnerability reduction

- Vulnerability avoidance

2. Identify mitigation options for one of the following hazards assigned by your teacher:
- Earthquakes
- Tsunamis
- Landslides
- Liquefaction
- Subsidence
- Secondary hazards