Nayeli and Izaiah were very excited to see each other on the first day of school. Nayeli couldn't wait to tell Izaiah about his summer trip to see his grandparents and their visit to Mount Saint Helens in Washington State.

"Izaiah, Mt. St. Helens was amazing! Did you know that it had a huge eruption in 1980, and the side and top of the mountain blew off? It used to be a beautiful cone-shaped mountain surrounded by forests, and now there's a huge hole in the top and still no trees. It sent ash into the atmosphere that traveled all over the world!" Nayeli explained.

"Whoa," responded Izaiah. "Could you imagine seeing that in real life? Do you think it's going to erupt again?"

"Well," said Nayeli, "the park ranger said that it had a small eruption in 2004. What's amazing is that they knew something was up because they measured more earthquakes under the mountain. And the only reason the mountain is there in the first place is because of a lot of eruptions building it up over a super long time."

Izaiah pondered for a moment. "But wait! My grandparents live near Mt. Hood in Oregon, which is near Mt. St. Helens. Now I'm worried!"

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What causes volcanic eruptions and earthquakes? Is one likely to occur where you live? How can we use technology to monitor the movement of Earth's surface? How do natural hazards, like volcanoes, earthquakes, and landslides, affect the people who live near them? How do changes on Earth's surface affect the availability of natural resources?

In this unit, you will explain how geological processes cause gradual and sudden changes to Earth's surface. You will analyze and interpret data to explain how the Earth's surface has changed over geological time. You will use and develop models to investigate how different kinds of rocks and natural resources form as a result of geological processes.

1 Storing Nuclear Waste

TALKING IT OVER

EACH YEAR, THE United States produces between 2,000 and 2,400 metric tons of nuclear waste at nuclear power plants. **Nuclear waste** is the leftover radioactive material produced by nuclear reactors. Radioactive materials radiate energy, some of which is harmful. It can't be seen, felt, or heard, but it can damage living cells and cause diseases, such as cancer. Currently, most nuclear waste is stored at the power plants where it is produced. If the containers storing nuclear waste were to leak, it could be released into the air or nearby bodies of water. This could be dangerous for people living nearby who breathe the air and interact with the water. Individuals who inhale or ingest radioactive materials are more likely to develop radiation-related illnesses than people who do not. The level of risk depends on the dose and length of exposure to radiation.

For more than 50 years, scientists have been considering ways to store nuclear waste safely. They have proposed sending it into space, placing it in the ocean floor, and burying it on a remote island. But those options all pose problems. Most experts now agree that the safest solution is to store nuclear waste in containers engineered to contain the waste and place them in a central location deep underground. In January 2012, a group of experts appointed by the president, called the Commission on America's Nuclear Future, recommended that the country should find and develop one or more deep underground storage sites. In order to pursue this recommendation, there are many scientific and social issues involved in choosing a site for nuclear waste storage.

Electricity is generated at a nuclear power plant.

GUIDING QUESTION

What factors must be considered when deciding where to store nuclear waste?

MATERIALS

For each student

1 Student Sheet 1.1, "Considering Where to Store Nuclear Waste"

PROCEDURE

Part A: Reading about Nuclear Waste

1. With your group, read the background information about nuclear waste on the pages that follow. Have each person read one section aloud.
2. Based on the background information you read, discuss what you would look for in a site to store nuclear waste.

   Remember to listen to and consider the ideas of the other members of your group. If you disagree with others in your group, explain why you disagree.

Background Information about Nuclear Waste

Where is nuclear waste generated?

Reactors create nuclear waste at nuclear power plants, nuclear medical treatment facilities, and nuclear research and technology facilities. The materials have high to low levels of radioactivity depending on the technology they are used for. Nuclear reactors at power plants and government defense projects generate the most nuclear waste. Most of it is in the form of highly radioactive solids made of metal, ceramic, or glass. Some of these solids will remain radioactive for a few years, but others are likely to remain radioactive for at least 250,000 years.

How are people protected from nuclear waste?

The most likely danger from nuclear waste is the accidental release of radiation into the air or water, where it can spread through the environment and might be ingested or inhaled. Nuclear waste is stored in containers made of lead, steel, and concrete to protect people from its harmful effects and to prevent it from leaking into air and water supplies. The containers are built to resist impact, high temperatures, and corrosive chemicals. However, water is present everywhere underground, and it is possible that water could damage

these containers over long periods of time and cause them to leak. Thus, experts have determined that it is best to store nuclear waste containers in dry areas with little rainfall.

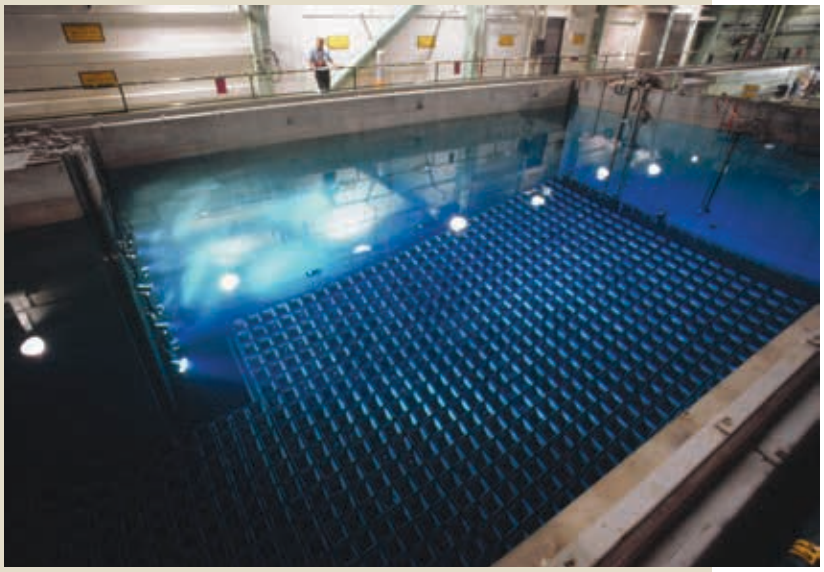
How much waste comes from nuclear power plants?

The United States has 99 operating nuclear reactors at 60 power plants. About 20% of the electricity in the United States comes from these power plants. Over time, they have produced more than 70,000 metric tons of nuclear waste. If these reactors continue to operate and no additional nuclear power plants are built, the amount of nuclear waste to store will be over 140,000 metric tons by the year 2050. If more plants are built to help meet our electricity demands, this number would increase.

A nuclear power plant

How is nuclear waste stored now?

Nuclear waste is currently stored at 75 sites in 33 states. When nuclear fuel is first removed from reactors, it is placed in deep pools of water. The water helps to cool the fuel and protect workers from radiation. About 50,000 metric tons of nuclear waste is currently stored in pools. At some power plants, the cooled nuclear waste is transferred to dry storage. About 15,000 metric tons of nuclear waste is currently stored in dry containers above ground. Nuclear experts believe that it is possible to create places hundreds of meters (m) below Earth's surface where up to 70,000 metric tons of nuclear waste can be safely stored for at least 10,000 years.

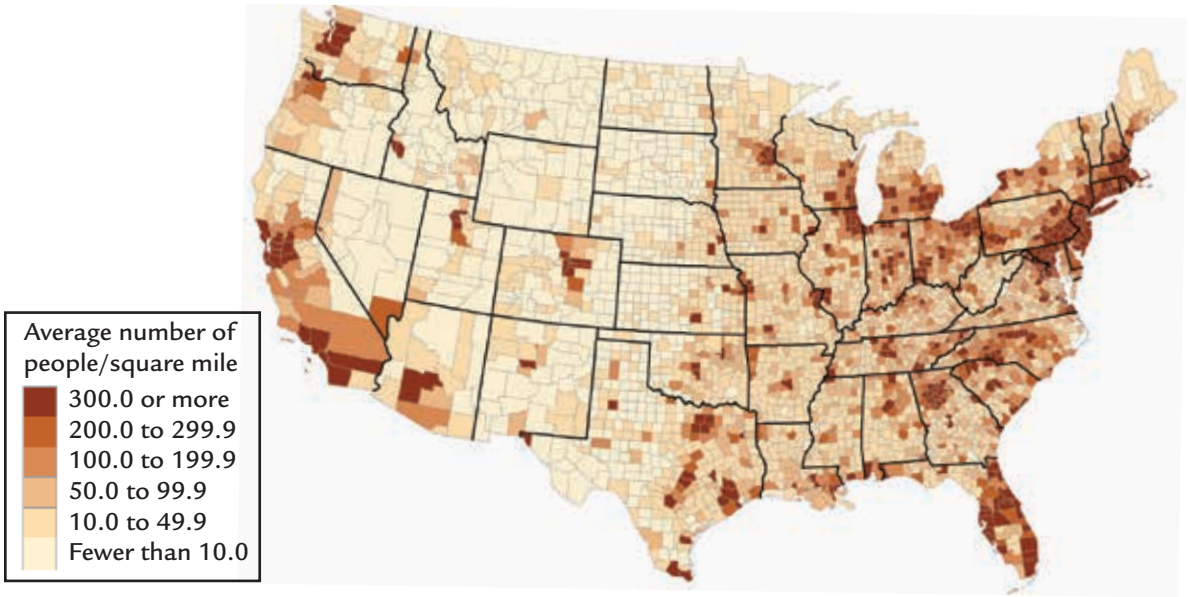


Nuclear power plants use radioactive fuel rods. When these rods can no longer be used to produce energy, they are first placed in pools of water to cool.

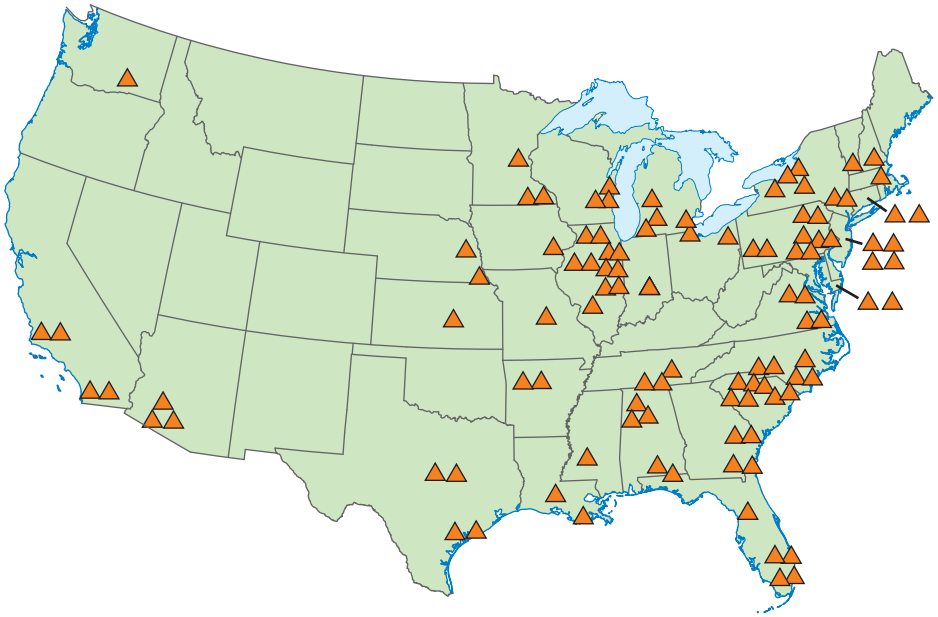
Part B: Analyzing Maps

3. Examine the two maps below and on the following page: "Population Density by County" and "U.S. Locations of Operating Nuclear Reactors." Describe the patterns you notice in the data presented on the maps with your group. Then, discuss how these data influences your thinking about where to store nuclear waste.
4. Record your ideas about how the data from the two maps would inform your decision about where to store nuclear waste on Student Sheet 1.1, "Considering Where to Store Nuclear Waste." In the first column, write the two considerations about which you gathered data from the maps: human population density and locations of operating nuclear reactors. In the second column, write the action you would recommend in regard to each consideration. Explain why you would recommend taking this action when deciding where to store nuclear waste.
5. In your group of four students, discuss and share your ideas from Student Sheet 1.1.

Population Density by County in the Contiguous U.S.



Locations of Operating Nuclear Reactors in the Contiguous U.S.



ANALYSIS

1. Do you think that storing nuclear waste in one or two sites deep in the ground would be better than the current situation where nuclear waste is stored at the sites where it is produced? Explain by
   a. stating your decision.
   b. supporting your decision with as many pieces of evidence as you can. **Evidence** is factual information or data that support or refute a claim
   c. discussing the trade-offs of your decision. A **trade-off** is a desirable outcome given up to gain another desirable outcome.
2. What other information would you like to have before you make a decision about where to store nuclear waste? Be sure to explain how this information would be helpful.
3. Choose one of the recommended actions you described on Student Sheet 1.1. Are there any disadvantages associated with taking this action? Explain why or why not.

4. As you learned in this activity, advances in technology often lead to advances in science. Sometimes they also lead to new challenges.
   a. In what ways has the development of nuclear energy led to advances as well as challenges for society?
   b. What other developments in technology have led to advances as well as challenges for people?

EXTENSION

In 1987, the U.S. government selected Yucca Mountain in southern Nevada as an underground storage site for nuclear waste. However, in 2011, government officials decided not to build there. Visit the *SEPUP Third Edition Geological Processes* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition* for links to more information about the long-term storage of nuclear waste at Yucca Mountain. What new questions do you have about the long-term storage of nuclear waste?