Nayeli and Izaiah *were very excited to see each other on the first day of school. Nayeli couldn't wait to tell Izaiah about her summer trip to Mount St. 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!"

Izaiah opened a map of Washington State on his cell phone and located the volcano. "That's interesting. My Uncle Albert works at a nuclear waste site about 150 miles away from Mt. St. Helens. I wonder if he worries about being so close to an active volcano?"

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In this unit, you will:

- *Explore the phenomenon* of Earth's surface changing over time
- *Analyze and interpret data* to explain how Earth's surface has changed over geological time
- *Use and develop models* to investigate how different kinds of rocks and natural resources form as a result of geological processes
- *Investigate the issue* of how natural hazards associated with geological processes have implications for the safe storage of nuclear waste

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, the waste 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 considered how 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 then 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 find and develop one or more deep underground storage sites. But before pursuing this recommendation, there are many scientific and social issues to consider.

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 what 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?

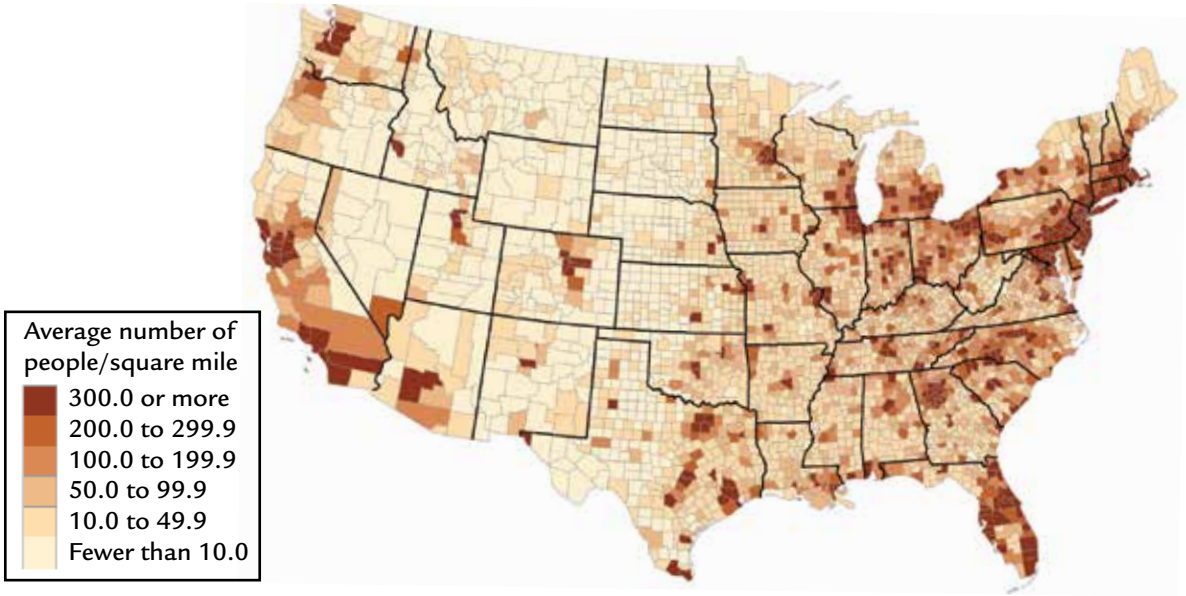
Nuclear waste is currently stored at 75 sites in 33 states. When nuclear fuel is first removed from reactors, it is placed in deep pools of water. The water helps to cool the fuel and protect workers from radiation. About 50,000 metric tons of nuclear waste is currently stored in pools. At some power 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.

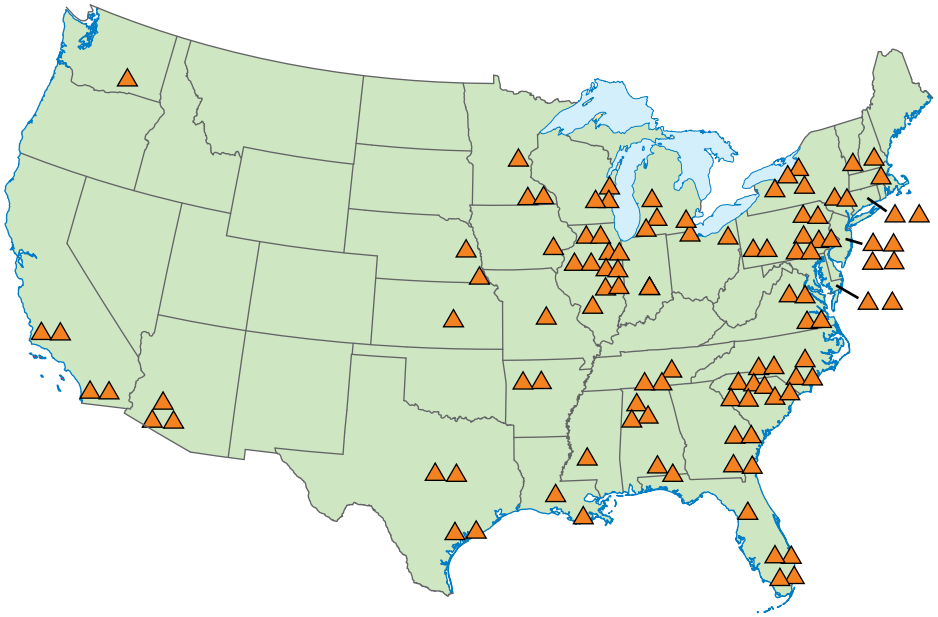
Part B: Analyzing Maps

3. Examine the two maps below and on the following page: "Population Density by County in the Contiguous United States" and "U.S. Locations of Operating Nuclear Reactors in the Contiguous United States." With your group, describe the patterns you notice in the data presented on the maps. Discuss how these data influence your thinking about where to store nuclear waste.
4. Use Student Sheet 1.1, "Considering Where to Store Nuclear Waste," to record your ideas about how the data from the two maps inform your decision about 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 the locations of operating nuclear reactors. In the second column, write the action you recommend in regard to each consideration. Explain why you recommend taking this action when deciding where to store nuclear waste.
5. In your group, discuss and share your ideas from Student Sheet 1.1.

Population Density by County in the Contiguous United States



Locations of Operating Nuclear Reactors in the Contiguous United States



ANALYSIS

1. Do you think that storing nuclear waste in one or two sites deep in the ground is better than the current situation: storing nuclear waste at the sites where it is produced?

   a. State your decision.

   b. Support your decision with as many pieces of evidence as you can. **Evidence** is factual information or data that supports or refutes a claim.

   c. Discuss 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 actions you recommended 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 both advances and challenges for society?

   b. What other developments in technology have led to both advances and challenges for people?

EXTENSION

In 1987, the U.S. government selected Yucca Mountain in southern Nevada as an underground storage site for nuclear waste, and the project was approved in 2002. However, in 2011, government officials decided not to build there after all. 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?