Activity 1: What's the Problem? Worksheet

Your engineering team will design caverns for the people in the fictional state of **Alabraska**. Approximately 10 million people live in Alabraska and your team will save them all!

Your teacher will give you two maps. The **General Map** shows the elevation or topography of Alabraska and the locations of major cities, rivers, airports and railroads. The **Geology Map** shows the different rock types present in the terrain of Alabraska.

The first task that all engineering teams do when faced with an important project like this is to carefully **define and understand the problem**. Working in your team, discuss each question below to help you better understand and define the problem. These questions have *no wrong answers* so feel free to share your wild ideas with your team and work together.

1. How big does the cavern need to be? — The size of the entire state, half the size of the state, one-tenth the size of the state? When answering this question, think about how long 10 million people have to live in the caverns.

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2. What information on the General Map might help you with your decision about possible cavern locations?

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3. What "natural features" of the Earth should you be concerned about when designing the caverns?

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4. Should you design and build more than one cavern? What are the pros and cons? List some reasons for building only one cavern and some reasons for building more than one cavern.

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5. If the asteroid has a diameter of 1 mile, how deep do you think a safe cavern needs to be?

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6. List the information your engineering team needs to gather before you can design the size and location of your cavern(s). List three pieces of information that would be helpful to know.

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Activity 2: How Big? Worksheet

Your engineering team's goal for this activity is to determine the size of your cavern(s). Just like activity 1, discuss each question with your team and write your answers below.

1. Let's use the classroom size to help us determine how much space people need for sleeping. Measure the length, width and height of your classroom in meters. Record the measurements in the table below. Talk to your teacher about ways to measure the classroom height.

A	B
	Classroom dimensions in meters
length	
width	
height	

2. Use the length, width and height measurements to calculate the area and volume of your classroom. Round your answers to the nearest whole number.

A	B	C
		Classroom dimensions in meters
area	**length × width**	
volume	**length × width × height**	

Info tip: Units of length, width and height are in meters (m). Units of area are in meters squared (m^2). Units of volume are in meters cubed (m^3). *Have you labeled your measurements correctly?*

3. Next, determine how many beds can fit in the classroom. It is helpful to use graph paper to draw a layout of the classroom and beds. Assume that each graph paper square represents 1 m x 1 m and that a typical single bed is 2-meters long by 1-meter wide (area of one bed = __________ m^2).
Remember to leave room between the beds for people to walk!

How many beds could your classroom hold? __________

If you use bunk beds, how many beds could your classroom hold? __________

How many students are in your class? __________

What is the total area your class needs for sleeping? __________ m^2

How many classes would be able to sleep in your classroom with bunk beds? __________

4. Fill in the table below with your information from Question 3 on the total of classrooms and total area needed for sleeping. *That's just for sleeping!* What about space for eating, playing, food and water storage, closets and bathrooms? Fill in how many of your classrooms your class would need for eating, playing, etc.

Activities	Classrooms required	Area required (m^2)
sleeping		
eating		
playing		
food/water		
closets		
bathrooms		
TOTAL		

5. Now add up the area required. The total area required for ________ people is _______ m^2. How much area is needed for each person? _______________ per person

We visited with agricultural and biological engineers Maya and Brannon to help us design an underground farming system. Creative engineers like Maya and Brannon help people around the world by designing new crops, fertilizers and irrigation systems. These engineers design ways to grow crops in deserts, keep weeds out of fields, and get energy from plants. To learn more about agricultural engineering careers, go to http://www.asabe.org/ > *Career Resources*.

Maya and Brannon have developed an underground farming system design for us. They estimate that the underground farming system will require an extra 22 m^2 of area for each person.

6. Using the data from Question 4 and the agricultural engineers, calculate the total area required per person.

7. The entire state of Alabraska has 10 million people; that's 10,000,000! Since your team has determined the area required per person, calculate the total cavern area required for 10 million people in m^2.

8. Convert the total required area in m^2 (from Question 7) to square kilometers. Round your answer to the nearest whole number. Use your conversion chart.

________________ km^2

9. Looking at your answer to Question 8, think about how large an area is required. Compare the required area with some areas in your neighborhood. Is it a similar-sized area to your school campus, city block or soccer field? Discuss with your team whether your answers make sense! Write your explanation and conclusions below.

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Activity 3: Scaling the Map Worksheet

Every map tells a story. The General Map tells us a lot about Alabraska's surface features—information like city locations, transportation, rivers and fault lines. The Geology Map tells us the types of rocks that exist in Alabraska. Let's learn how to read our maps and gain important information on how and where to build our cavern(s).

1. Looking at the General Map, use a ruler to measure the distance in centimeters from city **a** to city **d**. Distance city **a** to **d** = ________ cm

   The scale on your map helps you determine the distance in kilometers from city a to city d. Measure 1 cm on the General Map scale.

   How many kilometers does 1 centimeter equal? __________ km per cm

   Use the formula below to determine the distance in kilometers from city **a** to city **d**.

   __________________ x __________________
   (# cm from a – d) (# km 1 cm equals on map scale)

   = _______________ km (distance)

   Using the same method, find the distance from city **b** to city **c**.

   __________ x __________ __________ km

2. You can also use your scale and grid lines to help you find area. Refer to the General Map as you fill in the chart below. Measure and record the length and width of 1 grid space in cm. Use the scale to record how many kilometers the length and width represents.

	With ruler (cm)	Actual (km)
length		
width		

   What is the area in kilometers squared for 1 grid space? _______________ km^2

3. Since you know the area of 1 grid space, find the area of the military base.

   _______________ km^2

4. Is the size of your cavern about the same as the military base, smaller than the base, or larger than the base? Remember, you can find the size of your cavern in Activity 2, Question 8!

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5. Using the General Map scale, estimate the average length and width of Alabraska. Multiply the average length by the average width to estimate the area of Alabraska. Note: This is just a rough estimate because Alabraska is not a perfect rectangle!

Average Length (km)	Average Width (km)	Average Area (km^2)

   Compare the area of Alabraska to the area needed for your caverns. Is Alabraska large enough to hold the caverns? Explain below.

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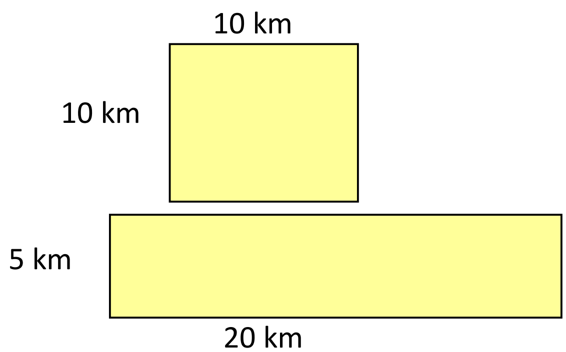
Activity 4: Possible Locations Worksheet

We call engineering projects “open-ended” design projects because every problem has more than one possible solution! For example, civil engineers in your community are continuously designing new highways or expanded highways through and around your city to help people travel. Many possible routes could be chosen to move people through the city—that means that *many possible solutions exist!* The engineers consider many possible routes and then pick the one that they consider to be the *best one* based on many factors. In this case, factors (unique requirements, limitations, constraints) might include keeping costs low, trying not to disrupt neighborhoods, and trying to lower noise.

Your engineering team now has some important information and it is time to suggest some possible cavern locations! Remember that many possible location solutions exist; your job is to figure out which locations make the most sense for what you are trying to accomplish.
You will need the two maps to complete this activity.

1. Many rectangle shapes have the same area. These two shapes have the same area in km.



What is the area of each shape? ________ km^2

2. You have already determined the area needed for your cavern in square kilometers. What 2 numbers can you multiply together to equal your cavern size? How many combinations can you come up with?

3. Using the General Map scale, cut a piece of paper to the cavern size required to house all of Alabraska’s people. If your team is proposing more than one cavern, cut more than one piece of paper. Refer to Question 2 to come up with cavern shape ideas.

a. __________ x _________ = _________ km^2
(cavern size)

b. __________ x _________ = _________ km^2

c. __________ x _________ = _________ km^2

4. Using the cutout paper piece(s) of the cavern size, the General Map and the Geology Map, identify up to 3 possible cavern locations. Use map grid locations to identify the possible locations in the table below. Also provide reasons for why you selected each possible location. *Hint:* Review *Activity 1: What’s the Problem?* answers. Also consider elevation, and the location of airports, cities, rivers, highways, railroads, earthquake fault lines and other features may influence your decisions.

Location		Explanation: Why?
1		
2		
3		

Activity 5: Rocks, Rocks, Rocks Worksheet

What if your proposed locations are in “bad” rock formations? What if the caverns collapse? What if the rock is too hard to dig through? What if water flows right through the rock? These are important questions. Civil and mining engineers deal with these sorts of issues all the time. Civil engineers design auto and train tunnels under cities, rivers, mountains and even oceans. Mining engineers design deep caverns—miles below the surface—for mining precious metals and diamonds. It is critical to investigate and understand rock properties when designing caverns and tunnels in solid rock. Some rocks are like chalk—they crumble and snap. Other rocks are extremely hard. So, the strength of the cavern depends on the *rock properties*.

It is time for your engineering team to begin to test the rocks in Alabraska to determine their properties. Knowing these rock properties will help you determine the best cavern locations.

Follow the rock testing procedure below and fill in the “**Rock Test Data Table**.” Also refer to the “**Rock Identification Flow Chart**” to complete the table. After correctly identifying each rock, answer all the worksheet questions.

Rock Testing Procedure

1. After receiving rock samples from the teacher, record the sample ID number in the ID# column of the table.
2. Using the **Mohs Hardness Scale** (to the right ➔), conduct the hardness tests and record the hardness value in the hardness column.
3. Record the brightness of each rock.
4. Observe the particles of the rock sample. Can you see grains, like beach sand? Record your answer in the granular column of the table.
5. Observe the surface of the rock sample. Does it appear to have holes in it where water could penetrate, or is the surface more solid? Record your observations in the data table.
6. Record the luster. Is the rock dull or shiny?
7. Put a drop of vinegar on each rock. Record whether it fizzes or not. Then use a paper towel to dry it off.
8. Put each rock in a glass of water. Does it float or sink? Dry off each rock after testing it.
9. Follow the **flow chart** to identify each rock type. What is its name?
10. Use your **textbook** to classify the rock as igneous, sedimentary or metamorphic.

Mohs Hardness Scale

Hardness	Meaning
1	Softest known mineral. It flakes easily when scratched by a fingernail.
2	A fingernail can easily scratch it.
3	A fingernail cannot scratch it, but a copper penny can.
4	A steel nail can easily scratch it.
5	A steel nail can scratch it.
6	Cannot be scratched by a steel nail, but it can scratch glass.
7	Can scratch steel and glass easily.
8	Can scratch quartz.
9	Can scratch topaz.
10	Hardest known mineral. A diamond can scratch all other substances.

1. If you hammered a nail into pumice, what would happen? Into granite? Explain.

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2. How important is rock hardness to designing and constructing caverns? What if the rock is too hard? What if the rock is too soft?

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3. Look at your rock test results and determine which rock is the hardest (not including diamond) and which is the softest.
   The hardest rock is _________________ and the softest rock is ____________________.

   Look on your Geology Map to see where these rocks are found in Alabraska. Identify them by the grid (nearest letter and number). The hardest rock is found in these areas:

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   The softest rock is found in these areas:

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4. How might the presence of pores or holes affect your cavern design? Which of the rocks are solid? (Refer to the **Rock ID Flow Chart**.)

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5. Is rock color an important property for underground caverns? Explain.

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6. Is the luster of the rock an important property for underground caverns? Explain.

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Activity 6: Ranking the Rocks Worksheet

Now you are going to rank the rock types based upon the rock test data you collected in the previous activity. Engineers often create guidelines to help them compare potential solutions.

Remember that even though more than one right answer exists, *some answers are better than others!* For example, locations A and B may both be suitable cavern locations, but location A might cost less to construct and be closer to a major highway.

To rank the rocks, we will assign "desirability" points based upon the different rock properties. What are our preferred rock characteristics? Below is what we have learned about the importance of the different rock characteristics for building caverns:

Hardness: Very important! Caverns built in soft rock might collapse. But, really hard rock might be difficult to build in.

Color: Not important for design or construction but may be important for how it looks.

Granular: Important. Solid rocks are stronger than granular rocks.

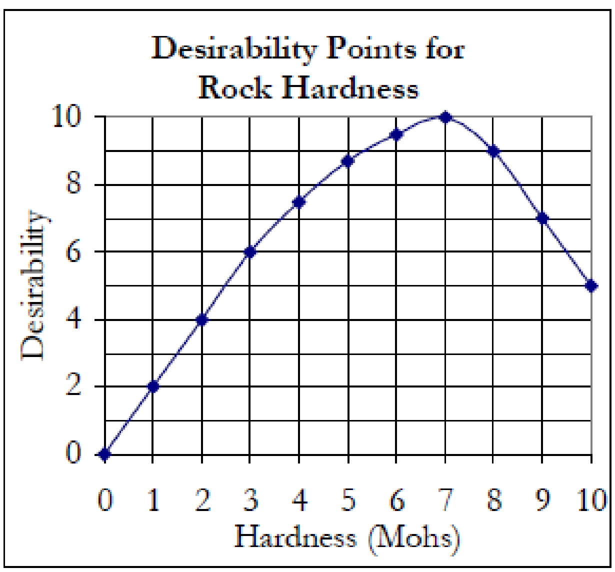
Porosity: Important. Rocks with holes permit water to penetrate and are usually not as strong.

Luster: Not important for design or construction but may be important for how it looks.

The graph and table below provide desirability points for 5 characteristics.

Using the graph, table and **ID flow chart**, fill in the desirability points table on the next page for the rocks you tested.

Desirability Chart



Rock Characteristics	Desirability Points
Hardness	See graph
Color	0
Granular	3 pts if solid; 0 if granular
Porosity	4 points if solid; 0 if rock has holes
Luster	0

Tips: Look at the **Rock ID Flow Chart** to identify a rock's hardness.
Then look at the Desirability Chart and find its hardness.
Use the chart to assign desirability points by the line curve.

Desirability Points and Rock Ranking

Rock Type	Hardness	Color	Granular	Porosity	Luster	TOTAL POINTS	RANKING
limestone							
basalt							
obsidian							
pumice							
sandstone							
slate							
granite							
gneiss							

1. Based on desirability points, what are the most important and least important rock properties for designing and building caverns, tunnels and underground structures?

   Most important rock property:

   ____

   Least important rock property:

   ____

2. Look again at the top three locations you listed during Activity 3. Do your top three sites rank in the top three rock types? Fill in the table below with your site evaluation.

Location from Activity 3	Rock Ranking?	Good Choice?

3. Do you notice a highly ranked rock that did not make your top three potential locations? With this new information, if necessary, revise your top three potential locations in the table below.

Location	Explanation why

Activity 7: Drum Roll Please! Worksheet

Your engineering team has worked hard to collect data and analyze information—all to save the grateful people of Alabraska from the impending asteroid impact. The Governor of Alabraska and President of the United States appreciate your effort. Now it is decision time!

Your team's task is to decide on the best location(s) for your cavern(s). You have rock data, maps that show the location of rivers, earthquake faults, rock types, cities, railroads, airports and the capital. Review your data and discuss as a team until you reach a final decision.

Recommended cavern location(s) by grid: ____

Write a paragraph explaining your recommendation:

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The final step that engineers perform when solving a problem is *presenting the final results.*

Now that you have decided where to locate your cavern(s), prepare a report for the rest of your class.

- ❑ Refer to the **Design Presentation and Report Guidelines** for the required components.
- ❑ Get ready to explain and defend your team decision as your recommended best design solution!
- ❑ Make a paper cutout using the large map scale and put your team name on it.
- ❑ When the teacher calls on your group, place a star or sticky note on the large Alabraska map indicating your final location recommendation.
- ❑ Then give your presentation to the class.

Congratulations on a job well done, engineers!!