Lesson 1: What's the Problem?

Your engineering team will be designing caverns for the people in the fictional State of Alabraska. There are approximately 10 million people in Alabraska – 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 in Alabraska.

The first task that all engineering teams do when faced with an important project is carefully "Define and Understand the Problem". Your team should discuss each question below to help you define the problem. There are no wrong answers to these questions so don't be scared to share your wild ideas with your team.

1. How big does the cavern need to be - the size of the whole State, half the size of the State, one tenth the size of the state? Think about how long 10 million people have to live in the caverns when answering this question.

(no wrong answer)

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

(no wrong answer)

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

(no wrong answer)

4. Should you design and build more than one cavern? List some reasons for building only one cavern and some reasons for building more than one cavern.

(no wrong answer)

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

(no wrong answer)

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 info.

(no wrong answer)

Lesson 2: How Big?

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

1. Let's use your classroom to help determine how much space people will need to sleep. Measure the length, width and height of your classroom in meters. Fill in the table below. Your teacher will give you ideas about how to measure the height of your classroom.

A	B
Dimension	**In meters**
Length	16 tiles × 0.6m = 9.6 m
Width	17 tiles × 0.6m = 10.2m
Height	14 bricks × 0.2m = 2.8m

2. Calculate the area and volume of your classroom using the length, width and height. Round your answers to the nearest whole number.

A	B	C
		Meter Units
Area	Length × Width	9.6m × 10.2m = 97.92m² → 98m²
Volume	Length × Width × Height	9.6m × 10.2m × 2.8m = 274.17m³ → 274m³

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

3. Now you will determine how many beds can fit in your classroom. To help you, you may want to draw your classroom and beds on graph paper. Assume that each square on your graph paper equals 1 m by 1 m and that a typical single bed is 2-meters long by 1-meter wide (area of one bed = 2 m^2). Don't forget to leave room between the beds for people to walk!

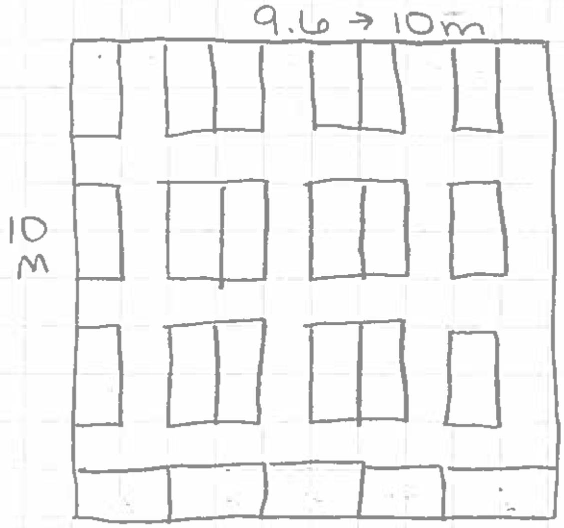
How many beds could your classroom hold? 23. How many bunk beds? 46.

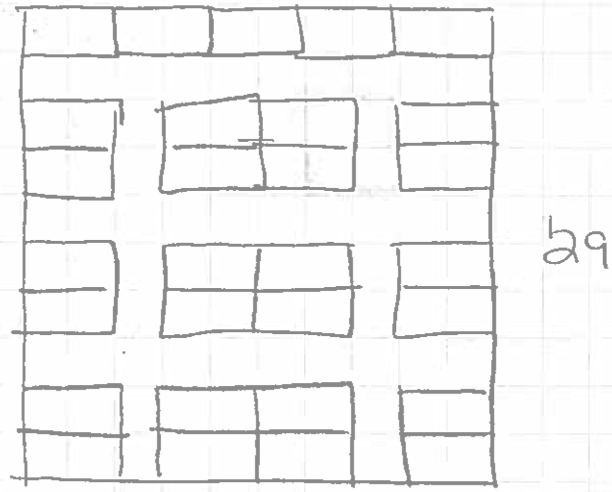
How many students are in your class? 23.

What is the total area your class needs for sleeping? 98 m^2. (98m² for 23 = 4.3m per person)

How many classes would be able to sleep in your classroom (with bunk beds)? 2.

1 square = 1m x 1m





these are 2 different ways the beds can be arranged for Lesson 2 #3.

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

Item	Classrooms required	Area required (m^2)
Sleeping	1	98m²
Eating	1	98m²
Playing	3	294 m²
Food/Water	2	196 m²
Closets	2	196 m²
Bathrooms	1	98 m²
Total	10	980m²

5. Now add up the area required. The total area required for 46 people is 980 m^2. How much area is needed for each person?

21m² per person.

We visited with Maya and Brannon, two creative agricultural engineers, to help us design an underground farming system. Agricultural engineers like Maya and Brannon have helped humankind tremendously by designing new crops, fertilizers and irrigation systems for the world. Agricultural engineers design ways to grow crops in deserts, to keep weeds out of fields, and to make energy out of plants. To learn more about careers in agricultural engineering, go to www.asae.org and click on 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.

21m² + 22m² = 43m²

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.

10,000,000 people × 43m²/person =
430,000,000 m²

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.

$430{,}000{,}000\,m^2 \times \left(\frac{1\,km}{1000\,m}\right)^2 = 430$ km^2.

9. With your answer in Question 8, think about how large an area is required. Compare the required area with some areas in your neighborhood – is it the same as your school campus, a city block, or a soccer field? Discuss with you team whether your answers make sense!

430 km² is a little larger than Denver, CO.
(to compare, a football field is only 0.0055 km²)

Lesson 3: Scaling the Map

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

1. Using a ruler, measure the distance in centimeters from city **a** to city **d** using the General Map.
Distance from city **a** to **d** = 13.5 cm.

The scale on your map helps you determine the actual distance in kilometers from city **a** to city **d**. Measure one centimeter on your General Map scale.

How many kilometers does one centimeter equal? 10 km per cm.

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

13.5cm x 10 km/cm
(# cm from a – d) (# km one cm equals on map scale)

= 135 km (actual distance).

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

8.5cm x 10 km/cm = 85 km.

2. You can also use your scale and grid lines to help you find area. Fill in the chart below using the General Map. Measure and record the length and width of one grid space in centimeters. Use the scale to record how many kilometers the length represents and the width represents.

	With ruler (cm)	Actual (km)
Length	1	10
Width	1	10

What is the area in kilometers squared for one grid space? 10 km×10 km = 100 km²

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

What is its area? 11×100 = 1100 km².

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

smaller
(cavern = 430 km² < 1100 km² = military base)

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

Average Length (km)	Average Width (km)	Average Area (km²)
160 km	240 km	38,400 km²

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

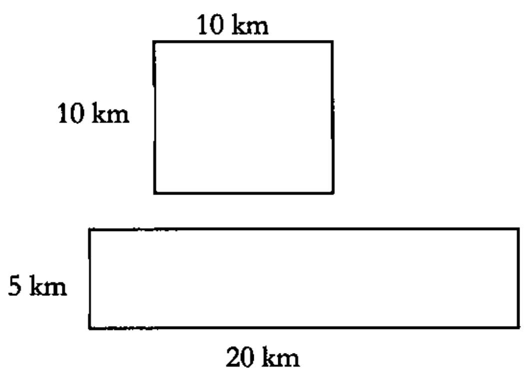
yes!
Alabraska ~ 38,400 km²
cavern = 430 km²

Lesson 4: Possible Locations

In engineering, there is usually more than one answer to a problem. For example, civil engineers are probably designing and building a new highway or expanded highway through or around your city to help people travel. There is more than one route that the engineers could have chosen to move people through your city. Therefore, there is more than one answer! The engineers proposed many possible routes and then picked one route – a best route – based on many factors. Among the factors, the engineers tried to lower cost, tried to lower the disruption to neighborhoods, and tried to lower noise.

Your engineering team now has some important information, and it's time to suggest some possible locations! You will need the two maps to complete this activity.

1. Many rectangle shapes have the same area. The two shapes below have the same area in kilometers.



What is the area of each of these shapes?

______100______ km^2.

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

a. 43 km x 10 km = 430 km^2 (cavern size)

b. 86 km x 5 km = 430 km^2 (cavern size)

c. 21.5 km x 20 km = 430 km^2 (cavern size)

3. Using the scale on your General Map, cut out a piece of paper to the size of the cavern required to house all of Alabraska's people. If your team is proposing more than one cavern, then you should cut out more than one piece of paper. Use question two for ideas on your cavern shape.

4. Using the cutout piece(s) of paper of the cavern size, the General Map and the Geology Map, identify up to 3 possible locations for the cavern(s). Use the grid locations on the map to list the possible locations in the Table below. You must list reasons for selecting each of the possible locations. Hint: review your Lesson 1: What's the Problem answers. Your team should also consider elevation; the location of airports, cities, rivers, highways, railroads, earthquake fault lines and other features that may influence your decisions.

Location	Provide explanation why
example: north center (C10 - C12 \ DE10 - DE12)	relatively low elevation, no highways or cities

Lesson 5: Rocks, Rocks, Rocks

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 engineers and mining engineers deal with these questions all the time. Civil engineers design tunnels under cities, rivers and even oceans for cars and trains. Mining engineers design deep caverns – miles below the surface – for mining precious metals and diamonds. It's critical to investigate and understand the properties of the rocks when designing a cavern or tunnel in that rock. Some rocks are like chalk – they crumble and snap. Other rocks are extremely hard. You can imagine that the strength of the cavern depends on the rock. Your engineering team should now begin to test the different rocks found in Alabraska to determine their properties. These rock properties will help you determine the best locations for your cavern(s).

Follow the rock testing procedure below and fill in the "Rock Test Data Table". You will also need to use the "Rock Identification Flow Chart" to complete the table. After correctly identifying each rock, answer all the questions at the end of this worksheet.

Rock Testing Procedure

1. Your teacher will provide you with rocks. Record the sample ID number in the ID# column of the table.
2. Using the Mohs Hardness Scale (on the right), perform the hardness tests and record the hardness value in the hardness column of the Rock Test Data Table.
3. Record the brightness of each rock in the table.
4. Observe the particles of the rock sample. Can you actually see grains - like the sand on a beach? Record your answer in the granular column of the data 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, and then dry off each rock with a paper towel.
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 the name of each rock.
10. Use your textbook to classify the rock as igneous, sedimentary or metamorphic.

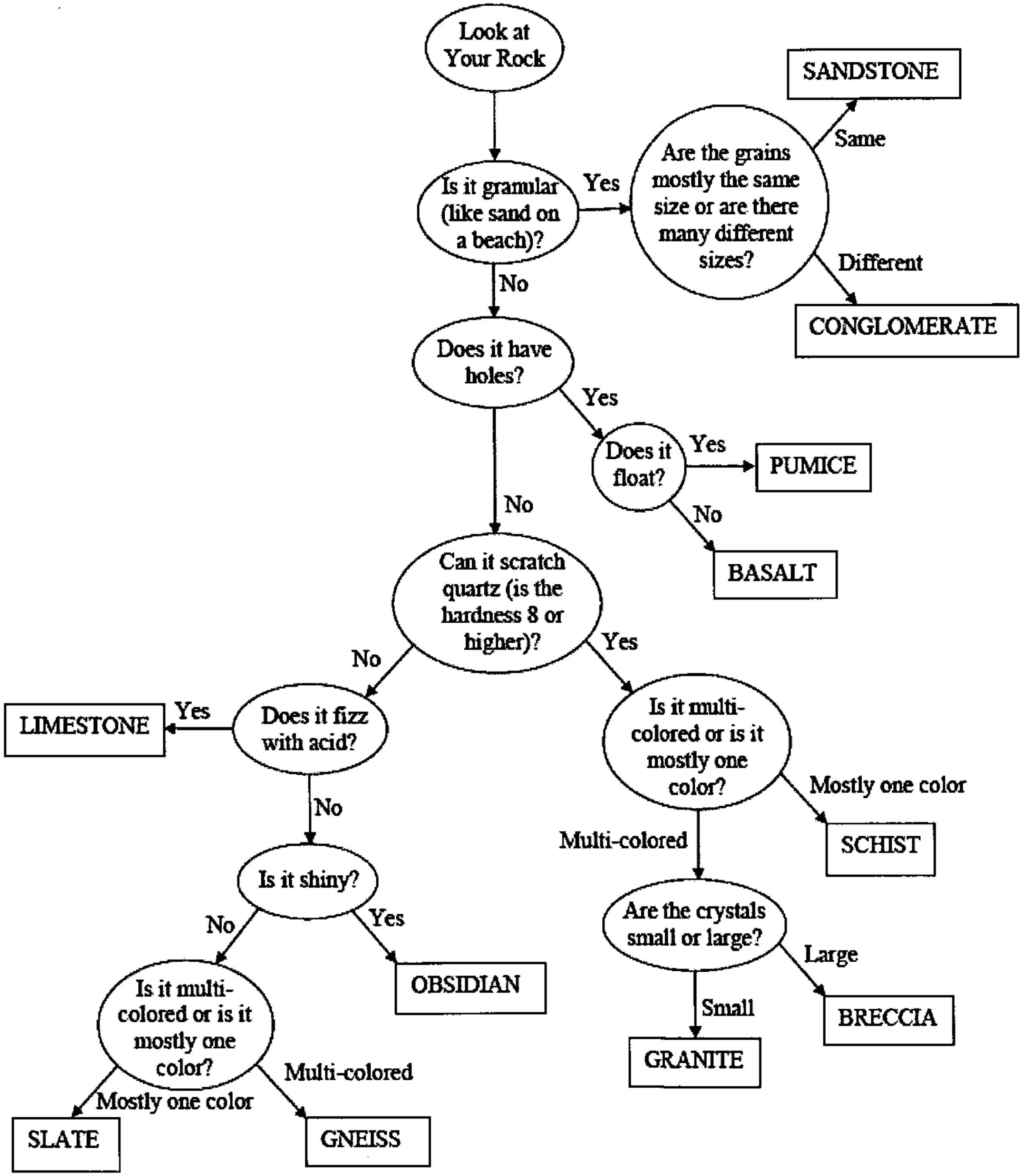
Mohs Hardness Scale

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. Diamond can scratch all other substances.

Rock Test Data Table

ID #	Hardness Number	Brightness Light or Dark	Granular Yes or No	Holes Yes or No	Luster Dull or Shiny	Reactivity Fizz or No	Buoyancy Float or Sink	Rock Name (use flow chart)	Classification I, S, or M
1	6-7	dark	no	yes	dull	no	sink	Basalt	I
2	5-6	dark	no	no	shiny	no	sink	Obsidian	I
3	7	light	no	no	dull/shiny	no	sink	Gneiss	M
4	5.5	dark	no	no	dull	no	sink	Slate	M
5	6	light	no	yes	dull	no	float	Pumice	I
6	6.5-7	light	yes	no	dull	no	Sink	Sandstone	S
7	6-7	dark/light	no	no	shiny	no	Sink	Sand/Gravel	M
8	3	light	no	no	dull	yes	Sink	Limestone	S
9	6-7	light	no	no	shiny	no	sink	Granite	I
10	10	Light	No	No	Shiny	No	Sink	Diamond	M

Rock Identification Flow Chart



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

You could hammer a nail into pumice, but not into granite, because granite is about ten times as dense as pumice.

2. How important is rock harness to designing and constructing caverns? What if rocks are too hard? What if rocks are too soft?

Very important! If the rock is too hard, it's too difficult to cut into the rock to form the cavern. If it's too soft, the cavern could collapse.

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 gneiss and the softest rock is limestone. Look on your geological map to see where these rocks are found in Alabraska. Identify them by the grid, using the nearest letter and number. The areas where the hardest rock is found are center and southwest. The softest rock is found in what areas?

center and northwest to south.

4. How might the presence of pores or holes affect your cavern design? Which of the rocks are solid? (Use Rock ID chart).

Pores or holes allow for water penetration and make the rocks less strong/solid, which could a cavern of this rock to collapse. The most solid rocks include obsidian, granite, slate, and gneiss

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

The color is not important for the structure. (It may be important for lighting the cavern, though)

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

The luster is not important for the structure of the cavern. (It may be important for lighting the cavern.)

Lesson 6: Ranking the Rocks

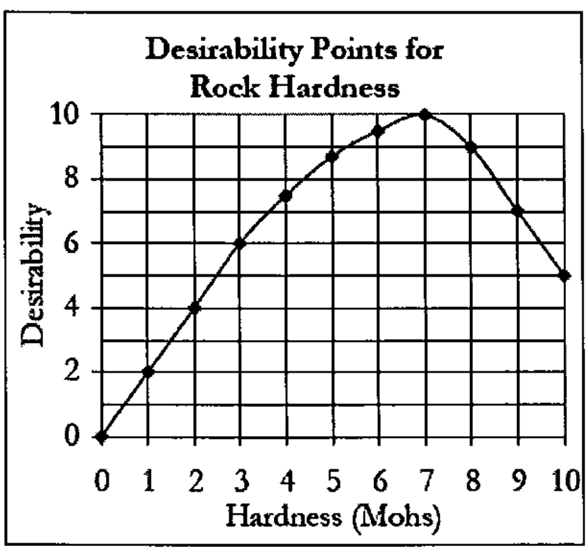
This activity has been designed to help you rank the rock types based upon the rock test data that you collected in the previous lesson. Engineers often have guidelines to help rank potential solutions. Remember there is more than one right answer; however, some right answers are better than others! For example, location A and location 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 use "desirability" points based upon the different rock characteristics. We need to know those which have the most pleasing characteristics. Here's 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. However, a really hard rock might be difficult to build in.
Color: not important for design or construction but may be important for looks.
Granular: important – solid rocks are stronger than granular rocks.
Porosity: important - rocks with holes allow water to penetrate and are not as strong.
Luster: not important for design or construction but may be important for looks.

The graph and table below provide the desirability points for each of the five characteristics. Using the graph the table and ID rock chart, fill in the desirability points table on the next page for each of the rocks that you tested.

DESIRABILITY CHART



Rock Characteristic	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

Look at your Rock ID Chart to identify the rocks hardness. Look at 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	6	0	3	4	0	13	6
Basalt	10	0	3	0	0	13	6
Obsidian	9	0	3	4	0	16	3
Pumice	9.5	0	3	0	0	12.5	8
Sandstone	10	0	0	4	0	14	5
Slate	9	0	3	4	0	16	3
Granite	9.5	0	3	4	0	16.5	2
Gneiss	10	0	3	4	0	17	1

1. Based on desirability points, what is the most important and least important rock property for designing and building caverns, tunnels and underground structures?
Most important rock property? hardness.
Least important rock property? color / luster.

2. Take a look again at the top three sites you previously listed during Lesson 3. Do your top three sites rank in the top three rock types? Use the table below.

Location from Lesson 3	Rock Ranking?	Good Choice?
north center (C10 - C12 D/E 10 - D/E 12)	gneiss #1	yes!

3. Is there a highly ranked rock that did not make your top three potential locations? Revise, if necessary, your top three potential locations in the table below.

Location	Provide explanation why

Lesson 7: Drum Roll Please!

Your engineering team has worked very hard to collect data, analyze information – all to save the very grateful people of Alabraska. The Governor of Alabraska and President of the United States are very proud of your effort. It's decision time!

Your team's objective 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 have reached a final decision.

Recommended location by grid (locations if more than one cavern):

north center (B10-B12/C/D10 - C/D12)

Write a paragraph explaining your recommendation:

- gneiss = #1 ranked rock
- away from cities, railroads, highways, airports, earthquake faults, rivers, and the capital
- relatively low elevation → easier to get to and to do construction

The final step that engineers perform when solving a problem is presenting the final results. Now that you have decided where your cavern will be, you should prepare a report for the rest of your class. Use the Design Presentation and Report Guidelines handout to make a final presentation. When your teacher calls upon your group, please place a star or sticky note on the large class map indicating your final decision. Use the large map scale to make your cut out. Be sure and put your team name on it. After putting your star on the big map, give the class your presentation. Be ready to defend your decision!

Congratulations on a job well done engineers!!