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 <u>no wrong answers</u> 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.

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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? 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 your 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 info.

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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	
Width	
Height	

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	
Volume	Length × Width × Height	

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 = __________ m^2). Don't forget to leave room between the beds for people to walk!

How many beds could your classroom hold? ___________. How many bunk beds? ________________.

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 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		
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?

____.

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 from the agricultural engineers, calculate the total area required per person.

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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.

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8. Convert the total required area in m^2 (from Q7) to square kilometers. Round your answer to nearest whole number. Use your conversion chart.

____ km^2

9. With your answers in Question 9, 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 your team whether your answers make sense!

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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 inches from city **a** to city **d** using the General Map. Distance from city **a** to **d** = ______ inches.
The scale on your map helps you determine the actual distance in miles from city **a** to city **d**. Measure one inch on your General Map scale. How many miles does one inch equal?
____________miles per inch.

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

__________________ x ________________________

(# cm from a – d) (# km one cm equals on map scale)

=____________________km (actual distance).

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

____________ x _________ = _________ 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 inches. Use the scale to record how many miles the length represents and the width represents.

	With ruler (cm)	Actual (km)
Length		
Width		

What is the area in miles for one grid space?

____________km²

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

What is its area? ________________________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!

____

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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)**

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

____

____

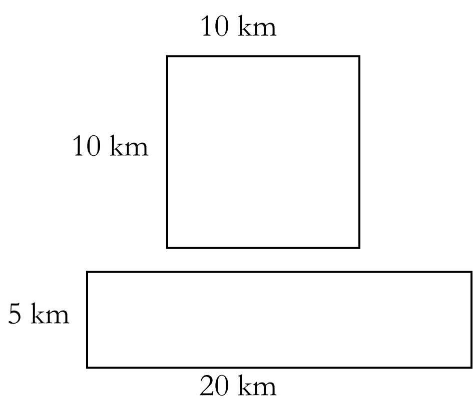
____

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 miles.



What is the area of each of these shapes?

____________________________________km².

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

a. _________ x __________=__________km²
(cavern size)

b. _________ x __________=__________km²

c. _________ x __________=__________km²

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 maps 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**

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" on Page 7. You will also need to use the "Rock Identification Flow Chart" on Page 8 to complete the table. After correctly identifying each rock, answer all the questions on Page 9.

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 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.

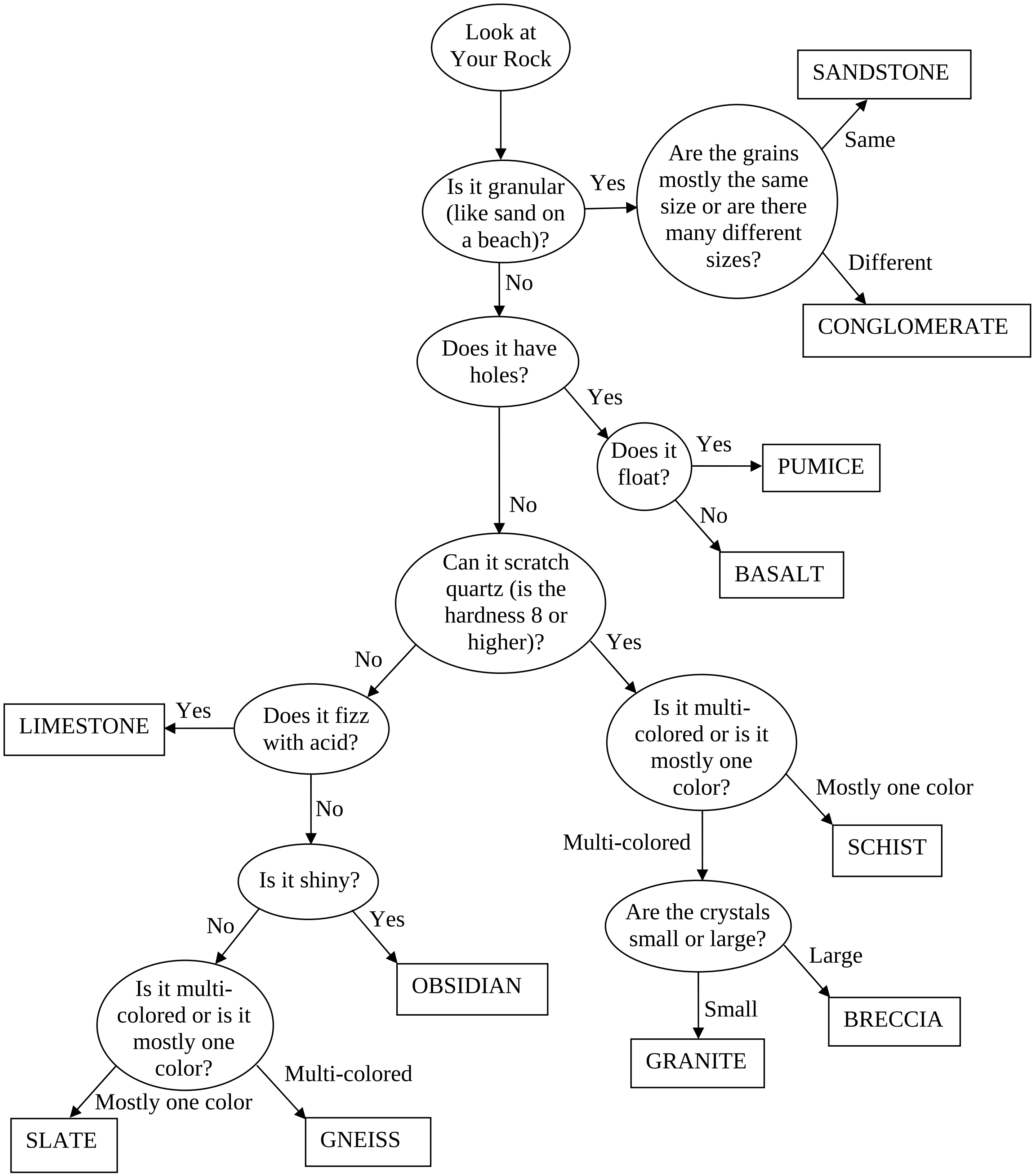
Mohs Hardness Scale

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 of No	Holes Yes or No	Luster Dull or Shiny	Reactivity Fizz or No	Bouyancy Float or Sink	Rock Name (use flow chart)	Classification I, S, or M
1									
2									
3									
4									
5									
6									
7									
8									
9									
10	10	Light	No	No	Shiny	No	Sink	Diamond	M

Rock Identification Flow Chart



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

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____

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2. How important is rock hardness to designing and constructing caverns? What if rocks are too hard?
What if rocks are 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 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 _____________________. The softest rock is found in what areas? _______________________________________.

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

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5. Is the color of the rock 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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Lesson 6: Ranking the Rocks

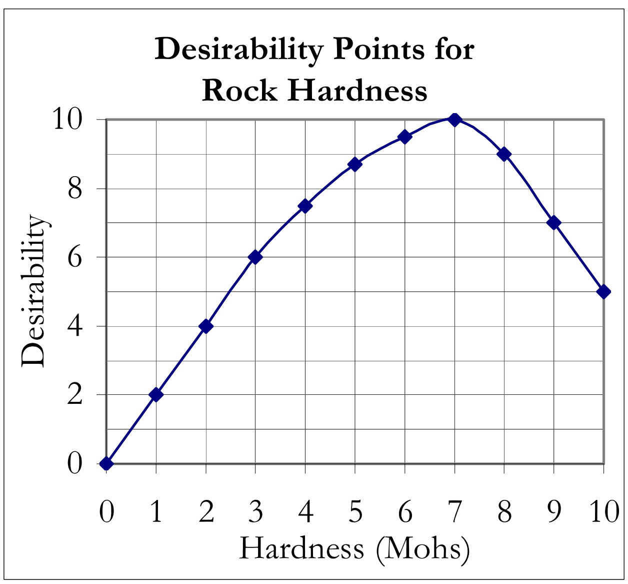
This activity has been designed to help you rank the rock types based upon the rock test data that you collected in the previous lesson. Engineers often have guidelines to help rank potential solutions. Remember there is more than one right answer; however, some right answers are better than others! 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							
Basalt							
Obsidian							
Pumice							
Sandstone							
Slate							
Granite							
Gneiss							

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? ______________.

Least important rock property? ______________.

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?**

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, you have maps that show the locations 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):

____

Write a paragraph explaining your recommendation:

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 presentation guidelines on 13 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!!

Design Presentation and Report Guidelines

The presentation of your design solution should include the following components:

1. Introduction – Explain the scenario and what your engineering team was asked to accomplish. Make sure that you list the members of your engineering team as well as your team name and each person's responsibility or role.

2. Define the problem – State your problem definition from Lesson 1.

3. Summary of gathered information – List the information used to determine the solution. For example, you used accessibility information based on the distances, you tested the different properties of the rocks, and analyzed data to determine how big the cavern needed to be. For each of these (and anything else you did) explain what you did and how you did it and what results your tests gave you.

4. Preliminary locations – Detail all the possible locations that your team initially chose. Include information about why your team chose these locations.

5. Analysis of solutions – Explain why the different tests you performed helped you come up with the best location for your cavern. Analyze each test you did and note the specific reasons why this test helped you.

6. Give your final appropriate site location and its characteristics including the rock type(s), the distance to different important things, and why your team chose that location above the other possible locations.

Reference Page

Vocabulary:

1. **Cavern** – cave, to hollow out a space.
2. **Crater** – a hole shaped depression made by a meteorite.
3. **Diameter** – the length of a straight line through the center of an object.
4. **Elevation** – height above the level of the sea.
5. **Engineering** – using math and science to solve problems that improve the quality of life. Examples include: turning wind into energy, creating the artificial heart, taking pollution out of the air, bringing water into your home, designing the heating and air condition for your home, developing ways to grow more food, the space shuttle, designing clothes that keep you warmer and cooler.
6. **Fault line** – a fracture in the earth.
7. **Meteorite** – a rock that falls to earth from outer space. When this rock was in outer space, it was called an asteroid.
8. **Orbit** – a circular path of 1 object revolving around another.
9. **Porosity** – full of pores, allows for fluids to flow.
10. **Science** - my favorite and most interesting class. ☺
11. **Sea Level** – level of the surface of the sea.
12. **Topography** – survey of the surface of the earth detailing its features.

Conversions and Formulas:

Area = L × W

Volume = L × W × H

ft ÷3.3 = m

ft^2 × .09 = ______________m^2

m^2 ÷ 1,000,000 = _______________km^2

km^2 × .39 = _____________mi^2