**Activity Sixteen**

**Thermal Expansion and Sea Level Rise**

Student Activity Sheet

Name _____ Date _____ Class_____

A blanket of gases called the atmosphere surrounds the surface of the Earth**.** The energy from the sun passes through the atmosphere and about half is absorbed by the Earth's surface. Some of this heat energy is reflected back into the atmosphere and is absorbed by the gases present there. Carbon dioxide, methane, and nitrogen oxides are examples of the heat absorbing gases and these are called ***greenhouse gases.*** Greenhouse gases occur naturally in the atmosphere, but humans have added a lot more by burning fossil fuels and wood. More of these gases in the atmosphere means that more heat can be absorbed, which results in an increase in the temperature. This increase in the Earth's temperature is called ***global warming.*** The average temperature in 1990 was 59.8˚ F, the highest temperature yet recorded! In 1995 scientists predicted that in the next hundred years the average global temperature will increase by 2- 3.5˚C (3.6- 6.3° F) [IPCC 1995]. Although this isn't as high as scientists had originally predicted, it is the highest rate of warming seen in the last 10,000 years. As the temperature increases, ***thermal expansion*** will cause sea level to rise. Warmer temperatures may cause mountain glaciers and the ice sheets covering Greenland and Antarctic to melt, also causing sea level to rise.

***Sea level*** is simply the average height of the ocean between high and low tide. Sea level has fluctuated throughout Earth's history. For instance, during the ice ages when glaciers covered much of the land, sea level was much lower than it is now because so much water was frozen. Most of the increase in sea level as the result of global warming will be from the thermal expansion of the oceans. Thermal expansion is caused when seawater expands because of the higher temperature of the water. Since the oceans absorb heat from the atmosphere, when the atmosphere becomes warmer so will the oceans. Warm sea water has a greater volume than cold sea water. As the temperature of the ocean increases so will the total ocean volume. The increased volume will cause the level of the water in the oceans to rise. Over the next hundred years we can expect the sea level to rise from 15 to 95 centimeters (6- 37 inches). This is much different than the 6-37 centimeters (4- 10 inches) that the sea level rose over the last hundred years! In general, for every 1 centimeter (0.39 inches) that the sea level rises, 1 meter (39.3

inches) of coastal land will be lost. Places with very flat coasts, like Florida, could lose up to 1,000 feet of coastal land.

If the sea level rises as predicted, freshwater will be contaminated with salt water (including much of our drinking water supply), ports will be destroyed, coastal cities will be flooded or ruined, wetlands and swamps will be damaged, coastal erosion will speed up, large numbers of plants and animals will die, hurricanes would increase in intensity and number, and precipitation patterns will change so that there would be droughts in some areas. The tourism and recreational businesses that depend upon coastal areas will collapse. The economic impacts of rising sea level due to global warming will be devastating.

Rising sea level will severely affect humans and other organisms. In this activity, you will see how coastal areas and businesses may be effected by rising sea level. First your teacher will demonstrate how thermal expansion works, then you will work with ***topographic maps*** to learn exactly how different amounts of sea level rise may affect the coastal zone.

**Objectives**:

- Observe the thermal expansion of water.
- Discover how rising sea level will affect coastal areas and the economy.
- Learn to use topographic maps.

**Materials**:

| | |
|---|---|
| Handout on Topographic Maps | Topographic Maps A, B, C, or D |
| Colored Pencils (Student supplied) | Question Pages for Maps A, B, C, or D |

**Procedure**:

1. After you read the introductory material, your teacher will demonstrate how thermal expansion works- that when water is heated its volume increases.
2. To work on the topographic maps, divide into groups. First, familiarize yourselves with topographic maps by going over the handout on how to use this type of map. Answer the questions on the handout to make sure you're understanding how these maps are set up. If you can't figure something out, ask your teacher to explain it to you.
3. Each group will have a different topographic map. (The heights on the maps are in feet.) Using a brown or green colored pencil, outline the shoreline. Your teacher will tell you how much the water level has risen for your map area. Color the new shoreline in blue. Color the

area of land between the old and new shoreline in crisscrossing lines so that your group can easily see how much land will now be under water.

4. A set of questions goes with each map. After you have finished coloring, answer the questions.
5. Choose a spokesperson for your group who will share with the class what happened in your area when the sea level rose and how the area was economically affected.

## Vocabulary

**Atmosphere:** The blanket of gases that surrounds the Earth. Our atmosphere consists primarily of the gases oxygen and nitrogen .

**Greenhouse gases:** When certain gases in the atmosphere are present in excessive amounts, they absorb rather than reflect the sun's heat energy. This causes the atmosphere to heat up. Carbon dioxide is the main greenhouse gas.

**Global warming:** When the Earth's atmosphere is heated from excessive amounts of greenhouse gases that enter the atmosphere as the result of human activities. More greenhouse gases trap more heat than normal near the Earth's surface, causing the average temperature of the Earth to increase.

**Thermal expansion:** The increased air temperature resulting from global warming will cause the temperature of the oceans and lakes to increase. When water is heated, the space between its' molecules increases, causing the volume to increase. In the ocean, this increased volume will cause the sea level to rise.

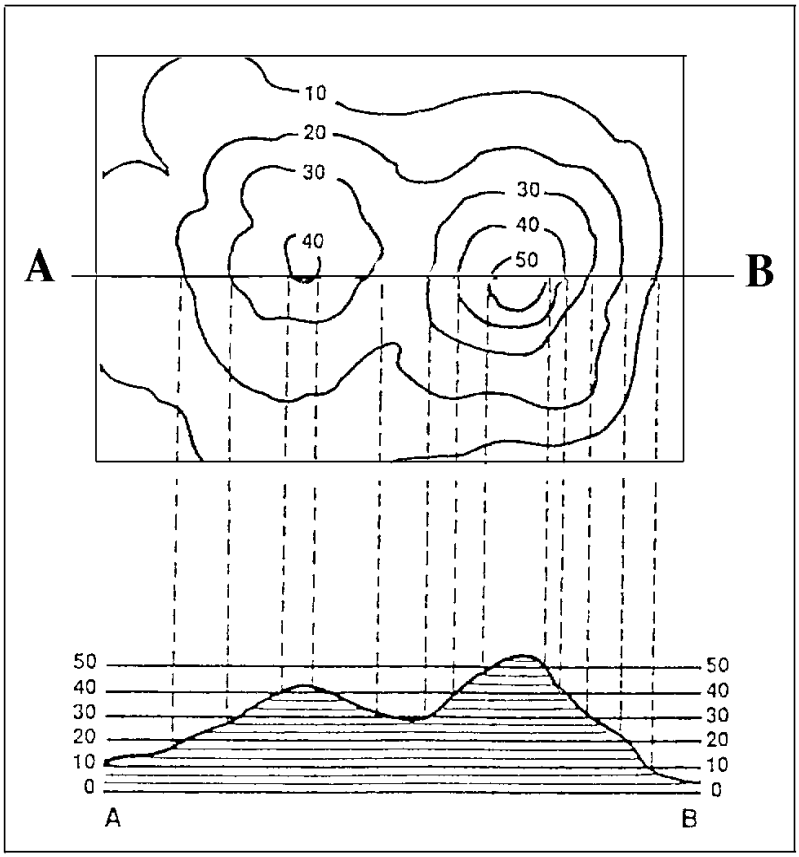
**Sea level:** The average height of the ocean measured midway between high and low tide.

**Topographic maps:** A map that shows the shapes and elevations or heights of the land with contour lines. Contour lines connect points of equal heights.

## HOW TO READ A TOPOGRAPHIC MAP

(adapted from a U.S. Geological Survey publication)

A topographic map is different from a road map because it shows the shapes and elevations (the height) of land with *contour lines*. Contour lines are lines that connect places with the same elevations and are sometimes called level lines because they show points that are at the same level. For example, if the number 5 is written on a contour line of a topographic map, you know that every place along that line is 5 feet high. Here's how topographic maps work.




This diagram shows two different ways of looking at the same landscape. The top part of the diagram is a topographic map of the hills illustrated in the lower part of the diagram. In the topographic map, you are looking down at the hills from above, but in the lower drawing, you are looking sideways at the hills. If this is confusing to you, do this exercise with your hands. Interlock the fingers of both your hands together and hold them in front of your stomach. Look down at the top of your hands. This is what you "see" in the topographic map. Keeping your fingers together, move them up in front of your eyes so that you're looking at your thumbs. This

is what you're "seeing" in the lower drawing. The dashed lines connect the same places on both the map and the drawing. In the drawing you'll notice that the height or elevation of the hills goes up by 10 foot steps. The contour lines on the topographic map are also in 10 foot intervals.

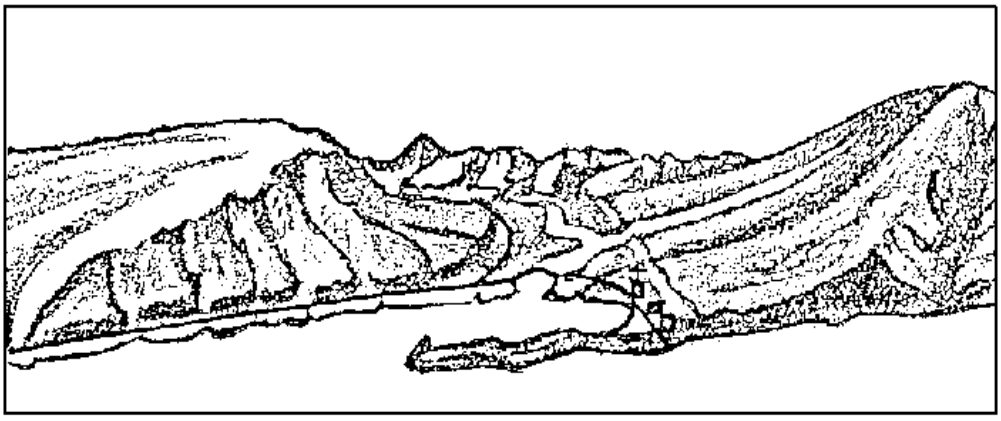
1.) Which is higher, hill A or hill B? Which is steeper, hill A or hill B?

2.) How many feet of elevation are between the contour lines?

3.) How high is hill A? How high is hill B?

4.) Are the contour lines closer together on hill A or hill B? What does this mean when the contour lines are close together?

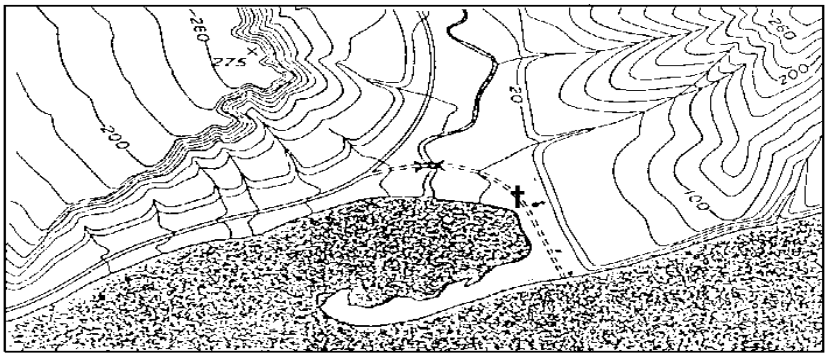
Now look at this next drawing. It shows a river valley, a spit of land, and several nearby hills.



Use colored pencils to circle the places you'll locate on this drawing. Locate and draw a colored circle around each of the following:

1.) a road along the coast
2.) a stream that flows into the main river
3.) a bridge over the river
4.) a hill that rises steeply on one side and more smoothly on the other.

Here is a topographic map showing the same area. Topographic maps use symbols for certain features like roads and bridges. Look at the topographic map on the next page and find the same places that you found on the figure above.




1.) Circle the symbol for a church and draw that symbol here.

2.) Put a square around the map symbol for a bridge and then draw the bridge symbol here.

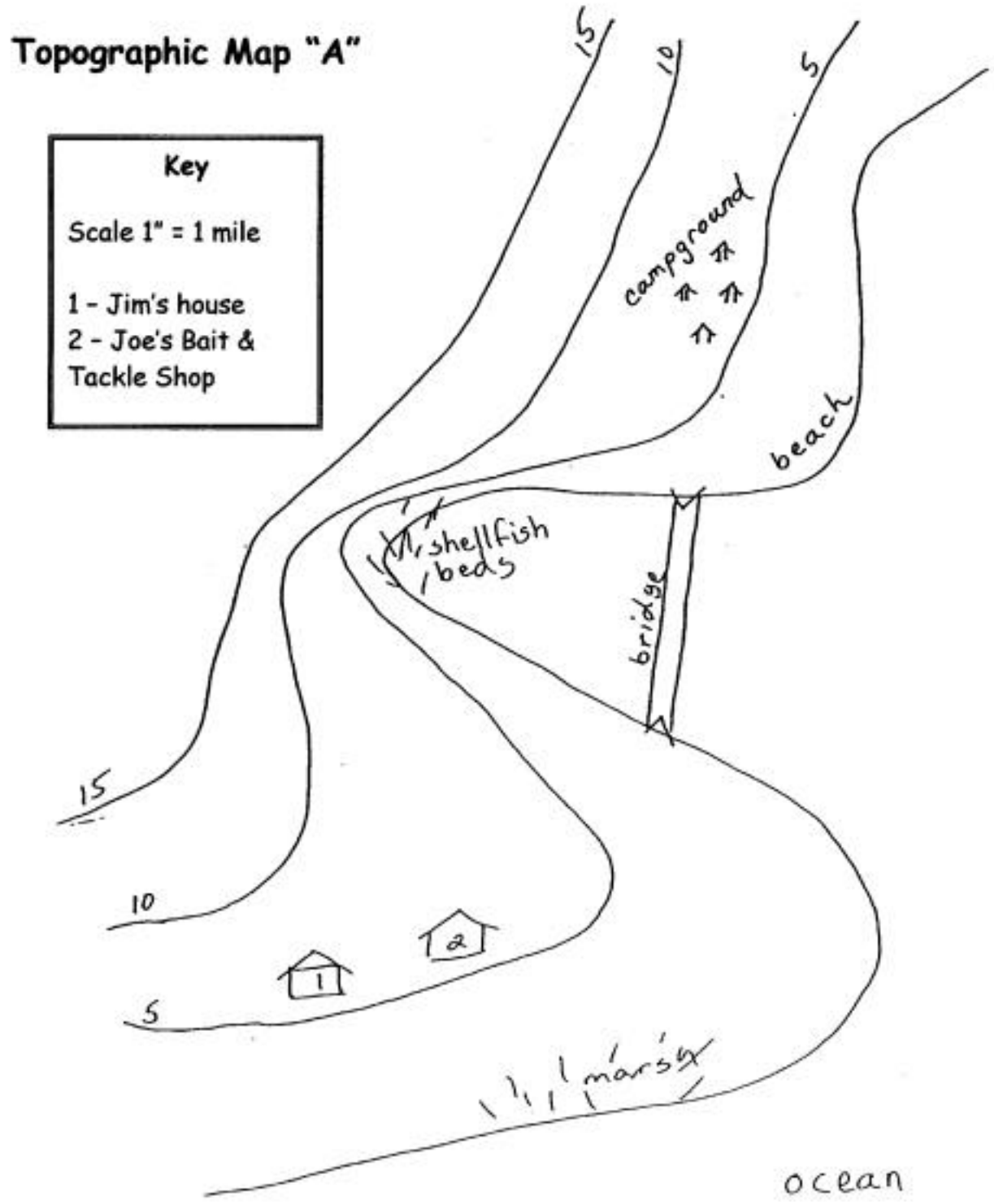
3.) Put an X on the oceanside cliff.

4.) What is the elevation of the contour line at the top of that cliff?

5.). Locate a stream that flows to the main river. Draw a colored line down that stream. Put an * where the stream joins the main river. On a actual topographic map, streams are shown in blue and contour lines are shown in brown.

6.) Draw a colored line along the road that is found along the coast.

## Topographic Map "A"



## Topographic Map A Questions

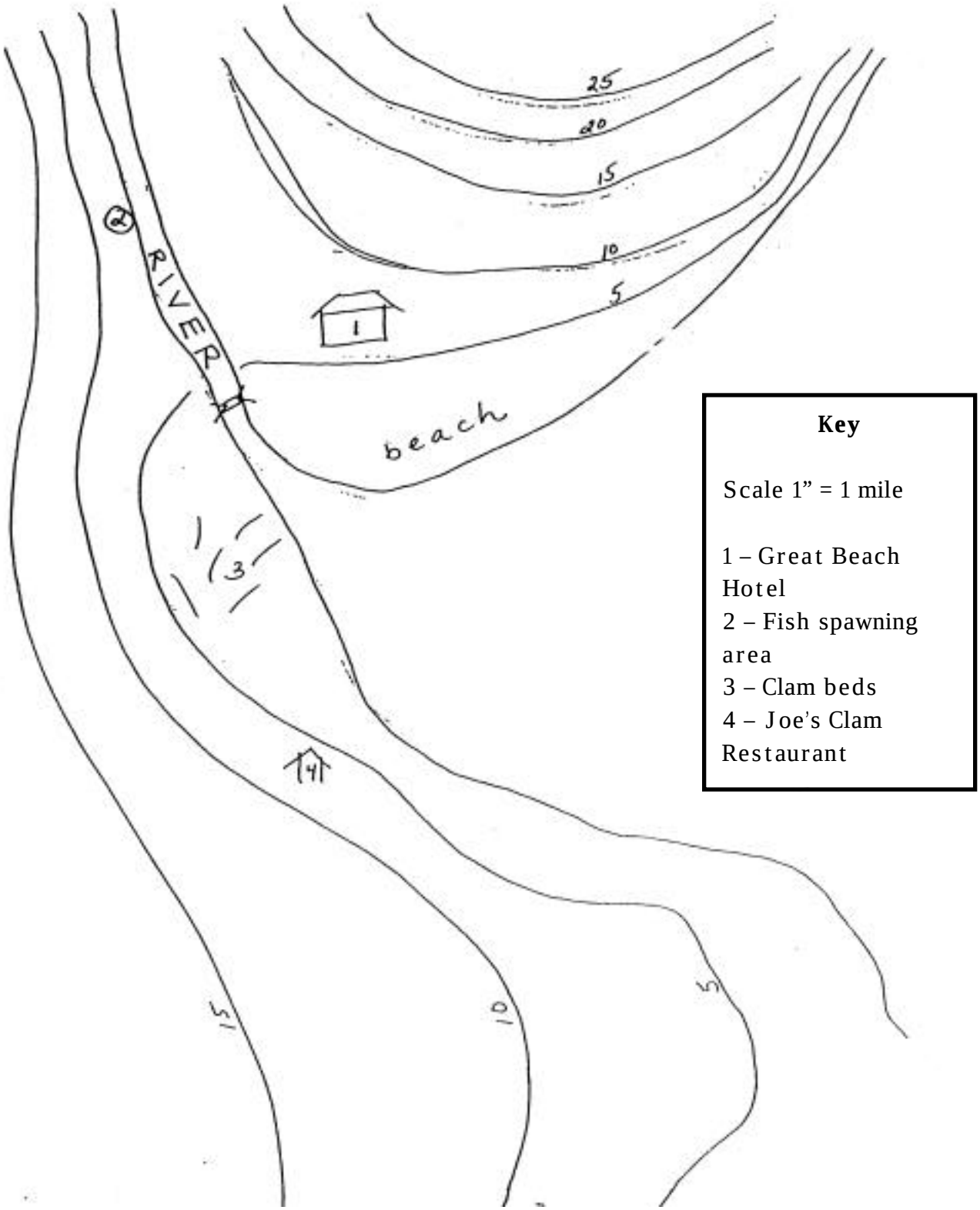
1. On Topographic Map A, were all parts of the coastline affected equally by the rising sea level?

2. How many buildings were lost due to the higher sea level? Do you think the bridge was affected by the higher water level?

3. What organisms were affected by the higher sea level? (Hint: Think of what animals or plants might live in the three different coastal environments that are shown on the map.)

4. How do you think the economy of this area was affected by the higher sea level? List the businesses that were affected.

## Topographic Map "B"



## Topographic Map B Questions

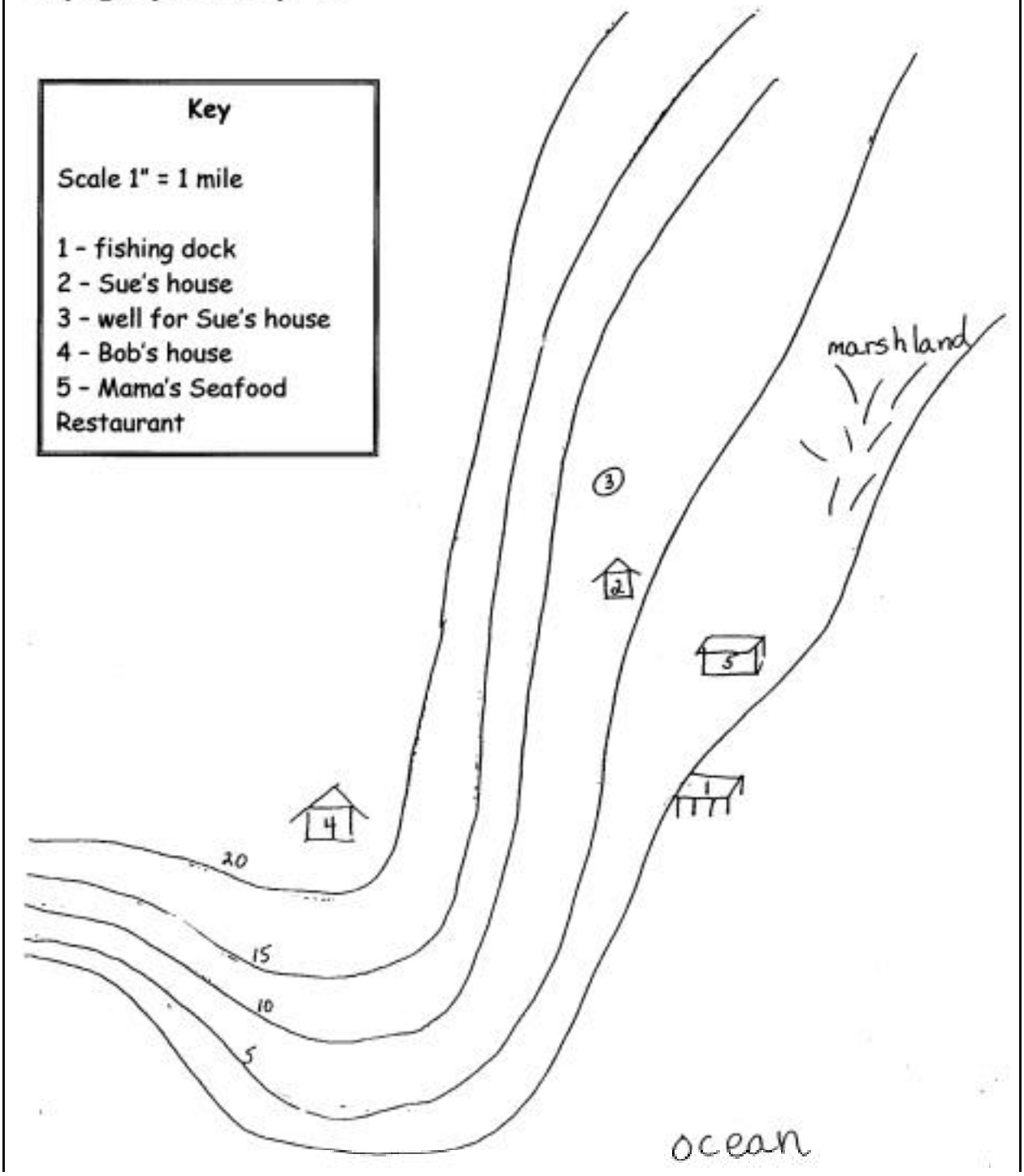
1. On Map B, were all parts of the coastline affected equally by the rising sea level? Which parts were affected the most?

2. Were any buildings lost due to the higher sea level? Did the water rise enough to affect the bridge?

3. Were any natural areas (ecosystems) besides the beach affected by the higher sea level? If so, what do you think happened to those areas and the animals and plants that lived there?

4. Was the economy of your map area affected in any way by the changes that occurred when the sea level rose?

## Topographic Map "C"



## Topographic Map C Questions

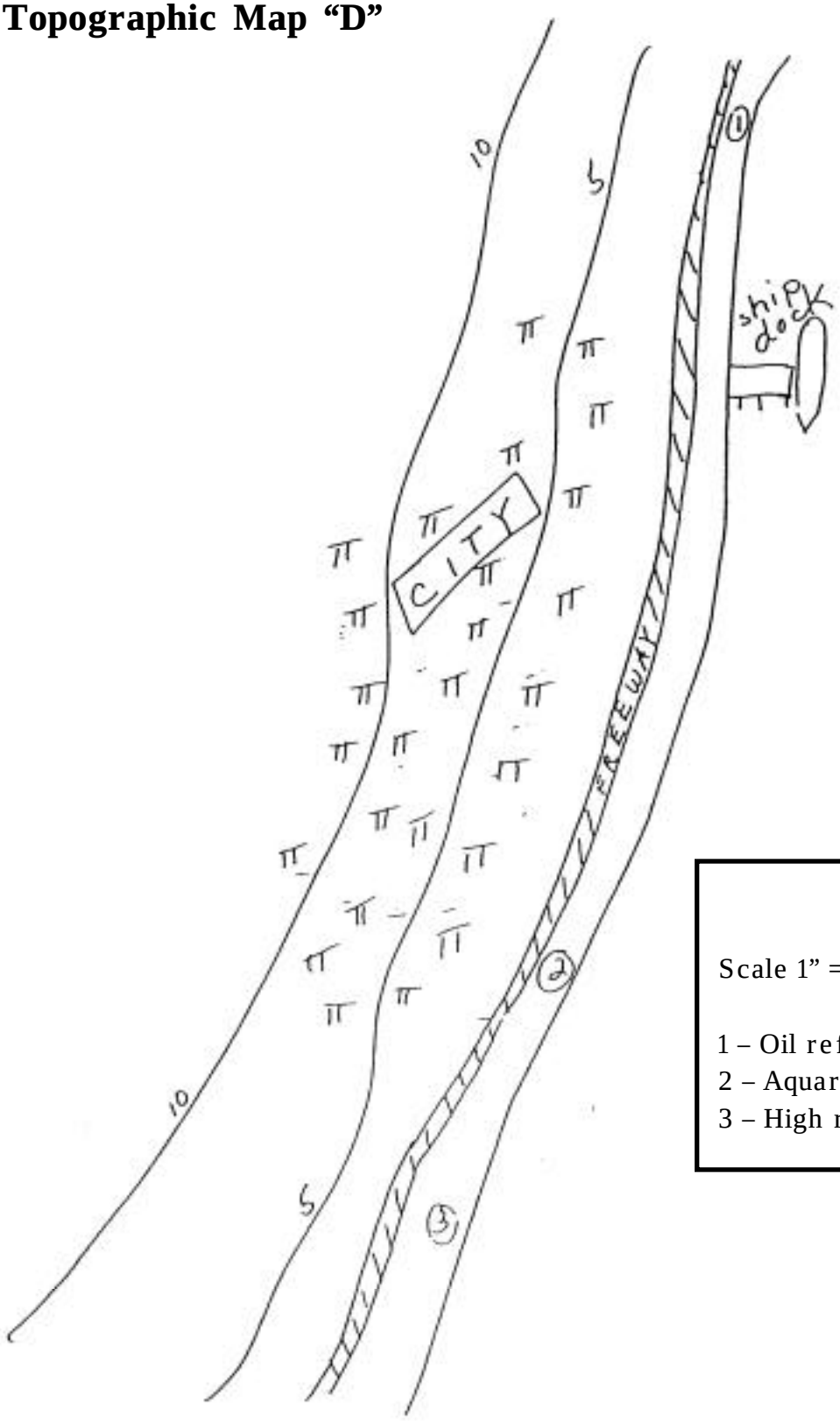
1. Were all parts of the coastline on Map C affected equally by the rising sea level?

2. Were any buildings or structures lost due to the higher sea level?

3. How many types of organisms were affected by the higher sea level?

4. List the economic effects of the changes that occurred on Map C when the sea level became higher.

## Topographic Map "D"




**Key**

Scale 1" = 1 mile

1 – Oil refinery
2 – Aquarium
3 – High rise hotels

## Topographic Map D Questions

1. On Map D, were all parts of the coastline affected equally by the rising sea level?

2. How many buildings or structures were lost because of the higher sea level?

3. Were any plants or animals affected by the higher sea level?

4. How was the area on Map D affected economically by the rising sea level?

## Teacher Strategies

**Materials for Demonstration**:

Rubber stopper fitted with glass tube
Screen
Overhead projector
Colored water
Glass-marking pen (i.e., permanent marker, grease pencil)
Test tube

**Pre-Lesson Preparations**:

1. Add colored water to the test tube. Into the test tube, carefully insert the rubber stopper fitted with the glass tube. Be sure that the lower end of the glass tube is below the level of water in the test tube. Mark a line on the glass tube to show the starting position of the water
2. Set up the projection screen and overhead projector.

**Instructional Strategies**:

1. Have students read the introductory material or read it to them. After reading the introduction, go over the vocabulary terms that are italicized. Make sure your students understand all the vocabulary terms and concepts presented in the introduction.
2. Now demonstrate how thermal expansion of water works. To do this, you'll need the equipment you set up before class. Place the test tube apparatus on the overhead projector. A paper clip on either side of the tube will prevent it from rolling. Note: If test tube is on side, water may not fill glass tube so expansion will be less visible. Place test tube apparatus in empty beaker (just used for support). Mark water level in glass tube with grease pencil.
3. Turn the overhead projector on. At one minute intervals, mark the level of the water in the protruding glass tube. Leave the projector on for as many minutes as necessary to show a noticeable change. The length of time will vary as heat output of projectors varies. As the water in the test tube absorbs heat energy, the molecules in the water move faster and collide with more force, causing the water volume to expand, or thermal expansion. While waiting for the time to pass and the volume to expand, make sure students understand the concept of volume so they will grasp the importance of volume change. A helpful analogy might be to have them imagine what problems might occur if their personal volume suddenly expanded

to five times its' present size. Would they fit through doors? In their desks In their beds? On the school bus?

4. After a noticeable change has occurred, ask and discuss these questions:

   a) As the water became warmer, what happened to the amount of space occupied by the water?

*It increased as seen by the rising level of water in the small tube. Tell them that a volume increase caused by heat is called thermal expansion.*

   b) If the water in the oceans becomes warmer, what will happen to the volume of the oceans?

*The amount of space occupied by the oceans will increase and cover up some of what is now dry land. In other words, the level of the sea or ocean will rise.*

   c) How will the change in ocean volume affect coastal areas?

*Some of them will now be under water. Cities, wetlands, beaches, and roads in these areas will be destroyed.*

The topographic map activity will help your students understand more clearly the consequences of global warming and subsequent sea level rise. Tell students they will now do an activity to help them see the consequences of sea level rise.

5. Divide your students into cooperative learning groups, the size of which will be dictated by your overall class size. There are four different maps for this activity. You can divide your students into four large groups each using a different map or have more groups with fewer students. The scenario with more than four groups means that two or more groups will use the same map version (e.g., Map A) and questions.
6. Hand out a copy of Map A, B, C, or D and their respective questions to each group. If students have never used topographic maps before, have them do the "How to" handout on topographic maps first. Display an actual topographic map either on the board or spread out on a table so that your students can gather around to look at it.
7. Tell each group how many feet the water will rise in their map area. The students will color the outline of the old shoreline brown, the land area green, and the ocean area blue, including the area of land that will now be under water. The purpose of coloring the old shoreline is so the change in sea level can more readily be seen.
8. Instruct your students to answer the questions corresponding to their topographic map after they have finished coloring.
9. Have a spokesperson from each group share with the class what happened in their area when the sea level rose and how their area was affected economically by the sea level rise.

10. Discuss the changes that occurred in the four different areas. Besides the elevation, the shape of the coastline will greatly affect how much damage the sea level changes will have. For the same amount of seawater rise, more land will be covered on a gently sloping beach than on vertical rock cliff. Some predictions call for a maximal 100 cm rise in the sea level over the next 100 years. The present shoreline will be 100 meters further inland than it now is. That means that about 3,900 feet or three-fourths of a mile of coastline will be lost. The beaches we now visit will be underwater and much of the land area of Rhode Island would be greatly reduced. Additionally, your students should have noted these consequences of rising ocean water: houses and businesses flooded; property destroyed; docks, roads, and bridges underwater; well water contaminated with salt water; and wetlands flooded or submerged resulting in loss of nursery areas for commercially fished species.

**Approximate time**: One to two class periods

**Target audience**: Science.

**Extensions**:

**<u>Grades 4- 6</u>**

1. Give students a map of Rhode Island. Have each student mark on the map the town they live in. Depending upon the grade, have students complete research to find out how many feet above sea level their town is. (The teacher may have to find this information for them.) Ask students to describe their neighborhood. Are there any rivers or streams nearby? Do they live near the ocean? What type of buildings do they live near? Have students draw a map of their house and the land and environment around it (ex. forest, pond, shopping mall, etc). Ask students to imagine what would happen the water in the ocean or in the nearby rivers or streams overflowed their banks. How would this affect their community? What problems would occur? Help students realize that many things would be effected. The sewer system, drinking water, plants and animals, and buildings would all be affected. If they live near the ocean how would the rise in sea level affect the coastline? What features of the coastline would be underwater? What organisms would be affected by the rising sea level? After the students have finished this activity, now have them imagine that they live in the Midwest, perhaps near the Mississippi River. Compare the sea level in the Midwest with that of Rhode Island. Would this area around the Mississippi River be affected by sea level rise?
2. Ask students to imagine what it would be like if the Mississippi River overflowed its banks. What would some of the results be? Try to find pictures of the Midwest during one of its

recent flooding seasons. Reinforce to students the connection between global warming and the rising sea level. Students need to understand this important concept.

3. Have students write poems or stories about what it would be like to live in a place that has experienced a rise in sea level. They should also include what they think could be done to help prevent something like this from occurring (global warming solutions).

**Grades 9- 12**

1. Students or those experienced with laboratory work can do the thermal expansion experiment themselves. Have them set up a test tube and place it in warm water and record the volume change data. They can then graph their results.
2. Students can also prepare 30 ml of 0.63 M NaCl solution in water to simulate natural sea water. Place the solution in a small graduated cylinder and measure the volume carefully by reading the meniscus. The temperature should be measured using a 0- 100° C thermometer after the temperature reading has stabilized. Temperature should be recorded. Students should heat 100 ml of tap water in a 250 ml beaker over a Bunsen burner for one minute. While the water is heating, the graduated cylinder containing the salt solution should be transferred to a medium test tube fitted with a one-hole stopper. The solution level should be marked with a grease pencil holding the test tube as level as possible. At the end of one minute, the water temperature of the beaker should be recorded and the Bunsen burner temporarily moved to the side. The test tube should be inserted into the water, allowed to remain in the warm water for several minutes. The new water level in the test tube should be marked with a grease pencil. Several more measurements should be taken. Repeated heatings of the beaker water will produce a variety of temps. Resulting in many expansion changes which will be recorded on the test tube using the grease pencil. When sufficient measurements have been taken, students should empty the test tube and replace with tap water to the level of the indicated markings, measuring the volume of the test tube at each grease pencil mark. Students as a class will share data, to be calculated by the teacher and recorded on the board. Students will graph class data for thermal expansion as temperature versus volume for seawater. Students should answer some or all of the following questions as applicable.

   Questions

   a.) Is the relationship between temperature and volume a direct relationship? Why or why not?

   b.) Using the first measurement taken during heating, predict the new volume of the test tube for a 3° increase in temperature.

c.) The new volume predicted from question 3 is a what percent increase in volume from the original?

d.) Is it possible to drive an equation for thermal expansion from class data? Explain.

e.) Develop an equation for thermal expansion of seawater.

f.) Calculate the molarity of seawater if seawater is 96.53% water, 3.47% dissolved salts.

3. Research an area like the Netherlands where rising sea level has already had an effect.
4. Use an atlas or world map and list the cities that would be endangered by rising sea level.
5. Have students examine the greenhouse gas information sheet. Have the student's research each of the gases listed. Have your student's research the gases to find their chemical formulas, then write and balance chemical reactions for each of the gases produced.

## Greenhouse Gases Information Sheet

Since the beginning of the industrial revolution, human activities have led to increased amounts of greenhouse gases. The major types are discussed below:

1. **Carbon dioxide-** A gas released when fossil fuel (gasoline, coal, wood, natural gas, heating oil) is burned. Carbon dioxide is also a waste product of respiration- humans exhale carbon dioxide with every breath we take. Organisms release it as they decay or as materials burn. Plants and other organisms that photosynthesize (use sunlight and carbon dioxide to make sugar) take in carbon dioxide. Until humans started burning large amounts of fossil fuels for their machines and to make electricity, the amount of carbon dioxide taken in by plants balanced out the amount released by organisms. Since then the balance is way off– the amount of carbon dioxide in the atmosphere is now 25% more than it was before the industrial revolution and it has increased markedly in the last few decades.

2. **Water vapor-** Water in its gaseous form (water vapor) is the most abundant greenhouse gas. The amount in the atmosphere depends upon the temperature. The hotter it is, the more liquid water evaporates and becomes gaseous water. When the temperature is cooler, there is less water vapor in the atmosphere.

3. **Methane-** This comes from natural gas wells and leaking gas pipelines. It is also a waste product of some types of bacteria and is released from rice paddies, cows, termites, garbage rotting in landfills, and wetlands.

4. **CFCs or chlorofluorocarbons-** These chemicals were invented as refrigerants for refrigerators and air conditioners. They were also used as solvents to clean electronic parts, in aerosol spray cans, and in Styrofoam-making processes. Each CFC molecule can absorb several times as much heat as a carbon dioxide molecule. When the CFC molecules drift far up into the atmosphere, they destroy molecules called ozone. Ozone absorbs dangerous ultraviolet rays from the sun. Nations have agreed to stop making CFCs, but they are still in the atmosphere and will continue to be there for many decades to come.

5. **Nitrogen and sulfur oxides-** Car and factory exhaust, agricultural fertilizers, and volcanoes release these chemicals. These gases are not as plentiful in the atmosphere as the other greenhouse gases.