EDUCATOR'S GUIDE

TABLE OF CONTENTS

INTRODUCTION

Welcome to the *Angkor: The Lost Empire of Cambodia* Guide for Educators

Mention "Angkor" and many people will nod knowingly and respond, "Oh yes, Angkor Wat." While the temple is an amazing feat, few know that Angkor was a bustling city in the Khmer Empire. Between the 9th and 15th centuries, it spanned an area larger than current day Los Angeles and featured an extensive water system that represented the engineering capabilities of the people who lived there.

This educator guide helps students dig deeper into some of the science, engineering, and culture that represent both ancient and modern-day Cambodia. Students have opportunities to engage with the work scientists do to learn about the people of Angkor, examine how climate affected life during the city's prime and today, and begin to understand the importance of water to communities.

Although the educator guide is best paired with the film ***Angkor: The Lost Empire of Cambodia***, it offers a valuable learning experience for all students. Geared toward students in grades 3 through 8, the guide offers the flexibility and extensions to adjust the activities for different levels. Where relevant, we have connected the appropriate Next Generation Science Standards (NGSS), Common Core English Language Arts (ELA), Common Core Mathematics, and geography standards. This can help educators align the activities with learning objectives.

The activities use student-driven inquiry to ensure that students are curious and motivated to learn. Inquiry helps students develop the habits of mind to think critically and work toward solutions. Phenomena and problems serve as the basis for the activities, ensuring that students can track learning as they work through an activity by accomplishing a goal or being able to explain their ideas.

By using this educator guide, you can engage your students with content that they might not otherwise experience while still addressing standards and practicing important skills. Learning about Angkor helps students understand more about the universal challenges and successes all humans face and they do so while considering new perspectives, ways of thinking, and technologies.

We hope you and your students enjoy discovering more about ***Angkor: The Lost Empire of Cambodia***.

BACKGROUND INFORMATION

Angkor was a city that flourished between the 9th and 15th centuries. It was the capital of the Khmer Empire with an area larger than current-day Los Angeles. Today, it is an important archaeological site located in northern Cambodia.

Many people have heard of Angkor Wat, one of the temples in the city, which was built in the 12th century. The city also had an extensive water system, walls that surrounded the city, and a grid organization. While the city was large and well-populated, by the 15th century, it was basically abandoned. Scientists and archaeologists have worked to learn more about what happened to cause this vibrant city to collapse.

Monsoons

One idea about the collapse of Angkor is changing climate patterns. Southeast Asia is affected by monsoon seasons. While many people often call the heavy rains the "monsoons," it is important to realize that monsoon refers to shifting winds. There is a dry monsoon and a wet monsoon season. In Angkor, there were several years of heavy rains followed by years of serious drought. This pattern continued for several cycles.

When this happened, it affected life in Angkor by damaging infrastructure. For example, archaeologists have found evidence of the water system being rerouted, presumably to try to fill particular reservoirs. In addition, they have found canals that are filled with sand and soil. The layering of the materials indicates that the canals filled quickly in the same way it would if dry land was affected by sudden floods that led to severe erosion.

Evidence from Tree Rings

There are multiple lines of evidence that these cycles of drought and flooding happened during the time of the Khmer Empire. One type of evidence is from tree rings. Each year, a tree grows a new layer around its trunk. If a tree is cut down, the rings show how many years the tree lived. The thickness of this layer depends on how much water is available. When there is plenty of water, the new layer is thick while in dry years it is thin. Analyzing tree ring data has helped scientists know that there were two major drought periods in Angkor in the 14th and 15th centuries. Each of these droughts lasted for decades.

Evidence from Cave Formations

Data from cave formations is another important line of evidence. Stalactites and stalagmites are structures that form very slowly. They result from rainwater picking up carbon dioxide from decaying organic matter, seeping through limestone and picking up calcite, and dripping into caves. Once in the cave, the carbon dioxide is released, which causes the calcite to precipitate which stays as a deposit in the cave. As water continues to drip, the calcite builds up, leading to cave formations.

The climate of an area affects the formations. When it is very hot, plants and animals that have died decompose more rapidly. This leads to more carbon dioxide for water to pick up. When it is very wet, there is more water, which leads to a thicker layer of deposits.

By analyzing samples from cave formations and comparing them to other local caves, scientists can see what the climate was like over a period of time.

Life in Angkor

Archaeologists have been able to glean some information about what life was like in Angkor before its collapse. One way they have gotten information is through artifacts found during archaeological digs. They have found that temples were the center of a community with living areas surrounding the temple in a grid. Archaeologists have found evidence, such as bowls, charcoal, and hearth stones to indicate where people were living and eating. Decorative bricks often show where temples were located. Flat stones made floors for housing areas, so when archaeologists find those, it often indicates a housing area.

Light Detection and Ranging (LiDAR) is a technique that uses laser measurements taken from an aircraft to make an image of an area. In LiDAR, laser pulses are sent from the aircraft and the system uses the amount of time it takes to reflect back to determine the distance. Each pulse can provide up to 5 returns, or reflections back to the aircraft. In this way, LiDAR can help to create a three-dimensional image of an area. It also helps to reach remote, heavily foliaged areas so archaeologists know where to focus their efforts.

LiDAR data shows additional evidence of temples in the middle of a community surrounded by a grid of living areas. It also shows small depressions, like little ponds, near each residence. Scientists believe these were areas where a household would store water to use and access even in the dry season. Water was important part of life for people in Angkor as they used it for farming and irrigation, transporting materials, moving through the area in boats, and many other uses. During the heavy rains, flooding would impact the area so houses in Angkor were on stilts. It seems that the people of Angkor were able to balance the seasonal changes caused by monsoon winds. It was only when the droughts and rains became extreme that the city collapsed.

With new technologies, scientists are learning more about life in Angkor and what may have contributed to the disappearance of this vibrant community. In the following lessons, students have an opportunity to explore these lines of evidence and data to learn more about ***Angkor: The Lost Empire of Cambodia***.

ARCHAEOLOGY IN ACTION

Lesson Overview

In this lesson, students have an opportunity to learn about how archaeologists use evidence from artifacts to find out about people and their lives from long ago. They do this by mapping artifacts from Angkor and finding patterns to create a sketch of how Angkor may have looked.

Standards

This lesson helps students develop skills toward the following standards.

Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.
- How to apply geography to interpret the past.

Science elements

- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
- Identify the evidence that supports particular points in an explanation.
- Patterns can be used as evidence to support an explanation.

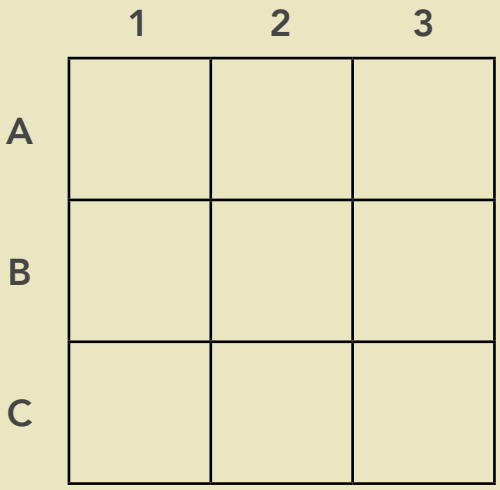
Materials

- ☐ *Archaeologists at Work* pictures
- ☐ *Artifacts from Angkor* cards, see Preparation
- ☐ Butcher paper, optional, see Preparation
- ☐ Marker
- ☐ Tape
- ☐ *Angkor Sketch* handout, 1 copy per student

Preparation

- Plan how to display the *Archaeologists at Work* pictures, either using a projector or sharing printed copies with students.
- Make a copy of *Artifacts from Angkor* and cut apart the cards.
- On the board or butcher paper, draw the diagram in Figure 1. Each square should be at least 9-12 inches.

Figure 1. Diagram for mapping artifacts.



Facilitation

1. Show students the pictures on the master, *Archaeologists at Work*. Tell them, "These are scientists that are working to learn about Angkor, which was established as a city around the year 800 A.D." Give students time to observe the pictures. Ask students to think quietly about what they notice or what they wonder about.

2. Have students join with 3 other students and share what they notice or wonder. After they have had time to discuss their ideas, hold a class discussion about what students think the scientists might be able to collect or learn from their work. It is likely that students will wonder how scientists can learn about a city that was from so long ago.

3. Have the group of 4 students split to be 2 pairs of students. Tell students that they are going to do an activity the same way archaeologists do to see what they can learn about the people who lived at Angkor. Give each pair one of the cards from the *Artifacts from Angkor* card set. Tell them that they are scientists and as they were digging at Angkor, they found the item on the card. Ask them to read the card to learn more about something scientists found. The two partners should discuss the information to make sure both understand.

4. Ask students to notice the letter and number combination in the bottom left corner of the card they received. Then ask them to look at the chart and see if they can determine where the card would belong. Tell them that as a class, they are going to create a type of map to show where scientists found each of the items on the cards.

5. Share that each of the items on the card is an **artifact**, or an object that humans made or used in a historical time. Have each pair share the information from their card. Then have them tape the card in the proper square on the grid. Check the placement of the cards as this step will be key as they look for patterns in the next step.

6. Once all the groups have shared the information on the cards and taped them to the grid, distribute the handout *Angkor Sketch*. Ask students to write down at least 3 observations they see. To help them, you might prompt students with the following questions. Give students a few minutes to work individually, then talk in small groups about their observations.

- Where do you see several similar items close together? What are the items and where do you see them?
- Where do you see different items close together? What are the items and where do you see them?

7. Once students have written down their observations, ask them what they think each piece of evidence means. For example, if students saw that there was a charcoal artifact near a burnt food artifact, they might say that this was a place that people cooked food. You may want to give them a little time to work individually and then discuss ideas with their small groups.
8. Hold a class discussion about students' evidence and what they think each means. Some points that should be included are as follows:
    - The temple was in the middle of this area. Like many Hindu temples, there were 5 towers with one in each corner and one in the middle.
    - The three grid squares on the left show wall stones. Angkor was surrounded by walls, so these show leftover evidence of a wall. There would likely have been a moat outside the wall.
    - There is evidence of houses outside the temple. Examples of evidence can be charcoal, burnt food remains, hearth stones, and flat stones that may have been floors in houses.
    - In B3, there are artifacts, that may have indicated a dump. People in Angkor often had a common area for garbage, such as burnt food remains and broken ceramics.
9. Give each student a copy of master, *Angkor Sketch*, and ask them to sketch their ideas about what Angkor may have looked like, based on the class map. Remind them that the map includes pictures of artifacts and the descriptions, but that they should try to draw buildings and other items to show a more complete picture.
10. Have several students share their sketches, explaining why they included different aspects. Allow students to revise their drawings if they hear new ideas they would like to include.
11. Tell students that the type of scientist who studies artifacts and learns about human history is an **archaeologist**. Archaeologists have been studying the mysteries of Angkor for many years to learn more about the people who lived there and what caused the empire to disappear. They use evidence, such as the artifacts that the students examined, to come up with ideas about how the buildings were arranged or the types of activities that people did.

Extension

Ask students to create a map of their own room or house. Have them imagine what evidence an archaeologist 1000 years from now might use to learn more about them. Students should list at least 5 artifacts on their maps and describe what it might tell a scientist in the future.

Master: Archaeologists at Work

Master: Archaeologists at Work - Image 01

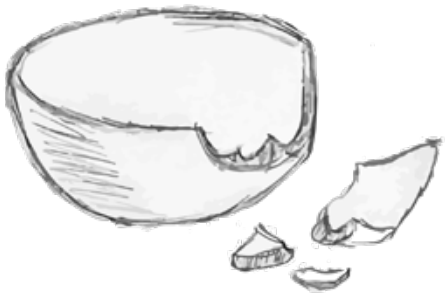
Master: Archaeologists at Work

Master: Archaeologists at Work - Image 02

Master: Archaeologists at Work

Master: Archaeologists at Work - Image 03

Master: Artifacts from Angkor

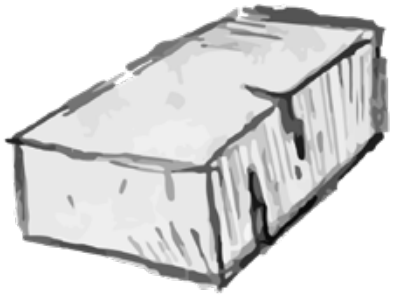


Artifact: broken ceramic bowl
Notes: type of bowl people would eat from
Location: A1

Artifact: flat stone
Notes: often used for floors in houses
Location: A1

Artifact: burnt charcoal
Notes: used as cooking fuel
Location: A3

Artifact: ceramic bowl with burnt food bits
Notes: near broken bowl pieces
Location: A3



Artifact: stone brick
Notes: may have been a hearth stone
Location: A3

Artifact: decorative stones
Notes: Stones like those from temple towers. Found a pile in each corner of B2 grid. Also a pile in the middle of the grid square.
Location: B2

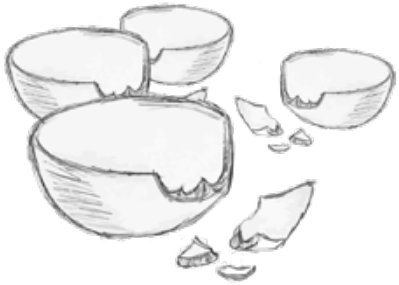
Master: Artifacts from Angkor

Artifact: wall stone
Notes: many stones on the left border of grid square
Location: A1

Artifact: wall stone
Notes: several stones on the left border of grid square
Location: B1

Artifact: wall stone
Notes: few stones on the left border of grid square
Location: C1

Artifact: burnt charcoal
Notes: used as cooking fuel
Location: C1

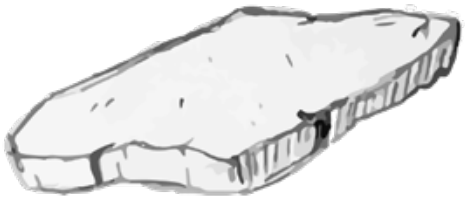


Artifact: approximately 10 broken bowls
Notes: may have been a dump between houses
Location: B3

Artifact: many different types of burnt food, some attached to broken bowl pieces
Notes: may have been a dump between houses
Location: B3

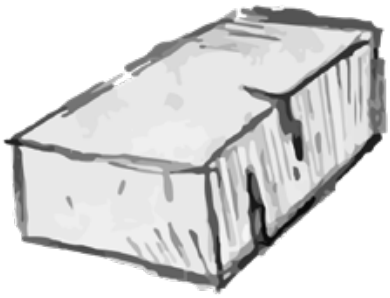
Master: Artifacts from Angkor

Artifact: burnt food remains from many meals
Notes: may have been a dump between houses
Location: B3



Artifact: flat stone
Notes: often used for floors in houses
Location: C3

Artifact: ceramic bowl with burnt food bits
Notes: near broken bowl pieces
Location: C3



Artifact: stone brick
Notes: may have been a hearth stone
Location: C3

Master: Angkor Sketch

Evidence: What I see	What I think the evidence means

Sketch of Angkor

A1	A2	A3
B1	B2	B3
C1	C2	C3

MONSOON SEASON IN CAMBODIA

Lesson Overview

In this lesson, students analyze the average yearly rainfall in Siem Reap, Cambodia, which is a modern-day city where Angkor once was. They have an opportunity to determine when monsoon season occurs using the data. Students then use historical data to determine what the climate was like in Angkor.

Standards

This activity helps students develop skills toward the following standards.

Science

- 3-ESS2-1 Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.

Mathematics

- CCSS.MATH.CONTENT.3.MD.B.3 Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories.

Materials

- *Average Precipitation in Siem Reap* handout, 1 copy per student
- *Tree Rings handout*, 1 copy per student
- *Asia Tree Ring Data* handout, 1 copy per student

Facilitation

1. Tell students, in the film *Angkor: The Lost Empire of Cambodia*, the narrator states, "Life is defined and driven by monsoons. For six months, it's dry. And then, for six months, it pours." Hold a class discussion about this statement and make two charts of student ideas—one for what they know and another for what they want to know.

2. Students may be able to say that monsoons are heavy rains, but they may have this as a question. They also may want to know about the timing of the 6 months of rain. Tell them that you have some data that will help them learn more.

3. Distribute the handout, *Average Precipitation in Siem Reap*. Tell students that Siem Reap is a city in Cambodia where Angkor once was. Have students work with a partner to analyze the graph. To do this, tell students to focus on the question, when is monsoon season in Siem Reap? Ask students to do the following:

    a. Above each bar on the graph, write the number of inches of precipitation for the month.

b. Put a check mark next to the six highest amounts.

c. Make a claim (an answer to the question, when is monsoon season in Siem Reap?) under the graph.

d. Describe the evidence that led to the claim.

4. Ask some students to share their claims and evidence. They should claim that the six months of monsoon season are May to October because those are the months with the highest rainfall. Share that monsoon rains happen most years, so this is part of the **climate** in that area—the pattern of weather that the area has over many (30 or more) years.

5. Ask students, do you think that this pattern of monsoon rains was happening at the time the Angkor empire was at its peak? Students may have different ideas. Tell them that scientists have worked to find out if that was the case.

6. Distribute the *Tree Rings* handout. Ask students to read the information in the handout. You may wish to have them use a reading strategy, such as read-summarize with a partner. Discuss the ideas from the handout as a class.

7. Share that scientists have taken samples from very old trees in Cambodia, where Angkor was. Distribute the *Asia Tree Ring Data* handout. Tell students that they will have a chance to analyze the data as well. To do this, ask students to do the following:

   a. Draw arrows to places that they see trends, or repeating patterns, and extreme peaks or valleys in the data.

   b. For each arrow, have students write a statement describing what they see, or the observation that led them to draw an arrow.

   c. For each statement, have students add what they think the observation means.

8. Discuss the findings as a class. Make sure students see that the graph shows the pattern that some years were wetter, and some were drier. The weather did not consistently get wetter or drier in a linear fashion.

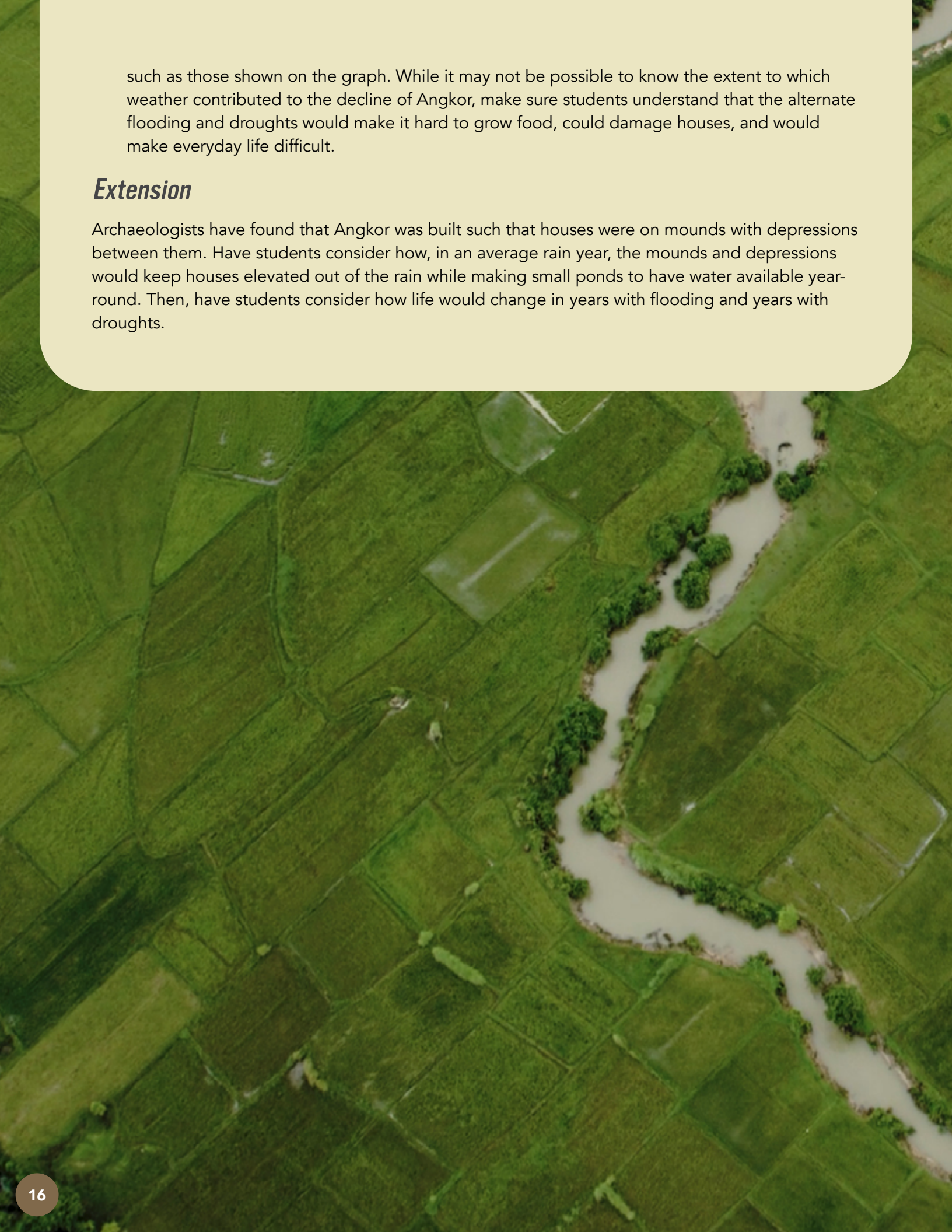
9. Help students refine their observations by focusing them on the highest peaks and lowest valleys to see which years were wettest and driest. Also have them assign years to the observations if they did not already. They should note that scientists found that there were extreme droughts in the years around 1350-1360 and 1400-1420.

10. Share that the graph shows the last 250 years of the Angkor empire. Some scientists think that the climate played a role because it alternated between droughts and flooding. Even today, monsoons can cause water levels to rise by up to 40 feet in the area. Ask students to consider what might happen to houses, farms, and other aspects of everyday life in climate conditions

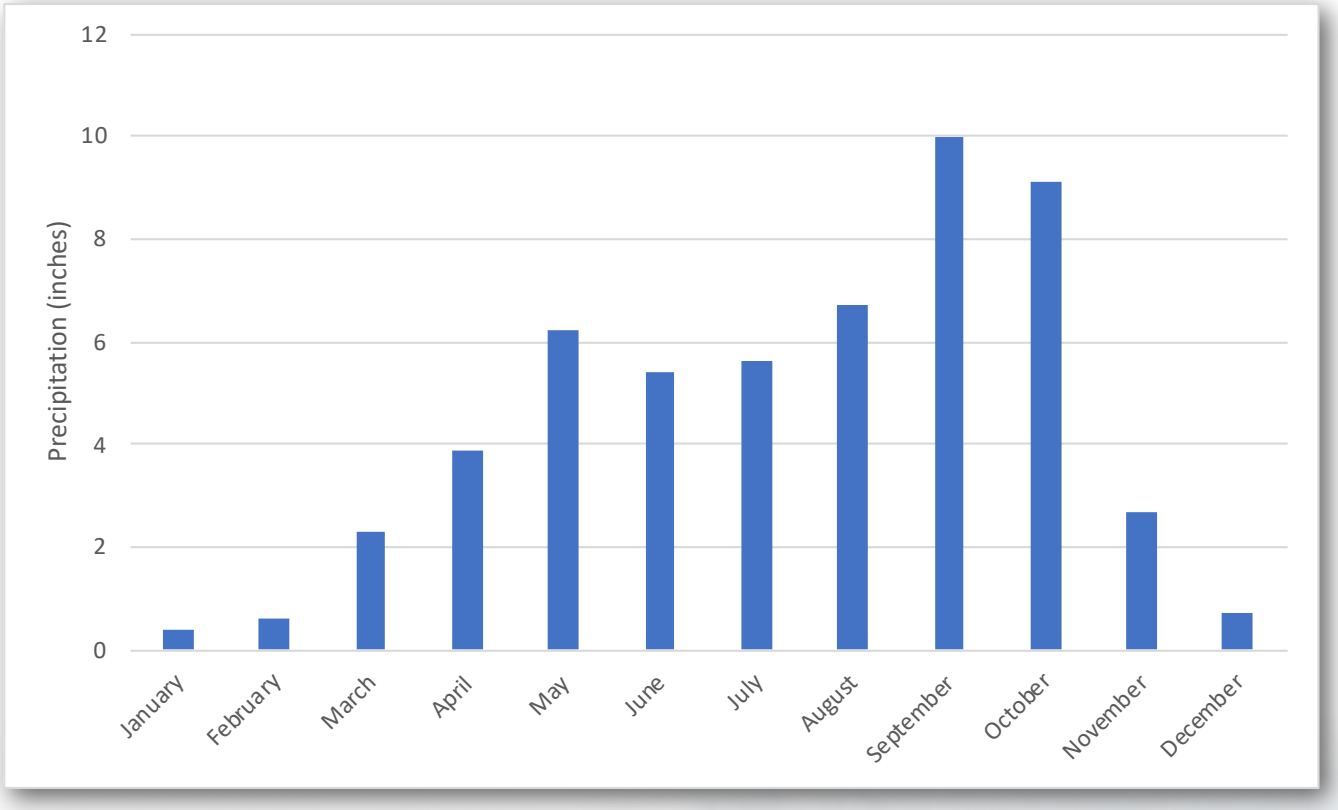
such as those shown on the graph. While it may not be possible to know the extent to which weather contributed to the decline of Angkor, make sure students understand that the alternate flooding and droughts would make it hard to grow food, could damage houses, and would make everyday life difficult.

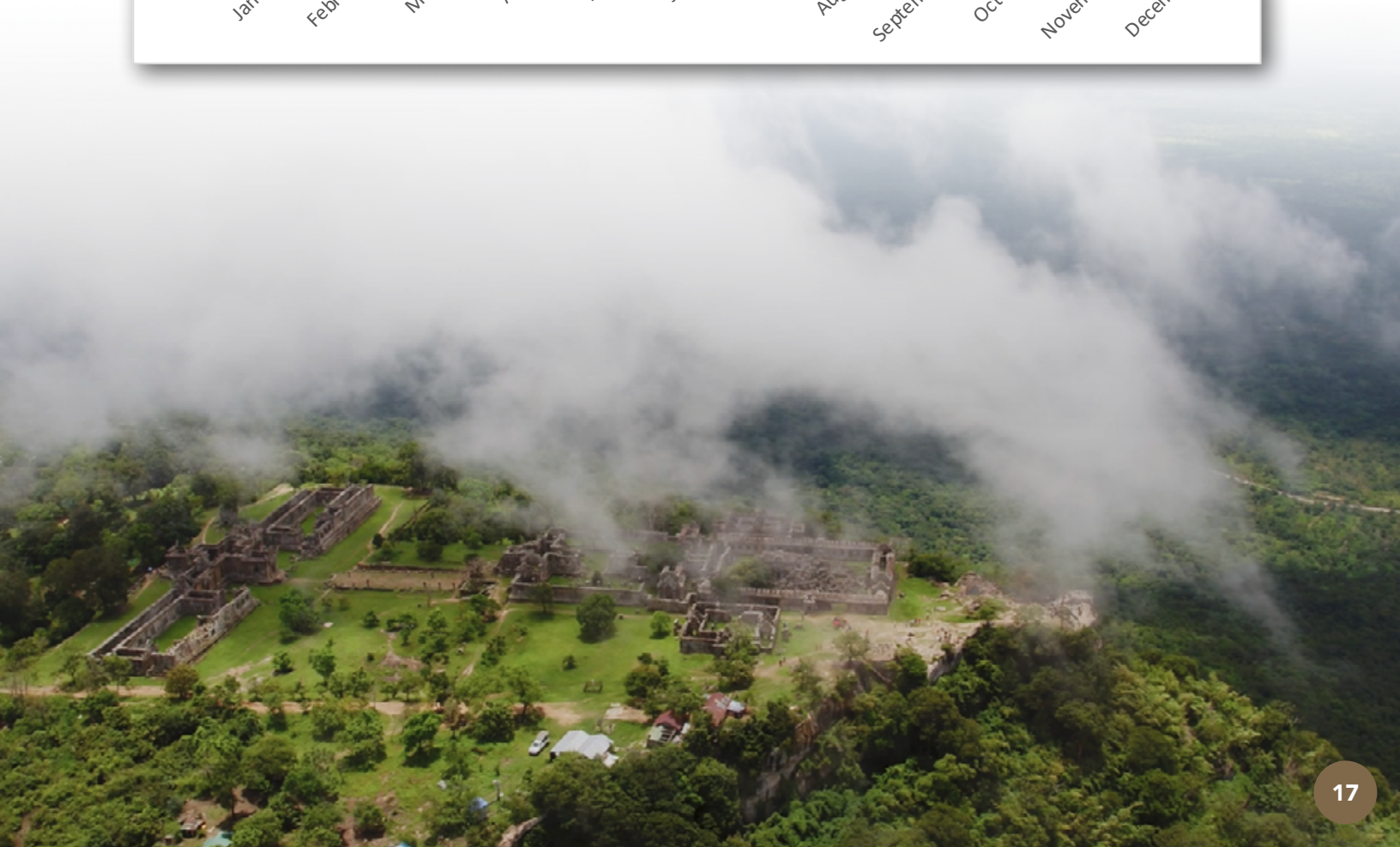
Extension

Archaeologists have found that Angkor was built such that houses were on mounds with depressions between them. Have students consider how, in an average rain year, the mounds and depressions would keep houses elevated out of the rain while making small ponds to have water available year-round. Then, have students consider how life would change in years with flooding and years with droughts.



Average Precipitation in Siem Reap





Tree Rings

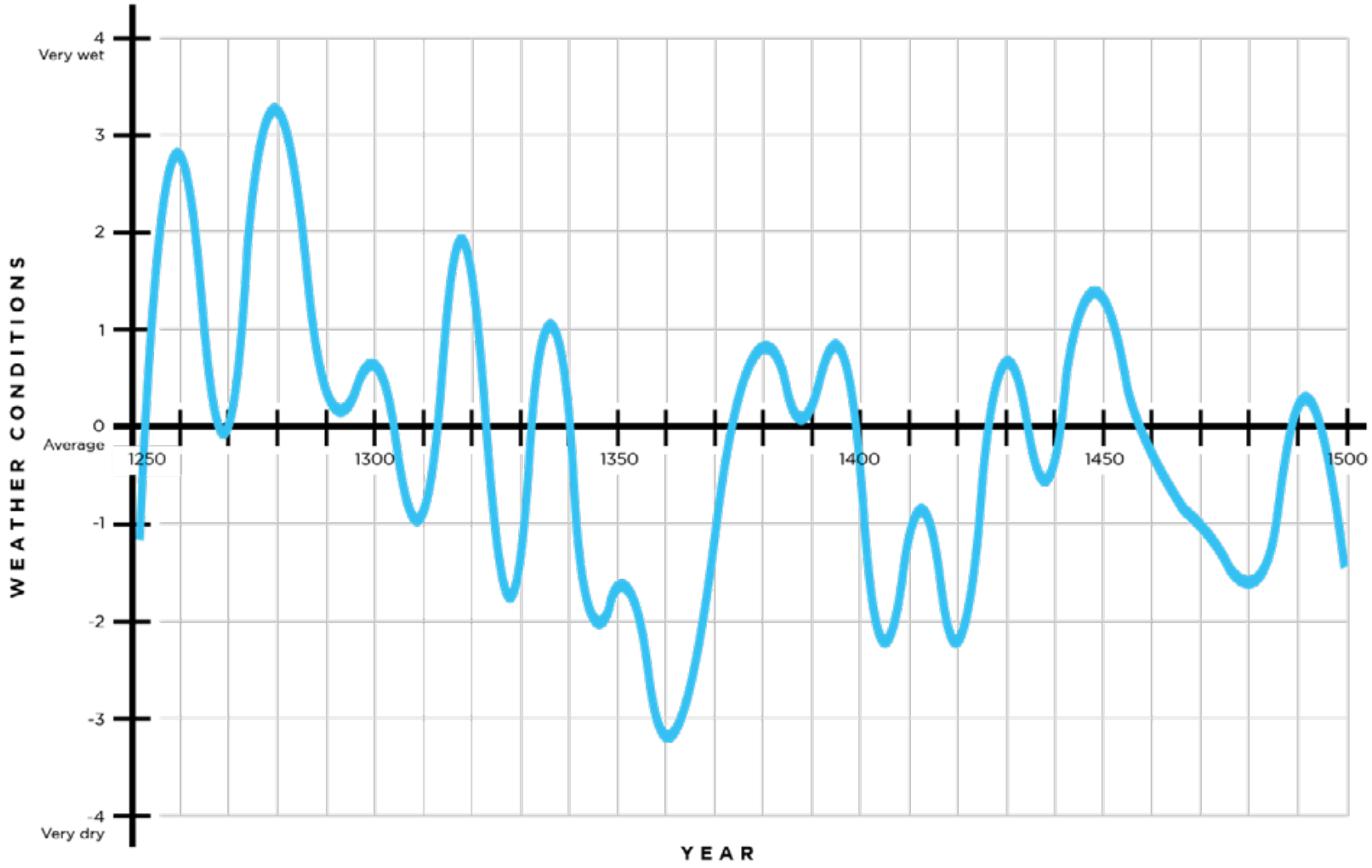
Did you know that trees can tell us how old they are? They can also share some of what they have lived through. They cannot tell us a story. How do you think they might give information?

If you look at the stump of a tree that has been cut down, you can see rings. Trees add a ring each year. If there are 25 rings, the tree is 25 years old.

We can get more information from the rings on a tree. When there is plenty of water, the tree can make plenty of food. This makes a thick tree ring. In years where there is a drought so it does not rain much, the tree cannot make as much food. The tree ring for that year is thin.

Scientists can learn about the weather from many years ago using tree rings. They use a special kind of drill. It lets the scientists take a small piece of the tree all the way across the trunk. It does not hurt the tree. From this, scientists can count the rings and see how thick they are. This tells them which years had a lot of rain and which years had a drought.

Asia Tree Ring Data



LETTER FROM A NEW FRIEND

Lesson Overview

In this lesson, students read a letter from a fictional child in Cambodia. They learn information about her life and compare to their own lives. Students then write a letter to share about themselves.

Standards

This activity helps students develop skills toward the following standards.

Geography

- How culture and experience influence people's perceptions of places and regions.

English Language Arts

- Use information gained from illustrations (e.g., maps, photographs) and the words in a text to demonstrate understanding of the text (e.g., where, when, why, and how key events occur).
- CCSS.ELA-LITERACY.W.3.2.A Introduce a topic and group related information together; include illustrations when useful to aiding comprehension.
- CCSS.ELA-LITERACY.W.3.2.B Develop the topic with facts, definitions, and details.
- CCSS.ELA-LITERACY.W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic (Extensions).

Materials

- ▫ *Letter from Cambodia* handout, 1 per student
- ▫ *Venn Diagram* handout, 1 per student

Facilitation

1. If students have seen the film ***Angkor: The Lost Empire of Cambodia***, ask what they think life is like in Cambodia. Accept any ideas that students have.
2. Share that you have a letter from a child in Cambodia that you want to share with them. Distribute copies of the handout, Letter from Cambodia. Have students read the letter using an appropriate reading strategy.
3. When students have finished reading the letter, distribute the Venn Diagram handout. Tell students that you would like for them to think about Li Peou's life and compare it to their own.

If students have never done a Venn diagram before, share that it is a way to compare and contrast items. They should write shared interests or ideas in the overlapping area. Interests or ideas that are unique to Li Peou should be written in the circle with her name and interests or ideas that are unique to the student should be put in the circle labeled "you."

4. Once students have had time to complete their Venn diagrams, you may wish to have them share in a small group.

5. Tell students that you would like for them to write a letter back to Li Peou to tell her about themselves. They should notice that she organized ideas in paragraphs by topic and that they should do the same. They may want to use the information on their Venn diagrams to ensure they are including information similar to what she shared with them. Remind students that she does not know about their lives, so they may need to explain foods, games, or other interests. Consider also asking students to include information such as:

    - who makes up their families,
    - whether they have pets,
    - a map of your location,
    - or other information about their lives.

    This will allow students to not only practice writing letters, but also offers a low stakes way to engage in thinking about social interactions, such as keeping a conversation going.

Extensions

To address additional English Language Arts standards, have students think of something they would like to know about Cambodia or what it is like to live there. Have them do a brief research project to learn more and then include it in their letter or present it to the class.

Dear Friends,

My name is Li Peou and I live in Cambodia. Li is my family's name and Peou means "youngest daughter." Do you know where Cambodia is? It is a country in Asia, near Thailand and Vietnam. I have put 2 maps in my letter for you to see.

I am 9 years old. I go to school every day. In school, we study several subjects. Khmer is our language class. We also study math, science, and social studies. We learn about physical education and health, too.

I live far outside the city in a rural area. Most of the time we eat rice and fish for our meals. We add mint, lemongrass, ginger, or red curry paste to it to make it taste good. My parents like to add hot peppers, too. There are a lot of people here who grow bananas, mangoes, and papayas so we eat those fruits often.

Our village has a television that we can watch sometimes. I like to play games outside with other children. My favorite is Chab Kon Kleng. It is a game of chase where one person is a crow. Another person is a hen who protects her chicks who are all the other players. We cheer for football (but I think you call it soccer there). I also like playing badminton.

I want to learn about where you live, too. Please write back soon!

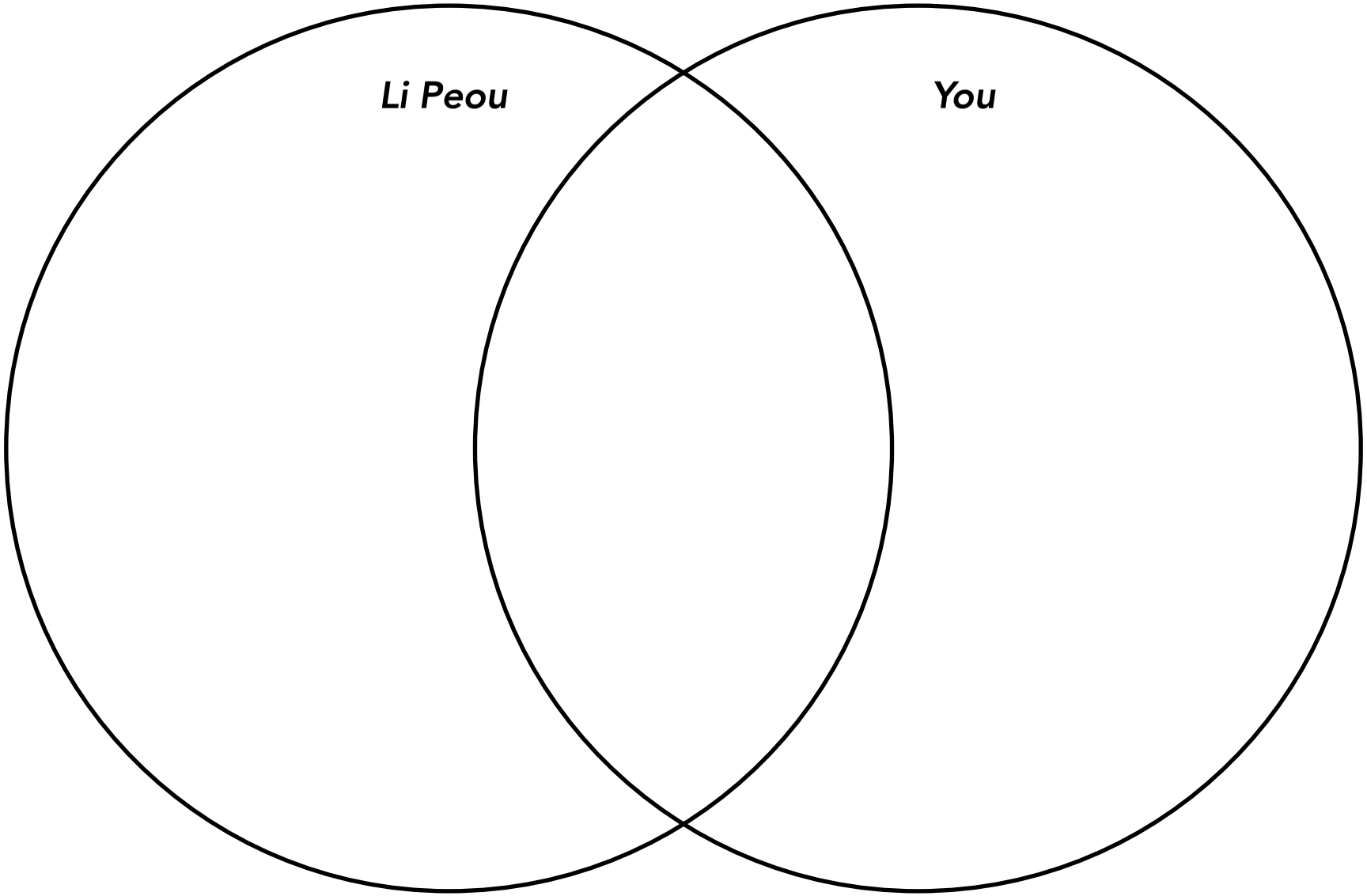
Your new friend,

Li Peou

World Map

Indochina Peninsula

Venn Diagram



FLOOD ENGINEERS

Lesson Overview

In this lesson, students consider what makes a house well-equipped to withstand seasonal flood conditions. They design houses and test their ideas to learn more about features that help a house stay dry and in good condition during a flood.

Standards

This lesson helps students develop skills toward the following standards.

Geography

- How to analyze the spatial organization of people, places, and environments on Earth's surface.
- How physical systems affect human systems.

Science

- 3-ESS3-1. Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
- 4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth's features.
- 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

Materials

- ▫ *Map of Cambodia* handout, 1 copy per student
- ▫ *Cambodia Dry Season* master, display copy
- ▫ *Cambodia Wet Season* master, display copy
- ▫ Materials to build a model of a house, based on student design
- ▫ Materials to test a house model in a flood, such as a plastic bin and water
- ▫ *Engineering Design Process* master, display copy

Facilitation

1. Distribute the ***Map of Cambodia*** handout to each student. Ask students to study the map individually for a few minutes to see what they can learn about the country. After a few minutes, hold a class discussion about their ideas. Any answer they share at this point is acceptable, such

as seeing that there are mountains or that the western side of the country is a coastline. Make sure that students notice the following points:

- There are several rivers in the country.
- There is a large lake called Tonlé Sap. These words are often translated as "great lake."

2. Share with students that Angkor was just north of Tonlé Sap. Ask them to mark where Angkor would be on their maps and label it.

3. Display *Cambodia Dry Season* for students. Have them compare their maps to the image. Ask them to point out anything they recognize between the map and the image, such as the coastline, any of the islands off the coast, or the Mekong River. Make sure that they find Tonlé Sap on the image. Then ask them to point out where Angkor would be.

4. Ask students to mark up their maps to show areas that seem to be forested or sandy. This step helps them to create a better mental model of Cambodia by drawing information from two different types of representations. Remind them to use the features they have identified to help them with accuracy as they complete this step. You may wish to have them develop a legend with symbols, such as triangles for areas that seem to be forested. In general, the plains around Tonlé Sap are sandy and many rural regions are tropical forests.

5. Display *Cambodia Wet Season*. Share that during several months of the year, starting in the fall, Cambodia experiences monsoon rains. Monsoon refers to a shift in the direction of the strongest winds in an area. This leads to a wet season and a dry season. Ask students to examine the image and talk in small groups about what changes during the wet monsoon season.

6. Students should notice that the area around Tonlé Sap and the rivers in the south part of the country flood. Have them add a rough outline of the flooded area to their map. Make sure that they notice the flood waters extend north of the lake and would have covered Angkor.

7. Ask students to brainstorm about what they would do if they knew the area where they lived was going to flood for several months each year. Have them share their ideas in a class discussion.

8. Some students will likely mention ideas to protect houses. Tell them that for the rest of this lesson you will be focusing on the idea of how to build houses that can withstand flooding several months of the year.

9. Ask students to work in their small groups to discuss what features a house might need to have if it is going to be in an area that floods. After they have had time to talk, hold a class discussion. You may wish to have students contrast a flood during a rainy season, where the flood waters rise and stay high for a period of time, compared to floods during a hurricane, where a house must withstand wind, rain, and possibly crashing waves.

10. Have students work in their small groups to design a house to withstand several months of rain and flooding. Encourage them to be creative in their approaches while still remembering that they need something that would be realistic to build. For example, it would be difficult to design a retractable dome that extends over the house and keeps it safe during a flood. That would also make it difficult for people to leave and go about their daily activities.

11. Once students have their design ideas, have them draw and label a "blueprint" of the design. Offer them graph paper if they would like to use that for their drawings.
12. Have groups present their ideas. Other students in the class should listen and ask questions or offer constructive feedback. Give groups time to revise their ideas based on the questions and new ideas.
13. Decide if you would like to have each group test their designs or if you would like to have the class work together to build one design. If you will only build one design, you may wish to have students vote on the one they think would be most effective or to work as a class to add in the best features from each of their group designs. Once you have established whether you will build as a class or in small groups, have students brainstorm the materials they will need to build a model that will allow them to test their ideas. On the other hand, a house that floats might work well. Guide them to materials that you can obtain easily. You may also wish to have them design how they will test the water rising, such as slowly pouring water into one side of a plastic bin with the house in the middle.
14. Discuss how the class will know if the design is successful. Students may say that the inside of the house stays dry, the house does not fall apart, and other ideas.
15. Obtain the materials that students will need for the design test. Test the design(s) using the method the class established. Ask students to take notes on their observations during the test.
16. Have students consider how they could improve the house design to address any issues or questions that arose during the test. If possible, allow them to revise the model and test again.
17. Display the ***Engineering Design Process*** master for students. Tell them that they have been working as engineers to design a house to withstand floods during monsoon rains. Ask them to discuss with their small groups how they completed each step of the process during this activity.

Master: Map of Cambodia

This map is provided by FreeWorldMaps.net
https://www.freeworldmaps.net/asia/cambodia/map.html

Master: Cambodia Dry Season

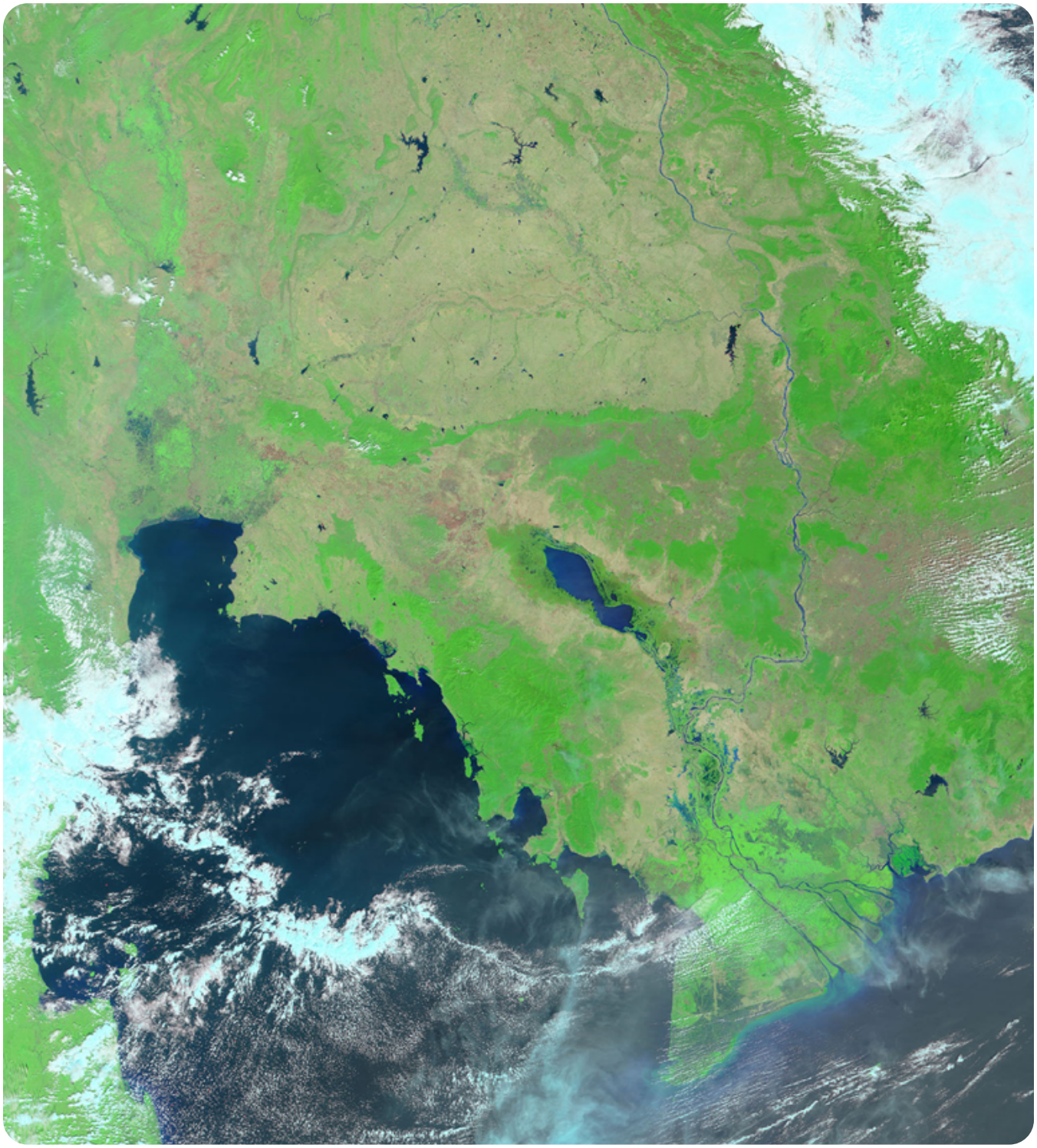


Image courtesy Jesse Allen, based on data from the **MODIS Rapid Response Team** at NASA GSFC

Master: Cambodia Wet Season

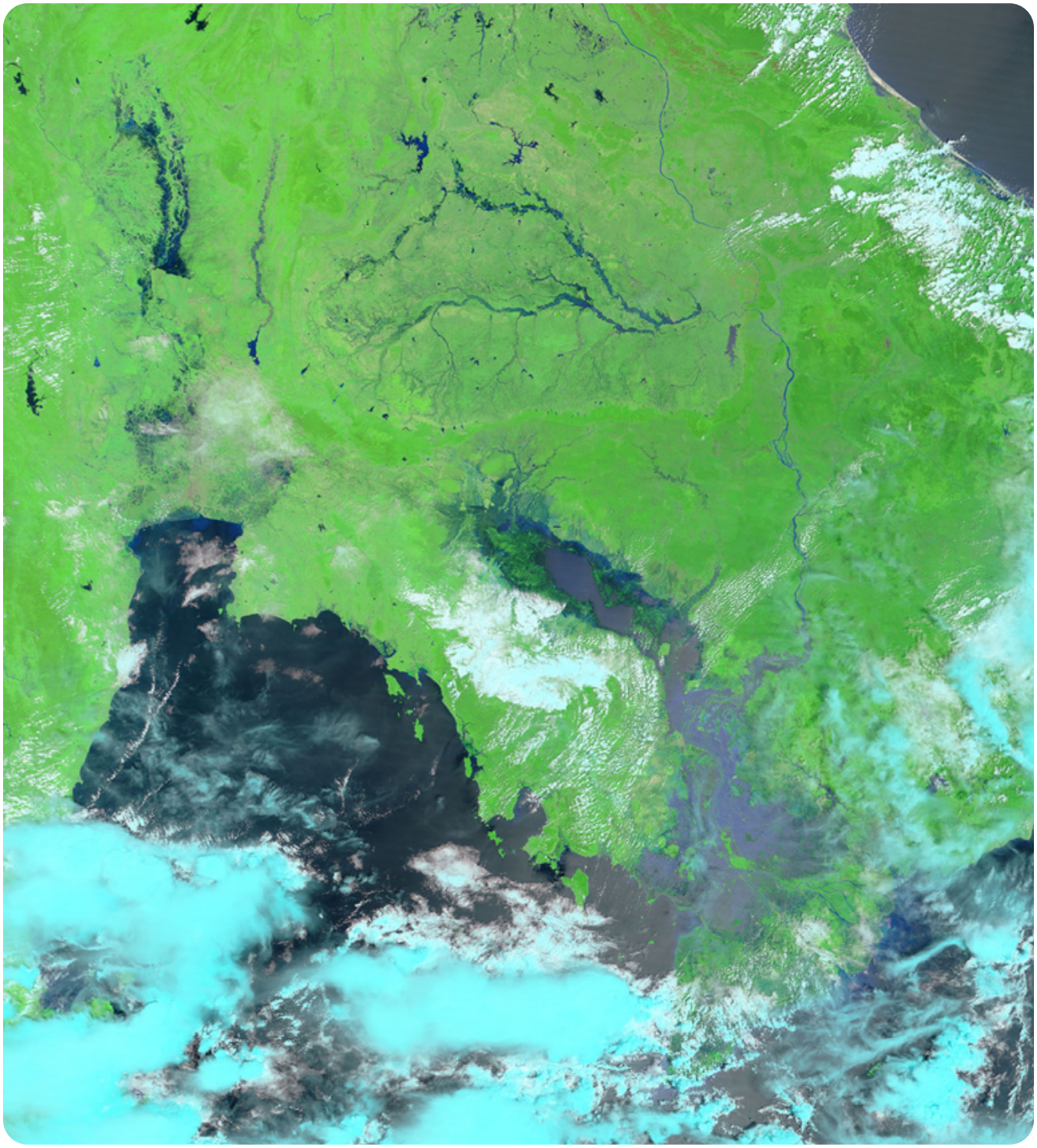
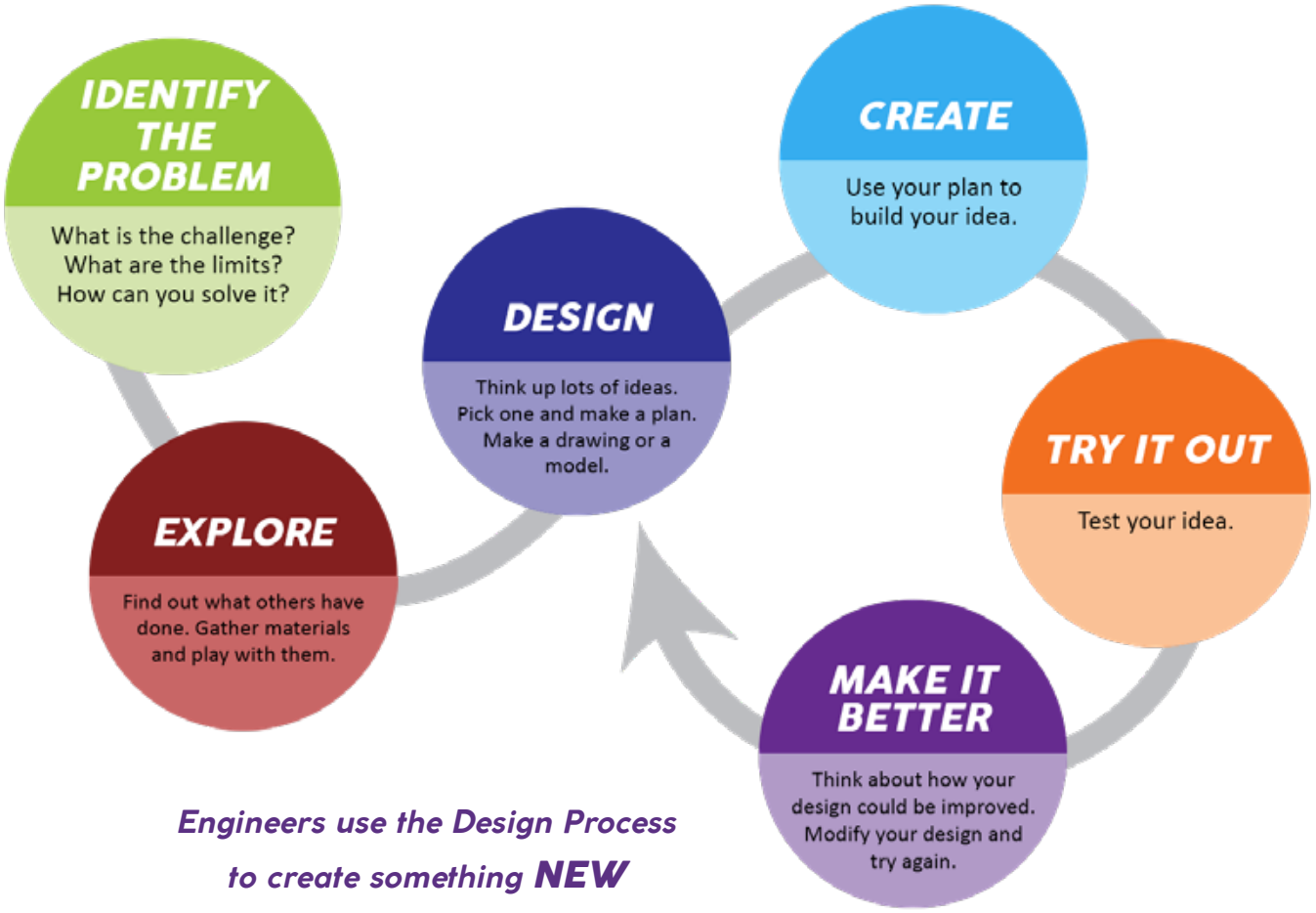


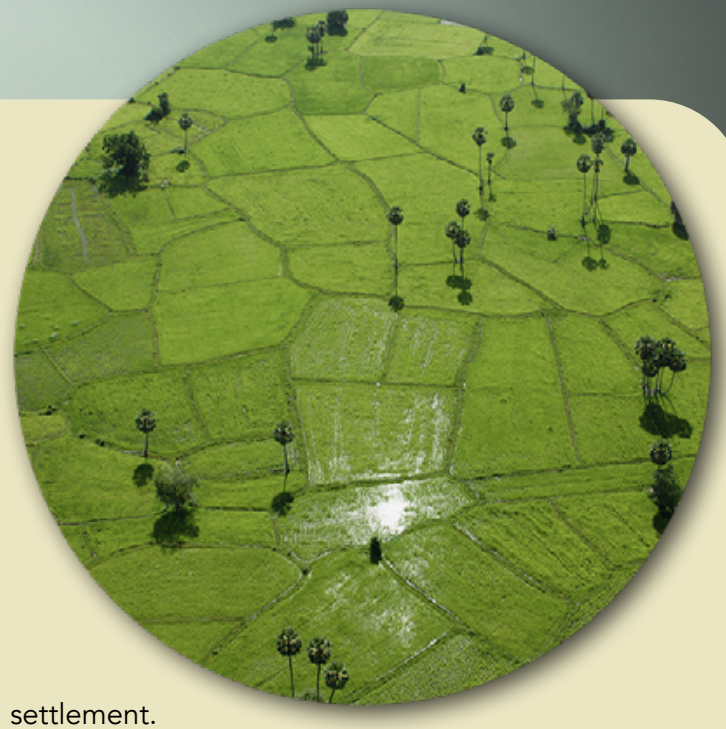
Image courtesy Jesse Allen, based on data from the **MODIS Rapid Response Team** at NASA GSFC

Master: Engineering Design Process



Engineers use the Design Process
*to create something **NEW***
*or make something **BETTER***

WATER WAYS



Lesson Overview

In this lesson, students consider the many ways that people use water. They compare the ways that the people of Angkor used water to how people use water today. They consider why cities are often built near water.

Standards

This lesson helps students develop skills toward the following standards.

Geography

- The process, paterns, and functions of human settlement.
- How to apply geography to interpret the past.
- How to apply geography to interpret the present and plan for the future.

Science elements and standards

- Organisms can survive only in environments in which their particular needs are met.
- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Materials

- ▫ *Water Use in Angkor* handout, 1 per student

Facilitation

1. In small groups, ask students to brainstorm all the ways that they use or interact with water in a week. Alternately, ask them to keep a record of how they use and interact with water for a few days prior to beginning this activity.
2. Hold a class discussion to make a well-populated list of ways that the class interacts with water. Ask the class if there are ways that they think others in the community might use or interact with water that could be added to the list.
3. In small groups, have students sort the list into categories. Ask them to begin thinking about which ways are connected, then assigning a name to that category. For example, swimming and canoeing might both fall into a "fun" or "entertainment" category. Allow flexibility for their ideas and tell students that if they think of additional ways that humans interact with water that they may add them.
4. Have each group briefly share their categories and an example or two of what they put into

each one. Tell them to listen carefully to other groups as they will have a chance to revise their own. Once all the groups have presented, give the groups some time to add categories or change their sorting.

5. In the small groups, ask students to think about whether they think the people of Angkor used water in the same ways as they do. Remind students that the Angkorian Empire lasted from the 9th century (around the year 802) to the 15th century. Ask them to mark ways that they think are similar between the ways the people in Angkor used water and the ways the students use water with a star. Have them mark differences in the ways with an X.

6. Give each student a copy of the handout, ***Water Use in Angkor***. Have them work with their groups to fill in the table.

7. Once the groups have had a chance to complete the table, hold a class discussion to talk about the different ways people used water in the past and today. Guide the discussion with questions such as:

    - What is similar between a way that people of Angkor used water and a way people use it today?
    - What is a category of water use that you had in your sorting and that you added to the middle column?
    - Are there any categories of water use that are common today that were not apparent in the handout? Do you think that people would have used water in that way?

8. Ask students if they have ideas about why cities were traditionally established near rivers and lakes. They should understand that water is an important part of daily life and is necessary to live. By establishing cities near water sources, it made it easier to carry out many of the tasks that people did each day, even when there were not elaborate water systems like we have today.

Extensions

Traditionally, we see rice paddies depicted as flooded fields. But, rice does not have to grow in water. Have students research the process of growing rice and why water is often used.

The water system in Angkor provided water for 750,000 people and was an engineering feat that earned a reputation as a hydraulic city. Ask students to research the building and/or organization of the system to learn how it provided food, transport, and water for so many people.

Water Use in Angkor

Way the People of Angkor Used Water	Category of Use	Similar Way that People Use Water Today
In Angkor, people developed irrigation systems for farming. Many farmers grew rice, which is a crop that can grow in water. The people would flood the fields to keep pests and weeds away from the crop.		
Scientists have found reservoirs, called balays, where the people of Angkor stored water they could use in the dry season. People also built small ponds near their homes to store water.		
The lake near Angkor, called Tonlé Sap, is home to many freshwater fish. People who lived in Angkor fished for some of their protein. Today, the lake provides half of modern-day Cambodia's protein.		
In the time of the Angkor Empire and today, water in the Tonlé Sap was considered sacred. 1000 years ago, people carved Hindu symbols into the stones of the riverbed to bless the water as it ran down the mountains.		
There was an elaborate system of canals in Angkor. One way the people used them was to travel to different areas and transport goods from once place to another.		

CLIMATE IN CAMBODIA

Lesson Overview

In this lesson, students have an opportunity to examine data related to the climate in Cambodia. They consider how it has changed and what impact that may have on the people who live there.

Standards

This lesson helps students develop skills toward the following standards.

Geography

- The physical processes that shape the patterns of Earth's surface.

Science

- MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Mathematics

- CCSSI.6.SP.A.2. Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

Preparation

Decide if you would like to conduct the investigation as a demonstration for the class or as a lab with students working in small groups.

Materials

- ▫ *Monthly Rainfall in Cambodia* master, 1 copy for display
- ▫ *Monthly Rainfall in Cambodia Over Several Years* handout, 1 copy per student
- ▫ *Tree Ring Data* master, 1 copy for display
- ▫ 3 plalstic, shoebox-sized bins (demonstration) or 1 bin per group (lab)
- ▫ Soil or sand, enough to fill each bin about halfway
- ▫ Large pitchers, beakers, or bottles, 1 to 3 for the class (demonstration) or 1 per group (lab)
- ▫ Water source
- ▫ *Climate and Its Effect on the Angkor Water System* handout, 1 copy per student

Facilitation

1. Share with students that while it is difficult to know definitively, scientists have some ideas about what may have contributed to the collapse of Angkor. One idea is that differences in the rainy season may have had a role. Tell them that in this lesson they will have a chance to explore some of the data and evidence that scientists have used to develop this explanation.

2. Tell students that the first information they need is about the rainy season. Display the graph on the *Monthly Rainfall in Cambodia* master. Ask students to talk in their groups about when they think the rainy season might be, based on what they see.

3. Hold a class discussion about the rainy season. By the end, students should conclude that the rainy season is the six months from May through October. Ask students if they think that the amount of rain that falls is the same or different every year. Ask probing questions to find out their ideas, such as:

    - How similar do you think the rainfall amounts need to be to be considered the "same"?
    - How different do you think the rainfall amounts might be from year to year?
    - Do you think that some months might have the same amounts of rain each year, while others have different amounts?

4. Tell students that they are going to have an opportunity to analyze data to determine if a given month gets about the same amount of rain each year. Give each student a copy of the *Monthly Rainfall in Cambodia Over Several Years* handout. Assign small groups to look at a particular month across all the years.

    - Students should, at a minimum, use the data table to determine how the rainfall amount varies across years. You may wish to have them create bar graphs if you would like for the students to work on this skill. Alternately, you may wish to have them plot the numbers on a number line.
    - Ask students to describe the data using ideas such as the average, the range, the mean and median, and the shape of the data, if they visualized the rainfall in a way that allows it. You can ask them to add other informal descriptions as well.

    Students should come to understand that across the years, a given month does not get the same amount of rain. Have groups share their analysis for different months and use the discussion to get a feel for whether students are comfortable with the idea that some years get more rainfall than others, based on looking across the months.

5. **Optional.** Students may not be comfortable generalizing that some years get more rain than others. Some may observe a year where the rainfall

amount was particularly low or high and wonder if that was common for all months in the year. If your students are interested in this, ask them to graph the data for the year, similar to the *Monthly Rainfall in Cambodia* graph. This may help them assess whether some years get more rain overall or if the data point was an anomaly.

6. Tell students it is also possible to know if the rains fluctuated year by year or if there were long periods of rainy years followed by many years of drought. To do this, scientists use data from tree rings. Each year, a tree gets a new ring of growth. When conditions are good, with plenty of rain, the ring is thick. When it is very dry, the trees cannot grow as much, and the ring is thin.

7. Display the *Cambodia Tree Ring Data* graph for students. Share that PDSI is a measure of the tree rings and that the information they need is that when the line drops below 0 (negative PDSI), the year was drier and when it is above 0 (positive PDSI) conditions were wetter. Support the students in interpreting the graph by asking questions such as:

    - Where do you see periods where there was a lot of rain? Where do you see periods of drought, when it was very dry? *The top of the graph, above 0, shows when the year was wet. The bottom of the graph, below 0, shows when the year was dry.*
    - Can you tell if some years were a little wetter than average and some were much wetter? How can you tell? *Years that were very wet have taller peaks above 0 than those that were only slightly wetter than average.*
    - Does it seem that one year was wet and the next year dry or did the periods of wet and dry last longer? What is your evidence? *It seems that there would be a period of years that was dry or wet, rather than changing each year. This is evident because the line will be above or below 0 for several years before crossing to the other half of the graph.*
    - Angkor collapsed between 1250 and 1500. What do you see happening as far as the climate during that time? *Students should notice that there were two major droughts during this time.*

8. Ask students what impact they think the wet and dry conditions may have had on Angkor. You will do a demonstration/lab (see the note at the beginning of the "Materials" section in this lesson) to get more information. To set up the demonstration or lab, do the following steps:

    a. Set up 3 bins with soil or sand in the bottom. Do not add any water to 1 bin. Add some water to the second bin to make the substrate a little damp. Add more water to the third bin to represent land that is saturated with water. Make a slope at one end of the bin to represent a landscape. If you are doing this as a lab, students can reuse one bin several times, draining out most of the water for the second setup and some water for the third setup.

    b. Have students sketch the setup

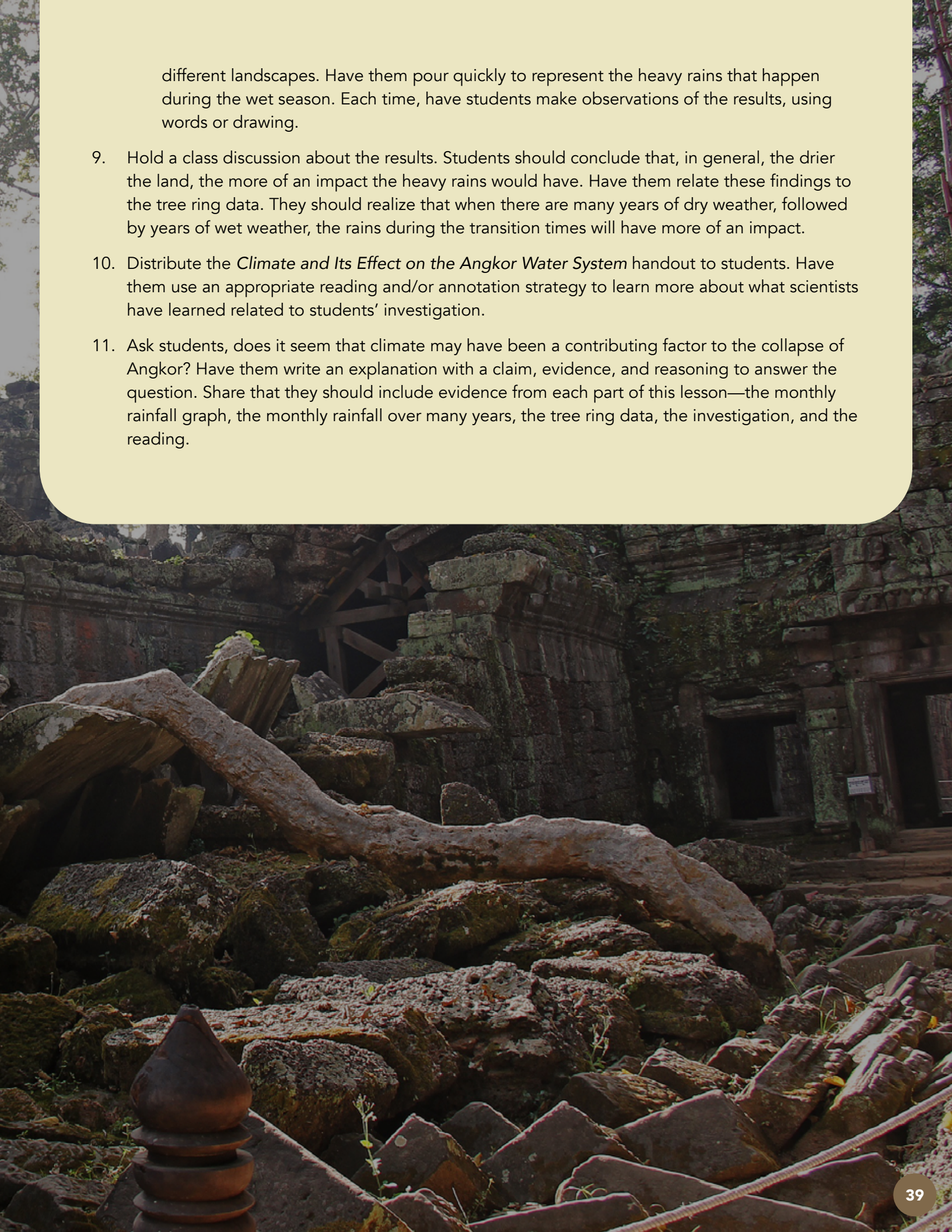
    c. Give students a container with a set amount of water. Students will first pour the water over the three

different landscapes. Have them pour quickly to represent the heavy rains that happen during the wet season. Each time, have students make observations of the results, using words or drawing.

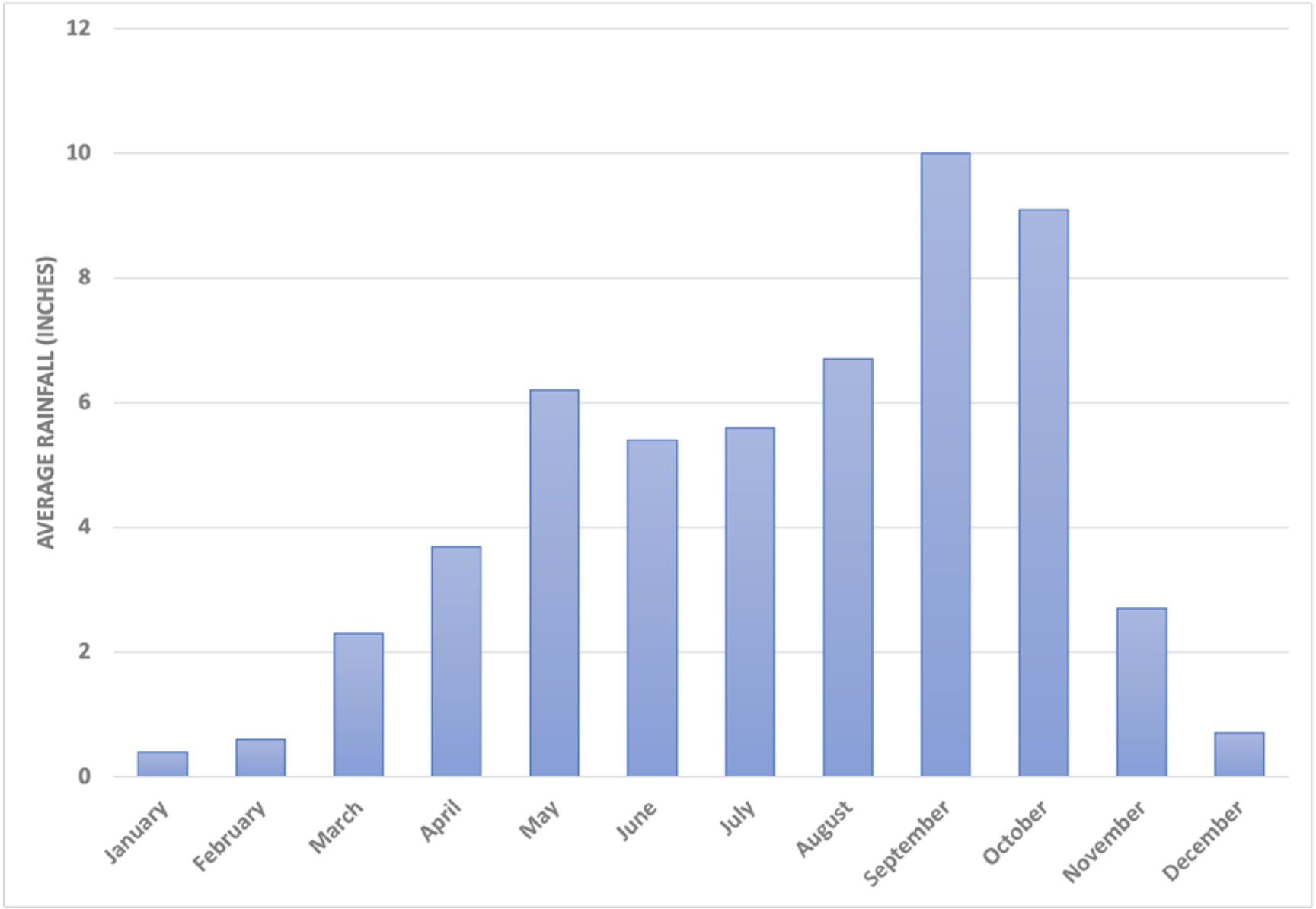
9. Hold a class discussion about the results. Students should conclude that, in general, the drier the land, the more of an impact the heavy rains would have. Have them relate these findings to the tree ring data. They should realize that when there are many years of dry weather, followed by years of wet weather, the rains during the transition times will have more of an impact.

10. Distribute the *Climate and Its Effect on the Angkor Water System* handout to students. Have them use an appropriate reading and/or annotation strategy to learn more about what scientists have learned related to students' investigation.

11. Ask students, does it seem that climate may have been a contributing factor to the collapse of Angkor? Have them write an explanation with a claim, evidence, and reasoning to answer the question. Share that they should include evidence from each part of this lesson—the monthly rainfall graph, the monthly rainfall over many years, the tree ring data, the investigation, and the reading.



Master: Monthly Rainfall in Cambodia

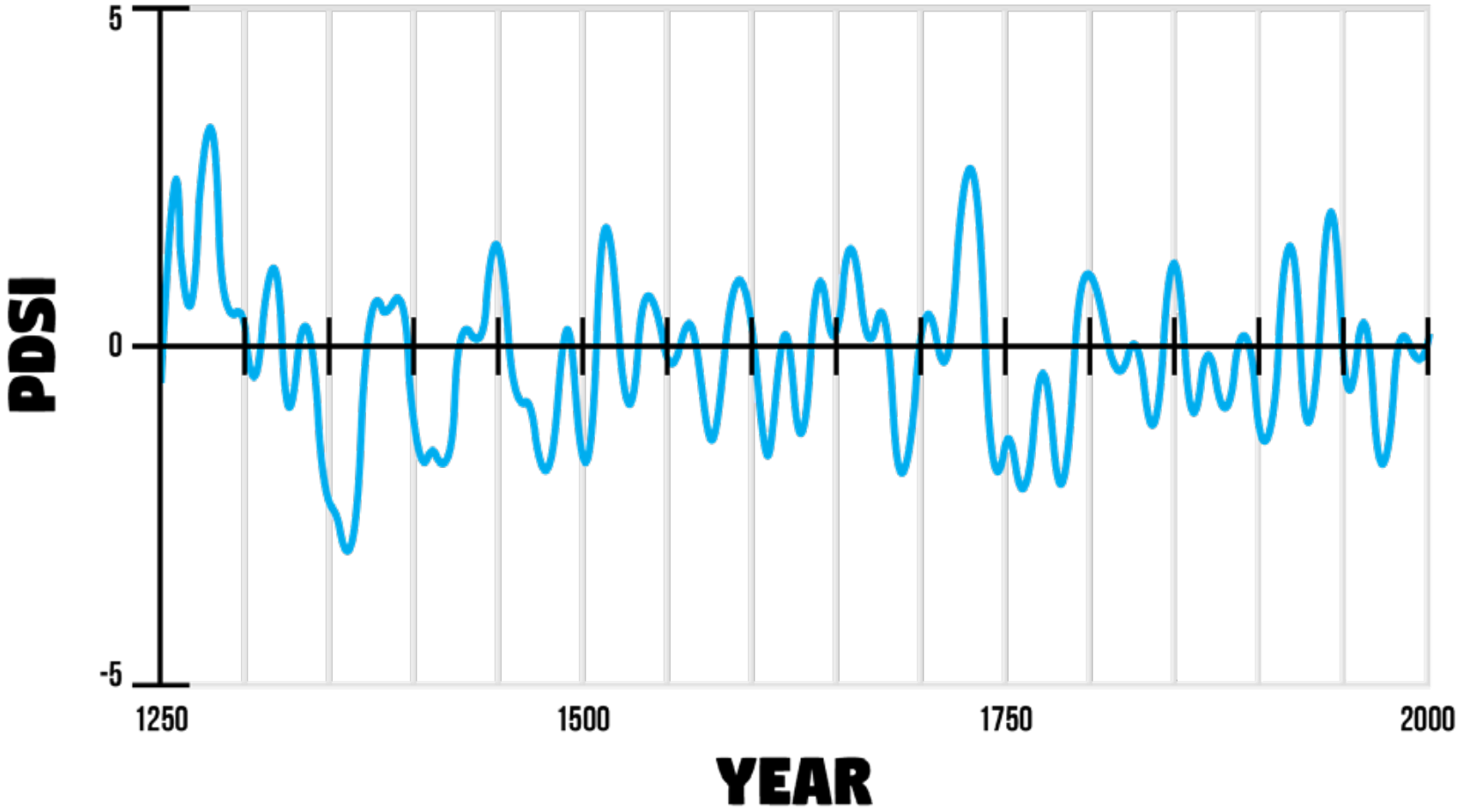


Monthly Rainfall in Cambodia Over Several Years

All data is given in inches of rain.

Month	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020
January	0.57	0.35	0.22	0.12	0.59	0.24	0.42	0.45	0.39	0.91	0.80	0.57
February	0.88	0.26	0.98	0.45	0.85	0.67	1.23	0.44	0.68	1.06	0.82	0.30
March	3.73	1.28	1.35	0.45	1.13	2.20	4.55	1.29	2.59	1.22	1.66	1.92
April	3.19	2.87	2.78	2.33	3.41	1.78	3.02	3.25	2.28	5.64	2.69	2.69
May	7.50	6.41	7.96	7.06	6.76	9.78	7.71	8.75	6.35	9.11	5.49	6.16
June	11.48	10.28	9.56	10.73	11.87	9.91	9.35	13.10	10.10	12.69	9.38	9.90
July	11.10	12.22	9.53	9.19	8.90	9.56	9.93	12.89	14.42	14.35	9.43	10.17
August	13.04	8.84	9.83	11.88	12.12	14.25	15.58	12.67	10.51	14.14	15.56	11.04
September	12.49	11.61	13.46	13.22	13.29	12.07	10.93	13.04	12.96	9.48	9.83	11.80
October	9.39	9.31	5.53	5.32	13.70	13.94	7.44	9.29	11.85	10.57	11.95	15.13
November	4.03	3.19	5.10	3.42	3.63	5.13	3.36	4.09	4.60	1.97	1.94	2.99
December	1.33	1.89	1.04	0.89	0.82	0.63	5.65	0.56	0.46	0.94	1.09	0.95

Master: Cambodia Tree Ring Data



Climate and Its Effect on the Angkor Water System

By the 12th century, Angkor had an extensive water system. It had a web of canals and reservoirs. It connected the main part of Angkor to its suburbs. The water system reached over 1000 km2 of land. With a system this large and connected, it is not easy to make changes. This means that if part of the system is damaged, it is hard to make adaptations.

Scientists who have studied what remains of the water system have found evidence of failures and attempts to fix it. They have also found canals that have filled with sand. Scientists have studied these canals and use one that still exists today as an example.

In this canal, there is coarse sand and gravel. It is cross-bedded, which means it came into the canal all moving in one direction. There are no materials layered in a different direction. This evidence makes scientists think that all the sand came into the canal very quickly, such as in a flood. The scientists have used scientific techniques to determine when this flooding may have happened. Radiocarbon dating shows that it occurred in the 14th century.

This canal filling up would have had serious impacts. It was one of the main canals between the city and a major lake where the people could get water. The scientists have also found sand in other canals from the same time, showing this was a widespread event.

There is also evidence that there may have been water shortages. Certain canals have materials that first narrowed them. Later they were blocked completely to send water through a different canal. This canal ended in the reservoir, so scientists think that the water managers were trying to fill it when there was a lack of water. Although they have not been able to get a specific date for these modifications, they know that people built them after the 13th century.

Adapted from "Climate as a contributing factor in the demise of Angkor, Cambodia." Brendan M. Buckley, Kevin J. Anchukaitis, Daniel Penny, Roland Fletcher, Edward R. Cook, Masaki Sano, Le Canh Nam, Aroonrut Wichienkeeo, Ton That Minh, Truong Mai Hong. *Proceedings of the National Academy of Sciences*, Apr 2010, 107 (15) 6748-6752; DOI: 10.1073/pnas.0910827107.

SECRETS OF THE CAVE

Lesson Overview

In this lesson, students learn about how information from caves can help scientists understand more about what happened in the past. They have a chance to think about how stalactites and stalagmites form and what information scientists can glean from them.

Standards

This lesson helps students develop skills toward the following standards.

Geography

- The physical processes that shape the patterns of Earth's surface.
- How physical systems affect human systems.
- How to apply geography to interpret the past.

Science

- MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
- MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.

Preparation

Print one copy of the *How Cave Formations Develop* master for each small group and cut them apart into card sets. Mix the cards up and keep one uncut copy for yourself as it shows the correct order of cards as you read across each row, then down.

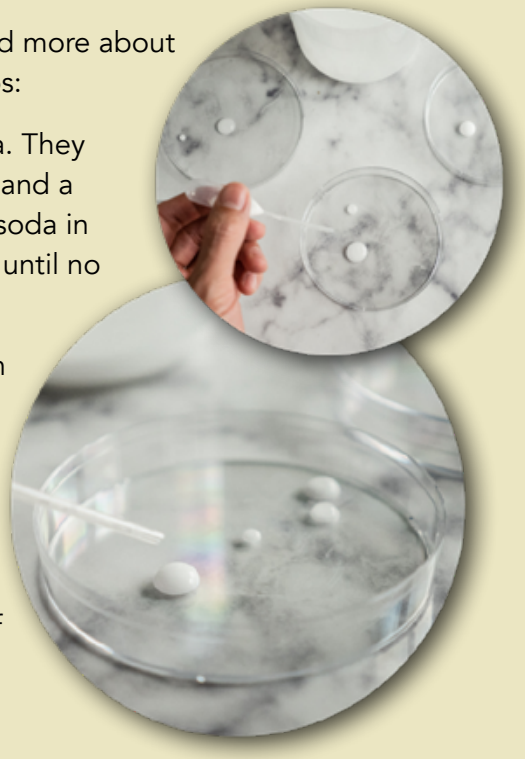
Materials

- ▫ *Cave Pictures* master, 1 copy for display
- ▫ Baking soda
- ▫ Water source, with hot water or a hot plate to heat it
- ▫ Beakers
- ▫ Spoons or spatulas
- ▫ Stir rod or other utensil

- Petri dishes or squares of aluminum foil
- *How Cave Formations Develop* master, cut into card sets, 1 set per small group

Facilitation

1. Tell students that in the movie *Angkor: The Lost Empire of Cambodia*, scientists used information found in caves to learn more about Angkor. Show students the images on the *Cave Pictures* master. Tell them that caves have different kinds of formations, such as the ones in the photos. They take hundreds to thousands of years to form. In small groups, have students discuss their ideas on the process of how the cave formations develop.
2. Share with students that one piece of information in the movie was that there were 14,000 years of climate data in the stalactites of a cave. Ask students to continue talking with their small groups about how that might be possible and how scientists might access the data. Share that at this point this discussion is simply to get their ideas and that they are not expected to know the answers.
3. Hold a class discussion to share what students think they know about cave formations and about how the formations might contain climate data. Create a chart to show what students know and what questions they have at this point.
4. Have students set up an investigation to help them understand more about cave formations. Students should complete the following steps:



   a. In small groups, make a saturated solution of baking soda. They will need a spoon or spatula, beaker, water, baking soda, and a stir rod or other utensil. Students should dissolve baking soda in hot water (hot tap water or water warmed on a hot plate) until no more will dissolve.

   b. Give each small group a Petri dish or a piece of aluminum foil and a dropper. These will need to sit, undisturbed until the next class, so consider if you would like to have students work in an area other than at their desks so they do not have to move the dishes.

   c. Have students make a small drop of the solution on the dish or foil. Then have them place additional drops of different sizes on the dish or foil, making sure that each drop stays discrete and does not run into others. They should make a total of 3 or 4 drops.

   d. Ask students what they think they will see when they come to the next class. You may want to have them write down a prediction.

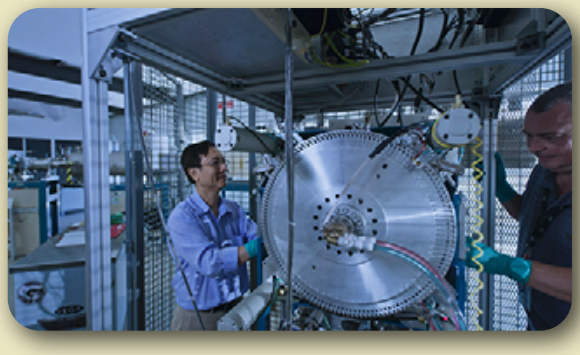
5. The next time the class meets, ask students to observe their dish or foil setup. They should see that the water has evaporated and left a thin layer of baking soda where their dots were. Have them look at the results from several other groups as well. As they do a gallery walk to examine others' results, have students consider the following questions.

- Can you tell if there was a group that had slightly more or less baking soda dissolved in the water?
- What happened in the places where there were bigger drops of the solution?

Students should understand that there may be more or less baking soda left on the setup, depending on the amount dissolved and the amount of solution.

6. Give small groups the *How Cave Formations Develop* cards. Ask them to read through each one and put them in the order that they think describes the process.
7. Ask groups to examine another group's work and see if they agree on the order of the process. If not, they should discuss their ideas. Have them try to tell the "story" of a cave formation to make sure they understand the process.
8. Have students return to their small groups and discuss how the baking soda investigation fits with the process of forming cave formations. Hold a class discussion to make sure that students understand that:
    - some years are wetter than others, so there is a thicker layer that forms, and
    - different concentrations of minerals can be dissolved in the water, which affects how thick the layer is. Share that temperature outside affects the concentration because it causes differences in how fast plants and animals decay, which then affects the amount of carbon dioxide in the soil.
9. Once students have an understanding of the process that develops cave formations, have them draw and label the process.
10. Share with students that in the movie *Angkor: The Lost Empire of Cambodia*, scientists used data from cave formations to learn about climate. To do this, the scientists analyze samples from the layers of cave formations. Ask students to come up with an explanation of how scientists would be able to learn about the amount of rainfall in a year and about the outside temperatures. This is an opportunity to do a claim-evidence-reasoning if your students are familiar with it. However, you can also have them do a simple description of what scientists would be able to determine.

Extensions



Scientists use an instrument called an accelerator mass spectrometer to analyze samples from cave formations. Have students learn more about how these instruments work and how scientists process samples for use in the machine.

Share that scientists do not use data from just one cave formation to learn about climate data. They use information from multiple caves and may also use other types of data, such as from tree rings. Have students describe why multiple forms of evidence would be important for coming up with climate information.

Master: Cave Pictures

NPS Photo by Ronal C. Kerbo

Master: Cave Pictures

Photo from the U.S. National Park Service

Master: Cave Pictures

Photo from the U.S. National Park Service

Master: Cave Pictures

NPS Photo by Dale Pate

Master: How Cave Formations Develop

Rain falls and the water seeps into the ground.	Rainwater passes through materials in and on the ground that used to be living. These materials are plants and animals that have died and are decomposing. The water picks up carbon dioxide as it moves through.
Water with dissolved carbon dioxide makes a weak acid. It is called carbonic acid. It seeps through joints and cracks in the limestone that makes up the outside of caves.	Weak carbonic acid can dissolve some minerals in limestone as it moves across it. The acid picks up the mineral calcite.
Once inside a cave, the liquid is exposed to air again. Carbon dioxide gas is released from the liquid into the air in the cave.	As carbon dioxide leaves the water, calcite becomes a solid. The calcite stays on the ceiling, walls, or floor of the cave, and builds up over time.
After many years, people can see the cave formations. Their shapes depend on how the water entered the cave—dripping, seeping, or splashing.	

LOOKING WITH LASERS

Lesson Overview

In this lesson, students have a chance to see how Light Detection and Ranging (LiDAR) can help scientists learn more about archaeological sites, such as Angkor. They have a chance to examine images from LiDAR and explain how the technique works.

Standards

This lesson helps students develop skills toward the following standards.

Geography

- How to use maps and other geographic representations, geospatial technologies, and spatial thinking to understand and communicate information.

Science

- MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Mathematics

- CCSSI.7.G.A. Draw, construct, and describe geometrical figures and describe the relationships between them.

Preparation

Decide if you will display the tables on the Laser Measurements from Ceiling master or if you will give students copies. If you plan to give students copies, print enough so that students can share them and cut apart the two tables.

Materials

- ▫ Laser measuring tool, if available
- ▫ Video of using a laser measuring tool, if a tool is not available to have in the classroom
- ▫ Graph paper
- ▫ *Laser Measurements from Ceiling* master, display copy or enough copies for students to share, with Table 1 and Table 2 cut apart
- ▫ *LiDAR and Aerial Image Comparison* master, 1 copy for display
- ▫ *Angkor LiDAR Image* master, 1 copy for display

Facilitation

1. Show students how laser measuring tools work, either using a tool or showing them a video of someone using one. If you have a tool available, consider setting up some measurements with rulers, tape measures, and the laser tool to compare. This will help students see that the laser tool is very accurate. Discuss how the tool works by sending a laser beam then determining how long it takes for the laser light to reflect back to the tool. It then calculates the distance based on the speed.
2. Have students draw a picture of how the laser tool works to measure distances.
3. Distribute graph paper to students. Ask them to assume that every square represents 1 foot. Have them draw a picture that meets the following criteria.
    - Draw a straight, horizontal, line in the middle of the page that is 12 feet long. That is the floor.
    - Draw a wall on each side that is 9 feet tall.
    - Draw the ceiling at the top of each wall, parallel to the floor.
    - Draw the back of a chair that is 4 feet tall and 2 feet from the right wall.
    - The seat of the chair should be 2 feet from the floor and 2 feet wide.
    - Draw the front leg of the chair from the seat to the floor.
    - In the middle of the ceiling, draw a light.
        - The cord holding the light should be 2 feet long.
        - At the end of the cord, the light should be 2 feet wide and 1 foot tall.
4. Tell students to pretend that they were at the left wall and were taking a measurement with a laser tool every foot from the ceiling to the floor. Have the students draw a line from the left wall to the first object the laser would reflect from. Ask them to write the number of feet from the left wall to the object. They should have 8 measurements.
5. Ask students to describe how the measurements help them know where objects are in the room. They should be able to share that when there is an object, the length of the laser measurement is shorter and when it goes all the way to the wall it is 12 feet.
6. Have students move to a different area on the graph paper and tell them that now they are going to use measurements that were taken from the ceiling to the floor in a room that is 10 feet wide and has 8 foot ceilings. Suggest that students number the lines to help them keep track of the measurements. They should number from 0-10 along the horizontal axis from left to right. Because the measurements are starting at the ceiling, 0 should be at the top of the left wall and 8 should be at the bottom (floor).
7. Display Table 1 from the *Laser Measurements from Ceiling* master or provide students with a

copy. From the left side, students should draw the lines to show the laser measurements. Note that you may want to suggest that students number the lines to help them keep track.

8. Ask students to talk in their small groups about whether they can tell what is on the floor and where.

9. Display Table 2 from the *Laser Measurements from Ceiling* master or provide students with a copy. Ask students to add in the additional measurements on their drawings. Once they have done that, ask if they have a better idea about the shape of what is on the floor. Have them discuss how the additional helped or did not help.

10. Share with students that the work they have been doing is similar to Light Detection and Ranging (LiDAR), a technique that scientists can use for many different uses. One of them was to learn more about the structure of the temple and other buildings in Angkor. However, instead of taking a laser measurement every foot or 6 inches, LiDAR uses a helicopter or airplane that can scan the landscape and deliver 50,000 laser pulses per second. In addition, it can get up to 5 returns, or measurements, per pulse.

11. Display the image on the *LiDAR and Aerial Image Comparison* master. Share that the image on the left is an aerial picture of an area. The image in the middle is the first return, or highest measurement, for the area. The image on the right is the last return, or ground level measurement, for the area. Ask students what they notice. Share that LiDAR is a great way to make a 3D scan of an area.

12. Display the image on the *Angkor LiDAR image* master. Ask students what they can tell about Angkor based on what they see.

13. Share that scientists have used LiDAR in Angkor to help them "see" through heavy foliage and dense forests. This technique is helping archaeologists understand much more about the size of the empire and the people who lived there.

Extensions

LiDAR is used in many different ways. Have students research another way that LiDAR is used to learn about an area.

Master: Laser Measurements from Ceiling

Table 1

Distance from Left Wall (feet)	Measurement from Ceiling (feet)
1	8
2	8
3	8
4	6
5	4
6	2
7	4
8	6
9	8
10	8

Table 2

Distance from Left Wall (feet)	Measurement from Ceiling (feet)
0.5	8
1.5	8
2.5	8
3.5	7
4.5	5
5.5	3
6.5	3
7.5	5
8.5	7
9.5	8

Master: LiDAR and Aerial Image Comparison

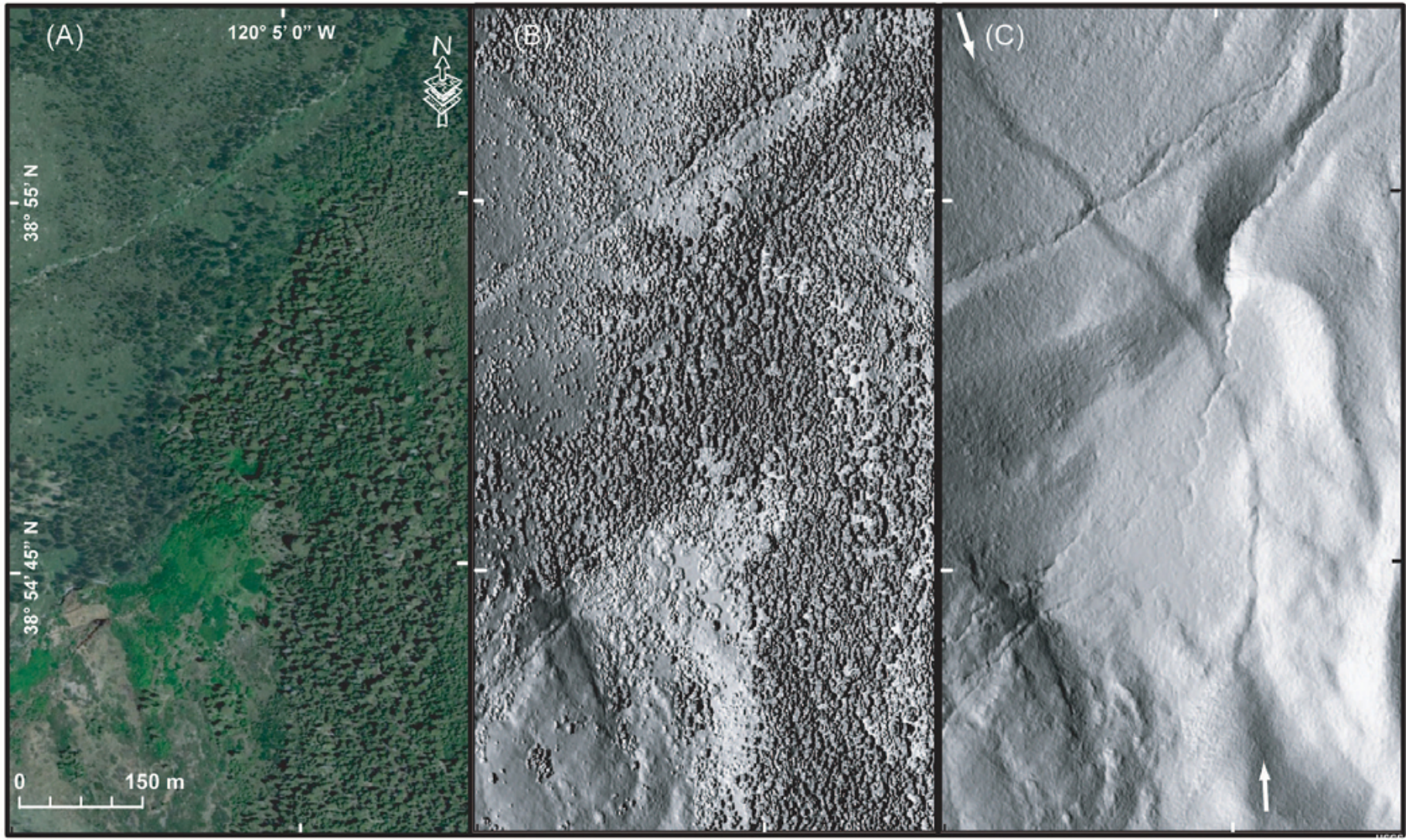


Photo credit: James Howle, U.S. Geological Survey. Public domain.

Master: Angkor LiDAR image

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CREDITS

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