Earth Systems Science

Grades 5-8

Lesson 2: Water Resources

The Earth can be considered a family of four major components; a biosphere, atmosphere, hydrosphere, and geosphere. Together, these interacting and all-encompassing subdivisions constitute the structure and dynamics of the entire Earth. These systems do not, and can not, stand alone. This Module demonstrates, at every grade level, the concept that one system depends on every other for molding the Earth into the world we know. For example, the biosphere could not efficiently prosper as is without gas exchange from the atmosphere, liquid water from the hydrosphere, and food and other materials provided by the geosphere. Similarly, the other systems are significantly affected by the biosphere in one way or another. This Module uses Earth's systems to provide the ultimate lesson in teamwork.

March 2006

Lesson 2: Water Resources

Lesson at a Glance

Lesson Overview

This lesson addresses the water resources that are important to millions of people in North America and Africa. Each activity focuses on the physical nature of a water resource, how humans depend upon the resource, and how human use affects the resource, creating both problems and opportunities. Students will use data and satellite images to examine how human actions can degrade, improve, or maintain the quality of each resource. Then they will analyze and interpret graphic data to make recommendations for improving future use of these resources.

Lesson Duration

Three to five 45-minute class periods

Core Education Standards

National Science Education Standards

Standard F2: Causes of environmental degradation and resource depletion vary from region to region and from country to country.

Essential Questions

- How do natural processes and human actions affect the Chesapeake Bay and the Nile River as water resources?

Concepts

Students will learn the following concepts:

- Fresh water is a limited resource on Earth that we must protect and conserve for future generations.
- Humans affect the quality of the water resources around them.
- The health of the water resources in turn affect the organisms that live in them or rely on them.

Objectives

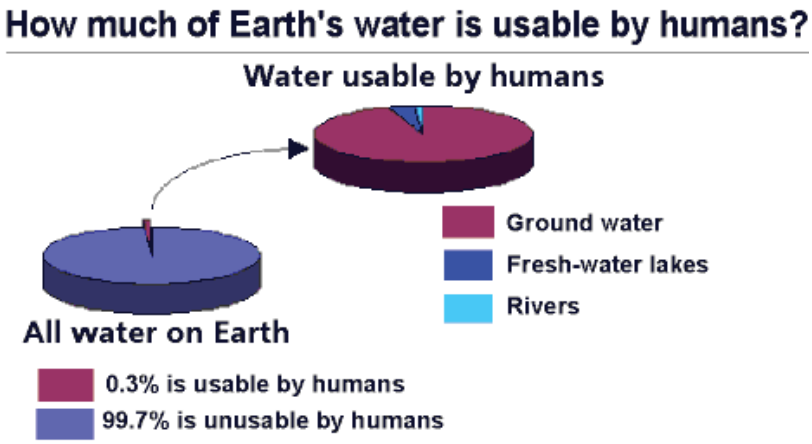
Students will be able to do the following:

- Simulate a town forum to investigate the quality of the Chesapeake Bay as a water resource.
- Analyze graphs and images to investigate water use along the Nile River.
- Debate the use of water resources from different perspectives.

Science Overview

Water is one of the key resources needed to sustain life on Earth. Three-fourths of our entire planet is covered by liquid water, which exists in three forms: liquid water, solid water (ice), and gaseous water (water vapor).

The Earth is nearly a closed system, powered by sunlight, with few significant losses of material to space and only very small amounts of matter entering the atmosphere as cosmic dust and meteors. The water on Earth has been recycled for billions of years with a few relatively tiny additions of new water from occasional impacts by comets. The water we drink today may be mingled with the water that our ancestors drank in the past. However, not all of the water can be used for drinking. Only 0.3% of the water on Earth is suitable for human consumption, most of that is ground water.

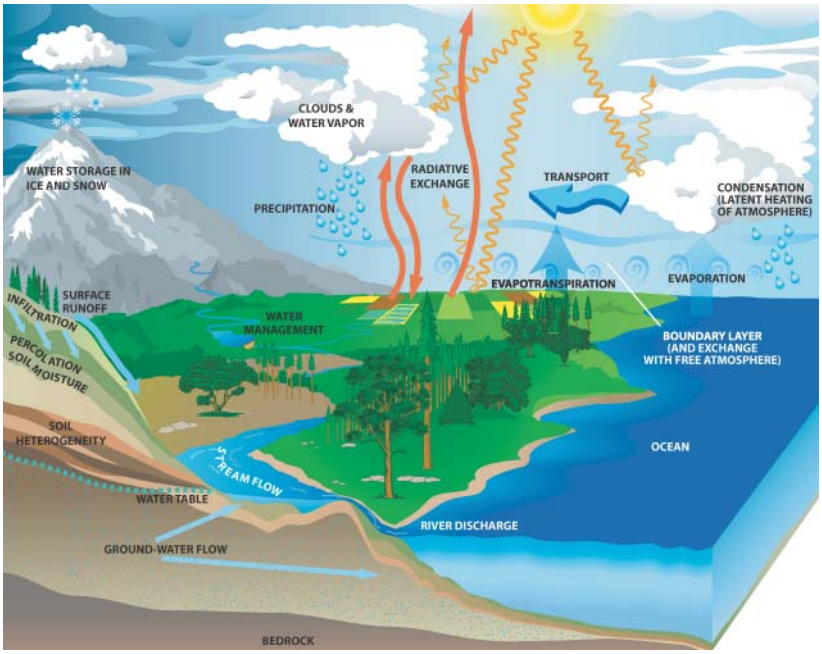


The Earth's Water. *Source: USGS, http://ga.water.usgs.gov/edu/earthwhere-water.html*

The oceans, composed of salt water, make up 97.22% of the total water on Earth, with a volume of 1,321,314,000 km^3. Most fresh water is found in icecaps and glaciers, making up 2.15% of the total water on Earth and 29,177,000 km^3 by volume. However, this water is not available for human consumption- since icecaps and glaciers are largely in the polar regions. Ground water, which is the primary source of drinking water, has a volume of 8,336,000 km^3 and makes up 0.61% of the total water on Earth.

While it is compelling to know that only 0.3% of water stored (at any given moment) is usable, it is also important to realize that storages of water are constantly replenished by precipitation. The cycling of water

(i.e., the "hydrologic" or "global water" cycle) provides quite a bit more than the amount of water stored on land. On average, the amount of water that falls as precipitation on land is about 76,000,000 km^3/yr, which is about three times as much water than is stored, at any given moment, on the land (of course, the land is constantly depleted of its supplies from runoff, evaporation, and consumption). The amount of water stored that is "usable" is a small fraction, but the climate system is constantly transforming water from the largest "unusable" storage in the ocean, to a more usable form in our freshwater continental storages via atmospheric transport and precipitation.



Hydrologic Cycle.
Image courtesy of C. Adam Schlosser, Paul Houser, & Debbie Belvedere, NASA GSFC Code 974 Hydrological Sciences Branch, http://watercycle.gsfc.nasa.gov/

Dependence on the Earth Systems

All of the Earth's oceans, rivers, lakes, water in the soil, groundwater, water in the air, and every other body of water make up one of the four Earth systems, called the hydrosphere. Each of the other three—geosphere, atmosphere, and biosphere—interacts with and modifies the hydrosphere significantly.

Geosphere

All of the rocks and minerals that make up the surface and interior of the Earth are known as the geosphere. On a basic level, the geosphere (along with the atmosphere) provides a home for the hydrosphere.

Water rests in lake beds, on ocean floors, in river valleys, and in the soil, all of which are part of the structure of the geosphere. By studying the structure of the water beds on Earth, scientists can create a picture of how the geosphere and hydrosphere have shaped one another over billions of years. The Earth's crust consists of about 14 tectonic plates, which slide over the Earth's surface, changing its structure on a timescale of millions of years. In this manner, the locations and sizes of the oceans, seas, and rivers have been changing throughout time with respect to the positions of the continents and the plates themselves. The hydrosphere, atmosphere, and geosphere work together to create and modify the surface of the Earth.

Atmosphere

The atmosphere contains all of the air surrounding the Earth, and extends to about 560 kilometers above the Earth's surface. It includes all clouds and weather that occur on and near the surface. Clouds are made almost entirely of water droplets, which have evaporated from the hydrosphere on the surface of the Earth. When they accumulate and reach a certain size, they fall back to the surface in the form of rain or snow, replenishing all other Earth systems.

Wind created in the atmosphere can become very strong over the oceans, because there is nothing impeding its path, such as mountains or buildings, which exist on land. This wind can create large waves and storms. The right combination of warm tropical water, moisture, and wind can produce violent hurricanes, typhoons, and tropical cyclones. In these cases, the wind can reach speeds of hundreds of miles per hour, and the damages can be devastating to tropical locations.

Biosphere

The biosphere is the system that contains all living things on Earth. The most apparent way in which the hydrosphere interacts with the biosphere is the fact that many plants and animals live in and depend on water. These organisms depend on the water to survive, and extract dissolved oxygen from water in the same manner that land animals extract oxygen from the atmosphere. Plants living in water replace the oxygen. Therefore, the composition of the water changes depending on the living organisms, which in turn depend on the water, and our system comes full-circle. Animals that do not live directly in the water depend on the hydrosphere also. Humans as well as every other land animal need to consume water in order to survive.

Although humans depend on water resources for survival, they pollute the hydrosphere on a daily basis. The most common source of human

pollutants is agricultural runoff. Pesticides and fertilizers containing toxic chemicals and heavy metals are swept into rivers, lakes, and oceans, usually by rainwater. This can affect not only drinking water, but plants and animals that live in the water. Raw sewage can also travel to beaches through the water system, and eventually seep into ground water.

One of the most publicized and controversial ways in which humans contaminate water is from crude oil spills. Large ships carry crude oil to and from refineries, and sometimes will crash and spill their oil into the water through which they are passing. The worst oil spill in U.S. history was in 1989, when the oil tanker Exxon Valdez spilled more than 10 million gallons of oil into Prince William Sound in Alaska. It is impossible to know exactly how many animals died, but the best estimates include hundreds of thousands of seals, whales, and birds (including over 200 bald eagles), and billions of salmon and herring eggs. The cleaning effort cost $2.1 billion.

Because water is almost everywhere, we sometimes take it for granted. However, human actions can affect its quality and its availability as a resource. This lesson explores how human actions have combined with natural processes to affect the Chesapeake Bay, one of the most significant water resources for fishing and recreation in the United States. Because the Chesapeake Bay is such an important resource, many citizens and government agencies are concerned about its present and future status. The Nile River also is examined for its sustainability for irrigation and development needs around Ethiopia and Eritrea, Egypt, Sudan, and other Nile Basin countries. The Nile River is critical for the well-being of agriculture and life in the surrounding region, and, therefore, the Nile is a life-supporting resource.

Studying Chesapeake Bay

The Chesapeake Bay is located in the mid-Atlantic region of the United States in the most densely populated region of the nation. Figure 1 from the Briefing Document indicates its location and the regions contributing water to the Bay through various river systems. Figure 6 from the Briefing Document shows the land use in this highly industrialized, highly urbanized region.

Several federal, state, and local organizations and agencies have combined their efforts to study the Bay in order to provide ideas and programs to insure its future health. NASA (National Aeronautics and Space Administration), USGS (United States Geological Survey), EPA

(Environmental Protection Agency), and NOAA (National Oceanographic and Atmospheric Administration) are federal agencies conducting this research. Three NASA missions have contributed data to Bay studies: SeaWiFS (Sea-viewing Wide Field-of-view Sensor), AVIRIS (Airborne Visible Infrared Imaging Spectrometer), and LANDSAT 7. The data gathered from SeaWiFS and AVIRIS have contributed to a better understanding of the ability of the Bay to support plant and animal life. The data produced by LANDSAT 7 allow smarter land-use planning and better estimates of polluted water runoff across the 110,000 square kilometer Chesapeake Bay watershed.

Studying the Nile River

The Nile River is formed by three major tributaries: the Blue Nile, the White Nile, and the Atbara. The White Nile begins in Burundi and flows through Lake Victoria into Southern Sudan. Near Khartoum, the capital of Sudan, it meets the Blue Nile, which begins in the highlands of Ethiopia. North of Khartoum, the Atbara joins the river. The Nile flows north through Lake Nasser, the second largest human-made lake in the world, and Aswan Dam. Then it splits into two distributaries north of Cairo—the Rosetta, to the west, and the Darneita, to the east. Eight capital cities—Cairo, Khartoum, Asmara, Addis Ababa, Kampala, Nairobi, Kigali, and Bujumbura—are in or near the Nile River's watershed area.

NOTES:

Conducting the Lesson

Warm-Up & Pre-Assessment

Teacher Materials

- Maps or globe including the Chesapeake Bay and the Nile River regions.

Preparation & Procedures

1. Conduct a discussion on water as a resource. Ask students the following questions:
   - How do humans use water? *(Desired answer: drinking, cleaning, transportation, recreation, industry, etc.)*
   - What percentage of the water on Earth is fresh water and immediately available for human consumption? *(Desired answer: very little, 0.3%)*
   - What are some ways in which water quality is affected by natural processes? *(Desired answer: drought affects the flow of fresh water; storms affect the amount of sediment and water flow)*
2. Relate these issues to water resources in your region.
3. Have students locate the Chesapeake Bay and the Nile River on a map. Ask students what are some ways in which water quality is affected by human actions and processes in each area? *(Desired answer: pollution from industry, runoff, sewage, diversion/reduction of feeder streams/rivers, sedimentation, destruction/development of wetlands)*

NOTES:

Activity 1: Chesapeake Bay, Resource Use or Abuse?

In this activity, students will role play members of the community and discuss how they use the Bay and how they can work to protect it.

Teacher Materials

- Color transparencies of images at the end of the Briefing Document

Student Materials (per student)

- Student Worksheet 1: Briefing Document
- Student Worksheet 2: Role Information Cards
- Student Worksheet 3: Investigator's Key (for Investigator group only)
- Student Worksheet 4: Instructions to Regional Planners

Preparation & Procedures

1. Make color transparencies of the images located at the end of Student Worksheet 1: Briefing Document.

2. Make at least two copies of Student Worksheet 2: Role Information Cards, each group will need a copy of their role and the investigator group will need a complete copy.

3. Explain that water is such a key resource that citizens and scientists often join forces to ensure the quality and supply of water. This investigation focuses on how this has occurred in the Chesapeake Bay.

4. Have students locate the Chesapeake Bay on a map or globe, and the watersheds that drain into the Bay. Ask them to note the major cities in the Chesapeake Bay Watershed. Background information, including a map, on the Chesapeake Bay can be found in Student Worksheet 1: Briefing Document.

5. Distribute Student Worksheet 1: Briefing Document. Ask students to read the entire document.

6. Explain the premise of the role-playing scenario:
   - A public forum will be broadcast on public television, moderated by the League of Women Voters under the auspices of the federal government.

- The purpose of the forum is to give citizens and scientists the opportunity to voice their opinions on key issues related to the Chesapeake Bay, to collect information, and to begin to develop a sustainable policy to make use of, to preserve, and to maintain the integrity of this national resource.
- Students play roles representing individuals involved in exploring the use and abuse of Chesapeake Bay, one of the United States' most significant water resources.

7. Explain the format for the role playing:
   - Ten individuals (concerned citizens, public officials, scientists) testify before the hearing. Each individual is protrayed by a small group of students. They are questioned by a team of three or four invited investigators.
   - Role Information Cards for each individual are provided in Student Worksheet 2, in the back of the lesson. These are in the form of questions that may be asked of each role-player during the testimony. Students learn their role and develop answers to the questions that may be asked of them during their testimony by reading and discussing Student Worksheet 1: Briefing Document.
   - The investigators receive the list of questions each role-player is prepared to answer (located on Student Worksheet 2: Role Information Cards) and the points that they should make (Student Worksheet 3: Investigator's Key). They must sequence the presenters and questions to ensure the points are made effectively and logically.
   - The regional planners (all students, when not role playing) keep a summary of points made. All students may ask questions of witnesses. After hearing the testimony, they will draft a policy statement and justification for it.

8. Seek volunteers for each of the individual roles and the investigator roles. Distribute Student Worksheet 2: Role Information Cards. Each student must find the answers to the questions from Student Worksheet 1: Briefing Document and play the part of the character. Require presenters to prepare a visual (e.g., a map, diagram, overhead of images appearing in the Briefing Document, graphs made from additional data obtained by researching the suggested resources, etc.) to support their testimony. For example:
   - Susan Elliott: diagram showing local, state, and federal agencies that have cooperated to study the Bay.
   - Fred Kyle: diagram showing changes in sea grass, fin fish, oysters, and crabs over the past 100 years.

- Pam Gibbons: LANDSAT images and maps showing population growth in the region.
- Chris Sprinski: graphic illustrating how excess nutrients in the water and air degrade the Bay.
- Georgina Giovingo: pictures of her husband fishing on the Bay.
- Phil Klein: graphic describing how sediments flow into the Bay.
- Kristin Hyche: graphic illustrating the role of climate in the Bay's ecosystem.
- LeVar Jenks: graphic showing relationships among agriculture, industrialization, urbanization, and Bay health and productivity.
- Evalia Tweedle: a sample poster or flyer used to heighten public awarenesss.
- Steve Sui: images from AVIRIS, SeaWiFS, and LANDSAT.

9. Distribute the list of roles and questions (Student Worksheets 2 and 3) to the investigators. Allow them to divide the questions among themselves and to coordinate a strategy to ensure that they are efficient and logical in their questioning.

10. Distribute directions to the regional planners (Student Worksheet 4). Explain that all students will contribute to the preparation of the policy recommendations. While some students prepare for and present the testimony, others will need to listen carefully, take notes, and synthesize and evaluate the testimony to form policy recommendations later. All students may ask questions.

11. Have participants make name tags for themselves. Check that students are comfortable with their roles. Arrange the room in a town forum setting.

12. Begin the role play. Forum Moderator Susan Elliott calls the forum to order, explains its purpose, and introduces the team of investigators. The investigators proceed by calling the concerned citizens and scientists to testify in any order that they wish. Continue until all of the individuals have testified.

Reflection & Discussion

Debrief the town forum:

1. Discuss the points presented by the individuals, the major concerns, and the key issues.

2. Discuss possible policies that could be made to ensure the health of the Bay. Analyze each suggestion to determine how well it reflects a new understanding of the natural and human processes that affect water quality and use? What would be the short-term and the long-term impacts of such a policy on water quality within the Bay and on the human communities and industries affected by the policy? Who would be most affected? Least affected? Most importantly, would the policy work? Students should use the ideas genereated in the discussion to complete the Transfer of Knowledge section below.

Transfer of Knowledge

In order for students to apply what they have learned, have them draft a policy, as regional planners on Student Worksheet 4, to perserve and maintain the integrity of the Chesapeake Bay.

Extensions

- Develop a list of things the class can do to conserve water and to decrease water pollution.

- Have students research and write a report about individual scientists and activists or entire organizations that are working to clean and preserve the Chesapeake Bay.

- Have students research and write a report about the economic importance of the Chesapeake Bay. Will policies intended to protect the Bay have a negative impact on industries (e.g., agriculture, fishing) that need to use the resources of the Bay watershed?

Placing the Activity Within the Lesson

Review with students that only 0.3% of the water on Earth is immediately usable for human consumption. Lead the students into the next activity by asking them if they think people in other regions, such as Africa, have the same concerns about their water resources?

Assessment Criteria for Activity 1

4 Points
- Demonstrates a thorough understanding of the material.
- Consistently and actively works toward group goals.
- Willingly accepts and fulfills their individual role within the town forum.
- Consistently and actively contributes knowledge, opinions, and skills.

3 Points
- Demonstrates a good understanding of the material.
- Works toward group goals without prompting.
- Accepts and fulfills their individual role within the forum.
- Contributes knowledge, opinions, and skills without prompting.

2 Points
- Demonstrates a satisfactory understanding of the material.
- Works toward group goals with occasional prompting.
- Contributes to the forum with occasional prompting.

1 Point
- Needs improvement.
- Works toward group goals only when prompted.
- Contributes to the forum only when prompted.

0 Points
- Does not participate.
- No work turned in.

Notes on Activity 1:

Activity 2: The Nile: A Sustainable Resource?

In this activity, students examine how humans influence the Nile River, and how these problems in turn affect all of the countries in the Nile River Basin.

Teacher Materials

- Teacher Script/Briefing Points
- Overheads of Figures 1-4 at the end of the Teacher Script/Briefing Points

Student Materials (per group)

- Student Worksheet 5 : Location
- Student Worksheet 6: Water Stress
- Student Worksheet 7: Representative Discussion Points
- Student Worksheet 8: Discussion Points Data Organizer
- Small paper cups
- Water (optional)
- Graph paper
- Blue crayon

Preparation & Procedures

1. The class will be divided into groups, the proportions for a class of 25 are listed on the chart. For larger or smaller classes, the proportions will need to be modified accordingly.

2. Make overhead transparencies of Figures 1-4 located at the end of the Teacher Script/Briefing Document.

3. Distribute Student Worksheet 5. Ask students to follow the path of the Nile River, using a blue crayon, from its origins in the highlands of Ethiopia and Burundi to its mouth in Egypt.

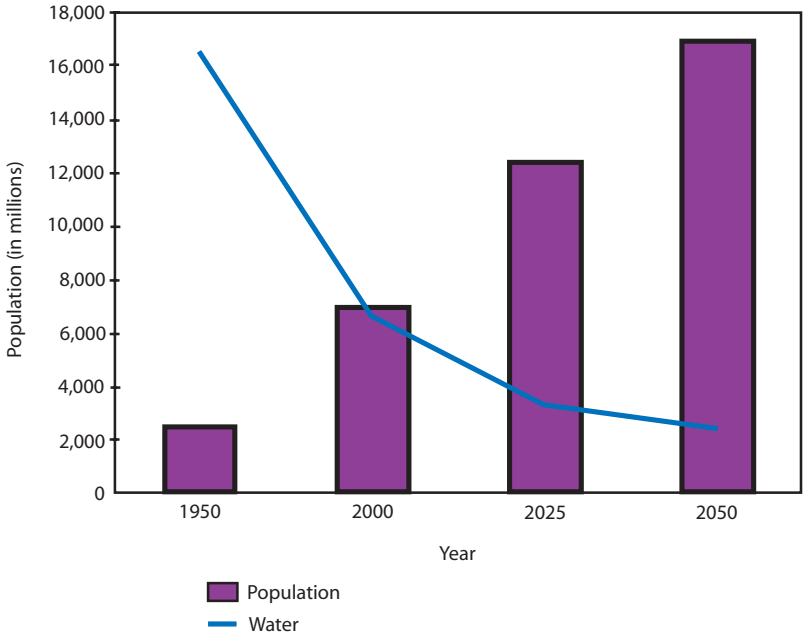
4. Have students identify the 10 countries within the Nile River Basin. (*Desired answer: Burundi, Rwanda, Tanzania, Kenya, Congo [Zaire], Uganda, Ethiopia, Eritrea, Sudan, Egypt*) Point out to students that 40% of Africa's population lives in these 10 countries, which constitute only 10 percent of its landmass.

5. Now divide the class into groups roughly proportional to the size of the population of each nation in the Nile River Basin, using the chart below.

Country	Population	% of Total Population	# of Students
Burundi	6,064,000	2	1
Rwanda	5,184,000	2	1
Tanzania	30,026,000	11	2
Kenya	27,154,000	10	2
Congo	45,453,000	16	4
Uganda	19,689,000	7	2
Ethiopia	56,404,000	20	5
Eritrea	3,171,000	1	1
Sudan	26,707,000	9	2
Egypt	62,096,000	22	5
Total	***281,948,000***	***100***	***25***

6. Distribute Student Worksheet 6: Water Stress, which includes the data cards for each country. Explain that each team of students will represent a country from the Nile River Basin. First, they must do some research on their nation, its water resources, and population prospects using the data cards. Students will graph population growth against water resource availability to determine water stress in the past, present, and future. Students can draw the graph by hand or use a computer-based graphing program. The left-hand scale will represent population, shown as bars; the right-hand scale will represent the per capita water available in cubic meters (the water stress index), shown as a line graph. Data for Burundi are graphed below as an example. Have students analyze their graphs and answer the questions on Student Worksheet 6: Water Stress.

Water stress in Burundi



7. When students have completed Student Worksheet 6, check to make sure they understand the relationship among population growth, water resource availability, and the water stress index through a discussion of their Log answers.

8. Group the students by nation or groups of nations: Egypt – 5 students, Ethiopia and Eritrea – 6 students, Sudan – 2 students, other Nile Basin countries (Rwanda, Burundi, Tanzania, Kenya, Congo, and Uganda form one block) – 12 students.

9. Distribute Student Worksheet 7: Representative Discussion Points to each group. Ask students to use the data cards from Student Worksheet 6 to fill in the blanks.

10. Have students create three-dimensional histograms, using paper cups, representing the per capita water availability for their nation(s) in 1950, 2000, 2025, and 2050. Allow students to work out a proportion of water per cup.

11 Identify students to play the role of representative from each nation or group of nations. Students may share the responsibility, or one student may play the position. Student Worksheet 7: Representative Discussion Points contains the information they need to share.

12. Distribute Student Worksheet 8: Discussion Points Data Organizer to all students.

13. Call a meeting of the Nile River Basin Initiative (a real organization).

- Establish that the purpose of the meeting is to make plans to manage existing and proposed water development projects in the Basin—specifically, to seek international funding to monitor the Basin's water resources using remote sensing.
- As was clear in the previous activity, water is in short supply in the region. Following the Teacher Script/Briefing Points, introduce the past and current situation in the region. Use Figures 1–4 to support your points.
- Ask each representative to present each nation's (or group of nations') water status, point of view on management issues, and water resource objectives or goals. Representatives should use the histogram and graph from Student Worksheet 6 to illustrate their status.
- Students complete Student Worksheet 8 using the information presented during the meeting.

Reflection & Discussion

Ask students to summarize the major problems affecting the Nile. Ask students how these problems then in turn affect the countries within the Nile River Basin. Ask students to brainstorm a list of strategies to help conserve and preserve the water of the Nile.

Transfer of Knowledge

Ask students, working alone or in groups, to use the information presented by each group to prepare a summary to support funding to continue to monitor basin changes from space. Students should include evidence obtained in the meeting of the Nile River Basin Initiative to substantiate their request for funding (e.g., specific water stress data, current and past water projects in each country, and each country's perspective on water management).

Placing the Activity Within the Lesson

Have students create a Venn diagram to compare and contrast the Chesapeake Bay and the Nile River as water resources. Students may choose to focus on a variety of topics, such as the challenges facing each resource or how each resource is used.

Assessment Criteria for Activity 2

4 Points
- Demonstrates a thorough understanding of the material.
- Consistently and actively works toward group goals.
- Willingly accepts and fulfills their individual role within the meeting.
- Consistently and actively contributes knowledge, opinions, and skills.

3 Points
- Demonstrates a good understanding of the material.
- Works toward group goals without prompting.
- Accepts and fulfills their individual role within the meeting.
- Contributes knowledge, opinions, and skills without prompting.

2 Points
- Demonstrates a satisfactory understanding of the material.
- Works toward group goals with occasional prompting.
- Contributes to the meeting with occasional prompting.

1 Point
- Needs improvement.
- Works toward group goals only when prompted.
- Contributes to the meeting only when prompted.

0 Points
- No work is turned in.
- Does not participate.

Notes on Activity 2:

Lesson Wrap-Up

Transfer of Knowledge for the Lesson

Have students research a local water resource, such as the Mississippi River or the Great Lakes. Have them determine its current level of health and how it is used by the community and industry. Have students use that information to create a plan to preserve or improve the water quality for future generations. Students should create a brochure to present their plan that contains visuals such a graphs, diagrams, or pictures to support their information.

Assessment Criteria for Activity 2

4 Points
- The brochure has very attractive formatting and well-organized information.
- The visuals go very well with the text.
- All facts in the brochure are accurate.
- Student's plan shows a deep understanding of the issues.

3 Points
- The brochure has well organized-information.
- The visuals are related to the text.
- Some facts in the brochure are accurate.
- Student's plan shows an understanding of the main issues.

2 Points
- The brochure has organized information.
- The visuals are related to the text, but there are too few of them.
- A few facts in the brochure are accurate.
- Student's plan shows an understanding of most of the main issues.

1 Point
- The brochures formatting and organization is confusing to the reader.
- No visuals were included.
- Few facts in the brochure are accurate.
- Student's plan shows a limited understanding of the main issues.

0 Points
- No work was completed.

Lesson Closure

Return to the following *Warm-Up & Pre-Assessment* questions to see how students may have changed their thinking about water as a resource.

- How do humans use water?
- What are some ways in which water quality is affected by natural processes?
- What are some ways in which water quality is affected by human actions and processes in each area?

Resources

Internet Resources & References

Student-Friendly Web Sites:

Bays and Streams Education
www.dnr.state.md.us/bay/education/kids.html

Chesapeake Bay for Kids
sarbanes.senate.gov/pages/chesapeake_bay_for_kids.html

Kids Fun - Chesapeake Bay
www.chesapeakebay.net/info/kids/kids.cfm

Mysteries of the Nile
www.pbs.org/wgbh/nova/egypt/resources.html

Teacher-Oriented Web Sites:

Chesapeake Bay Foundation
www.cbf.org/

National Geographic Xpeditions Lesson Plans
www.nationalgeographic.com/xpeditions/lessons/matrix.htm-

National Science Education Standards
www.nap.edu/readingroom/books/nses/html/

The Chesapeake Bay Matters
www.mcps.k12.md.us/schools/travilahes/ches/chesbay.html

Acknowledgements

This lesson was adapted from NASA's Mission Geography, A NASA/GENIP Project.

NOTES:

These are the points you should make at the opening of the meeting of the Nile Basin Initiative:

- The Nile is the longest river in the world at 6,601 km and is the main source of water for the nations that make up the Nile watershed.

- Currently, the water provided by the system barely meets the demands of the region. In the near future it is expected that many of the nations that share the Nile's water will experience water stress.

- Access to the Nile's waters has already been defined as a vital national priority by countries in the region. As more of the countries in the region develop their economies, the need for water will increase. Although the demand for resources increases, the supply is likely to remain unchanged, increasing the chances for conflict over a scarce resource.

- Development projects that are aimed at increasing the flow of the Nile remain endangered by tension and instability in the region, as well as environmental and financial concerns.

- Figure 1. As you can see from these figures, the Nile is in an arid region. Figure 1, a hand-held Space Shuttle photograph, shows clearly the contrast in land use along the Nile River. Water is used for irrigation in a narrow strip on either side of the river. Beyond is the desert. (This bend of the river is the home of many historical points of interest—Valley of the Kings, Valley of the Queens, Temple of Luxor, the Tomb of Tutankhamen, and the Necropolis of Thebes.)

- Figure 2. Figure 2 is a radar image of an area west of Cairo, Egypt, approximately 20 by 30 km in size. The Nile is the dark band along the right side of the image. It flows almost due north from the lower edge of the image to the right. The boundary between dense urbanization and the desert is seen between the bright and dark areas. This boundary is the extent of the yearly Nile flooding, which played an important part in determining where people lived in ancient Egypt. The pattern persists today. As the population of Egypt grows, the irrigated land along the river becomes more and more densely settled. Egypt is eager to disperse its population to newly irrigated areas.

- Figure 3. Figure 3 is the delta of the Nile, which contains 60% of Egypt's cultivated land. This figure shows the stark contrast between desert and irrigated land along the river. Cairo is at the center of the image. The Mediterranean Sea is to the north.

- Figure 4. Figure 4 shows the Nile River, the Aswan Dam, and the lake created by the dam, Lake Nasser, located in southern Egypt on the border with Sudan. Changing a significant resource in a vulnerable, dry environment can have serious consequences. The Aswan Dam, completed in 1971, provides examples of the array of potential and actual problems. One major problem is that silt from the river, which for thousands of years fertilized Egypt's cropland, no longer flows down the river. Chemical fertilizers are needed to enrich the soil. In addition, there is more erosion along the banks of the Nile, which previously was replenished by the silt being carried down river.

- Much of the delta shown in Figure 3 is being swept into the Mediterranean Sea. If barriers near the Nile's outlet erode any more, low-lying delta land could find itself in the sea, causing a devastating loss of cultivated land. The Nile also is bringing more salt to the fields of Egypt. Increased evaporation in Lake Nasser makes irrigation water more saline. The evaporation also presents a severe problem in terms of water loss.

- The Nile belongs to no one country or people. It is a shared resource.

- It is also an interconnected system—what affects one part of the system affects all parts of the system.

- It is difficult to monitor watershed changes over a large area and to communicate information to stakeholder groups, such as governments and scientists. However, remote sensing is a very effective and efficient means to accomplish this goal.

- Organizations, such as the Nile River Basin Initiative, meet regularly to coordinate water policies, especially in relation to development needs. But there is a need for good, reliable information about the entire water basin. This is especially true today as countries balance climate change, population growth, and development issues.

Figure 1
Source: STS026-041-058 Valley of the Kings, southern Egypt, October 1988

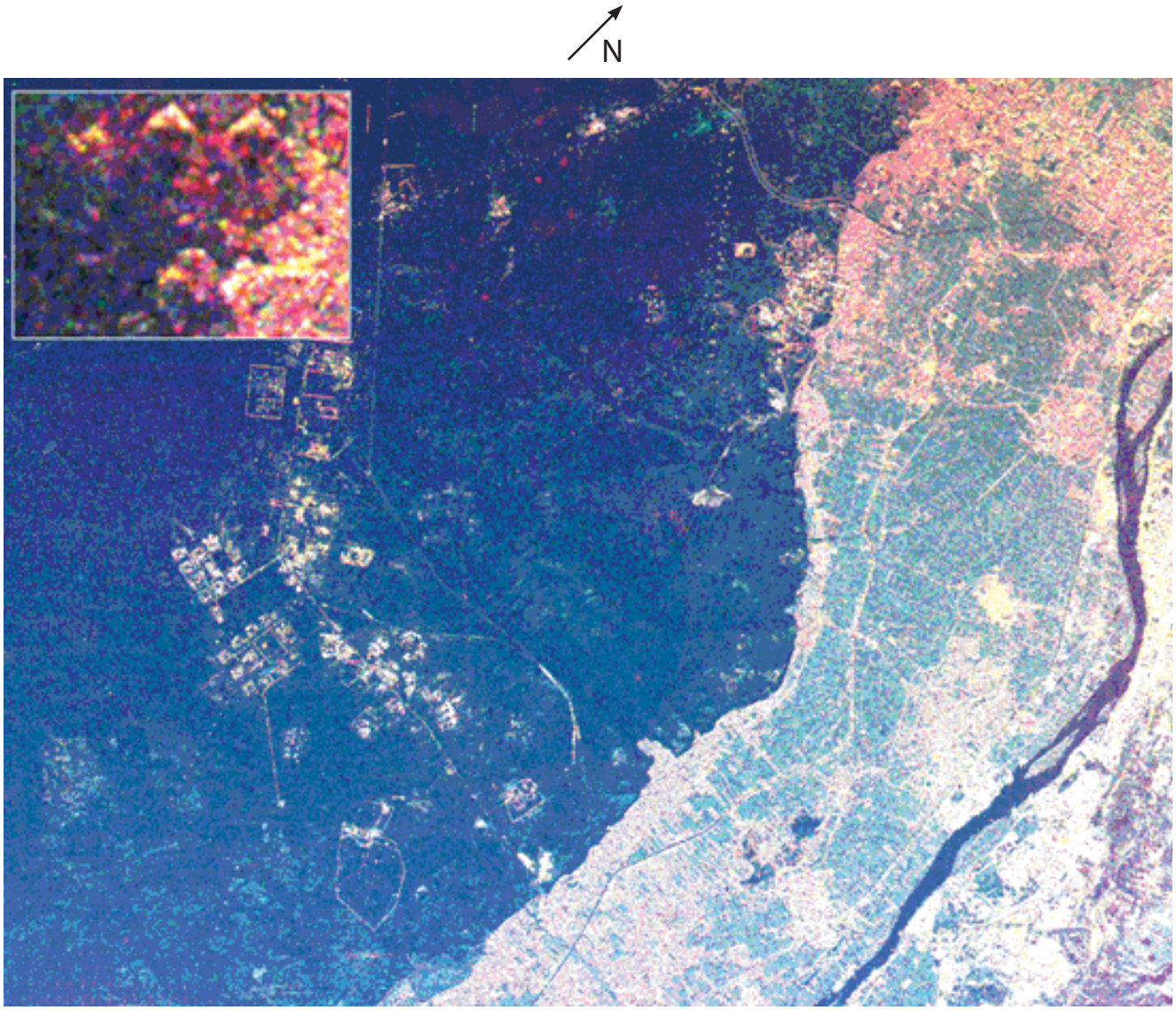


Figure 2
Source: SIR-C/X-SAR image, April 1994

Figure 3
Source: STS077-710-091 Nile River Delta, Suez Canal, Egypt, May 1996

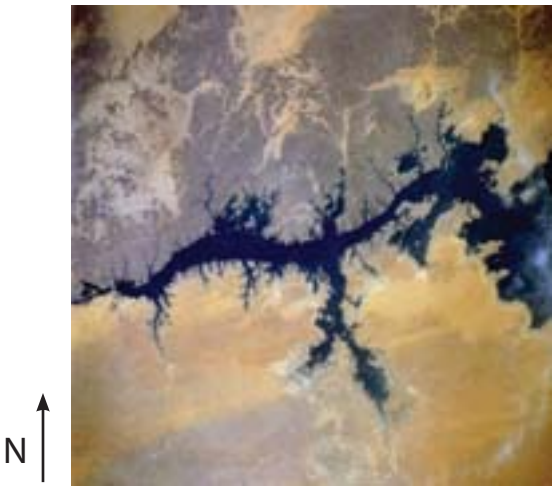


Figure 4
Source: STS046-075-018 Nile River and Aswan Dam, Egypt, August 1992

Student Worksheet 1
Chesapeake Bay: Briefing Document

Name _____ Date _____

How do natural processes and human actions affect the Chesapeake Bay as a water resource?

Background

Water is essential to life on Earth. Three-quarters of Earth's surface is covered by water. Because it is almost everywhere, we sometimes take it for granted, but we do things that affect its quality and quantity. This briefing shows how human actions have combined with natural processes to affect the Chesapeake Bay, one of the United States' most significant water resources. Because the Chesapeake Bay is such an important resource, many citizens and government agencies are concerned about its present and future status. Several federal, state, and local organizations and agencies have combined their efforts to study the Bay in order to provide ideas and programs to insure its future health. NASA, USGS, EPA, and NOAA are federal agencies doing this research. Three NASA missions have contributed data to Bay studies: SeaWiFS (Sea-Viewing Wide Field-of-view Sensor), AVIRIS (Airborne Visible InfraRed Imaging Spectrometer), and LANDSAT 7. The data gathered from SeaWiFS and AVIRIS have contributed to a better understanding of the ability of the Bay to support plant and animal life. The data produced by LANDSAT 7 allow smarter land use planning and better estimates of polluted water runoff across the 110,000 square kilometer Chesapeake Bay watershed. Chesapeake Bay is located in the northeastern United States in the most densely populated region of the nation. Figure 1 indicates its location and its watershed, or the region of river systems that flow into the Bay. Turn to Figure 6 to see the land use in this highly industrialized, highly urbanized region.

Figure 1: Location of theChesapeake Bay its watershed, or region of river systems that flow into it.

Ecosystem Trends and Response: Chesapeake Bay

The Nation's Largest Estuary

Chesapeake Bay, the nation's largest estuary, has had serious environmental degradation during the past century. The evidence of damage includes declines in sea grass acreage, reduction of fin fish and shellfish (oysters and crab), seasonal depletions of dissolved oxygen, and increases in sedimentation. These changes raised serious concern in the 1970s because they threatened major commercial and recreational activities. Most scientists attribute these changes, at least indirectly, to human activities. Land use changes in the Bay watershed (deforestation, agriculture, and urbanization) brought added pollution and sewage. Future stress on Bay ecosystems is likely to worsen, as the Chesapeake Bay Commission predicts that the population in the Bay watershed will swell to over 18 million by the year 2020.

Critical Issues for Ecosystem Management and Restoration

Chesapeake Bay is a complex natural ecosystem with many interrelated human and natural sub-systems. Changes in each sub-system ripple through others, causing various effects. Ecosystems recycle chemicals needed by living things; redistribute wastes; control pests that cause disease in humans, plants, and animals; and offer a huge pool of resources for humans and other living creatures. Ecosystems are affected by natural events such as drought. But ecosystems are more drastically changed by human activities. The model used for Bay ecosystem management is a system that shows links among land, sea, and living creatures that result in changes in the watershed affecting the Bay. For example:

- Land use and population changes increase the amount of agricultural fertilizers and urban sewage treatment plants, which cause increased phosphorus and nitrogen loading in surface and ground water.
- Excess nutrients from water and air can lead to an increase in algal blooms, reduced dissolved oxygen levels on the bottom, habitat degradation, and depleted living resources.
- Algal blooms can reduce the clarity of the water, which prevents sunlight from penetrating to the bottom and can inhibit the growth of sea grasses or subaquatic vegetation (SAV).
- Subaquatic vegetation helps absorb nutrients, adds oxygen to the water, and provides a sheltered habitat for organisms, especially juvenile blue crabs. It is also a food source for water birds living on the Bay.
- Sedimentation is another critical problem. Over the last 100 years,155 million metric tons of sediment were deposited in the Maryland portion of the Bay. Sedimentation rates have increased since colonial times because of land use changes. Sediment can cloud the water so much that SAV cannot survive.

Causes of Recent Trends in Dissolved Oxygen and SAV

Fluctuations in the amount of freshwater entering the Bay from its tributary rivers (termed discharge) result from changing precipitation patterns over the last few decades. Recently, these fluctuations have become extreme. Trend data show the influence of discharge on the total nutrients entering the Bay and on Bay salinity. These influence phytoplankton growth and oxygen levels. Climatic factors play a role in controlling water quality. For example, the drought years of the 1950s and 1960s caused low tributary discharge into the Bay. Bay restoration efforts began in the early 1980s. Surveys have indicated that sea grasses have begun to grow again in several tributaries of the Bay.

In theory, this reflects a response to improved water quality. But there were areas where subaquatic vegetation (SAV) did not return despite improved water quality. This continued absence of SAV concerns scientists and resource managers, in part because SAV provides habitat for young blue crabs. The Bay provides 50 percent of the nation 's total blue crab harvest. The Bay crab harvest was worth $126.6 million in 1993. Chesapeake Bay is a significant source of fish and shellfish.

A Complex System

What do recent trends in discharge, anoxia (too little oxygen in the water), sea grasses, and blue crabs mean? Are they caused by habitat change, overharvesting, or natural mortality related to long-term climatic factors? These questions remind us of how complex the Bay ecosystem is, and of how little we know about the relations among individual species, their environment, and climate. They also illustrate how difficult it is for scientists to separate natural versus human effects on critical species and their habitats based solely on monitoring. Detection of a trend can be easy, but assigning cause is much more difficult.

Cross-country Sources: Side Effects Spread from Land to Sea

Identifying a water polluter is easy when the source of the pollution is a single point, such as a single pipeline spewing wastes. But it's not so simple when considering non-point source pollution that comes from nearly everything humans do on land, which contributes to polluted runoff that enters surface and ground water, as well as oceans. It can lead to beach and shellfish bed closings, and spoiled habitats for fish and other aquatic life.

Below are some of the sources of pollution entering the Bay.

Agriculture and Livestock

Runoff from barnyards, feedlots, and cropland contributes nutrients from manure and fertilizers, as well as pesticides and eroded soil.

Urban Runoff

Urban runoff from buildings and paved surfaces carries sediment, nutrients, bacteria, oil, trace metals, chemicals, road salt, pet droppings, and litter.

Automobiles

Leaking oil and motor fluids run off roadways and into waterways. Emissions send nitrogen and other contaminants into the atmosphere that eventually settle into coastal waters.

Land Clearing

Construction, clearing land, and logging often lead to soil erosion, putting more sediment in rivers and coastal waters. Filling in wetlands takes away vast natural water filters that can break down many common pollutants before they reach other water bodies.

Sewage

Sewage, leached from faulty septic systems or dumped directly overboard instead of emptied at boat pump-out stations, contributes nutrients and disease-causing organisms.

Air Pollution

Airborne pollutants, chiefly from factories and automobiles, are responsible for almost one-third of all contaminants and nutrients entering marine waters.

Industrial Waste

Industrial runoff brings heavy metals and other compounds into marine waters, from industrial-waste landfills, from mining, and from storm water draining off of industrial sites.

Warning Signs

Too Many Nutrients Lead to Too Little Oxygen

Too much nitrogen (from fertilizers, sewage, feedlot runoff, or air pollution) or too much phosphorus (from the same sources, as well as detergents or water-treatment chemicals) can set off explosive growth of algae and aquatic plants. As the overpopulated plants and algae die, bacteria can deplete oxygen from the water as they decompose the dead plants. Lack of oxygen kills fish and other animals.

Managing Hazardous Waste Hits Home

Many products for home and garden can burn, explode, corrode, or poison. Dumped down the drain, onto the ground, or into the trash, they can pollute water, pose health risks, and damage water-treatment systems. Since 1980, thousands of community programs have begun to collect household hazardous waste.

Chesapeake Bay's Health Depends on the Kindness of Many Strangers

The Bay's watershed covers six states and the District of Columbia. It drains 150 rivers and streams—an enormous catchall for urban, suburban, and agricultural pollution. Environmental problems often occur over large areas that fall into the control of more than one governmental Using Remote Sensing as a Research Tool: Three Examples from NASA

Using the unique perspective from space, NASA observes, monitors, and assesses large-scale environmental processes, such as the oceans' productivity.

AVIRIS Analysis of Chesapeake Bay

During 1997-1998, NASA's Ames Research Center performed a remote-sensing demonstration project in collaboration with the Chesapeake Bay Program (CBP). The CBP wanted to evaluate the use of remote sensing in its monitoring program, hoping that point measurements could be used with satellite imagery to develop water quality data.

Previously, University of Maryland scientists had explored the use of airborne remote sensing to map chlorophyll concentration in the Bay. NASA's AVIRIS (Airborne Visible InfraRed Imaging Spectrometer) was chosen for the demonstration. The objective of AVIRIS is to identify, measure, and monitor Earth's surface and atmosphere. Research with AVIRIS seeks to understand global environmental processes such as climate change. The instrument flies aboard a NASA ER-2 airplane at an altitude of about 20 km. It flew over the Bay on August 17, 1997, and July 3, 1998. The data it collected allowed scientists to estimate chlorophyll and suspended sediment concentrations. These data were compared with CBP shipboard measurements. The 1998 flight identified submerged aquatic vegetation (SAV). Scientists compared the satellite images with aerial photography and found that imagery analysis was useful in determining sea grass distribution.

SeaWiFS

Figures 2, 3, and 4 show views of the Chesapeake Bay from SeaWiFS (Sea-Viewing Wide Field-of-View Sensor). Figure 2 shows data taken on September 16, 1997, and Figures 3 and 4 record data from September 19, 1997. SeaWiFS data allow assessment of global vegetation patterns, both land and ocean, needed to understand ecosystems and global change. The SeaWiFS instrument observes the oceans from space to measure "ocean color." SeaWiFS is essential to NASA's efforts to study how the global environment is changing. SeaWiFS observes Earth from a noontime sun-synchronous orbit, which means that the sensor always views Earth around local noon at an altitude of 705 km. This orbit provides data at the maximum solar illumination, the most desirable for detecting concentrations of phytoplankton, which live just beneath the ocean surface. These green plants absorb sunlight during photosynthesis.

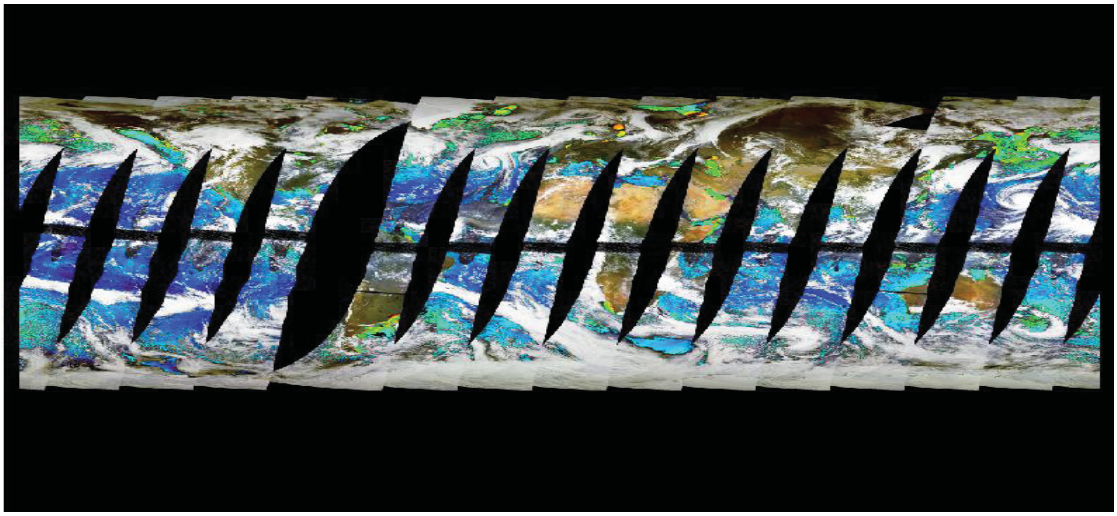


Figure 2: SeaWiFS data from September 16, 1997

In Figure 2, the red colors show high concentrations of chlorophyll in the water, the yellows/greens indicate intermediate concentrations of chlorophyll, and the blues/purples show low concentrations of chlorophyll. The black swaths indicate no data because of gaps between the orbits.

On Earth, coverage is every two days. The two images of Chesapeake Bay offer SeaWiFS high-resolution data obtained over the mid-Atlantic on September 19, 1997. Figure 4 highlights vegetation associated with the coastal plain and mountain ridges and valleys. White areas are clouds and dense aerosols. Note that ocean features are not noticeable. In Figure 4, ocean patterns are evident, such as plumes of material discharging out of Delaware Bay. Red and yellow areas in the Chesapeake Bay indicate turbid (sediment filled) waters, while the blue hues offshore represent clear oceanic water. Black areas, such as in the right bottom corner, are locations where the processing could not be completed.

Figure 3: SeaWiFS, September 19, 1997, New York – Chesapeake Bay true color

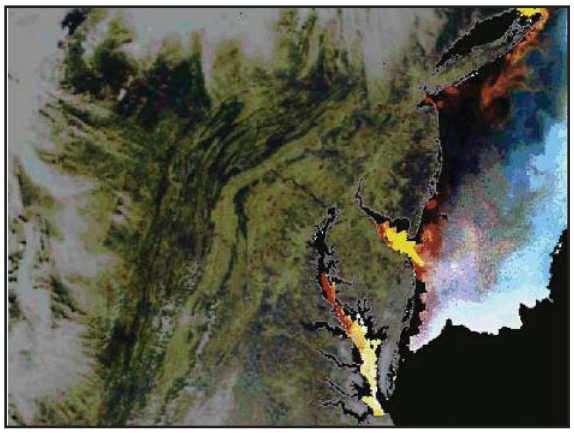


Figure 4: SeaWiFS, September 19, 1997, New York – Chesapeake Bay showing ocean radiance

LANDSAT

LANDSAT (Land Remote Sensing Satellite) is designed to gather data on Earth 's resources in a regular and systematic manner. It collects information related to land use, geological and mineralogical exploration, crop and forestry assessment, and cartography. The image in Figure 6 was produced by LANDSAT 7 to assess the amount of different land cover types in the Bay region, including residential development, wetlands, forests, and crop lands.

The maps produced from LANDSAT will help make estimates of polluted river runoff flowing into the Bay by identifying pasture land and different types of crops. The amount of nutrient pollution entering the Bay can be measured by knowing the area of a type of land cover and estimating the average water quality of runoff from that type of land. Heavily fertilized agricultural fields, for example, produce higher levels of nutrients in runoff than the same acreage of pasture land. The image and maps also distinguish low- and high-density residential development from wetlands and different types of forest. These images will allow smarter land use planning and better estimates of polluted water runoff across the watershed.

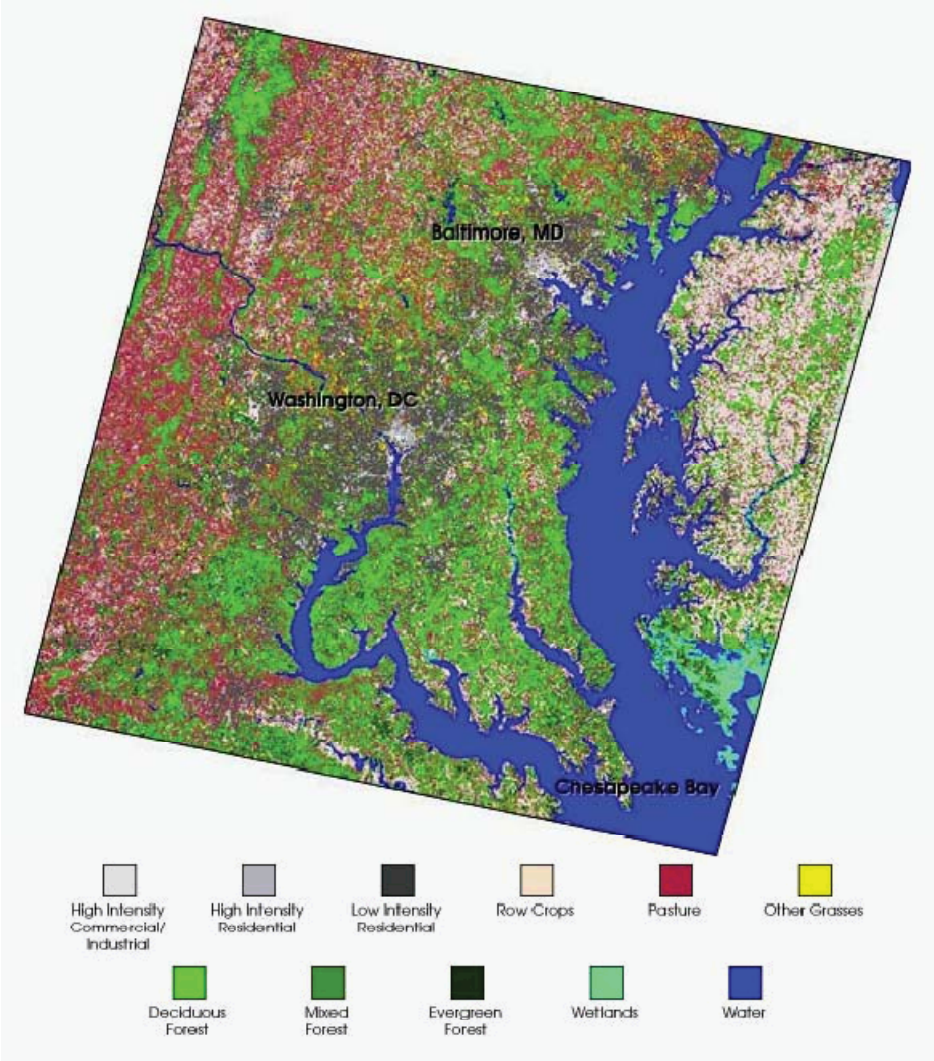
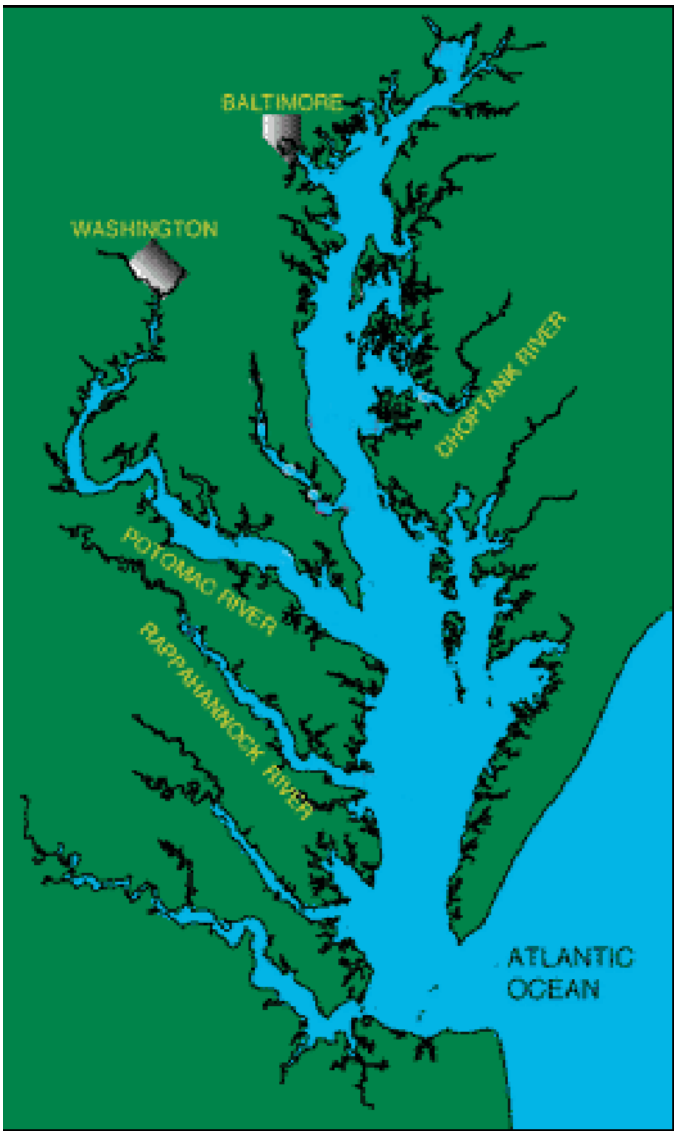


Figure 5: LANDSAT image showing land cover types in Chesapeake Bay area including residential development, wetlands, forests, and croplands.

Sources:

Figure 1 – md.water.usgs.gov/publications/fs-150-99/html/figure1_big.gif
Figure 2 – seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/SEAWIFS/revised_ocean_color_and_land_4096x1024.jpg
Figure 3 – seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/SEAWIFS/ches_combined.jpg
Figure 4 – seawifs.gsfc.nasa.gov/~grey/slides/october97.html
Figure 5 – veimages.gsfc.nasa.gov/196/chesapeake_cc.jpg



Map of the Chesapeake Bay Region
Source: http://pubs.usgs.gov/fs/fs125-01

Student Worksheet 2

Chesapeake Bay: Role Information Cards

Name _____ Date _____

Susan Elliott

You are the president of the League of Women Voters. Because of its impartiality, your organization has been asked to sponsor a town forum on the Chesapeake Bay. You are moderating the forum.

As moderator you should:

1. State the purpose of the town forum and provide some background (see the questions listed below).
2. Introduce the investigators, citizens, and scientists; ensure that order is maintained and that everyone is polite and has an opportunity to speak.
3. Remind all participants that they will, as regional planners, develop a policy to preserve and maintain the health of Chesapeake Bay's natural and economic resources.

Questions You May Be Asked

- Why is water important?
- How is water used?
- Why have many local, state, and federal agencies cooperated to study the Bay?
- How successful have other partnerships of citizens and scientists been in setting environmental policies?

Fred Kyle

You are 44 years old and a concerned citizen employed by a technology company outside of Washington, D.C. You and your family have lived near Chesapeake Bay in Virginia for generations, and love it for its beauty and recreational opportunities. You enjoy taking your children out on the water and hope someday to take your grandchildren, but you're worried about the degradation of the Bay's water you have observed.

Questions You May Be Asked

- What is your name, where do you live, and what is your occupation?
- How has the Chesapeake Bay changed in the past 100 years in terms of sea grasses, fin fish, oysters, and crabs?
- When did you first become concerned with the health and quality of the Bay?

Pam Gibbons

You are 28 years old and have just completed a Master's degree in geography at the University of Maryland. Your first job is working for the state of Maryland doing long-range land use planning. Your research focuses on land use change in the Chesapeake, and you are considered an expert on the topic.

Questions You May Be Asked

- What is your name, where do you live, and what is your occupation?
- What river basins flow into the Chesapeake?
- What are some ways that the Chesapeake has changed over the last few decades?
- What factors have caused these changes?
- What are the likely population trends in this area in the next 20 years?
- How will population affect land use?
- What role does sedimentation play in affecting the health of the Bay?
- From your studies, what are the effects of land use and population change on the Bay?
- What tools/images can you use to help in planning?

Chris Sprinski

You are in your mid-30s and a life-long environmentalist. You have worked for several nonprofit organizations devoted to preserving the environment. In college, you majored in biology with an emphasis in marine sciences, and took environmental science courses as well. Currently you serve as a consultant to the Friends of Chesapeake Bay, a non-governmental organization funded by private donations.

Questions You May Be Asked

- What is your name, where do you live, and what is your occupation?
- What is the current model for Bay ecosystem management?
- From your studies, what are the effects of land use and population change on the Bay?
- What is the role that excess nutrients in water and air play in causing degradation in the Bay? Please explain what happens step-by-step, beginning with algal blooms.

Georgina Giovingo

You are in your late 50s and have been a widow for a year. You and your husband made your living fishing the Chesapeake. Most of your limited income was made harvesting blue crabs. Your late husband, Dave, died of a mysterious infection possibly related to contamination of the Bay. You are clearly upset about the degradation of the Bay; the decline in fish, oysters, and crabs; and the loss of recreational value of the Bay. You cannot contribute scientific information, but you show the forum that many people care passionately about the Bay and rely upon it for their livelihood.

Questions You May Be Asked

- What is your name, where do you live, and what is your occupation?
- How important is fishing to the economic well being of people in the Chesapeake region and the nation?
- From your experiences of fishing the Bay for 30 years, how has the Bay changed?
- Why do you think it is important to develop a policy to preserve and maintain the Bay?

Phil Klein

You are a legislative aide assigned to the governor of the state of Maryland. You have three young children and live close to your office in Annapolis, the capital. You are an expert in the development of environmental policy and environmental law, and act as the governor's liaison on Chesapeake issues, which include attending meetings of the Chesapeake Bay Program. The governor has asked you to make sure that the state of Maryland is not responsible for causing damage to one of its key resources, Chesapeake Bay.

Questions You May Be Asked

- What is your name, where do you live, and what is your occupation?
- What is the mission of the Chesapeake Bay Program?
- What actions have been taken or programs put in place related to the Chesapeake's health and well being?
- How much sediment enters the Bay from Maryland?
- What action has the state taken to affect the amount of sedimentation?

Professor Kristin Hyche

You are a professor at the University of Delaware specializing in climatology and hydrology in the Department of Geography. You study Bay ecosystems from a geographic perspective, looking at the interactions between human and natural processes. You live in Newark, Delaware.

Questions You May Be Asked

- What is your name, where do you live, and what is your occupation?
- How does the Chesapeake Bay ecosystem function?
- What role does climate play in the ecosystem? What are some of the effects of climate change on the health of the Bay?
- How have policies to preserve the Bay been helpful? For example, have sub aquatic grasses returned in some Bay tributaries?
- What are the causes of the changes observed in the Bay in discharge, sea grasses, and blue crabs?
- Which of these are caused by natural processes and which by human actions? Explain.

LeVar Jenks

You are a research scientist with the USGS (United States Geological Survey) assigned to the Chesapeake Ecosystem Response Project. You grew up in inner city Baltimore and, as a young boy, loved to fish the Bay with your grandfather and cousins. This inspired you to study the environment and to pursue a geology degree in college. You specialize in the geochemical analysis of sediments and worked hard to be assigned to the project. You are in your early 40s and live in a Maryland suburb of Washington, D.C. You are also a history buff interested in the way of life of your ancestors, enslaved persons in Virginia and Maryland.

Questions You May Be Asked

- What is your name, where do you live, and what is your occupation?
- What is the Chesapeake Ecosystem Response Project? What is the project investigating?
- What methods are being used?
- Why is the project investigating the impacts of agriculture, industrialization, and urbanization at different periods of time? What role do they play in Bay conditions?
- Do you have any research results to report yet?
- In your professional opinion, which do you think is having a greater impact on the Bay—human processes or natural processes? Why?

Evalia Tweedle

Your training as a classroom educator prepared you well for your current administrative position with the Public Affairs Office of the EPA (Environmental Protection Agency) in Washington, D.C., where you also live, sharing a house with five other recent college graduates. You primarily work to heighten public awareness and understanding of key scientific and environmental issues. Since you were an educator and work with the public a great deal, you come to the forum prepared with teaching tools to present what you feel are key ideas that will contribute to the forum's success.

Questions You May Be Asked

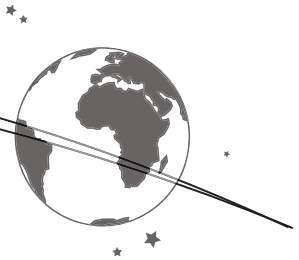
- What is your name, where do you live, and what is your occupation?
- What is the difference between point and non-point source pollution?
- What are some of the key sources of pollution?
- What are some strategies that the EPA suggests home-owners adopt to lessen their impact on the environment, in general?
- How important is this kind of recommendation for people who live in the Chesapeake Bay watershed?
- What tools and resources can help the EPA understand and control sources of pollution?

Steve Sui

You are employed as a research scientist specializing in remote sensing at NASA's Ames Research Center located near San Jose, California. You live close to San Francisco Bay and thus became interested in the Chesapeake Bay Project. You have worked closely with Phil Klein in the past; he invited you to participate in the forum. Your expertise is in using AVIRIS to remotely sense Earth, particularly its oceans. You are also expert in SeaWiFS, a sensing system to observe the world's oceans and monitor ecosystem change. You think you may be asked to explain two images produced by these sensors and plan to come prepared.

Questions You May Be Asked

- What is your name, where do you live, and what is your occupation?
- How did you become involved with the Chesapeake Bay Project?
- What is AVIRIS?
- How was it used to monitor the Chesapeake Bay? What was the end result?
- Can you draw any conclusions about the health of the Bay from the map that was produced?
- What is SeaWiFS? What is it being used for?
- What is LANDSAT? What is it being used for and by whom?
- What do the colors on the image of the Chesapeake Bay indicate?
- Discuss the usefulness of remote sensing for tracking changes on Earth?



Student Worksheet 3

Chesapeake Bay: Investigator's Key to Points Each Witness Should Make

Susan Elliott

- Water is important to human health and all its endeavors. It is equally important to other living creatures in the ecosystem upon which humans depend. It has a variety of uses, including transportation, irrigation, recreation, industry, and fishing.
- Chesapeake Bay is the nation's largest and one of the world's most productive estuaries.
- Chesapeake Bay is an important resource to many people in six states who live in urban and rural areas. A watershed is a complex system. It requires the cooperation of many agencies at different scales to address watershed-wide issues because the boundaries of governmental jurisdictions do not match the boundaries of watersheds.

Pam Gibbons

- Nine river systems flow into the Bay. They are the Susquehanna, Potomac, Patuxent, Choptank, Rappahannock, Mattaponi, Pamunkey, James, and Appomattox.
- Human activities play a role in the degradation of the Bay. Changes in how people use the land (land use change) are the major culprits, including deforestation, urban development, and expansion of agricultural land. As population grows, forests are cut and land cleared to build houses, malls, and businesses. Agriculture expands into new areas to feed the growing population. More people produce more sewage and pollution. When it rains, exposed dirt (sediments) disrupted by human activity washes into the Bay.
- The population will continue to grow in this already densely populated region of the nation, and land use changes will continue. There are about 18 million people living in the area now.
- Sediments cloud the Bay water so much that sub aquatic vegetation, such as sea grasses, cannot survive.
- Land cover maps and images, like the one from LANDSAT 7, are used to estimate polluted water runoff. Remote sensing is an important tool.

LeVar Jenks

- The U.S. Geological Survey (USGS) Chesapeake Ecosystem Response Project is designed to improve understanding of large-scale environmental changes that influence water quality and living resources in Chesapeake Bay. In particular, project workers investigate the links among changes in climate, precipitation, discharge, salinity, and dissolved oxygen over different time periods.
- The human factors that most affect these natural factors are industrialization, agricultural practices, and urban development.
- USGS scientists and other researchers are collaborating to study the Bay's sediments, which capture the history of its water, plants, and animals during the period before monitoring began in the 1980s. Using ecosystem "indicators" (microfossils), geochemical data preserved in the Bay's sediment, and historical and reconstructed discharge data, scientists have reconstructed trends and responses in the Bay since 1950 to determine the natural conditions in the Bay over the last few millennia, including periods prior to 17th-18th century colonial agriculture and 19th- 20th century industrialization and urbanization. The emphasis has been on separating natural versus human causes of and responses to extreme events.

Evalia Tweedle

- Point source pollution is pollution coming from a known, identifiable source, such as a pipeline spewing waste. Non-point source pollution is pollution that enters surface water, ground water, and the oceans from widespread and distant activities—that is, from no single point.
- The key sources of non-point source pollution are agriculture and livestock, urban runoff, automobiles, land clearing, sewage, factories producing air pollution, and industrial waste.
- The EPA suggests homeowners manage hazardous waste carefully. People need to be aware that they have an impact on the environment when they dump chemicals down the drain.
- This advice is especially important for the millions of people that live in the Chesapeake watershed. Something placed onto the ground anywhere in the region ultimately affects the health of the Bay.
- Remote sensing is helping us to better pinpoint the sources of polluted runoff.

Chris Sprinski

- The Bay is not a single thing, it is a complex combination of many different biological and physical systems. All elements of the various systems present in the Bay are linked, connected, and affect the other elements.
- Everything is interrelated; managing just one system element will not necessarily cause positive changes throughout the system.
- Land use and population changes increase the amount of agricultural fertilizers and urban sewage treatment plants, which cause increased phosphorus and nitrogen loading in surface and ground water.
- Excess nutrients from water and air can lead to an increase in algal blooms, a reduction in dissolved oxygen levels on the bottom, habitat degradation, and depleted living resources.
- Algal blooms can reduce the clarity of the water, which prevents sunlight from penetrating to the bottom and, thus, inhibiting the growth of sea grasses or sub aquatic vegetation (SAV). SAV is important because it helps absorb nutrients, adds oxygen to the water, and provides a sheltered habitat for organisms, especially juvenile blue crabs. SAV also is a food source for water birds living on the Bay.

Georgina Giovingo

- The Bay provides 50 % of the nation's blue crab harvest, worth about $130 million per year. There are many people who make their living from the Bay, and many more who make their living serving the needs of recreational boaters, birders, and beach-goers in the region.
- The Bay is not as clean as it once was. There are fewer fish and shellfish. Sometimes there are algal blooms that make people sick. The water is not as clear as it was. More people live around the Bay now. There are fewer birds because there are fewer fish.
- People's livelihoods depend on the health of the Bay.

Professor Kristin Hyche

- Ecosystem function is very complex, and there are gaps in our understanding of the relationships among river discharge into the Bay, the amount of oxygen dissolved in the water, and aquatic grasses.
- We have better tools now, like the data and images obtained through remote sensing, to measure nutrients in the Bay.
- The amount of rainfall affects the freshwater discharge entering the Bay. In recent years, fluctuating climate patterns have made this relationship especially evident. The amount of fresh water changes the nutrients entering the Bay and the salinity of the water. These factors in turn influence how Bay phytoplankton use the nutrients and thus, oxygen levels in the water.
- Historical trends, for example comparing the drought years of the 1950s and 1960s to later decades, indicate the importance of climate to Bay health.
- Aquatic grasses have returned in some areas and not others. We do not yet know precisely what works and what does not work to repair environmental damage. The factors of habitat change, over-harvesting, natural mortality, and climate change all play varying roles.
- The Bay ecosystem is very complex and little is known about the relationships among species and their environment and climate change. It is also difficult to separate human and natural effects.

Phil Klein

- The Chesapeake Bay Program (CBP) was formed in 1983 as a regional cooperative effort between the U.S. Environmental Protection Agency and various state and local governments of the Bay watershed including the states of Maryland, Pennsylvania, and Virginia; the District of Columbia; and the Chesapeake Bay Commission.
- Its primary mission is restoration of living resources including fish, shellfish, bay grasses, and other aquatic wildlife of the nation's largest, and one of the world's most productive, estuaries.
- The Chesapeake Bay Program monitors water quality and biotic resources in order to assess the Bay's ecological health on a regular basis, and to produce computer models to predict watershed quality and ecosystem response to nutrient loading.
- The CBP routinely conducts an ongoing ship-based monitoring program to collect in situ measurements of physical, chemical, and biological indicators of the Bay's health. The CBP is evaluating the use of remote sensing as an adjunct to the monitoring program, with the idea that highly accurate point measurements may be used in conjunction with appropriately processed imagery to generate a spatial data-set of water quality.
- About 155 million metric tons of sediment have entered the Bay in the last 100 years from the state of Maryland alone. That is a serious problem.
- Biological resource management plans have been developed to restore and preserve key species for commercial and recreational use.

Fred Kyle

- The Bay has degraded seriously in the last 100 years. Sea grass acreage has declined. There are fewer fish and shellfish, particularly blue crab, for which the Bay is famous. The amount of dissolved oxygen has decreased, and more soil is washing into the Bay.
- The changes really became noticeable in the 1970s when the commercial fishing industry started to notice declines in fish, and recreational users became aware of reduced water quality.

Steve Sui

- A NASA experiment showed the utility of remote sensing in monitoring the Chesapeake Bay watershed. A sensing device known as AVIRIS was flown over the southern part of the Bay to measure the amount of chlorophyll and sediments in the waters.
- AVIRIS is an acronym for the Airborne Visible InfraRed Imaging Spectrometer. It is a remote sensing instrument that flies aboard a NASA ER-2 airplane approximately 20 km above sea level. It is used to identify, measure, and monitor constituents of Earth's surface and atmosphere. Research with AVIRIS is directed toward understanding processes related to the global environment and climate change.
- SeaWiFS is a sensor mounted on a satellite that observes Earth from a noontime sun-synchronous orbit, which means that the sensor is always viewing Earth around local noon at an altitude of 705 km. This orbit provides data to detect concentrations of microscopic green plants, called phytoplankton, which live just beneath the ocean surface. These green plants absorb sunlight during photosynthesis, the most basic and essential chemical process necessary for life on Earth.
- The red colors show high concentrations of chlorophyll in the water, the yellows/greens indicate intermediate concentrations of chlorophyll, and the blues/purples show low concentrations of chlorophyll.
- In the image of the Chesapeake Bay, ocean patterns are clearly evident, such as plumes of material discharging out of eastern Long Island Sound. Red and yellow areas in the Chesapeake Bay indicate turbid waters, while the blue hues offshore represent clear oceanic water.
- LANDSAT is a satellite that picks up information particularly related to land cover, such as pasture, crop lands, different types of forest and wetlands, and different types of residential land uses. It is very useful for local and regional planning agencies.

Student Worksheet 4
Chesapeake Bay: Instructions to Regional Planners

Name _____ Date _____

The Situation

You are a planner on the Chesapeake Bay regional planning council. Prior to the town forum, summarize the situation in the Chesapeake in the space provided.

The Town Forum

The purpose of the town forum is to collect information about the Bay from different points of view. Everyone at this meeting is in favor of taking action to "Save the Bay." Your job will be to make recommendations to develop a sustainable policy to preserve and maintain the health of the Bay as a natural and economic resource. During the forum, investigators will call a series of concerned citizens, local and state government officials, and scientists to give testimony about the Bay. You will listen to the testimony and take notes summarizing the points made by each individual. As you listen, synthesize and evaluate the testimony. You will need the information to decide policy later. You may ask questions to clarify a point, but in general you should leave that to the investigators.

Writing the Policy

Your work really begins at the end of the forum when you develop the recommendations. Summarize your findings based on the testimony and then make at least three specific recommendations to preserve and restore the Bay.

Student Worksheet 5
The Nile: Location

Name _____ Date _____

Source: www.geosource.ac.uk/main/nile_map.gif

JOURNEY through the UNIVERSE

Student Worksheet 6
The Nile: Log 2: Water Stress

Name _____ Date _____

Sustaining Water

Water is a scarce resource, particularly in arid regions of the world. Water is used for irrigated agriculture, industry, and human consumption. As populations grow, demands on water resources grow. It is estimated that the minimum amount of water needed per person for drinking, bathing, and cooking is 100 liters per day (0.1 cubic meter), which is 36.5 cubic meters per year. It takes from 5-20 times this amount (183–730 cubic meters per person per year) to meet the demands of agriculture, industry, and energy production.

Water Stress Index

Scientists have developed ways to measure the balance between population and water supply, and the onset of water stress and scarcity.

- Adequate: More than 1,700 cubic meters of renewable fresh water per person per year. Countries with this amount of water will experience only minor water shortages.
- Water stress: 1,000-1,700 cubic meters of renewable fresh water per person per year. Countries at this level experience water stress—chronic and widespread water supply problems.
- Severe water stress: Below 1,000 cubic meters of renewable fresh water per person per year. Water scarcity is the rule in these countries, causing economic development problems and serious environmental degradation.

Nile River Basin

Water is a scarce resource in generally dry northeastern Africa. The Nile River is a significant source of water for this area. Some nations such as Rwanda, Uganda, Sudan, and Egypt depend on the Nile River as their primary source of water. Other countries in the Nile River Basin, such as the Congo, have additional water resources. The region is experiencing rapid population growth. More irrigated land is needed to grow food for the growing population. In addition, the standard of living is improving among many of the people who live in the Nile Basin, placing greater demand on water resources.

Task

Prepare a graph presenting the data on the card for your nation. Construct and use the left-hand scale to draw a bar graph showing population in your nation at four dates, 1950, 2000, 2025, and 2050. Construct and then use the right-hand scale, to plot per capita water availability as a line graph. Indicate on the graph the values of the water stress index corresponding to the different levels of water stress.

Burundi

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
2,458,000	1,496	6,961,000	591	12,341,000	292	16,937,000	213

Rwanda

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
2,120,000	2,972	5,184,000	1,215	12,081,000	485	16,937,000	372

Tanzania

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
7,886,000	11,288	30,026,000	2,964	62,436,000	1,425	88,963,000	1,000

Kenya

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
6,625,000	4,820	27,150,000	1,112	50,202,000	602	63,054,000	457

Congo (Zaire)

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
12,184,000	83,384	45,456,000	22,419	105,925,000	9620	164,605,000	6,180

Uganda

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
4,762,000	18,860	19,639,000	3,352	44,903,000	1,407	66,305,000	995

Ethiopia

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
18,434,000	5,967	53,404,000	1,953	136,298,000	807	212,732,000	517

Eritrea

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
1,140,000	7,719	3,171,000	2,775	6,504,000	1,353	8,808,000	999

Sudan

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
9,190,000	16,757	26,707,000	5,766	46,850,000	3,287	59,917,000	2,569

Egypt

1950		2000		2025		2050	
Population	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*	*Population*	*Per Capita Water Availability (cubic meters)*
21,834,000	2,651	62,006,000	936	95,766,000	607	115,480,000	503

Analyze the graph.

1. Does there appear to be a relationship between population growth and per capita water availability in your nation? What is the relationship?

2. Water stress index through time:
   a. What was the water stress index in your country in 1950? _____
   b. What was the water stress index in your country in 2000? _____
   c. What is the expected water stress index in your country in 2025? _____
   d. What is the expected water stress index in your country in 2050? _____

3. Do you think the citizens of your country should be concerned about water resources? Why or why not?

4. Based on the amount of available water, is economic development and population growth sustainable in your country? Why or why not?

Student Worksheet 7
The Nile: Log 3: Representative Discussion Points

Name _____ Date _____

Ethiopia and Eritrea

Our combined population is _____ people. We have just emerged from a long period of civil war and famine. Although Eritrea is now independent, we work closely on water resource issues. The economies of both nations are growing and developing rapidly in this period of peace. Our population is growing as well, at a rate of 3.3% per year. In 2025, our population is expected to be _____, and 25 years later it will be _____. In order to grow more food to feed our growing populations, we must develop a large portion of land. This will take more water for irrigation.

Eighty-six percent of the Nile's water originates in our nations, yet we have not taken full advantage of our key resource and are water stressed. The present total water usage by our two nations for all our people is _____ cubic meters of water per year. Ethiopia's situation is worse than Eritrea's. In 2000, Ethiopia had _____ cubic meters of water per person per year. In 2025, Ethiopia expects to have _____ and in 2050 _____. We are in the process of constructing more than 200 small dams to use Nile water to irrigate needed cropland. But, we are afraid this will anger Egypt, the most powerful nation in the region. We seek ways to peacefully share our common resource and to enhance our environment.

Egypt

Our population is _____ people and we occupy only 4% of Egypt's land—that strip along the Nile. For thousands of years Egyptians have relied on the Nile for almost all of our fresh water. We never worried about the supply of water. But now the nations upstream from us are using more and more Nile water. We are concerned—very concerned. This is a threat to our national security. Our population is growing at a rate of 2% per year. In 2025, our population is expected to be _____, and 25 years later it will be _____. In 2000, we used a total of _____ cubic meters of water per year, at a rate of _____ cubic meters of water per person. In 2025, we expect to have _____ cubic meters of water per person available per year, and in 2050 _____. We are developing new water projects to accommodate our population growth. We are especially proud of a project, the New Valley Project, to pipe 5 billion cubic meters of Nile water from Lake Nasser through the Western Desert to the New Valley. Seven million people will be persuaded to move away from the Nile to live in this new agricultural area. This project is very expensive, and the Nile may not provide enough water. Although in the past Egypt's official policy was to maintain a monopoly on Nile water, today we wish to cooperate to equitably distribute the river resources to bring stability to the region and to promote economic development. We also need help in monitoring the effects of our water development projects on the environment.

Sudan

Our population is _____ people. Our nation is suffering a civil war in the south, and we are struggling economically and politically. Our population is growing at a rate of 2.2% per year. In 2025, our population is expected to be _____, and 25 years later it will be _____. We need to use more of our Nile water to produce food for our growing population, but we know that this will anger the Egyptians. In 2000, we had _____ cubic meters of water per person, using a total of _____ cubic meters of water in that year. In 2025, we expect to have _____ and in 2050_____. We have ambitious plans for the Nile; it is our chief resource. We started a canal with money from the World Bank to increase supplies of Nile water in the 1970s; construction was halted in 1983 because of rebel action. This was a loss. We are building a dam north of our capital, Khartoum, where the Blue Nile and White Nile converge. We plan to work closely with Egypt and Ethiopia to develop the Nile in a way to help generations of people.

Other Nile Basin Countries

The other Nile Basin countries are Rwanda, Burundi, Tanzania, Kenya, Congo, and Uganda. Currently we use only a small proportion of the river's water. However, together our current combined population of _____ is expected to grow to _____ in 2025 and to _____ in 2050. Our nations use a total of _____ cubic meters of water per year.

- In 2000, in Rwanda, we had _____ cubic meters of water per person. In 2025, we expect to have _____ and in 2050, _____. Our population growth rate is 2.3% per year.
- In 2000, in Burundi, we had _____ cubic meters of water per person. In 2025, we expect to have _____ and in 2050, _____. Our population growth rate is 2.5% per year.
- In 2000, in Tanzania, we had _____ cubic meters of water per person. In 2025, we expect to have _____ and in 2050, _____. Our population growth rate is 2.9% per year.
- In 2000, in Kenya, we had _____ cubic meters of water per person. In 2025, we expect to have _____ and in 2050, _____. Our population growth rate is 2.1% per year.
- In 2000, in Congo, we had _____ cubic meters of water per person. In 2025, we expect to have _____ and in 2050, _____. Our population growth rate is 3.2% per year.
- In 2000, in Uganda, we had _____ cubic meters of water per person. In 2025, we expect to have _____ and in 2050, _____. Our population growth rate is 2.9% per year.

With this growth, it is inevitable that we will start to claim a larger share of the Nile's flow to meet our growing irrigation and development needs. We understand that this will not please the countries down river from us, particularly Sudan and Egypt. We are forming a joint program to develop our shared resource, but we need help to monitor our resource in all Nile Basin nations.

Student Worksheet 8

The Nile: Log 4: Discussion Points Data Organizer

Name ______________________________ Date __________

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?
Key Management Issues								

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?
Key Management Issues								

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?
Key Management Issues								

JOURNEY through the UNIVERSE

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?
Key Management Issues								

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?
Key Management Issues								

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?
Key Management Issues								

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?
Key Management Issues								

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?

Key Management Issues

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?

Key Management Issues

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?

Key Management Issues

Nation	Population 1950	Population 2000	Population 2025	Population 2050	Water Stress 1950?	Water Stress 2000?	Water Stress 2025?	Water Stress 2050?

Key Management Issues