What's up with Earth's water resources?

Module Overview

This module addresses issues that are of fundamental importance to life. Four case studies of a coastal bay, an inland sea, a river, and mountain snow pack investigate water resources important to millions of people in North America, Asia, and Africa. Each investigation focuses on the physical nature of the resource, how humans depend upon the resource, and how human use affects the resource creating both problems and opportunities.

***Investigation 1:* Chesapeake Bay: Resource use or abuse?**
Students play roles of concerned citizens, public officials, and scientists while learning about the Chesapeake Bay and its environs. They use data and satellite images to examine how human actions can degrade, improve, or maintain the quality of the bay in order to make policy recommendations for improving this resource for future use.

***Investigation 2:* What is happening to the Aral Sea?**
Students work as teams of NASA geographers using satellite images to measure the diminishing size of the Aral Sea. Then they analyze and interpret graphic and tabular data about the causes of the shrinking sea and its effects on habitat, resources, and people in order to make recommendations for improving this resource for future use.

***Investigation 3:* The Nile: A sustainable resource?**
Students analyze data and make graphs to explore the relationship between population, water resources, water stress, and sustainable economic development. A simulation of a meeting of the Nile River Basin Initiative provides students with an opportunity to consider the perspectives of nations within the Nile River Basin.

***Investigation 4:* Why is snow important in the southwestern United States?**
Students role-play U.S. senators from seven western states seeking to find solutions to important problems in the Southwest: recurrent drought, which reduces vital snowpack resources; and rapid population growth, which increases demand on those resources. Information from satellite images, in tandem with ground-based perspectives, assist students in playing their roles as senators seeking to make recommendations on these problems.

Geography Standards

World in Spatial Terms
- **Standard 1:** How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

Places and Regions
- **Standard 4:** The physical and human characteristics of places

Physical Systems
- **Standard 7:** The physical processes that shape the patterns of Earth's surface
- **Standard 8:** Characteristics and distribution of ecosystems

Environment and Society
- **Standard 14:** How humans modify the physical environment
- **Standard 15:** How physical systems affect human systems

The Uses of Geography
- **Standard 18:** How to apply geography to interpret the present and plan for the future

Science Standards

Unifying Concepts and Processes
- Systems, order, and organization
- Evidence, models, and explanation
- Evolution and equilibrium

Science as Inquiry
- Abilities necessary to do scientific inquiry

Life Science
- Structure and function in living systems
- Populations and ecosystems

Earth and Space Science
- Structure of the Earth system

Science and Technology
- Understandings about science and technology

Science in Personal and Social Perspectives
- Risks and benefits
- Science and technology in society

History and Nature of Science
- Science as a human endeavor

Connection to the Curriculum

"What's up with Earth's water resources?" provides an instructional unit—about a month in length—that can be integrated, either in whole or in part, into high school courses in world geography, environmental geography, regional geography (of North America, of Africa, and of Asia), earth science, and global studies. The materials support instruction about aquatic and terrestrial habitats and ecosystems, as well as the dynamic interactions between physical and human environmental changes at both local and regional scales. Connections to mathematics skills are easily made because the materials require students to work with a large amount of quantitative data in graphic and tabular form.

Time

Investigation 1: Four to five 45-minute sessions
Investigation 2: Five to eight 45-minute sessions
Investigation 3: One to two 45-minute sessions
Investigation 4: Five to nine 45-minute sessions

Mathematics Standards

Number and Operation
- Compute fluently and make reasonable estimates

Algebra
- Understand patterns, relations, and functions
- Analyze change in various contexts

Measurement
- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

Data Analysis and Probability
- Formulate questions that can be addressed with data, and collect, organize, and display relevant data to answer them
- Develop and evaluate inferences and predictions that are based on data

Communication
- Communicate mathematical thinking coherently and clearly to peers, teachers, and others
- Analyze and evaluate the mathematical thinking and strategies of others

Connections
- Recognize and apply mathematics in contexts outside of mathematics

Representation
- Create and use representations to organize, record, and communicate mathematical ideas
- Use representations to model and interpret physical, social, and mathematical phenomena

Technological Literacy Standards

Nature of Technology
- **Standard 3:** Relationships among technologies and the connection between technology and other fields

Technology and Society
- **Standard 4:** The cultural, social, economic, and political effects of technology

Abilities for a Technological World
- **Standard 13:** Assess the impact of products and systems

Chesapeake Bay: Resource use or abuse?

Investigation Overview

Students play roles of concerned citizens, public officials, regional planners, and scientists to explore the Chesapeake Bay and its environs. They use data and satellite images to examine how human actions can degrade, improve, or maintain the quality of this water resource in order to make policy recommendations for improving the resource for future use.

Time required: Four to five 45-minute sessions

Materials/Resources

Briefing (one copy per student)
Handout 1: Roles (one role card for each of 10 students)
Handout 2: Testimony Points (one copy for three-four investigators)
Handout 3: Regional Planner Instructions (one copy for each student in class)
Computer station(s) with Internet access (optional)

Content Preview

Human action in the sensitive, highly interdependent Chesapeake Bay ecosystem has led to environmental degradation during the past century. Land use changes related to deforestation, agricultural use of fertilizers, and urbanization have led to increases in sediments and pollutants flowing into the bay. Natural climate cycles, periods of drought for example, exaggerate the effects of human action on the bay.

Classroom Procedures

Beginning the Investigation

1. Conduct a discussion on water as a resource. Ask these questions:
   - How do we use it? *(Drinking, transportation, recreation, industry.)*
   - What are some ways that water quality is affected by natural processes? *(Drought affects flow of fresh water; storms affect amount of sediment and water flow.)*
   - What are some ways water quality is affected by human actions and processes? *(Pollution from industry, run off, and sewage, diversion/reduction of feeder streams/rivers, sedimentation, destruction/development of wetlands.)*

   Relate these issues to water resources in your region.

Geography Standards

Standard 1: The World in Spatial Terms

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

- Produce and interpret maps and other graphic representations to solve geographic problems.

Standard 8: Physical Systems

Characteristics and distribution of ecosystems

- Apply the concept of ecosystems to understand and solve problems regarding environmental issues.

Standard 14: Environment and Society

How humans modify the physical environment

- Develop possible solutions to scenarios of environmental change induced by human modification of the physical environment.

Geography Skills

Skill Set 5: Answering Geographic Questions

- Formulate valid generalizations from the results of various kinds of geographic inquiry.

2. 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 Chesapeake Bay.

3. Have students locate Chesapeake Bay and the watersheds that drain into the bay. Ask them to note the major cities in the Chesapeake Bay River Basin. Resources for students to use to situate Chesapeake Bay are listed in the **Briefing**.

Developing the Investigation

4. Distribute the Briefing. Ask students to read the entire Briefing but assign a few specific paragraphs to groups of three or four. Ask each group of students to generate several questions, summarize their assigned reading, and take turns asking and answering questions.

5. Explain the premise of the role playing:
   - 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 Chesapeake Bay, to collect information, and to begin to develop a sustainable policy to preserve and maintain the integrity of this national resource.
   - Students play a role representing individuals involved in exploring the uses and abuses of Chesapeake Bay, one of the United States' most significant water resources.

6. Briefly explain the format for the role playing.
   - Ten *individuals* (concerned citizens, public officials, scientists) testify before the hearing. They are questioned by a team of three or four invited *investigators*. All students are *regional planners*. They may ask questions of witnesses and will write a draft statement recommending future policies based on the testimony they hear.
   - Role summaries for each *individual* are provided (Handout 1). 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 by reading and discussing the **Handout**.
   - The *investigators* (three or four students) receive the list of questions each role player is prepared to answer (Handout 1) and the points that they should have each testifier make (Handout 2). 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 and draft the policy statement and justification for it after hearing the testimony.

7. Seek volunteers for each role and distribute the role cards (Handout 1). Each student must find the answers to the questions from the **Briefing** and assume the character. Require presenters to prepare a visual (for example, a map, diagram, overhead of images appearing in the **Briefing**, graphs made from additional data obtained by researching the suggested resources) to support their testimony. For example:
   - Susan Elliott: a diagram to show the local, state, and federal agencies that have cooperated to study the bay
   - Fred Kyle: a system diagram showing changes in sea grass, fin fish, oysters, and crabs over the past 100 years
   - Pam Gibbons: LANDSAT images and maps to show population growth in the region
   - Chris Sprinski: a graphic to illustrate the role of excess nutrients in water and air causing degradation of the bay
   - Georgina Giovingo: pictures of her husband fishing on the bay
   - Phil Klein: a graphic describing how sediments flow into the bay
   - Kristin Hyche: a graphic illustrating the role climate plays in the bay ecosystem
   - LeVar Jenks: a graphic showing the relationships among agriculture, industrialization, and urbanization and bay health and productivity
   - Evalia Tweedle: see role card
   - Steve Sui: copies of the AVIRIS, SeaWIFS, and LANDSAT images

You may wish to have two-person teams for each individual role to facilitate the preparation of the graphic.

8. Distribute the list of roles and questions (Handouts 1 and 2) to the investigators. Allow them to divide the questions among themselves and to coordinate a strategy to ensure they are efficient and logical in their questioning.

9. Distribute directions to the regional planners (Handout 3). 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. Decide on a format for the policy recommendations.

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

Developing the Investigation

11. Begin the role play. You may wish to act as moderator Susan Elliott or ask a student to play the role. 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 they wish. Continue through the testimony. At close, request that the regional planners (all students) draft a policy statement.

Concluding the Investigation

12. Debrief the town forum.
    - Review the points presented by the individuals, the major concerns, and key issues.
    - Give students time to meet as regional planners and draft a policy to preserve and maintain the integrity of Chesapeake Bay. When they are finished, ask for a summary.
    - Discuss it. How well does the policy reflect a new understanding of the natural and human processes that affect water quality and use? What would be the long-term impact of such a policy? Who would be most affected? Least affected? Would it work? Ask students to make generalizations about water resources in densely populated regions of the world as well as in your region of the United States.

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 Chesapeake Bay. You are moderating the forum.

As moderator you should

- state the purpose of the town forum and provide some background (see the Questions listed below);
- introduce the investigators, citizens, and scientists;
- ensure that order is maintained and that everyone is polite and has an opportunity to speak; and
- remind all participants that they will, as regional planners, develop a policy to preserve and maintain the health of Chesapeake Bay.

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 such partnerships of citizens and scientists been in setting environmental policies?

Fred Kyle

You are 44 years old and a concerned citizen employed by a high 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 recreation opportunities. You enjoy taking your children on the water and someday hope to take your grandchildren but are 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 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 lifelong 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 but took environmental science courses as well. Currently you serve as a consultant to the Friends of Chesapeake Bay, a nongovernmental 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 from the waters 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 includes 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 subaquatic 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 assigned to the Chesapeake Ecosystem Response Project. You grew up in innercity Baltimore and, as a young boy, loved to fish the bay with your grandfather and cousins. That 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 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 nonpoint source pollution?
- What are some of the key sources of pollution?
- What are some strategies 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 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 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 Chesapeake Bay indicate?
- Discuss the usefulness of remote sensing for tracking changes on Earth?

Handout 2: Investigator's Points That 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, suburban, 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, the Potomac, the Patuxent, the Choptank, the Rappahannock, the Mattaponi, the Pamunkey, the James, and the 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 subaquatic vegetation like 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 the 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, we 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 pollution is pollution coming from a known, identifiable source, such as a pipeline spewing waste. Nonpoint source pollution is pollution that enters surface, ground water, and the oceans from widespread and distant activities, that is, from no one, single point.
- The key sources of nonpoint 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. Householders 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 model is the system. 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, 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 thus inhibiting the growth of sea grasses or subaquatic 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. It is also a food source for water birds living in the bay.

Georgina Giovingo

- The bay provides 50 percent of the nation's blue crab harvest, worth about $130 million per year. There are many people who make their living by fishing 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 shell fish. 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, overharvesting, natural mortality, and climate change all play varying roles.
- The bay ecosystem is very complex, and little is known about the relations 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 dataset 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 shell fish, 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 fishermen 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 kilometers above sea level. It is used to identify, measure, and monitor constituents of Earth's surface and atmosphere. Research with AVIRIS is directed towards 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 kilometers. 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 Chesapeake Bay, ocean patterns are clearly evident, such as plumes of material discharging out of eastern Long Island Sound. Red and yellow areas in 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 types of residential land uses. It is very useful for local and regional planning agencies.

Instructions to Regional Planners

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 Situation

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.

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 each individual makes. 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 with 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.

Module 1, Investigation 1: Briefing
Chesapeake Bay: Resource use or abuse?

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 Chesapeake Bay, one of the United States' most significant water resources.

Because 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 ensure 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 the river systems that flow into the bay. Turn to Figure 6 to see the land use in this highly industrialized, highly urbanized region.

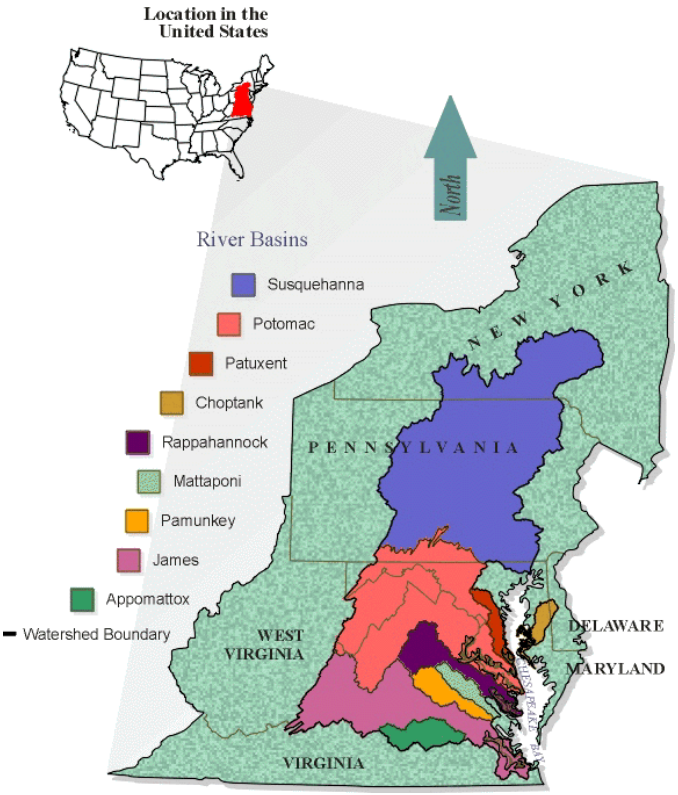

Figure 1: Location of Chesapeake Bay and the river systems that flow into it

Source: http://mapping.usgs.gov/mac/chesbay/overview_cbep_fig1.html

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.

Module 1, Investigation 1: Briefing
Chesapeake Bay: Resource use or abuse?

Critical Issues for Ecosystem Management and Restoration

Chesapeake Bay is a complex natural ecosystem with many inter-related 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 both humans and plants and animals, and offer a huge pool of resources for humans and other living creatures. Ecosystems are affected by natural events such as droughts. But ecosystems are more drastically changed by human activities.

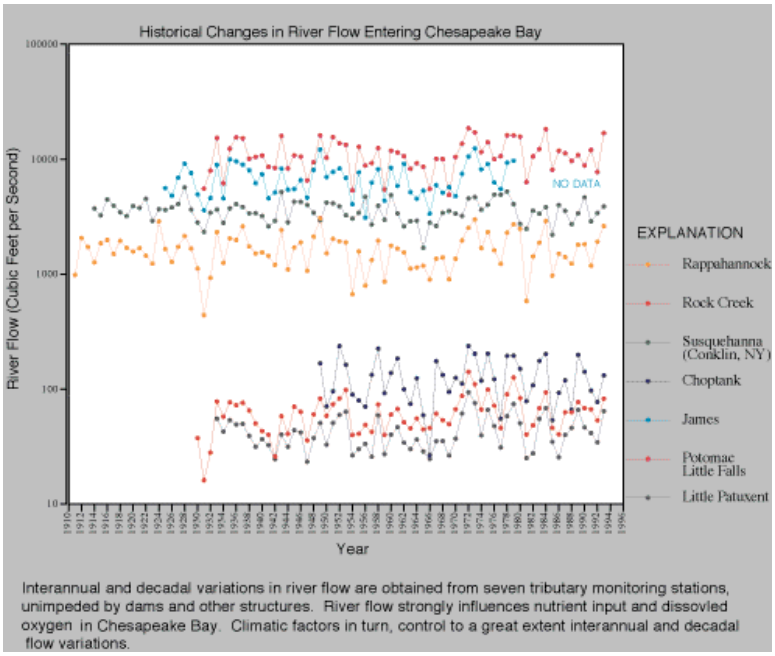

Figure 2

Source: http://geochange.er.usgs.gov/pub/info/facts/chesapeake/graph.gif

The model used for bay ecosystem management is a system which 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 in 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 (Figure 2). 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.

Module 1, Investigation 1: Briefing
Chesapeake Bay: Resource use or abuse?

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 you consider *nonpoint source pollution*, which comes from nearly everything we do on land that 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 a 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 over-populated plants and algae die off, 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 house-hold hazardous waste.

Module 1, Investigation 1: Briefing
Chesapeake Bay: Resource use or abuse?

Get a Handle on Household Hazards
To cut your "pollution contribution," use fewer hazardous or unsafe products if you can. If you can't, use only as much as you need; share leftovers with neighbors, businesses, or charities; and dispose of leftovers safely.

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 unit. For this reason, a landmark 1983 agreement formed the Chesapeake Bay Program (CBP).

The Chesapeake Bay Program is a partnership between the U.S. Environmental Protection Agency, Maryland, Pennsylvania, Virginia, the District of Columbia, the Chesapeake Bay Commission, and local governments of the bay watershed. The program has helped reduce nutrient pollution from farming and livestock, banned phosphate detergents and tributyl-tin boat paints, and protected ecologically sensitive shorelines.

The Chesapeake Bay Program
- aims to restore living resources, including fish, shellfish, bay grasses, and other aquatic wildlife;
- monitors water quality and biotic resources;
- produces computer models to predict watershed quality and ecosystem response to nutrient loading;
- used modeling studies to establish a goal of a 40 percent reduction from 1985 levels of nutrient input into the bay by 2000;
- developed biotic management plans to restore and preserve key species for commercial use and recreation; and
- conducts ship-based monitoring to collect measurements of physical, chemical, and biological indicators.

Taking Action: Research, Response, and Management

The U.S. Geological Survey's (USGS) Chesapeake Ecosystem Response Project is another effort to understand large environmental changes influencing the water quality and living resources in the bay. In particular, the project scientists
- investigate links among changes in climate, discharge, salinity, and dissolved oxygen over different time periods and geographical scales;
- study the effects of past events recorded in the layers of sediment deposited on the floor of the bay over time;
- collaborate with researchers from the University of Maryland, the Maryland Geological Survey, and the Virginia Institute of Marine Science to study the bay's sediments;
- 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;
- found a linkage between climate and land quality and habitat loss in the bay;
- continue to study trends in oxygen, nitrogen, and phosphorus levels, phytoplankton, benthic invertebrates, sedimentation, and biodiversity with emphasis on separating natural versus human causes of and responses to extreme events.

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.

Module 1, Investigation 1: Briefing
Chesapeake Bay: Resource use or abuse?

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 kilometers.

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 3, 4, and 5 show views of Chesapeake Bay from the SeaWiFS (Sea-Viewing Wide Field-of-View Sensor). Figure 3 shows data taken on September 16, 1997, and Figures 4 and 5 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 kilometers. 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.

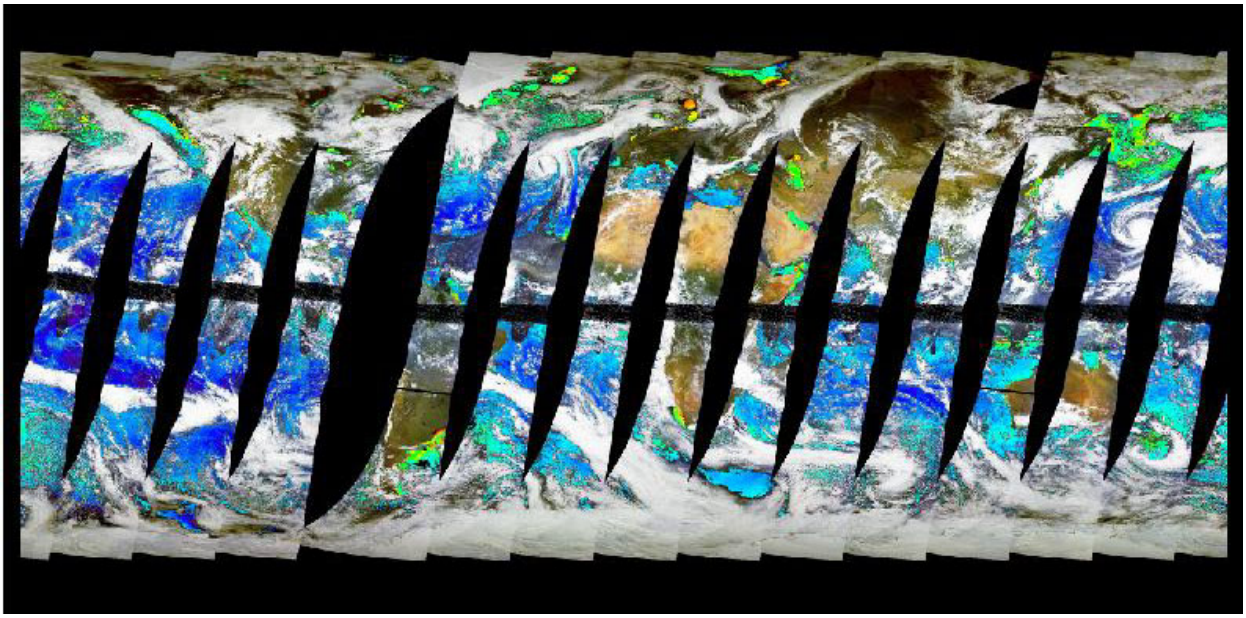

Figure 3: SeaWiFS data from September 16, 1997

Source: http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/SEAWIFS/revised_ocean_color_and_land_4096x1024.jpg

Module 1, Investigation 1: Briefing
Chesapeake Bay: Resource use or abuse?

In Figure 3, 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 5, ocean patterns are evident, such as plumes of material discharging out of Delaware Bay. Red and yellow areas in 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 4: SeaWiFS, September 19, 1997, New York—Chesapeake Bay, true color

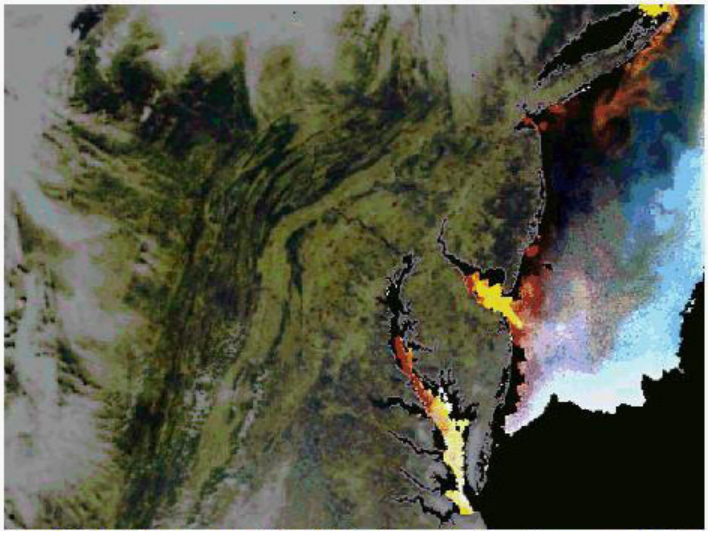

Figure 5: SeaWiFS, September 19, 1997, New York—Chesapeake Bay showing ocean radiance

http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/SEAWIFS/ches_combined.jpg
http://seawifs.gsfc.nasa.gov/~grey/slides/october97.html

Module 1, Investigation 1: Briefing
Chesapeake Bay: Resource use or abuse?

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.

References

Information on the AVIRIS mission
http://geo.arc.nasa.gov/sge/johnson/epa/chesbay.html

Information on the SeaWiFS mission
http://seawifs.gsfc.nasa.gov/~grey/slides/october97.html

Oblique view of Chesapeake Bay watershed and surrounding region
http://svs.gsfc.nasa.gov/imagewall/SeaWiFS/zoom_chesapeake.jpg

QuickTime movie locating the Chesapeake Bay
http://svs.gsfc.nasa.gov/imagewall/SeaWiFS/zoom_chesapeake.mov

USGS Chesapeake Bay web site
http://earth.jsc.nasa.gov/

Shuttle images of Earth
http://mapping.usgs.gov/mac/chesbay/index.html

Poster image of the Chesapeake Bay watershed
http://mapping.usgs.gov/mac/chesbay/poster.html

Site for Chesapeake Bay ecosystem background information
http://geochange.er.usgs.gov/pub/info/facts/chesapeake/

Resource site developed by the Chesapeake Bay Program
http://www.chesapeakebay.net/

Look up your community's watershed at this site
http://www.epa.gov/surf2/locate/

Site for population data
http://www.chesapeakebay.net/pop.htm

Site for human use background information
http://www.chesapeakebay.net/landscape.htm

USGS FactSheet FS-116-00. September 2000. "Effects of Climate Variability and Human Activity on Chesapeake Bay and the Implications for Ecosystem Restoration."

Module 1, Investigation 1: Briefing
Chesapeake Bay: Resource use or abuse?

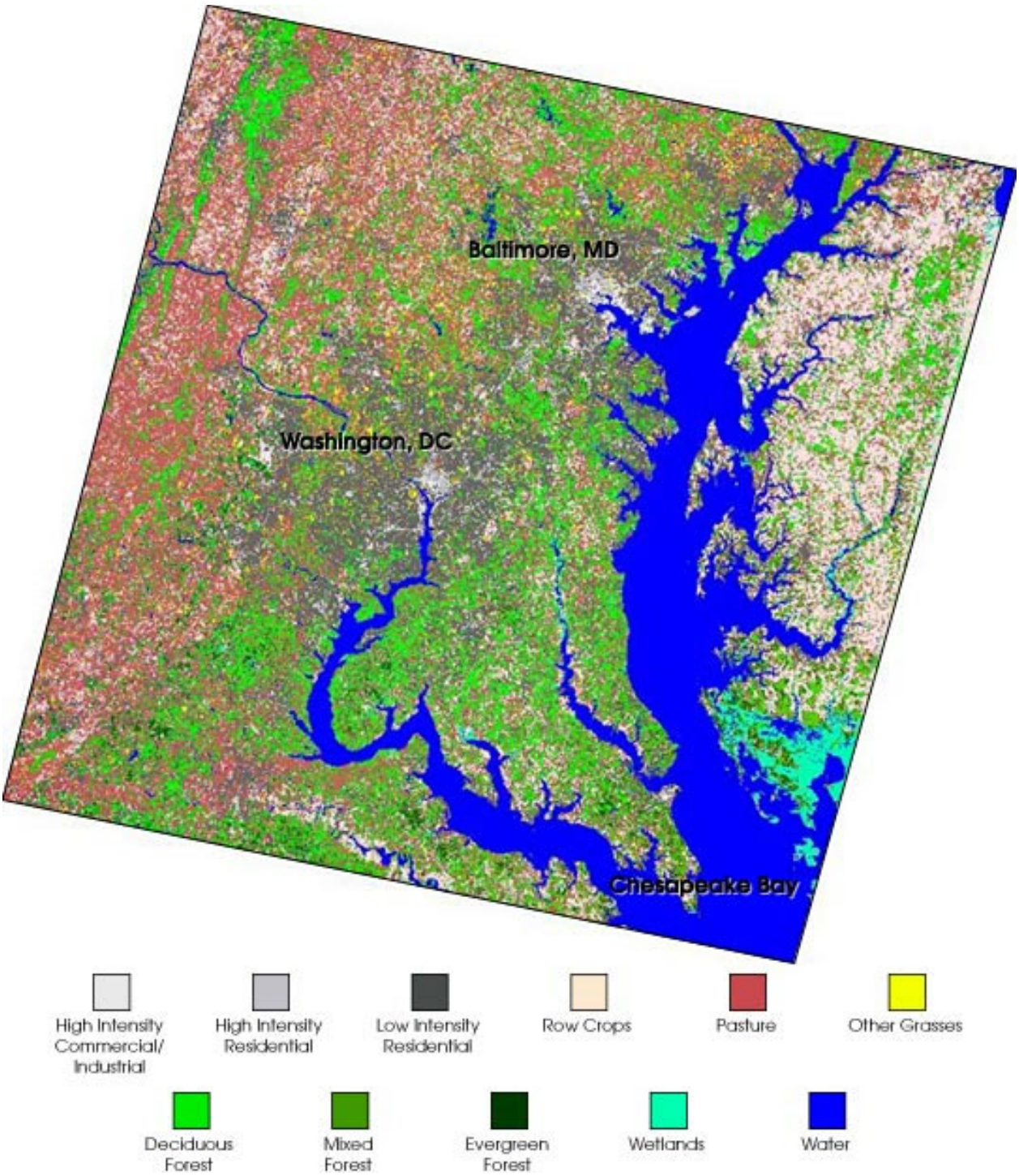

Figure 6: LANDSAT 7 image showing land cover types in Chesapeake Bay area including residential development, wetlands, forests, and croplands