Estuaries 101 Curriculum

Earth, Life and Physical Science Modules

Teacher's Guide

A Curriculum for Grade Levels 9-12

The Estuaries 101 Curriculum was produced for the National Oceanic & Atmospheric Administration (NOAA) and the National Estuarine Research Reserve System (NERR) by TERC.

To download the Estuaries 101 Curriculum and access other supporting materials, visit http://www.estuaries.gov

Teacher's Guide

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Foreword

Everyone loves the ocean, and most people know the ocean through their experiences at the shore, often in an estuary. A sunbather on a barrier beach, the captain of a cargo vessel maneuvering to offload freight in a seaport harbor, an artist painting a scenic salt marsh, shellfishers probing a mud flat, a family in a coastal city strolling along the waterfront, and a couple of kids out for a day sail in a protected coastal bay all depend on estuaries for their activities, yet few can even define the word if asked. Furthermore, human activities such as filling wetlands, armoring the shoreline, and discharging wastewater have seriously impacted the integrity of coastal ecosystems. When asked in a survey about the health of coastal waters, over a quarter of the public reported that they do not know enough about these areas to give an opinion (Belden et al., 1999). Though the public is aware of ocean and coastal resources, detailed knowledge of environmental science, ocean and coastal science, and the ocean's connection to humans' well-being is lacking (NEETF, 2005 and Belden et al., 1999). People need to know what estuaries are, how they are related to terrestrial and ocean systems, what important services they provide for humans, and how to restore and protect them.

In response to this challenge, we, in NOAA's National Estuarine Research Reserve System (NERRS), recognized an opportunity to build a national program that would help advance ocean and estuarine literacy, building on and integrating educational and scientific resources across the full NERRS system. Instead of a collection of locally-developed activities, we have worked to create a comprehensive national program, for use by all the NERRS education coordinators, as well as, students and teachers throughout the US. This integrated program was conceived and planned by all NERRS educators and built to meet the best pedagogical designs. Envisioned ultimately as a full K–12 set of activities, development begun with a high school set of modules that we called "Estuaries 101".

It is thus our pleasure to introduce the Estuaries 101 Curriculum. Focusing on estuaries, the curriculum modules feature hands-on learning, experiments, field work and data explorations. The curriculum consists of four modules, Life Science, Earth Science & Physical Science each using estuaries as the context for developing content knowledge and skills relevant to that domain, and a Chesapeake Bay Module which integrates and deepens the focus on estuarine concepts in a local context.

The Estuaries 101 Curriculum is comprised of four two-three week modules on estuaries. Designed for 9th–12th grade classrooms – with the flexibility to adapt to higher or lower grades – it covers key National Science Education Standards for Physical Science (Transfer of Energy and Properties, Changes in Matter), Earth Science (Structure of the Earth System), and Life Science (Interdependence of Organisms, Matter, Energy, and Organization in Living Systems).

While this version of the Estuaries 101 Curriculum, for grade level 9-12, is now available for distribution, we wish to remind all educators that curriculum design and review is a continuous, cyclic process. We wish to have a product that is truly effective for educators to implement in their classrooms. But to do so, we will evaluate it's effectiveness and continue to invite educators to provide us with feedback.

Many thanks go to all who have contributed to the development of the Estuaries 101 Curriculum: teachers, principals, parents, employer representatives, TERC staff, and to a very talented group of NERRS education coordinators. TERC, an educational non-profit with over 40 years of experience in science, math, technology, and engineering education, was the main partner in drafting and developing all the activities that form part of the Estuaries 101 Curriculum.

Our next steps? Building on this framework to offer our young people the most effective and meaningful teaching possible that will enable them in the future to make sound informed decisions about our estuaries and coasts.

Purpose & Goal

With the many threats that our nation's oceans face, it is time for a new era of ocean literacy and enhanced efforts to prepare today's children to be tomorrow's ocean stewards. Estuaries are an ideal topic to excite students about studying the ocean because of the strong personal connections people have with estuaries—from treasured recreation experiences, scenic views during transits, to making a living on the water. Advancing estuarine, coastal, and ocean literacy is a priority of NOAA's National Estuarine Research Reserve System (NERRS). It is our expectation that, through the Estuaries 101 Curriculum, students and teachers will gain an understanding of the great importance of estuaries and the intricate connections it has with the ocean and climate systems.

The goal of Estuaries 101 is for students and teachers throughout the nation to become more ocean literate through increasing their knowledge of coastal and estuarine science and how estuaries affect their daily lives. To achieve this increased literacy, teachers will use this estuaries.gov site to access the modules and activities for grades 9-12 and an online interface to real-time and archived estuarine monitoring data (from NERRS' System Wide Monitoring Program). Use of the Estuaries 101 Curriculum will be encouraged and supported through professional development trainings hosted at 27 Reserves and at professional meetings across the nation.

Using the Estuaries 101 curriculum, teachers will be able to teach their students about Earth System Science using coastal and ocean data. Through this curriculum—which includes interactive investigations, field studies, and data analysis—teachers and students will learn that estuaries provide shelter, spawning grounds, and food for many species, that they act as buffers to improve water quality, reduce the effects of floodwaters, and prevent erosion, and that coastal areas provide value to humans in the form of recreation, scientific knowledge, aesthetics, commercial and recreational fishing, and transportation (Thayer et al., 2003).

Why teach about estuaries?

Estuaries offer a wonderfully rich context for science education and inter-disciplinary learning. Estuaries are dynamic environments with a daily flux of ocean flows mingling with river water, creating a remarkably diverse range of life and ecosystems. As a result, they offer learners a convergence of such fields as Earth systems science, biology, chemistry, geography, geology and marine science. For example, students develop math skills through detailed measurements, modeling phenomena such as growth and cyclical variation, and analyzing data to make comparisons across multiple estuaries. They develop language skills as they read and write about estuary-related topics and communicate their explorations and findings with other students and scientists. Since estuaries have also played a significant role in human settlement, exploration and development, students gain new eyes on human history, geography and culture.

Most estuarine concepts and skills are part of the national and state science standards. Although "estuaries" per se may not appear prominently in many state standards, the underlying science concepts embodied in estuaries have broad connections throughout the standards. For example, most state science education standards refer to understanding "Earth as a system", with interwoven cycles and processes relating to land, air and water. Estuaries provide engaging and accessible examples of these processes at work. Estuaries also integrate key concepts in biology (e.g. habitat adaptations), chemistry (e.g. salinity analysis) and physics (e.g. wave motions). Furthermore, most state standards call for inquiry-based learning through hands-on experiments, direct observations and active use of data - all of which occur as students engage with estuaries.

In addition, while learning interdisciplinary skills using estuaries, students gain an appreciation for the importance of estuaries in their lives and learn how their behavior impacts coastal ecosystems. We believe that it is of utmost importance to prepare tomorrow's leaders to make sound decisions about the environment and the nation's oceans and coasts. Students must understand the crucial connection between estuaries, coastal, and upland areas, and the effects of a growing population.

Components of the Curriculum

About Estuaries 101

Recognizing the incredible power of estuaries to provide a rich environment for learning, exploration, and discovery, NOAA and TERC developed *Estuaries 101*—a series of three Modules: Life Science, Earth Science, and Physical Science—addressing different aspects of the estuary environment. You can do any or all of the Modules, which consist of a series of activities and a final assessment.

* The activities in the Estuaries 101 Modules have been field tested and found to be very engaging and popular with both teachers and students.

* They are inquiry-based, conveying both content knowledge and scientific thinking and problem solving skills.

* They are aligned with the National Science Education Standards and to some State Standards. Please check the estuaries.gov site to find new alignments to other State Standards.

* They are also based upon core principles and concepts identified by the National Estuarine Research Reserve System (NERRS) educators—key principles and concepts about estuaries that students need to master in order to become estuarine literate.

* They are grounded in specific estuaries within the NERR system, though you should feel free to adapt the activities for an estuary near your school or ones in parts of the world appropriate to your classroom and curriculum. (See the *About the Modules* section of this guide and each activity for specifics.)

* A number of the activities make use of Google Earth as a means of providing context to the students' investigations and offering virtual field experiences. A support guide on using Google Earth as part of the Estuaries 101 curriculum is available online and details related to exploring specific estuaries are included in the activities that use Google Earth. (See *Using Google Earth to Explore Estuaries*, available on the estuaries.gov site, and each activity.)

* And the activities all follow the same basic structure:
    - Teacher Guide, including an introduction and overview, learning goals and standards-matching, background information, materials and preparations, procedures, assessments, and extensions
    - Teacher Answer Key
    - Student Reading(s)
    - Student Sheet(s)
    - Student Data Sheet(s)

Finally, each Module concludes with an assessment piece, designed for use after completion of all the activities within that Module. These assessments, which overarch all the activities within a Module, provide a means for both grading, as appropriate, and checking in with student advances in understanding. Also, within each activity, there are opportunities for formative assessment.

About the Modules

Each Module tells the estuary story through one of three perspectives—through Earth, life, or physical science. With theses emphases on specific domains, each Module will appeal to different teachers, to be used together or separately.

Earth Science Module

Students investigate landforms and features associated with estuaries, tides and salinity in estuaries, watersheds and their relationship to the dynamic changes that occur in estuaries due to drainage and runoff, and how hurricanes can affect estuaries.

- Activity 1: Observing Estuaries: A Landform and Feature Scavenger Hunt
- Activity 2: Salinity and Tides in York River
- Activity 3: Estuary and Watershed
- Activity 4: Extreme Weather and Estuaries
- Final Earth Science Module Assessment

Life Science Module

Students investigate the range of conditions that selected animal and plant species need to survive in an estuary, model estuaries, consider algae blooms in estuaries, study how nutrients cycle through an estuary, suggest recommendations for reducing nutrient inputs to estuary waters, and investigate the incredible biodiversity that exists in estuarine environments.

- Activity 1: Survival in the Estuary
- Activity 2: Nutrients in an Estuary
- Activity 3: Biodiversity in an Estuary
- Final Life Science Module Assessment

Physical Science

Students investigate water quality parameters to study the nature of, and the cyclical changes inherent in, the chemistry of estuarine water, learn about dissolved oxygen and its effects on life, with a focus on the chemistry, model a pollution spill that occurred at Bangs Lake (a tidal lake within the Grand Bay NERR), and study the actual spill and how it changed water quality parameters in the estuary.

- Activity 1: Chemistry in an Estuary
- Activity 2: Dissolved Oxygen in the Estuary
- Activity 3: Human Impacts on Estuaries: A Terrible Spill in Grand Bay
- Final Physical Science Assessment

Curriculum Map—Earth Science Module

Enduring Understanding	Activities	Learning Objectives
Estuaries are unique, dynamic transition zones, between the watershed and the world ocean system. Earth processes create and determine the physical features of estuaries.	**Activity 1 — Observing Estuaries** Students investigate landforms and features associated with estuaries. They begin by taking a journey down a river to an estuary system where the river empties into the Gulf of Mexico near Weeks Bay NERR to investigate how landforms differ between uplands and riverine/estuarine environments. Student teams then use Google Earth and other resources to engage in a scavenger hunt to locate and identify landforms and features of estuaries.	**Students will be able to:** • Describe differences between upland non-estuarine and estuarine landforms and features. • Visually identify and describe various landforms and features associated with estuarine environments, including salt marshes, barrier beaches, peninsulas, headlands, spits, mud flats, fjords, deltas, coves, harbors, sounds, and others.
Earth processes, characteristics of the watershed, and the physical features of the estuary affect patterns of mixing of fresh and salt water in an estuary.	**Activity 2 — Salinity and Tides in York River** Students observe time-lapse models of tides and salinity distribution in the York River, part of the Chesapeake Bay, VA NERR. They learn how salinity changes with an incoming and outgoing tide, observing the dynamics of the salt wedge at various sites along the river. They make predictions about the salinity changes at each site based upon their observations of the animation. They then use salinity data from monitoring stations along the river to see changes during a typical day, and they describe the patterns of each salinity graph and compare the graphs.	**Students will be able to:** • Analyze different forms of data and synthesize information to develop a hypothesis. • Explain how tides and the geology of the estuary affect water circulation in an estuary. • Describe daily patterns of salinity changes in the estuary.
Estuaries are part of watershed systems. The characteristics of the watershed determine some of the characteristics of the estuary.	**Activity 3 — Estuary and Watershed** Students investigate the nature of watersheds and their relationship to the dynamic changes that occur in estuaries due to drainage and runoff. They begin by examining the San Francisco Bay Estuarine Research Reserve and tracing the extent of its watershed using Google Earth. Then they identify possible sources of pollution and contamination along the major rivers that feed into the bay. Students also examine water quality data in the San Pablo region of the estuary and identify changes that occur due to a storm event.	**Students will be able to:** • Identify the processes in the watershed that affect conditions in the estuary and explain some specific examples. • Apply their understanding of changes in the watershed and the resulting effects on the estuary to explain real-life situations regarding land use and weather in watersheds. • Understand how water quality factors are affected by natural and man-made sources of pollution and contamination.
Coastal processes and interactions within the ocean system play an important role in estuarine dynamics.	**Activity 4 — Extreme Weather and Estuaries** Students investigate how hurricanes can affect NERRS estuaries. Students begin by studying the North Carolina NERR in the Cape Fear area with Google Earth and predict which areas of the reserve might be more vulnerable to the onslaught of high winds, heavy rain and storm surge than others. Then students monitor and interpret the changes in water quality factors day by day as a severe storm approaches, strikes the estuary, and then dissipates.	**Students will be able to:** • Describe the features and landforms associated with a coastal estuary. • Predict how major storm events affect NERRS reserves in the United States. • Investigate and interpret changes in water quality in an estuary due to a severe weather event. • Determine the relationship between the characteristics of an extreme weather event (heavy wind, torrential rains and storm surge) and the subsequent change in water quality over time.

Parts of the Activity	Estuary	Science Concepts	Assessment
• What is an Estuary? • A trip down the Alabama River • Estuary Landforms and Features—Scavanger Hunt	Weeks Bay NERR, Alabama	Watersheds, coastal geography, coastal circulation, coastal processes, tides	Discuss the following: • How do the terrain and types of landforms change as you travel down a river toward a source of salt water? • Which of the landforms and features on your scavenger hunt list were fairly common? • Which landforms were not present at all? Have students sketch an imaginary estuary system on a piece of paper. Direct them to draw and label as many landforms and features on their diagram as possible. Collect and evaluate them for accuracy, clarity, and the number of landforms correctly identified.
• Tides in Chesapeake Bay • Salinity as York River Flows into the Bay • Interaction of Tides and River Flow	Chesapeake Bay, VA NERR	The water cycle, salinity and density, tides, ocean currents and circulation, coastal processes	1. Discuss the following: • How do the changes at each monitoring station compare with changes at those same areas in the animation? • Name several factors that determine why salinity changes are different depending on your location within the estuary. 2. Ask small groups to use their handouts to answer this question. Collect this assignment and use it as a final assessment. *Imagine that an intense rainstorm dumps 3 inches of rain over the entire Chesapeake Bay region. Predict how the salinity would change at all four stations in the bay for a period of 24 hours after the storm ends. Supply a graph and an explanation of what you might expect to see at each station.*
• Exploring the San Francisco Watershed • What's Upstream Comes Downstream • Water Quality at the Mouth of the Watershed • *Optional*: Mapping Your Local Watershed	San Francisco Bay NERR, California	Watersheds, water cycle, runoff, biogeochemical cycles, water pollution	1. Discuss the following: • How do agricultural areas, industrial sites, landfills, and sewage treatment plants affect water quality in a watershed? • Explain how an estuary can act as a filtration system for runoff in a watershed. 2. Supply students with a road map of the eastern U.S. and project a satellite image of the Chesapeake Bay watershed. Ask students to identify major urban areas around Chesapeake Bay and major rivers that drain the watershed. Ask students to predict where they would expect areas in the most danger of contamination and pollution if a major storm event such as a hurricane struck the region.
• Investigating an Estuary • Which NERRS are Affected by Hurricanes? • Impact of Extreme Weather on an Estuary	North Carolina NERR	Water cycle, climate change, sea level rise, ocean currents, coastal processes, food webs	Discuss the following with students: • What were the effects of a major storm event in the North Carolina NERR? • What caused the change in each of the four abiotic parameters studied in this activity? • Why is there a difference in the time it takes for the different parameters to return to normal? • What effects do you think the storm might have had on different plants and animals in the estuary?

Curriculum Map—Life Science Module

Enduring Understanding	Activities	Learning Objectives
Estuaries have unique communities that are adapted to variable, dynamic environment in these transition zones between watersheds and the ocean.	**Activity 1 — Survival in an Estuary** Students investigate the range of conditions that selected animal and plant species need to survive in an estuary. They examine data for abiotic factors that affect life in estuaries—salinity, dissolved oxygen, temperature, and pH. Students use archived data (trend analysis graphs) and real-time conditions at Elkhorn Slough to predict whether a particular animal or plant species could survive in an estuary.	**Students will be able to:** • Describe three types of estuarine environments. • Describe the particular environmental conditions necessary for organisms to survive in an estuary. • List four principal abiotic factors that influence the survival of aquatic life in estuaries. • Determine the range of pH, temperature, salinity, and dissolved oxygen tolerated by some common estuarine species.
The flow of matter and energy in the estuarine ecosystem reflects the flow, mixing, and circulation of estuary waters.	**Activity 2 — Nutrients in an Estuary** Students model estuaries, artificially enriching both fresh and salt water samples with different amounts of nutrients and observing the growth of algae over a several weeks. They relate their results to the phenomenon of algae blooms in estuaries. They then analyze data for different sites in a NERRS Reserve in Florida to discover the relationships between nitrogen, chlorophyll, and dissolved oxygen. Finally, they study how nutrients cycle through an estuary and suggest recommendations for reducing nutrient inputs to estuary waters.	**Students will be able to:** • Understand how water quality and nutrient parameters in an estuary can indicate disruptions to ecological processes in estuaries. • Interpret data from an experiment to explain the effects of over-enrichment on water quality and living things; and relate this lab experience to the phenomenon of algae blooms and eutrophication in an estuary. • Explain the phenomena of algae blooms and eutrophication in terms of total nitrogen, chlorophyll-a, and dissolved oxygen. • Describe the effects of eutrophication on the nitrogen cycle. • Explain how nutrients cycle in an estuary and how natural processes and human impacts affect this cycle. • Identify sources of nitrogen inputs to estuaries and identify some ways to limit them.
The biology of estuary species reveals their adaptations to the unique and variable estuarine habitats.	**Activity 3 — Biodiversity in an Estuary** Students investigate the incredible biodiversity that exists in estuarine environments. They begin by exploring the Rookery Bay National Estuarine Research Reserve using Google Earth. Students then produce an estuary biodiversity concept map and individual organism profile that becomes part of an estuary wildlife exhibit.	**Students will be able to:** • Describe the physical and biological components of habitats that exist as part of an estuary. • Explain the relationships between primary producers, consumers, and secondary consumers. • Describe some adaptations of living organisms to the changing conditions within an estuary. • Explain why biodiversity is important and worth preserving in an estuary.

Parts of the Activity	Estuary	Science Concepts	Assessment
• The Estuarine Environment • Surviving Changes: Abiotic Factors that Affect Life • Surviving in an Estuary: Extreme Conditions • *Optional*: Investigating Other NERRS sites	Elkhorn Slough NERR, California	Adaptation, habitats, communities, abiotic vs. biotic environment, biodiversity, zonation, water cycle, coastal processes, communities, adaptation	• Direct your students to the Central Data Management Office Web site: <cdmo.baruch.sc.edu/>. Help students navigate through the site until they can successfully download trend analysis data for 2005 from one monitoring station at four other NERR sites. Encourage them to choose sites both in your region and in other parts of U.S. coastal areas. OR, download sample data from four sites and hand them out to students. • Direct students to fill out an Extreme Conditions table for each site. • Have students create graphs comparing parameter ranges and time between extremes for new sites with South Marsh data. • Discuss with students the patterns they see and ask them to explain why the ranges and rates of change for each factor vary at different estuary sites. Or ask them to write their answers down and collect student work to serve as a summative
• Nutrients in an Estuary • Using Data to Study Eutrophication and Conditions in an Estuary • Eutrophication and the Nitrogen Cycle	Guana Tolomato Matanzas NERR	Food webs, trophic interactions, biogeochemical cycles, coastal circulation, life cycles, migration	Students write a short letter to the town council of this region outlining your recommendations about steps to take to reduce the amount of nutrient flow into the estuary.
• Investigating Habitats in an Estuary • Biodiversity in an Estuary • Portrait of Life in an Estuary	Rookery Bay NERR, Florida	Adaptation, habitats, trophic interactions, cell biology concepts, physiology concepts	• Use the concept maps from Part 2 as an assessment of student understanding of the relationships between habitats, characteristics of the habitats, and the species that inhabit the estuary. • A simple way to do this is to give 1 point for each link on the concept map between two of the three variables. Then, award 2 points for each double link (two lines that reveal a relationship). Add 3 points for complex interrelationships in the concept map (3 or more lines coming from one box). Establish a class scale based on the total points given for each poster. • Evaluate the Wildlife Exhibit posters as a summative performance assessment for this activity. • Have a discussion with students after the Wildlife Exhibit viewing has ended. Ask students: a. Which animals or plants in Rookery Bay are endangered? b. What conditions in the estuary have caused populations of each of the endangered species to decline? Are any actions being taken or projects underway to protect the remaining population

Curriculum Map—Physical Science Module

Enduring Understanding	Activities	Learning Objectives
Estuaries are unique, dynamic transition zones, between the watershed and the world ocean system. Earth processes create and determine the physical features of estuaries.	**Activity 1 — Chemistry in an Estuary** Students investigate water quality parameters to study the nature of, and the cyclical changes inherent in, the chemistry of estuarine water. They study key water quality factors at several stations in a single reserve over time—current, daily, and yearly time scales—and compare water quality values over a yearly time scale in three different estuaries. Then students take water quality measurements at a site near them and compare it to the water in the three geographically diverse NERR estuarine environ-	**Students will be able to:** • Describe how different chemical and physical properties affect and interact within an estuarine environment. • Explain how analyzing chemical and physical water quality data can lead to an understanding of estuary dynamics. • Name and describe four basic water quality monitoring parameters—pH, dissolved oxygen, salinity (conductivity) and temperature. • Explain how change in chemical water quality is evidence for change in the estuary system.
The mixing of water in estuaries creates unique habitats for estuarine organisms. The water chemistry of an estuary affects the health of the estuarine ecosystem.	**Activity 2 — Dissolved Oxygen in an Estuary** Students learn about dissolved oxygen (DO) and its effects on life, with a focus on the chemistry. First, they are introduced to, and analyze data gathered from, water quality sensors in Narragansett Bay NERR, observing how DO and chlorophyll-a change from the surface to the bottom and considering the relationships between DO and temperature. Then, in the unique environment of Azevedo Pond in the Elkhorn Slough NERR, CA, they analyze DO data and speculate about how hydrodynamics, abiotic factors, and biological processes cause extreme fluctuations in DO in the pond.	**Students will be able to:** • Explain the relationships between dissolved oxygen and water depth, chlorophyll-a and water depth, and dissolved oxygen and temperature. • Explain how these parameters interact during estuarine processes and in such phenomena as eutrophication, algal blooms, and supersaturation-hypoxia fluctuations. • Understand how photosynthesis, respiration, and decomposition affect dissolved oxygen. • Explain the role of these processes in daily or seasonal dissolved oxygen fluctuations in some estuaries. • Explain how hypoxia and anoxia occur, using data as evidence, and explain the affect on estuarine animals.
Human activities affect the chemistry of estuary waters and the estuarine ecosystem.	**Activity 3 — Human Impact on Estuaries: A Terrible Spill in Grand Bay** Students make a model of a pollution spill that occurred at Bangs Lake, a tidal lake within the Grand Bay NERR in Mississippi, in April 2005, and measure water quality parameters in their model. They then study the actual spill, analyzing various forms of data to determine the date of the spill and identify how the spill changed water quality parameters in the estuary during and after the spill. They speculate on how various life forms in the estuary were affected. Finally, students produce a timeline of the spill event with recommendations to the state Department of Environmental Quality about how to prevent large-scale pollution spills like this in the future.	**Students will be able to:** • Describe how a chemical reaction affects water quality parameters of a sample of estuary water. • Use their lab results to predict the effects of an actual pollution event on water quality and life forms in an estuary. • Revise predictions based on new evidence. • Analyze water quality and nutrient data to identify variables that are out of a typical range and that may be indicators of a disturbance to the estuary, such as a pollution event. • Explain how estuarine species are threatened by drastic changes in water quality and nutrients. • Explain how the water chemistry of an estuary affects the health of the estuarine ecosystem and how monitoring estuary water chemistry can account for and predict changes to the health of the ecosystem. • Summarize data and develop a hypothesis to make a timeline that describes the spill and explains how it affected the chemistry of and life in an estuary. • Suggest ways to prevent adverse human impacts on estuaries.

Parts of the Activity	Estuary	Science Concepts	Assessment
• What is an Estuary? • Investigating Water Quality in an Estuary • Investigating Water Quality Over a Day • Investigating Water Quality Over a Year • Comparing Water Quality Data Between Two Different Estuarine Environments	South Slough NERR, Oregon Delaware NERR Old Woman Creek NERR, Ohio	Physical properties of water, water circulation, solubility, physical properties of water, watersheds, tides	• Ask students to summarize the factors that make estuaries such dynamic sites of transition and change for all the organisms that live within their boundaries. • If at all possible, take students to one or more sites on or near your school grounds to measure water quality. Have students measure each of the four water quality factors if possible at each site and record their results. Then have students compare their values for water quality with values taken from each NERR water quality graph on the date of students' observations. How do the parameters differ between your local site (s) and NERR sites? Explain the cause of differences you find.
• Dissolved Oxygen in Narragansett Bay • What's Happening in Azevedo Pond?	Narragansett Bay NERR, Rhode Island Elkhorn Slough NERR, CA	Physical properties of water, light, tides, water chemistry monitoring	• Discuss the following: a. In general, what is the pattern of DO levels in a pond over the period of a single day? b. In general, what is the pattern of chlorophyll-a in the same pond over the period of a single day? c. What causes hypoxic conditions in an estuary? • Have students compare DO levels at various sites within NERRS. Download or let students download graphs using SWMP data to compare DO stability between an area where eutrophication is common (e.g. Childs River, Waquoit Bay NERR) and a well-flushed area (e.g. Menauhant). How are the DO levels different? Explain why differences occur.
• Modeling a Chemical Spill • Learning More about the Spill • Analyzing Data Before and After the Spill	Grand Bay NERR, Mississippi	Water pollution, chemistry of specific pollutants, biochemistry of specific pollutants, nutrient cycles, dissolved oxygen, turbidity, land use, watersheds, erosion and sedimentation	• Discuss the following: a. What caused the massive spill in Grand Bay? What could have been done to prevent it? b. What were the immediate effects on organisms living in the bay? c. What are the reasons that water quality returned to normal after a brief span of weeks?

Curriculum Design

Modular Approach

Estuaries 101 was developed as a series of Modules for very specific educational reasons. *AAAS Benchmarks* (1993) notes that an overstuffed curriculum overemphasizes short-term memorization and impedes “the acquisition of understanding." A modular approach can help combat the difficulty of "a mile wide and an inch deep". Modules that focus on select concepts can facilitate deeper interaction with content and allow for project-based work.

Modules also offer usability advantages. Modules allow teachers to diversify their curricula by selecting standards-relevant content from various sources. The *NSES Standards* recognizes that integrated and thematic approaches can be powerful. Indeed, it is rare for high school science teachers to have the opportunity to dedicate a full-year or semester-long curriculum to the study of estuaries exclusively. However, it is quite common for high school teachers to incorporate several plug-in modules that allow them to cover standards and meet curriculum objectives in novel ways, through different perspectives, or with a particular focus in a topic such as estuaries.

The concepts within a study of estuaries can be woven into existing Earth, life, or physical science courses via plug-in modules by meeting standards and without contributing to an "overstuffed" curriculum.

Types of Experiences

Students learn best when they are immersed in topics they care about and are pursuing questions of personal relevance. The Estuaries 101 Modules take advantage of this, embedding the learning in investigations of dynamic estuaries.

Specifically, there are three different types of experiences in the activities:

* Data analysis,
* Field experiences, and
* Classroom experiments.

In the data analysis experiences, students work with actual data collected at the estuary upon which an activity focuses. They analyze graphs, data tables, and maps for the purpose of understanding a broader concept, relationship, or system, just as the scientists who study the estuaries do. For example, in Earth Science Activity 4: Extreme Weather and Estuaries, students monitor and interpret the changes in water quality factors, such as salinity and turbidity, day by day as a severe storm approaches, strikes the estuary, and then dissipates.

In the field experiences, students explore actual estuary locations virtual and in person. The activities do not assume that teachers and students will be able to get outdoors and to an actual estuary for hands-on experiences, so virtual field trips are included, using Google Earth and other online systems. For example, in Physical Science Activity 2: Dissolved Oxygen in an Estuary, students use the Web to take a virtual field trip to two sites in Narragansett Bay, Rhode Island, where an interactive tool allows them to access various water quality sensors at different depths for the purpose of considering the relationships between dissolved oxygen and water temperature. In addition, the NERR system provides a range of award winning education programs, including hands-on field experiences for students, and the Estuaries 101 Modules are designed to complement and relate to such experiences if you are able to actually visit one of the 27 reserves around the country. (See the Web site for additional information.)

Finally, in the classroom experiments, students get hands-on with some of the various factors and conditions important to estuaries and to the data they are studying from those estuaries. Aspects of the estuaries are brought into the classroom, where variables can be controlled and changed, models can be made and manipulated, and experiments can be conducted. For example, in Life Science Activity 2: Nutrients in an Estuary, students create estuary models in which they artificially enrich both fresh and salt water samples with different amounts of nutrients, observe the growth of algae over time, and relate their results to the phenomenon of algae blooms in estuaries.

Scaffolding and Supports

In the activities, these experiences are scaffolded and supported by background information for both the teachers and students, since there is a role for reading and direct delivery of content in learning, as part of the overall process; by student sheets, which provide guidance through the experiences and ask both specific response and reflection questions to ensure that students are on track and are thinking about what they are doing and why; by assessment pieces for individual activities and for entire Modules, providing a means for both grading, as appropriate, and checking in with student advances in understanding; and finally by optional extension inquiries, which provide suggestions on how the concepts, skills, data, and questions addressed in the activities can be pursued in more depth by classes or individuals interested in taking their explorations to the next level.

Estuaries 101 takes a rich educational approach, with opportunities to engage a wide-variety of school and classroom situations and all types of learners in exploring the science and excitement of estuaries.

Design, Review, and Testing of the Materials

A great deal of thought and energy went into the initial design and development of the Estuaries 101 Modules. This involved extensive work on defining a scope, conceptual sequence, and detailed rationale for all of the activities; standards matching; the development of and alignment with core principles and concepts; and the identification of activity-specific learning objects. (See the Core Principles section of this guide, the Standards Matching materials available on the Web, and the individual activities for more details.)

In addition, the Modules were reviewed by NERRS educators and scientists at numerous stages during their design, development, and revision to ensure that the final activities are scientifically rigorous and meet the educational needs of the NERRS and the teachers and students with whom they work.

Finally, all of the Estuaries 101 activities were pilot tested by teachers and students. Feedback was gathered from this testing, and revisions and additions were then made to the activities and assessments to specifically address the needs, desires, and realities of implementing the Modules within real classroom settings.

How Learning about Estuaries meets State and National Science Education

When NOAA/NERRS launched Estuaries 101, it also decided to conduct a national study to see how estuaries can meet state and national standards. TERC, an educational non-profit, was contracted to conduct this study, the results of which are published in this site. This study relates broadly to the concepts and skills that can be embedded in estuaries learning activities, and specifically to Estuaries 101, NOAA's newly released high school curriculum materials. This study and the curriculum were developed in collaboration with NOAA's National Estuarine Research Reserve System.

For this study, we compared the Estuaries learning goals with the National Science Education Standards as a common framework, and sample state standards to illustrate the diversity among states. While the National Science Education Standards (NRC, 1996) provides a common framework on which many states base their standards, each state defines and vets its own standards. In some cases, differences among states reflect issues of local relevance (e.g. coastal states might have a greater emphasis on oceans and coastal processes), or policy priorities (e.g. the balance between content and process standards). For the sample states, TERC selected California, Illinois, Massachusetts, Virginia and Washington, as (relatively populous) representatives of the nation, including coastal and inland states. TERC looked at high school standards in biology, Earth science, chemistry and physics (combined into Physical sciences, below), as the context in which these modules will be used. While Estuaries ultimately will become a full K-12 program, the first released modules are for high school. They are designed as supplemental modules, for inclusion in Earth science, biology and physical science courses, although they may also be used by other educators.

TERC conducted the analysis at four levels of concepts and skills:

- *estuaries* – TERC began with a narrow focus, searching for the term "estuaries" and directly related terms in these standards. This is often the first level that people consider when deciding to use curriculum materials – if their state standards include "estuaries" per se.
- *big ideas in science* – TERC next broadened the scope, to explore how the estuaries activities support the learning goals of the three major subject domains of the modules: Earth science, biology and physical science – looking especially at the "big ideas" in each field.
- *developing science thinking skills* – TERC focused on how estuaries modules meet standards for science thinking skills, such as inquiry, experimental design and data analysis. These fundamental skills permeate science, and are well supported by the Estuaries 101 activities.
- *ocean and climate essential principles* – As an effort to develop a common framework for ocean and climate literacy, NOAA and other agencies have developed a set of essential principles for each of these fields. TERC cross-referenced the estuaries modules with these important documents.

The full report, "How Learning about Estuaries meets State and National Science Education Standards", details the findings in each of these levels. In brief, the study found that estuaries per se are inadequately represented in the state standards. Remarkably, only four states refer to estuaries by name. While other states used comparable terms like marine and salt water environments, freshwater habitats, tidal environments, wetlands, brackish, bay, salt marsh, coastal swamp, etc., the study concluded that there is not a strong enough explicit need for covering estuaries per se to drive large scale use. On the other hand, estuaries can be an exceptional vehicle for conveying the "big ideas" of science – such as "habitat adaptation" in biology, and "water as solvent" in chemistry and "interacting systems" in Earth science. These concepts are included in ALL state standards we reviewed, in one form or another. The study also found strong correlations between the inquiry-based approaches used in the modules and the scientific thinking skills, such as experimental design and data analysis, called for in all state science standards. Finally, the study found a strong alignment between the proposed modules and the essential principles of ocean and climate literacy.

Summary - Conclusions of the Study

Conclusion #1 – The specific word “estuaries” does not have a prominent role in most state standards, but estuaries-related terms do. If we use related terms, like tidal environments and fresh and saltwater habitats, the concept of estuaries is included in the standards of nearly a quarter of the states, Hence, we should use such terms in describing the learning goals and activities.

Conclusion #2 – To make a more compelling case for the estuary curricula, we should emphasize the big ideas that are covered in each module. Most of the topics in the modules align well with the big ideas in life, physical and Earth science, as well as the over-arching “unifying concepts and processes”. This is true at the national level and in the individual state standards.

Conclusion #3 – The estuaries modules align well with standards for science process and thinking skills. This is true in the national standards, and in our five representative states. Estuaries are an especially good domain for developing and applying these skills. We recommend making this point clearly when trying to establish the value of the estuaries modules.

Conclusion #4 – The estuaries modules strongly support ocean and climate literacy. The appeal and value of the estuaries models to help students learn about and apply these principles will increase as the Ocean Literacy and Climate Literacy documents become more visible and increase their impact on state and national standards.

The full report, “How Learning about Estuaries meets State and National Science Education Standards”, can be found at::

http://www.estuaries.gov/estuaries101/Resources/Default.aspx?ID=151

Monitoring and Evaluation

All the Estuaries 101 activities are scaffolded and supported by:

- background information for both the teachers and students, since there is a role for reading and direct delivery of content in learning, as part of the overall process;
- by student sheets, which provide guidance through the experiences and ask both specific response and reflection questions to ensure that students are on track and are thinking about what they are doing and why;
- by assessment pieces for individual activities and for entire Modules, providing a means for both grading, as appropriate, and checking in with student advances in understanding; and
- finally by optional extension inquiries, which provide suggestions on how the concepts, skills, data, and questions addressed in the activities can be pursued in more depth by classes or individuals interested in taking their explorations to the next level.

Each Module concludes with an assessment piece, designed for use after completion of all the activities within that Module. These assessments, which overarch all the activities within a Module, provide a means for both grading, as appropriate, and checking in with student advances in understanding.

NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM

NOAA National Estuarine Research Reserve System

NOAA's National Estuarine Research Reserve System (NERRS) strives "to enhance public awareness and understanding of estuarine areas, and provide suitable opportunities for public education and interpretation." The NERRS comprises 27 reserves, and is a great resource for all things related to estuarine ecology. The reserve system provides a range of award winning education programs ranging from hands-on field experiences for students to professional development opportunities for teachers. Reserve educators provide regularly scheduled public programs and special events and partner with local schools, community-based organizations and volunteers.

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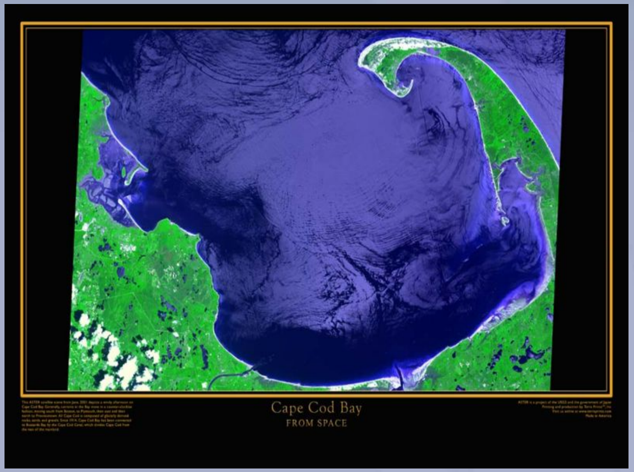
Estuary Landforms and Features

Preparing for an Earth Science Scavenger Hunt!

Estuary Landforms and Features

barrier beach — a linear strip of beach that separates the ocean from marshes and other habitat behind it

bay — an area of water bounded on three sides by land. Large bays are called gulfs.



Estuary Landforms and Features

bayou — a small, slow-moving stream located in low-lying areas such as the Mississippi delta

cove — a circular or round inlet with a narrow entrance or any sheltered bay

Estuary Landforms and Features

delta — a landform produced when a river flows into a larger body of water

harbor — a place where ships may be sheltered, usually a very large cove, or manmade with breakwaters or sea wall

Estuary Landforms and Features

headland — an area of land surrounded by water on three sides

lagoon — a body of shallow water separated from the ocean by sand bars or beaches

Estuary Landforms and Features

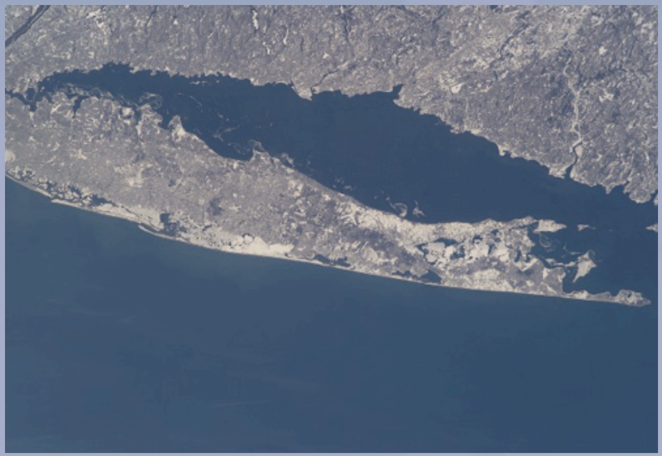
mangrove forest — an assemblage of mangrove trees found in salty coastal habitats

peninsula — a narrow piece of land surrounded on three sides by water

Estuary Landforms and Features

slough — a swamp or shallow lake system, usually a backwater to a larger body of water

sound — a large sea or ocean inlet larger than a bay



Estuary Landforms and Features

salt marsh — a type of marsh that is a transitional zone between land and salty or brackish water

Estuary Landforms and Features

tidal flats or mudflats — areas of mud deposited by the tides, rivers, and oceans. Found within bays, bayous, lagoons, and other estuarine features.

Teacher Guide—Earth Science Module
Activity 1: Observing Estuaries

Featured NERRS Estuary:
[Weeks Bay National Estuarine Research Reserve, Alabama]
http://nerrs.noaa.gov/WeeksBay/welcome.html

Activity Summary

In this activity, students investigate landforms and features associated with estuaries. They begin by taking a journey down a river to an estuary system where the river empties into the Gulf of Mexico near Weeks Bay National Estuarine Research Reserve (NERR) to investigate how landforms differ between uplands and riverine/estuarine environments. Student teams then use Google Earth and other resources to engage in a scavenger hunt to locate and identify landforms and features of estuaries.

Learning Objectives

Students will be able to:

1. Describe differences between upland non-estuarine and estuarine landforms and features.
2. Visually identify and describe various landforms and features associated with estuarine environments, including salt marshes, barrier beaches, peninsulas, headlands, spits, mud flats, fjords, deltas, coves, harbors, sounds, and others.

Grade Levels

9-12

Teaching Time

3 (55 minute) class sessions + homework

Organization of the Activity

This activity consists of 3 parts which help deepen understanding of estuarine systems:

What is an Estuary?

A trip down the Alabama River

Estuary Landforms and Features—Scavanger Hunt

Background

The Alabama River, in the state of Alabama, is formed by the Tallapoosa and Coosa Rivers, which unite about 10 km above Montgomery. The river flows west to Selma, then southwest until it is about 72 km from Mobile where it unites with the Tombigbee River, forming the Mobile and Tensaw

The river flows west to Selma, then southwest until it is about 72 km from Mobile where it unites with the Tombigbee River, forming the Mobile and Tensaw Rivers. Both rivers discharge into Mobile Bay.

The Alabama River meanders a lot. It is 502 km long and varies in width from 200 to 300 m, and its depth ranges from 1 to 2 m. The river crosses the richest agricultural and timber districts of the state, and railways connect it with the mineral regions of north central Alabama.

See the PowerPoint *Estuary Landforms and Features* for more background information on the major landforms and features of estuaries.

Download and prepare to present the PowerPoint *Estuary Landforms and Features.*

Preparation

Download Google Earth and install it on your class-room computer(s) or computer lab machines. To find a tutorial for using Google Earth, please check the box on the next page.

Preset the locations of your school and the beginning of the Alabama River trip (31° 08' 53.46 N, 87° 56' 56.46 W; altitude 4 km) in Google Earth. Refer to *Using Google Earth to Explore Estuaries* for a brief how-to guide. (See side-box for instructions on how to access this tutorial.)

In Google Earth, choose a starting point for students' Part 3 exploration of a coastal area and determine an address or location name to enter that will zoom in on this starting place. For example, if you want your students to begin exploring the coast of the Gulf of Mexico, a starting location might be Port Isabel, Texas. Or select one of the National Estuarine Research Reserves for students to investigate.

Browse the coastal area that you want your students to examine and identify potentially confusing borders or areas with only low-resolution imagery available.

Materials

Students

- ❑ Need to work in a computer lab or with a computer and projector
- ❑ Copy of the *Student Reading Observing Estuaries*
- ❑ Copy of the *Student Worksheet Observing Estuaries*
- ❑ Copy of *Student Reading Introduction to Weeks Bay NERR*
- ❑ *Copy of Student Worksheet — Scavenger Hunt*
- ❑ Copy of *Student Reading Using Google Earth to Explore Estuaries* (assuming you have computer access)

Teachers

- ❑ Download Google Earth
- ❑ If you wish to use hardcopy materials instead of Google Earth, obtain topographic or other types of maps for students to use in Part 2 of the activity
- ❑ PowerPoint *Estuary Landforms and Features* (available on the Estuaries.gov site, click under Teachers, Earth Science, and find the presenta-tion under Supporting Materials, Activity 1)

Equipment:

- ❑ Computer lab or
- ❑ Computer and Projector

Alternatives

If you want to use a local river and estuary instead of the Alabama River, produce an alternate river trip for Part 1 using Google Earth.

If you wish to use hardcopy materials instead of Google Earth, obtain topographic or other types of maps for students to use in Part 2 of the activity.

Procedure

Part 1 — What is an Estuary?

1. Begin by asking students what they know about estuaries.
2. Have students each sketch or describe what it might look like where the river meets the ocean. Select students to hold up their diagrams and describe what they drew. Emphasize the variety of estuaries and the fact that different types exist.
3. During the discussion, ask the following questions to get students to think more deeply about these places where fresh water from rivers and streams run into ocean water:
    - How big are these places?
    - How can you tell where the fresh water ends and ocean water starts? Can you see it clearly, like a waterfall into the sea or is it a little less obvious, like a hose underwater in a swimming pool?
    - What do you know about where fresh water meets the ocean? What landforms or features may be present?

National Science Education Standards

Content Standard A: Science as Inquiry

A3. Use technology and mathematics to improve investigations and communications.

A4. Formulate and revise scientific explanations using logic and evidence.

A6. Communicate and defend a scientific argument.

Content Standard C: Life Science

C4. Interdependence of organisms

Content Standard E: Science and Technology

E1. Identify a problem or identify an opportunity

E6. Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

F4. Environmental quality

F5. Natural and human-induced hazards

Google Earth

This activity *requires* the use of Google Earth. If students have computer access, the use of Google Earth (http://earth.google.com/) can help them develop spatial skills.

Find the Tutorial "*Using Google Earth to Explore Estuaries*" in estuaries.gov, click under Teachers, Classroom Activities and find the tutorial.

Part 2 — A Trip Down the Alabama River

4. Explain to students that they will now take a trip down a river in Alabama to investigate one type of estuary and the kinds of features that are present when a river meets the sea.

5. Show students an image of their school in Google Earth at an altitude of 4 km. Ask students if they recognize the image and its location. You may have to point out a few familiar landmarks.

6. Ask students to describe the environment around their school, pointing out the specific landforms and features they see. *(Ponds, rivers, streams, lakes, hills, canyons, and valleys are commonly mentioned, or there may only be city streets.)*

7. Demonstrate how to zoom in and out, move left and right, and up and down using Google Earth. Also show students how to leave a place mark on a Google image. Distribute *Student Reading — Using Google Earth to Explore Estuaries.*

8. Click on the placeholder for the beginning of the Alabama River trip if you have marked it or go to: 31° 08' 53.46 N, 87° 56' 56.46 W. Ask students what kinds of features they see in the image. *(Sand bars, farmland, forests, and a tributary flowing into the Alabama River)*

9. Hand out *Student Worksheet — Observing Estuaries.* Instruct students to explore the Alabama River, following the directions and answering the questions on the worksheet.

Part 3 — Estuary Landforms and Features Scavenger Hunt

10. Divide your class into teams and hand out the *Student Worksheet — Scavenger Hunt.*

11. Show the *Estuary Landforms and Features* PowerPoint presentation so students have a basis for selecting features in the scavenger hunt.

12. In Google Earth, have the teams go to your pre-selected starting point and challenge them to locate as many of the features as they can in 30 minutes.

13. Have teams exchange lists and verify the objects on each other's lists. Have students place question marks on features that they either cannot find or those they feel are misidentified.

14. Have students answer the summary questions.

Check for Understanding

Discuss the following:

- How do the terrain and types of landforms change as you travel down a river toward a source of salt water?
- Which of the landforms and features on your scavenger hunt list were fairly common?
- Which landforms were not present at all?

Have students sketch an imaginary estuary system on a piece of paper. Direct them to draw and label as many landforms and features on their diagram as possible. Collect and evaluate them for accuracy, clarity, and the number of landforms correctly identified.

Optional Extension Inquiries

Have students create a travelogue that documents a trip down a river that flows into another NERRS estuary.

Have students make a PowerPoint presentation that describes the differences between the geological landforms and features in upland versus estuarine environments.

Teacher Worksheet with Answers
Activity 1: Observing Estuaries

Part 2 — A Trip Down the Alabama River

2a. Use the vertical slider in the upper right-hand corner of the screen to zoom towards the river. What kinds of land and terrain border the river? Use the navigation buttons to survey the area. Can you locate farms or other signs of human habitation or industry?

Answer: Students will see a few patches of farmland and mostly flat, forested riverbanks. They will also notice sandbars on the inside of each curve of the river.

2b. Use the slider in the upper right-hand corner of the image to set your viewing altitude at 4 kilometers (2.4 miles). For the rest of your journey, zoom back to this altitude before moving further downriver. As you travel downriver, what signs of human interaction with the river (industry, towns, ships, etc.) do you see?

Answer: Large freighters, bridges, and large-scale mining operations can be seen as students go downriver.

2c. When you reach a fork in the river, take the west channel. When you reach Whitehouse Bend (31° 00' 07.06) on the river, you will see a large brown feature. Zoom in and explore this region. What do you think this feature is?

Answer: The feature at Whitehorse Bend appears to be a large borrow pit or surface mining operation.

2d. After you cross highway I-65, you will see two large areas on both sides of the river. Zoom in and zoom out to explore this area. Can you identify what type of terrain these areas consist of?

Answer: The terrain on both sides of the river consists of extensive bayous and swamps.

2e. Follow the river to Twelve Mile Island. How do you think this island formed? What kind of terrain surrounds the island?

Answer: Twelve Mile Island was formed by the river changing course. Bayous flank the river on both sides.

2f. When you reach Bear Creek, a channel of the Alabama River empties into a larger body of water. What is it?

Answer: The tributary of the Alabama River empties into Grand Bay.

2g. When you arrive at Blakely Island Reach in Mobile, Alabama, how has the terrain on both rivers changed?

Answer: Industrial sites line both sides of the river. No vegetation exists.

2h. Center the river and fly south until you see Gaillard Island. Find latitude 30° 30' 31" (on the right shoreline of the island) and zoom in. Describe what you see.

Answer: Students should point out the estuarine environment formed by a fresh water river flowing into a long linear lagoon. The barrier beach that forms the eastern shore of the island forms the lagoon.

2i. Move back to 4 km of altitude, and fly directly south from Gaillard Island to Mobile Point. Zoom in and describe the terrain you see.

Answer: Mobile Point has many beaches and salt marshes behind them. There are a few ponds situated toward the center. There is an old fort (star-shaped formation) there as well.

2j. Now fly east and explore the region to the north of the beach area beginning with Navy Cove. Describe the types of features and terrain you find there.

Answer: Headlands, coves, bays, bayous, inlets, ponds, and barrier beaches occur in this vicinity.

2k. Now fly directly north across the bay until you reach **Weeks Bay National Estuarine Research Reserve**. Can you identify a sediment plume at the mouth of the bay? Identify other features in the neighborhood of the estuary reserve.

Answer: Yes, a sediment plume is evident. Other features include a peninsula, wetlands, forested areas, beaches, and salt marshes.

2l. In your journey, you traveled from an upland region to an estuarine environment (Mobile Bay) to a coastal area. In general, how did the types of terrain change in each region as you made your way downriver?

Answer: The terrain changes dramatically as you travel downriver—from forested areas with occasional farmland to a complex of bayous, deltas, beaches, and salt marshes.

2m. How does the water change as you move down the river? What evidence can you give for any changes you see?

Answer: Students should notice that many different kinds of bodies of water increase the complexity of the river system as it moves towards the sea (inlets, bays, streams, bayous, wetlands, salt marshes, etc.). Evidence includes seeing sediment plumes and sand bars as streams and rivers empty into larger bodies of water.

2n. Describe how different human activities affect the nature of the river and the terrain on both sides of it.

Answer: Large-scale industrial activity on both sides of the river has in some cases diverted the flow of the river and certainly has contributed to waste products being washed into the river.

Part 3 — Estuary Landforms and Features Scavenger Hunt

3a. Which landforms and features were easiest to find?

Answer: Students' answers will vary depending on which section of coastline they are investigating.

3b. Which landforms or features were the most difficult to find?

Answer: Students' answers will vary. In particular, students may have difficulty finding reefs unless they search in tropical climates.

Student Reading—1
Activity 1: Observing Estuaries

An estuary is a partially enclosed body of water, and its surrounding coastal habitats, where saltwater from the ocean mixes with fresh water from rivers, streams, or groundwater. In fresh water, the concentration of salts, or salinity, is nearly zero. The salinity of water in the ocean averages about 35 parts per thousand (ppt). The mixture of seawater and fresh water in estuaries is called brackish water.

Estuaries are transitional areas that connect the land and the sea, as well as freshwater and saltwater habitats. The daily tides (the regular rise and fall of the sea's surface) are a major influence on many of these dynamic environments. Most areas of the Earth experience two high and two low tides each day. Some areas, like the Gulf of Mexico, have only one high and one low tide each day. The tidal pattern in an estuary depends on its geographic location, the shape of the coastline and ocean floor, the depth of the water, local winds, and any restrictions to water flow. For example, tides at the end of a long, narrow inlet might be heightened because a large volume of water is being forced into a very small space. However, the change in sea level for tides in wetlands composed of broad mud flats might appear to be rather small.

While strongly affected by tides and tidal cycles, many estuaries are protected from the full force of ocean waves, winds, and storms by reefs, barrier islands, or fingers of land, mud, or sand that surround them. The characteristics of each estuary depend upon the local climate, freshwater input, tidal patterns, and currents. Truly, no two estuaries are the same.

Landforms that occur on or near the coast are shaped by wave and wind erosion and glacial transport. Headlands are composed of the very hard rock left behind as softer rocks are eroded away by relentless wave action occurring over thousands of years. In contrast, sand bars, spits, and even entire beaches can form, or be completely obliterated, in a single severe storm. Estuary features such as salt marshes, bayous, and mangrove forests form in the areas protected by barrier beaches, islands, and strips of coastal land.

Besides the constant erosional forces of water and wind, coastal landforms and features are influenced by other large, long-term geologic events. Glaciers retreating during the last ice age sculpted the northeast coastline of the United States. One look at the peninsulas of Maine clearly shows the direction of retreat of the mile-thick ice sheets. Only the hardest rock was left behind to form the islands and the peninsulas of the coast. During this period, the entire bulk of Long Island was left behind by the forward edge of a massive glacier, deposited like a load of dirt from a huge dump truck. Long Island Sound formed in the gouge behind the rubble.

In this activity, you will explore how landforms and features change as you travel from the interior of our country to the place where rivers empty into the sea—estuaries. Then, you will explore coastal regions from above using Google Earth or other resources to identify landforms and features associated with estuarine and coastal environments.

Student Reading—2
Activity 1: Introduction to Weeks Bay NERR

The Weeks Bay National Estuarine Research Reserve (NERR) includes over 6,000 acres of coastal wetlands that provide rich and diverse habitats for a variety of fish, crustaceans and shellfish, as well as many unique and rare plants. Weeks Bay is a small estuary, about 8 km^2, receiving freshwater from the Magnolia and Fish rivers, and draining a 500 km^2 watershed into the lower portion of Mobile Bay. This sub-estuary of Mobile Bay averages just 1.5 meters in depth and is fringed with salt marshes dominated by black needle rush and cordgrass, as well as extensive swamps with pine, oak, magnolia, maple, cypress, bayberry, and tupelo trees.

The Weeks Bay ecosystem contains many freshwater and marine fish and invertebrate species. Collectively, these species support large commercial and recreational fishing industries. Weeks Bay is especially a critical nursery for shrimp, bay anchovy, blue crab and multitudes of other fish, crustaceans and shellfish. The Reserve lands also include upland and bottomland hardwood forests, freshwater marsh, submerged aquatic vegetation, and unique bog habitats. Many of these areas are especially important to the large number of trans-Gulf migratory birds as a resting and feeding area.

Additionally, the Weeks Bay NERR is home to many threatened or endangered species, including the West Indian manatee, eastern fox squirrel, red-cockaded woodpecker, wood stork, Alabama red-bellied turtle, gopher tortoise, and Alabama sturgeon.

Although the Reserve is relatively undisturbed, increasing development pressure and population growth within areas of the Weeks Bay watershed has resulted in increasing sources of pollution. These include storm water runoff from parking lots, industrial sites, leaking septic tanks, and landfills, as well as, agricultural runoff. Input of excessive nutrients and sediments from this runoff can have detrimental affects on estuary life including reduction in submerged aquatic vegetation, increase in algal blooms which cause fish kills, and accumulation of toxic substances within shellfish.

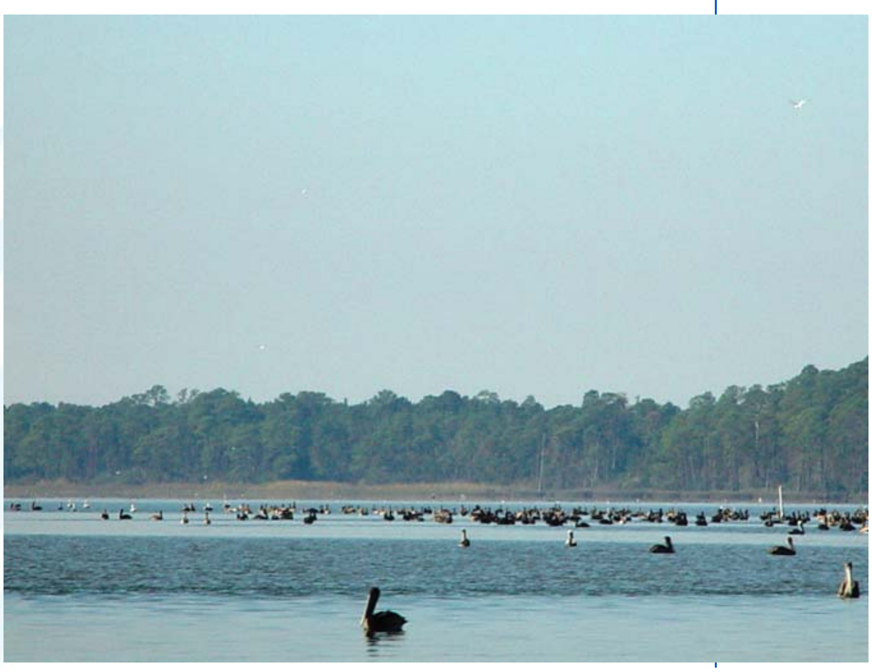


Figure 1. Weeks Bay NERR is home to many species of plants and animals.

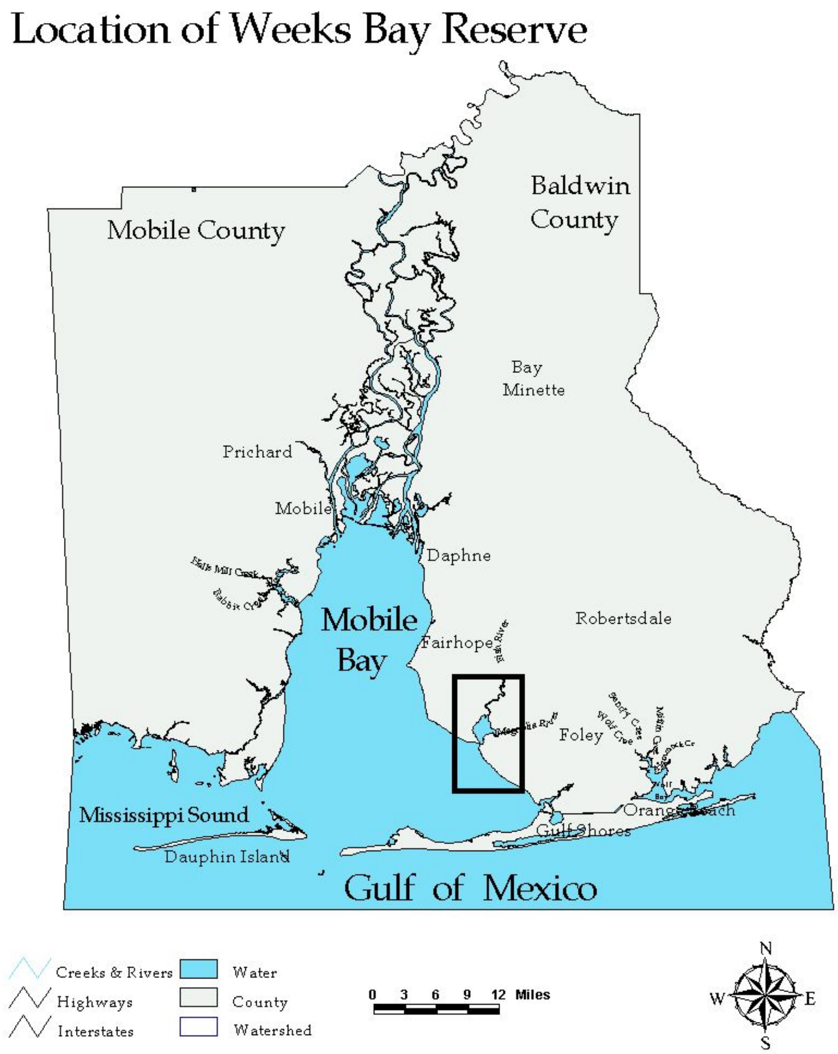


Figure 2.
Location of Weeks Bay Reserve

Student Worksheet - 1
Activity 1: Observing Estuaries

Student Name:____

Part 1 — What is an Estuary?

1. Use a blank piece of paper to sketch what you think an estuary looks like.

Part 2 — A Trip Down the Alabama River

Take an aerial tour of a section of the Alabama River in Alabama, following the river's course from a point in the south-central portion of the state, through to Mobile Bay where it empties into the Gulf of Mexico. To begin:

1.Open Google Earth

2.Click on the *Fly To* button, and enter these coordinates (31° 08' 53.46 N, 87° 56' 56.46 W).

3.Under the Layers menu, click on Terrain, Geographic Web, Places of Interest, and Roads

Figure 3.
The Alabama River in Alabama—the starting point for your tour.

2a. Use the vertical slider in the upper right-hand corner of the screen to zoom towards the river. What kinds of land and terrain border the river? Use the navigation buttons to survey the area. Can you locate farms or other signs of human habitation or industry?

2b. Use the slider in the upper right-hand corner of the image to set your viewing altitude at 4 kilometers (2.4 miles). For the rest of your journey, zoom back to this altitude before moving further downriver. As you travel downriver, what signs of human interaction with the river (industry, towns, ships, etc.) do you see?

2c. When you reach a fork in the river, take the left channel. When your reach Whitehouse Bend (31° 00' 07.06) on the river, you will see a large brown feature. Zoom in and explore this region. What do you think this feature is?

2d. After you cross highway I-65, you will see two large areas on both sides of the river. Zoom in and zoom out to explore this area. Can you identify what type of terrain these areas are?

2e. Follow the river to Twelve Mile Island. How do you think this island formed? What kind of terrain surrounds the island?

2f. When you reach Bear Creek, a channel of the Alabama River empties into a larger body of water. What is it?

2g. When you arrive at Blakely Island Reach in Mobile, Alabama, how has the terrain on both rivers changed?

2h. Center the river and fly south until you see Gaillard Island. Find latitude 30° 30' 31" (on the right shoreline of the island) and zoom in. Describe what you see.

2i. Move back to 4 km of altitude, and fly directly south from Gaillard Island to Mobile Point. Zoom in and describe the terrain you see.

2j. Now fly east and explore the region to the north of the beach area beginning with Navy Cove. Describe the types of features and terrain you find there.

2k. Now fly directly north across the bay until you reach **Weeks Bay National Estuarine Research Reserve**. Can you identify a sediment plume at the mouth of the bay? Identify other features in the neighborhood of the estuary reserve.

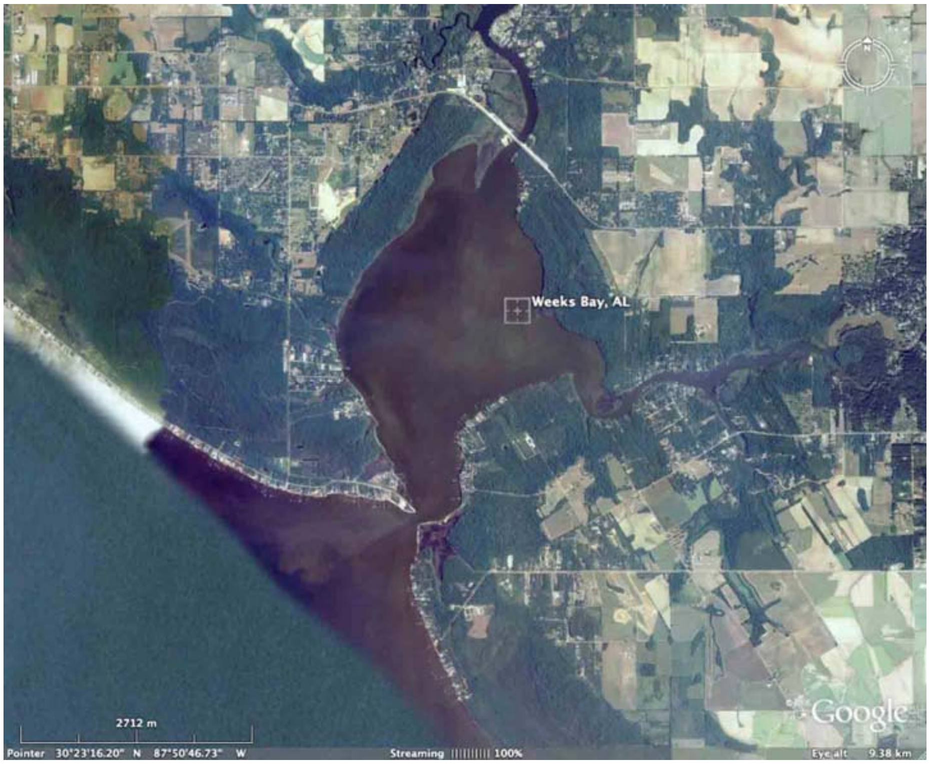


Figure 4. The end point of your Alabama River trip in the Weeks Bay NERR

2l. In your journey, you traveled from an upland region to an estuarine environment (Mobile Bay) to a coastal area. In general, how did the types of terrain change in each region as you made your way downriver?

2m. How does the water change as you move down the river? What evidence can you give for any changes you see?

2n. Describe how different human activities affect the nature of the river and the terrain on both sides of it.

Part 3 — Estuary Landforms and Features Scavenger Hunt

View the *Estuary Landforms and Features* PowerPoint presentation and take notes about the various structures and features.

Using Google Earth, explore regions of coastline and find as many landforms and features as you can on the *Student Worksheet — Scavenger Hunt*.

Your teacher may start you in a particular coastal region. You may then "fly" to other coastal areas and search for missing landforms and features if time allows.

Exchange your list with another team and check that team's results by flying to each location they recorded to verify whether the landforms and features have been correctly identified.

3a. Which landforms and features were easiest to find?

3b. Which landforms and features were the most difficult to find?

Student Worksheet - 2
Activity 1: Scavenger Hunt

Team Member Names: ____

____

When you identify a landform or feature in Google Earth, give the name if provided, and the exact coordinates (latitude and longitude). NOTE: You may not find all landforms and features in a particular stretch of coastline or estuarine region.

Landform	Name/Location (latitude and longitude)
barrier beach	______________________
bay	______________________
bayou	______________________
cove	______________________
delta	______________________
harbor	______________________
headland	______________________
lagoon	______________________
mangrove forest	______________________
peninsula	______________________
slough	______________________
sound	______________________
reef	______________________
salt marsh	______________________
tidal or mud flats	______________________

Teacher Guide—Earth Science Module
Activity 2: Salinity & Tides

Featured NERRS Estuary:
Chesapeake Bay Virginia National Estuarine Research Reserve
http://nerrs.noaa.gov/ChesapeakeBayVA/welcome.html

Activity Summary

In this activity, students learn about tides and salinity in estuaries. They observe time-lapse models of tides and salinity distribution in the York River, part of the Chesapeake Bay, VA NERR. Learn how salinity changes with an incoming and outgoing tide, observing the dynamics of the salt wedge at various sites along the river. Students also make predictions about the salinity changes at each site based upon their observations of the animation. They then use salinity data from monitoring stations along the river to see changes during a typical day. And, then describe the patterns of each salinity graph and compare the graphs.

Learning Objectives

Students will be able to:

1. Analyze different forms of data and synthesize information to develop a hypothesis.
2. Explain how tides and the geology of the estuary affect water circulation in an estuary.
3. Describe daily patterns of salinity changes in the estuary.

Grade Levels

9-12

Teaching Time

3 (55 minute) class sessions + homework

Organization of the Activity

This activity consists of 3 parts which help deepen understanding of estuarine systems:

Tides in Chesapeake Bay

Salinity as York River Flows into the Bay

Interaction of Tides and River Flow

Background

York River is one of several rivers flowing into Chesapeake Bay. As the nation's largest estuary, Chesapeake Bay contains a diverse collection of habitats including oyster reefs, seagrass beds, tidal wetlands, sandy shoals and mudflats. Chesapeake Bay and York River illustrate the complexities of tidal variation that respond not just to the gravitational pull of the sun and the moon, but also to the underlying topography of the bay and the dynamics of the estuarine river systems.

Chesapeake Bay Virginia National Estuarine Research Reserve has four sites on the York River, enabling research and education about the estuary, including extensive data from water quality stations and other observations by reserve scientists. In this learning activity, students use this multi-site system to explore tides and salinity from tidal freshwater to high salinity conditions along the York River estuary. Reserve components include Sweet Hall Marsh, Taskinas Creek, Catlett Island and Goodwin Islands.Rivers. Both rivers discharge into Chesapeake Bay.

Additional Resources

- For background on tides and estuaries, refer to *Student Reading — Estuarine Tides.*
- For a more thorough background on tides, see the NOS Tutorial on Tides and Water Levels: *oceanservice.noaa.gov/education/kits/tides/welcome.html*

Preparation

Make copies of *Student Reading — Estuarine Tides*, *Student Worksheet — Salinity and Tides*, and if you will not be providing computer-access to the data, *Student Data Sheet — Salinity and Tide Data for York River.* (Note that the data on the *Student Data Sheet* are for a specific date: March 21, 2007.)

Arrange for students to work with the animation and data, either in a computer lab or with a computer and projector. Bookmark the following sites:

- *nerrs.noaa.gov/ChesapeakeBayVA/welcome.html*
- *tidesandcurrents.noaa.gov/ofs/cbofs/wl_nowcast.shtml*
- *www.vims.edu/physical/web/presnt/qtime/Kimplot3.mov*
- *www2.vims.edu/vecos/SegmentChoice.aspx?param=MOBPH*

Figure 1.

The location of York River with respect to Chesapeake Bay

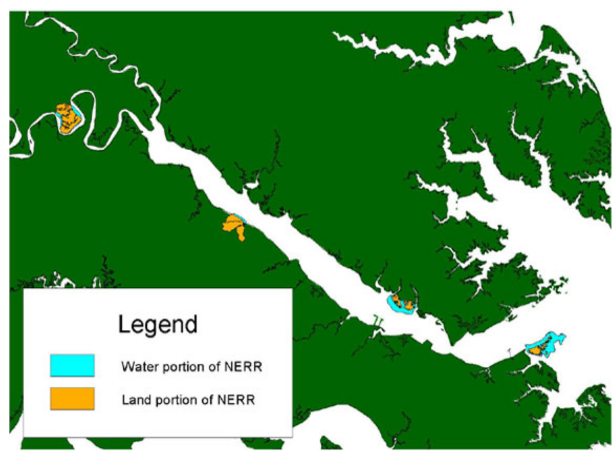


Figure 2.

Close-up Map of York River with NERR sites

Procedure

Part 1 — Tides in Chesapeake Bay

1. Introduce students to the Chesapeake Bay. If need be, use a U.S. Map to show students the location of Chesapeake Bay. Students can also learn more about the bay using Google Earth (refer to the *Student Reading — Using Google Earth to Explore Estuaries* for a brief how-to guide) or they can read more on the Chesapeake Bay Virginia NERR web site:

   nerrs.noaa.gov/ChesapeakeBayVA/welcome.html
2. Using a computer projector for the whole class or letting students work individually or in teams in the computer lab, demonstrate the Tides in Chesapeake Bay web site:

   tidesandcurrents.noaa.gov/ofs/cbofs/wl_nowcast.shtml
3. Have students complete Part 1 of the *Student Worksheet — Salinity and Tides.*

National Science Education Standards

Content Standard A: Science as Inquiry

A3. Use technology and mathematics to improve investigations and communications.

A4. Formulate and revise scientific explanations using logic and evidence.

A6. Communicate and defend a scientific argument.

Content Standard B: Physical Science

B4. Motions and forces
B5. Conservation of energy and the increase in disorder

B6. Interactions of energy and matter

Content Standard D - Earth and Space Science

D1. Energy in the earth system 189
D2. Geochemical cycles 189

Materials

Students

- ❑ Need to work in a computer lab or with a computer and projector
- ❑ Copy of the Student Reading — Estuarine Tides
- ❑ Copy of the Student Worksheet — Salinity and Tides
- ❑ Copy of the Student Data Sheet — Salinity and Tide Data for York River (if there is no computer-access to the data)
- ❑ U.S. Map and/or Google Earth
- ❑ Copy of Student Reading — Using Google Earth to Explore Estuaries (assuming you have computer access) - Find the tutorial in estuaries.gov, click under Teachers, Classroom Activities and find the tutorial.

Teachers

Bookmark the following sites:
nerrs.noaa.gov/ChesapeakeBayVA/welcome.html

tidesandcurrents.noaa.gov/ofs/cbofs/wl_nowcast.shtml

www.vims.edu/physical/web/presnt/qtime/Kimplot3.mov

www2.vims.edu/vecos/SegmentChoice.aspx?param=MOBPH

Equipment:
- ❑ Computer lab or
- ❑ Computer and Projector

Part 2 — Salinity as York River Flows into the Bay

Here, you focus on salinity, helping students think, in a general way, about the salinity gradient in the York River as the fresh water flows into the salty bay.

4. Make sure the students understand the location of York River in Chesapeake Bay.
5. Have students complete Part 2 of the *Student Worksheet — Salinity and Tides*, labeling the York River map with "fresh," "nearly fresh," "fairly salty," "close to seawater," or "seawater."

   If students have hands-on experiences in mixing fresh and seawater and/or have measured samples of fresh, brackish, and seawater, they can label the map with their best guesses about salinity, which will range from 0 (fresh) to about 35 parts per thousand (ocean).
6. Have students compare maps in small groups and explain why they marked them as they did.
7. Discuss daily and seasonal factors and Earth processes that affect salinity in an estuary.
8. Have students read *Student Reading — Estuarine Tides*. (This can be assigned as homework.)

Part 3 — Interaction of Tides and River Flow

With this part, students deepen their understanding of estuarine systems, focusing on the interaction of tides and rivers and how this affects salinity in the estuary.

9. Using a computer projector for the whole class or letting students work individually or in teams in the computer lab, demonstrate the animation of tides and salinity in York River at this web site: <*www.vims.edu/physical/web/presnt/qtime/Kimplot3.mov*>.

   Make sure students are aware that the animation shows the change in salinity over a tidal cycle of 24 hours. Explain that the animation is not a representation of salinity changes for a specific date, but rather a model of what salinity distribution might be like in the river on any given day.

   Provide a general orientation about the animation for students:

   - The bottom and larger part of the animation shows horizontal distribution—salinity changing from upstream to downstream.
   - There are four reference points on the animation. Three are sites for which students will analyze salinity graphs in Part 2. (GLPT is Gloucester Point, #1 is Yorktown, and #3 is Clay Bank.)
   - The three images to the right show transverse slices of each of the three points—cut-away views of those locations—and show how saltier and fresher water is mixing from the surface of the water to the bottom.
   - The scale on the left shows the amount of salinity in parts per thousand (ppt). Students should generally know that moving from blue to red on the scale represents fresh to increasingly saltier water.
   - Students should also be aware that arrows on the image indicate the direction of water flow.
   - The hour on the animation indicates the time of day on the 24-hour clock.
   - The isohalines (lines on a chart connecting all points of equal salinity) help students determine levels of salinity.

10. Encourage students to play this animation several times, looking for general patterns first, then at specific phenomena and distribution at specific places.
11. Have students answer the first set of questions in Part 3 of the *Student Worksheet — Salinity and Tides*.
12. Have students look at the cross-section views in the upper right of the animation, showing salinity with depth in the river, at the lines marked 1, 2 & 3, and answer the remaining questions.

Part 4 — Salinity as Measured by Water Quality Stations in York River

Having seen what a theoretical salinity distribution can look like in the river, students now observe actual salinity data for a specific day at five different sites along the river. You can do this activity either using computer access to near-current data or using the prepared data graphs in the *Student Data Sheet — Salinity and Tide Data for York River.*

13. If you use the computer access to data, follow the instructions in the *Student Worksheet — Salinity and Tides*. If you use the prepared graphs, hand them out to students.

Students will:

- Read information about the station including Salinity regime, Mean tidal range, Mean water depth, and Adjacent water.
- Make predictions about how fresher and saltier water will mix, and how salinity changes throughout the day will differ from site to site.
- Select data for the same date at each station. Students may select a date of their own choosing, but for the purposes of this initial activity, it will be best for the whole class to choose the same date for the sake of consistency when they are discussing results.
- Observe graphs of salinity data for that day at each site. It will be helpful for students to print out graphs for each site so they can compare changes from site to site, over time.

14. Encourage students to correlate the salinity graphs at the five sites with the generalized distribution shown in the animation. Students should pay particular attention to the graphs of Gloucester Point, Yorktown, and Clay Bank because this is the area marked by the three reference points in the animation.
15. Have students answer the questions in Part 4 of the *Student Worksheet — Salinity and Tides.*

Check for Understanding

1. Discuss the following:
   - How do the changes at each monitoring station compare with changes at those same areas in the animation?
   - Name several factors that determine why salinity changes are different depending on your location within the estuary.
2. Ask small groups to use their handouts to answer this question. Collect this assignment and use it as a final assessment.

   Imagine that an intense rainstorm dumps 3 inches of rain over the entire Chesapeake Bay region. Predict how the salinity would change at all four stations in the bay for a period of 24 hours after the storm ends. Supply a graph and an explanation of what you might expect to see at each station.

Optional Extension Inquiries

1. Have students access other data from the VIMS site to see how factors such as precipitation and temperature might have affected salinity on that date.
2. Have students investigate tides and salinity from other NERRS estuaries, using the NERRS data system: cdmo.baruch.sc.edu/QueryPages/googlemap.cfm
3. Other related activities include:
   - NOS Tides Lesson Plans oceanservice.noaa.gov/education/kits/tides/supp_tides_lessons.html
   - Waquoit Bay on Estuaries.gov, Time, Tides, and Quahogs www.estuaries.gov/pdf/timeandtide.pdf

Teacher Worksheet with Answers
Activity 2: Salinity & Tides

Part 1 — Tides in Chesapeake Bay

1a. At what time is the tide highest at the mouth of the bay near Norfolk? How high is the tide?

Answer: *Student answers will vary since this model is constantly updated to show near real-time. To determine the answer, work through the animation to find when the color at the mouth is deepest orange (or even red). Then read the time. For height, read the height (2-3 feet is a likely answer).*

1b. At what time did this tidal rise reach the northern tip of the bay near Baltimore? How high is the tide?

Answer: *Student answers will vary since this model is constantly updated to show near-real-time. To determine the answer, work through the animation to find when the color at the tip of the bay is towards the blue end of the scale. Then read the time. For height, read the height (.5 feet is a likely answer).*

1c. How long did it take the tide to move this distance?

Answer: *Student answers will vary. A typical answer is 12 hours.*

1d. Which location has higher tides? Why?

Answer: *Mouth of the bay because it is closer to the ocean where the tidal water enters the bay.*

1e. Which location do you think has saltier water? Why?

Answer: *Mouth of the bay because it is closer to the ocean where the salty ocean water enters the bay.*

Part 2 — Salinity as York River Flows into the Bay

2a. The map below shows the York River where it empties into Chesapeake Bay. On the map, indicate how you think the salinity might differ throughout the river and into Chesapeake Bay. Label parts of the map “fresh,” “nearly fresh,” “fairly salty,” “close to seawater,” or “seawater.”

Answer: *Student areas will vary. However, students should show some gradation of salinity, moving from less salty water upriver (upper left of the map) to more salty as they approach the ocean. The actual mean salinity of Taskinas Creek (upriver) ranges from about 3-5 ppt in winter to about 14-16 ppt in summer. The actual mean salinity of Goodwin Islands (in Chesapeake Bay) ranges from about 13-15 ppt in winter/spring to about 23-25 ppt in summer/fall.*

Part 3 — Interaction of Tides and River Flow

3a. At the mouth of the river (lower right), what are the highest and lowest salinity levels, in ppt, during this time frame?

Answer: *High 22, low 20 ppt (approximately)*

3b. Now look up river at the upper left of the animation. What are the highest and lowest salinity levels there?

Answer: *High 13, low 6 ppt (approximately)*

3c. Why is there such a difference between these two locations?

Answer: *Fresh water enters up river, salt water enters from Chesapeake Bay.*

3d. Play the animation and study the full extent of the river. How often do the arrows change direction? How does that affect salinity throughout the river?

Answer: *The arrows flow up (as the tide rises) for about 6 hours, then down (as the tide falls) for 6 hours. As tide rises, salinity increases and works it way up river, then vice-versa as tide falls.*

3e. At what point are there greatest changes in salinity throughout the day? Why do you think so?

Answer: *Saltier water moves up the river at high tide and fresher water moves seaward at low tide. Water with salinity of about 22 ppt moves from the mouth of the river to beyond Point 1 when the tide comes in. The area from Point 1 to Point 3 ranges from about 22 to 12 ppt. The area from Point 3 upriver ranges from about 16 to below 5 ppt.*

3f. Does the freshest water (the darkest blue) ever appear on the image? Where and for how long? Does the saltiest water (red) ever appear on the image? Where and for how long?

Answer: *The freshest water (less than 5 ppt) appears in the upper-most part of the river about every six hours when the arrows are moving seaward. Water of 25 ppt does not seem to appear on the map. The saltiest water is about 22 ppt and appears in the lower right-hand corner of the map. It does not go upriver much past station 1.*

3g. How does the water get mixed from top to bottom as the salinity changes from upstream to downstream?

Answer: *The water seems to get most thoroughly mixed from top to bottom in the area that is farthest upstream and especially where the river is shallow. The salinity in the areas most seaward, and especially the deeper parts of the river, does not change much at all.*

Part 4 — Salinity as Measured by Water Quality Stations in York River

4a. Describe the general pattern of salinity data for each site: Goodwin Island, Gloucester Point, Yorktown (this station is not included in the data sheets provided for March 21-22, 2007), Clay Bank, and Taskinas Creek.

***Answer**: Student answers for all the sites will vary depending on the dates they select.*

4b. Describe changes in salinity from site to site.

***Answer**: Generally, salinity decreases as you go from the coastal areas up the York River. Generally the lowest salinity values for a day occur during low tide (when water depth is low). Students will find that stations further upriver have salinity patterns that more closely resemble patterns of water depth or tide height. This is clearly seen in the graphs for Taskinas Creek. Stations closer to the ocean have more irregular patterns that may not resemble patterns in graphs of water depth. Salinity graphs at these sites show more frequent peaks and valleys.*

4c. What do you think explains the differences in salinity from site to site?

***Answer**: Sites further upriver are influenced not only by the brackish water of the York River, but also by fresh water entering from creeks and groundwater. High tides bring saltier water and salinity goes up. During low tides, fresher water predominates and salinity goes down. Salinity for sites closer to the coast may seem more erratic throughout the day. These sites are subject to more thorough mixing of fresher and saltier water because of waves, winds, and currents.*

Student Reading
Activity 2: Estuarine Tides — It's Not Just the Sun and Moon

What Affects Tides in Addition to the Sun and Moon?

The relative distances and positions of the sun, moon and Earth all affect the size and magnitude of the Earth's two tidal bulges. At a smaller scale, the magnitude of tides can be strongly influenced by the shape of the shoreline. When oceanic tidal bulges hit wide continental margins, the height of the tides can be magnified. Conversely, mid-oceanic islands not near continental margins typically experience very small tides of 1 meter or less. The shape of bays and estuaries also can magnify the intensity of tides. Funnel-shaped bays in particular can dramatically alter tidal magnitude. The Bay of Fundy in Nova Scotia is the classic example of this effect, and has the highest tides in the world—over 15 meters. Narrow inlets and shallow water also tend to dissipate incoming tides. Inland bays such as Laguna Madre, Texas, and Pamlico Sound, North Carolina, have areas classified as non-tidal even though they have ocean inlets. In estuaries with strong tidal rivers, such as the Delaware River and Columbia River, powerful seasonal river flows in the spring can severely alter or mask the incoming tide. Local wind and weather patterns also can affect tides. Strong offshore winds can move water away from coastlines, exaggerating low tide exposures. Onshore winds may act to pile up water onto the shoreline, virtually eliminating low tide exposures. High-pressure systems can depress sea levels, leading to clear sunny days with exceptionally low tides. Conversely, low-pressure systems that contribute to cloudy, rainy conditions typically are associated with tides that are much higher than predicted.

— Adapted from NOAA's National Ocean Service website, section on Tides &Water Levels.
URL:http://oceanservice.noaa.gov/education/kits/tides/tides08_othereffects.html.
Accessed: 2008-07-20. (Archived by WebCite® at http://www.webcitation.org/5ZS2dFx8h)

For a more thorough background on tides, see the NOS Tutorial on Tides and Water Levels:

Student Worksheet
Activity 2: Salinity & Tides

Part 1 — Tides in Chesapeake Bay

You might think of tides as the simple rising and lowering of the sea level based on the gravitational pull of the sun and moon. However, tides are much more dynamic and interesting, especially in estuaries. In Chesapeake Bay, it can take several hours for the high tide to move from the mouth of the bay to the northern tip. The rivers feeding into the bay add their own dynamics to the tidal variations. Here, you will study animations of tides in the Chesapeake Bay and York Rivers to understand these tidal dynamics and their effect on salinity.

Tides in Chesapeake Bay

Go to the following web site, which has an animation that shows tides throughout the bay for the past 3 days: <*tidesandcurrents.noaa.gov/ofs/cbofs/wl_nowcast.shtml*>.

Watch the animation and look for patterns in the tidal pulse as it works its way up the bay. Notice the scale on the right, with yellows and reds as high tide, greens and blues as low tides. Step through the animation, pressing the "Prev" and "Next" buttons, to watch the tide move up the bay.

1a. At what time is the tide highest at the mouth of the bay near Norfolk? How high is the tide?

1b. At what time did this tidal rise reach the northern tip of the bay near Baltimore? How high is the tide?

1c. How long did it take the tide to move this distance?

1d. Which location has higher tides? Why?

1e. Which location do you think has saltier water? Why?

Part 2 — Salinity as York River Flows into the Bay

Next, you take a closer look at York River to see how tides and the flowing river interact and affect salinity of the water.

The map below shows the York River where it empties into Chesapeake Bay. On the map, indicate how you think the salinity might differ throughout the river and into Chesapeake Bay. Label parts of the map “fresh,” “nearly fresh,” “fairly salty,” “close to seawater,” or “seawater.”

Figure 1.

The location of York River with respect to Chesapeake Bay

Figure 2.

Yorktown, Virginia is situated at the mouth of the York River.

Part 3 — Interaction of Tides and River Flow

Go to this web site: <*www.vims.edu/physical/web/presnt/qtime/Kimplot3.mov*>. The animation shows salinity in York River, and how it changes with the incoming and outgoing tide, over 24 hours.

Use the slide bar to control the animation at your own pace. Watch the animation several times, looking for patterns in the salinity. Notice the time counter at the top, marking half-hour increments, and the scale bar on the left showing salinity in parts-per-thousand (ppt).

3a. At the mouth of the river (lower right), what are the highest and lowest salinity levels, in ppt, during this time frame?

3b. Now look up river at the upper left of the animation. What are the highest and lowest salinity levels there?

3c. Why is there such a difference between these two locations?

3d. Play the animation and study the full extent of the river. How often do the arrows change direction? How does that affect salinity throughout the river?

3e. At what point are there greatest changes in salinity throughout the day? Why do you think so?

3f. Does the freshest water (the darkest blue) ever appear on the image? Where and for how long? Does the saltiest water (red) ever appear on the image? Where and for how long?

3g. Now look at the cross-section views in the upper right of the animation, showing salinity with depth in the river, at the lines marked 1, 2 & 3. How does the water get mixed from top to bottom as the salinity changes from upstream to downstream?

Part 4 — Salinity as Measured by Water Quality Stations in York River

The animations showed salinity distribution throughout a river based on a computer model. Now, you will observe actual salinity data for a specific day at five different sites along the York River. These sites use data buoys and other water quality stations to measure water depth, salinity, and other important data. These instruments support research at the Chesapeake Bay Virginia NERR and the affiliated Virginia Institute of Marine Science (VIMS).

You can do this activity in either of two ways: Use your computer to access real-time data and display your own graphs (see instructions below) or use the *Student Data Sheet* with its graphs for a sample date.

If you use your computer, follow these instructions:

- Open the Virginia Estuarine and Coastal Observing System site at: *www2.vims.edu/vecos/SegmentChoice.aspx?param=MOBPH*. This will bring up a page showing a regional view with some of the York River stations.
- Starting with Goodwin Island Continuous Monitoring Station (CHE019.38), click on each station, moving progressively up river (to Gloucester Point (YRK—5.40), Yorktown (YRK006.77), Clay Bank (YRKO15.09), and Taskinas Creek (TSK000.23).
- For each station, print the graphs of salinity and water depth.
- Read other information about the station including Salinity regime, Mean tidal range: 0.85 meters, and Mean water depth.

Figure 3. Location of selected monitoring stations in the Chesapeake Bay region.

Whether you use computer to access data or the pre-printed graphs, answer the following questions:

4a. Describe the general pattern of salinity data for each site:

Goodwin Island

Gloucester Point

Yorktown (this station is not included in the data sheets provided for March 21-22, 2007)

Clay Bank

Taskinas Creek.

4b. Describe changes in salinity from site to site.

Student Data Sheet
Activity 2: Salinity and Tide Data for York River

Salinity Data for March 21-22, 2007

Goodwin Islands Continuous Monitoring Station: CHE019.38

www2.vims.edu/vecos/StationDetail.aspx?param=CHE019.38&program=CMON

Location: N 37º 13' 01.2" W 76º 23' 19.2"

Tributary: York River

Salinity regime: Polyhaline

Mean tidal range: 0.79 meter

Mean water depth: 1.0 meter

Adjacent Water: located on the southern side of the York River, near the mouth of the River.

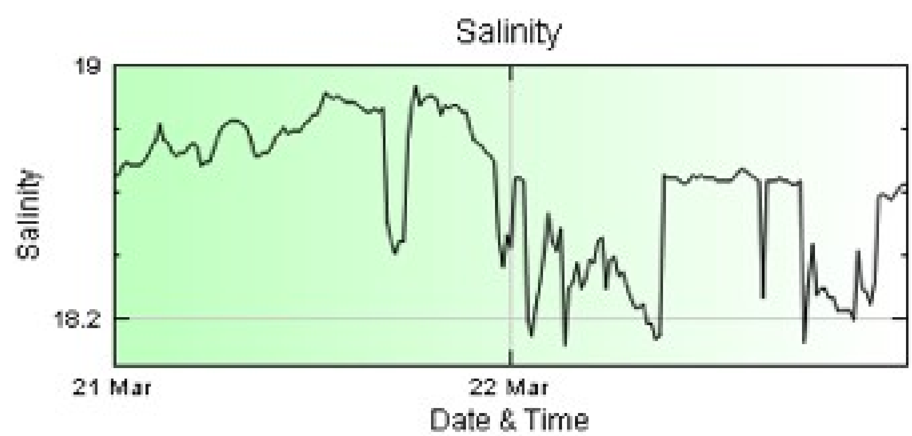


Figure 4. Salinity at Goodwin Islands Monitoring Station

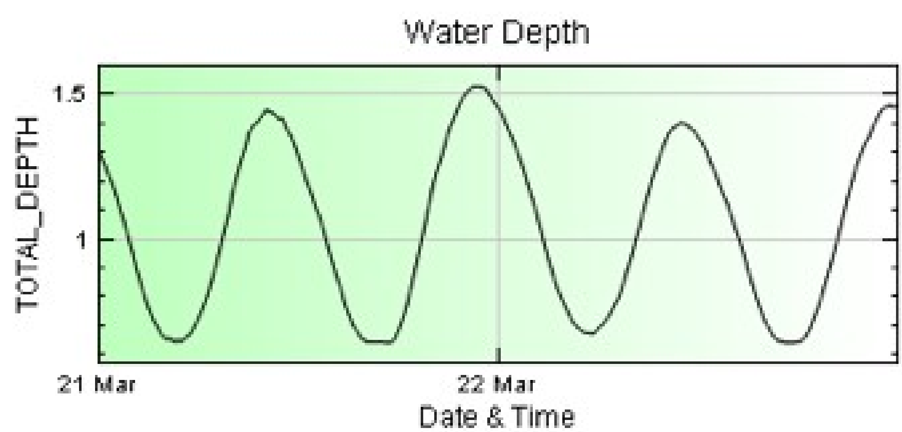


Figure 5. Water depth at Goodwin Islands Monitoring Station

Gloucester Point (GP) Continuous Monitoring Station: YRK005.40

Location: N 37º 14’ 53.82” W 76º 29’ 47.46” Tributary: York River

Salinity regime: Polyhaline

Mean tidal range: 0.73 meters

Mean water depth: 1.8 meters

Adjacent water: The Gloucester Point station is located north of the York River channel, approximately 5.4 nautical miles upstream from the River’s mouth.

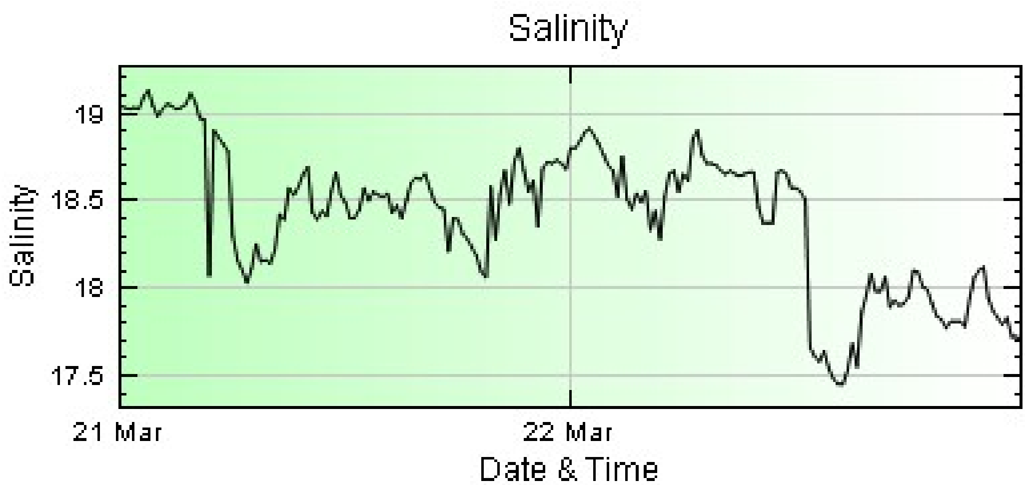


Figure 6. Salinity at Gloucester Point Monitoring Station

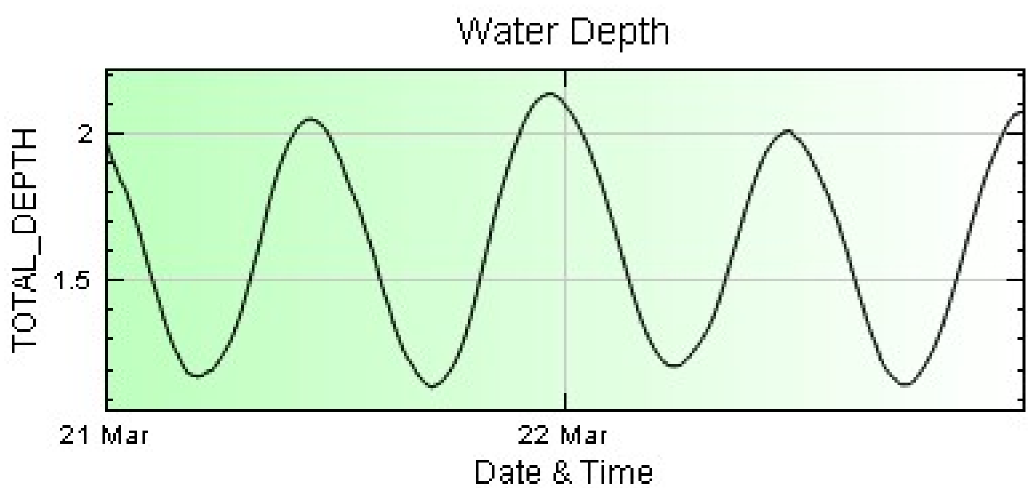


Figure 7. Water depth at Gloucester Point Monitoring Station

Claybank (CB) Continuous Monitoring Station: YRK015.09

Location: N 37º 20’ 49.5” W76º 36’ 41.94”

Tributary: York River

Salinity regime: Mesohaline

Mean tidal range: 0.85 meters

Mean water depth: 1.2 meters

Adjacent water: The Clay Bank station is located northeast of the York River channel, approximately 15.1 nautical miles upstream from the River’s mouth.

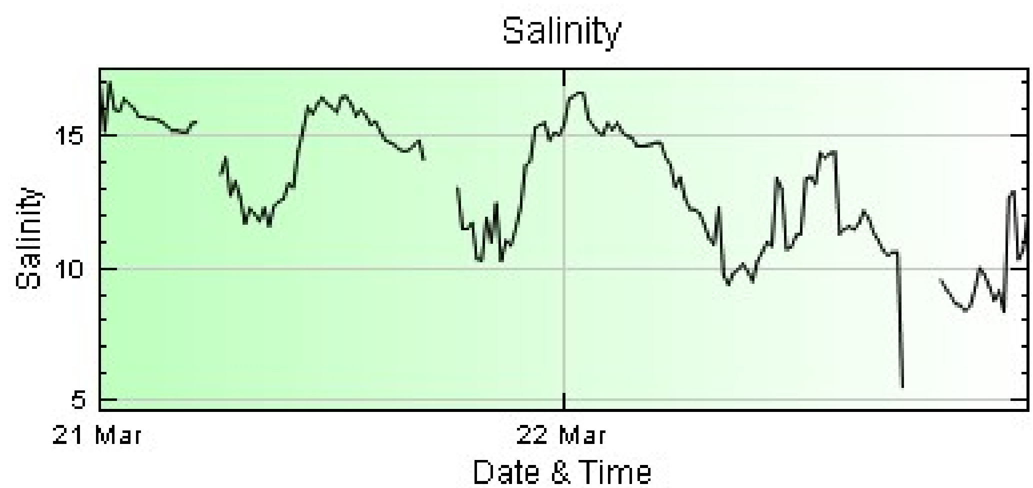


Figure 8. Salinity at Claybank Monitoring Station

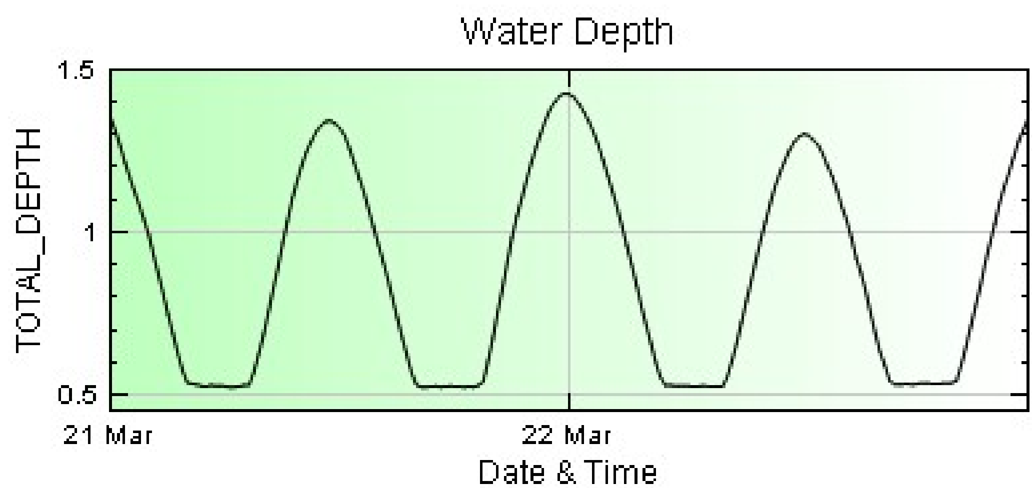


Figure 9. Water depth at Claybank Point Monitoring Station

Taskinas Creek (TC) Continuous Monitoring Station: TSK000.23

Location: N 37º 24’ 54.79” W 76º 42’ 52.74

Tributary: York River

Salinity regime: Mesohaline

Mean tidal range: 0.85 meters

Mean water depth: 1.5 meters

Adjacent water: The Taskinas Creek station is located southwest of the York River channel, approximately 23 miles upstream from the River’s mouth.

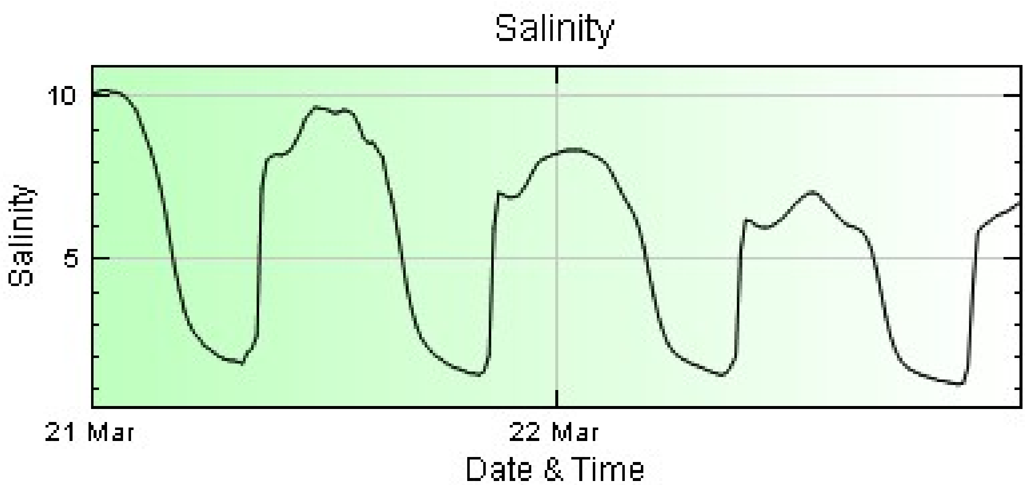


Figure 10. Salinity at Taskinas Creek Monitoring Station

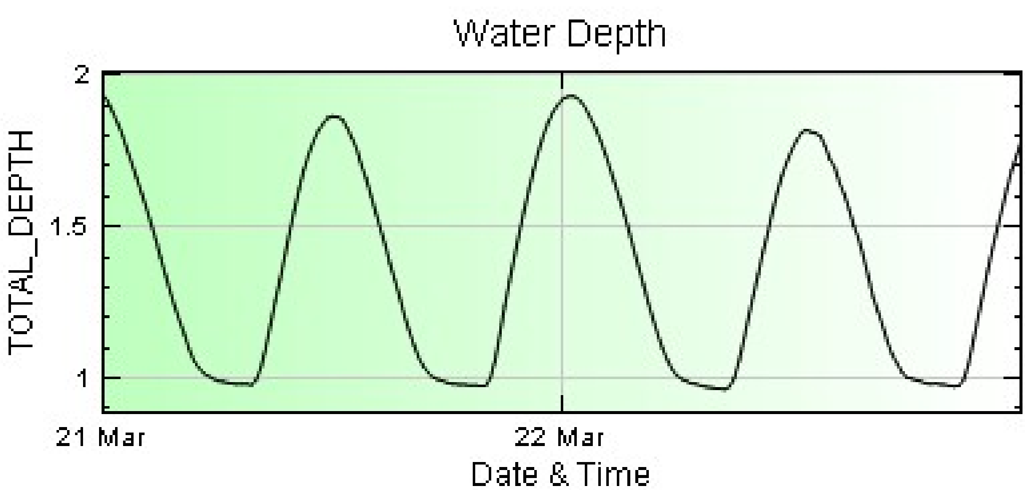


Figure 11. Water depth at Taskinas Creek Monitoring Station

Teacher Guide—Earth Science Module
Activity 3: Estuary and Watershed

Featured NERRS Estuary:
San Francisco Bay
National Estuarine Research Reserve
nerrs.noaa.gov/SanFrancisco/welcome.html

Activity Summary

In this activity, students investigate the nature of watersheds and their relationship to the dynamic changes that occur in estuaries due to drainage and runoff. Students begin by examining the San Francisco Bay Estuarine Research Reserve and tracing the extent of the watershed using Google Earth. Then they identify possible sources of pollution and contamination along the major rivers that feed into the bay. Students also examine water quality data in the San Pablo region of the estuary and identify changes that occur due to a storm event.

Learning Objectives

Students will be able to:

1. Identify the processes in the watershed that affect conditions in the estuary and explain some specific examples.
2. Apply their understanding of changes in the watershed and the resulting effects on the estuary to explain real-life situations regarding land use and weather in watersheds.
3. Understand how water quality factors are affected by natural and man-made sources of pollution and contamination.

Grade Levels

9-12

Teaching Time

4 (55 minute) class sessions + homework

Organization of the Activity

This activity consists of 4 parts which help deepen understanding of estuarine systems:

Exploring the San Francisco Watershed

What's Upstream Comes Downstream

Water Quality at the Mouth of the Watershed

Optional: Mapping Your Local Watershed

Background

San Francisco Bay is an extensive and shallow estuary that drains approximately 40% of California. Ninety percent of the water flowing into the bay comes from the Sacramento and San Joaquin rivers, whose headwaters are in the Sierra

Nevada Mountains. Both rivers flow into the Delta, a vast network of channels, agricultural lands and fresh water wetlands, and then into Suisun Bay where they begin mixing with salt water from the Pacific Ocean.

San Francisco Bay has lost approximately 80% percent of its historic tidal wetlands due to development pressures within and around the bay. Tidal wetlands are critical for flood prevention; sediment management; and habitats for small mammals, migratory birds and fish species, many of which are threatened or endangered.

Endangered species in the bay include the California clapper rail and salt marsh harvest mouse. The southwestern end of San Pablo Bay, near the town of San Rafael, was the site of a Chinese shrimp-fishing village where some 500 people lived in the 1880s, sending some 90% of their catch of bay shrimp back to China or to Chinese communities throughout the U.S. The location is now part of China Camp State Park. China Camp Park is part of the San Francisco Bay National Estuarine Research Reserve (NERR). The water quality data in this activity is taken from a monitoring station on this historic pier.

Preparation

Download Google Earth and install it on your classroom computer(s) or computer lab machines. To find a tutorial for using Google Earth, please read the box below.

Optional: Obtain topographic maps for plotting your local watershed for Part 4 of the activity.

You can obtain such a map from a nearby store or order one at <topomaps.usgs.gov/>.

Google Earth

This activity *requires* the use of Google Earth. If students have computer access, the use of Google Earth (http://earth.google.com/) can help them develop spatial skills.

Find Tutorial "*Using Google Earth to Explore Estuaries*" in estuaries.gov, click under Teachers, Classroom Activities and find the tutorial.

Materials

Students

- ❑ Need to work in a computer lab or with a computer and projector
- ❑ Copy of Student Reading
  Estuary and Watershed
- ❑ Copy of Student Worksheet
  Estuary and Watershed, Student Data Sheet 1 — Orienting Yourself to the San Francisco Estuary and Watershed
- ❑ Copy of Student Data Sheet 2 — Water Quality Data

Teachers

- ❑ Sheets of Mylar, acetate, or tracing paper
- ❑ Different colored markers
- ❑ Map(s) of the greater San Francisco area
- ❑ Download Google Earth <*http://earth.google.com/*>.

Equipment:
- ❑ Computer lab or
- ❑ Computer and Projector

Procedure

Part 1 — Exploring the San Francisco Watershed

1. Ask students what, if anything, they know about watersheds. If possible, walk outside your school and scanning your neighborhood, discuss your local watershed with students. Where does the water that passes through ditches, gutters, creeks, or steams near your school go?
2. Hand out all the student sheets (Student Reading — Estuary and Watershed, Student Worksheet — Estuary and Watershed, Student Data Sheet 1 — Orienting Yourself to the San Francisco Estuary and Watershed, and Student Data Sheet 2 — Water Quality Data) and materials, and have students read and look through them.
3. Have students follow the directions on the *Student Worksheet — Estuary and Watershed* to outline the general limits and confines of the San Francisco watershed. Explain to students that there are certainly watersheds within this huge area outlined on their image. Point out the Sacramento and San Joaquin Rivers if they have difficulty locating them.
4. Show students their starting point (Golden Gate Bridge) in Google Earth and have them complete Part 1 of the *Student Worksheet — Estuary and Watershed.*

   If students are using Google Earth for the first time, show them how to use the search tool, how to zoom in and out to change viewing altitude, and how to use the motion buttons to navigate around the image. (If necessary, refer to the *Student Reading — Using Google Earth to Explore Estuaries* in Activity 1 for a brief how-to guide.)
5. Review and discuss the Part 1 tasks and questions.

Part 2 — What's Upstream Comes Downstream

6. Have students complete Part 2 of the *Student Worksheet — Estuary and Watershed*, choosing one of the two rivers and taking a Google Earth trip to identify areas and man-made features that may be potential sources of pollutants and contaminants in a heavy rain/flooding event.
7. Review and discuss the Part 2 tasks and questions. Have students who studied each river report their findings to the class.

National Science Education Standards

Content Standard A: Science as Inquiry

A3. Use technology and mathematics to improve investigations and communications.

A4. Formulate and revise scientific explanations using logic and evidence.

A6. Communicate and defend a scientific argument.

Content Standard D: Earth and Space Science

D2. Geochemical Cycles

Content Standard E: Science and Technology

E6. Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

F4. Environmental quality

F5. Natural and human-induced hazards

Part 3 — Water Quality at the Mouth of a Watershed

8. Ask students what might happen to the salinity and turbidity in the San Francisco Bay-Delta Estuary after a rainstorm. Go over the water quality factors students will be analyzing.
9. Have students complete Part 3 of the *Student Worksheet — Estuary and Watershed.*

The data given in this section reveals a major rain event in the San Francisco watershed during the first days of January (1st -3rd). Several inches of rain fell over the area over the *two-day span.*

10. Review and discuss the Part 3 tasks and questions.

Part 4 — Optional: Mapping Your Local Watershed

It is said that everyone lives in a watershed. Do streams or rivers in your community flow into an estuary? Have students map their own watershed and identify the estuarine features and geologic landforms that comprise it.

11. Hand out copies of the topographic map of your local watershed, new clear sheets of Mylar, acetate, or tracing paper, and the markers, and have students complete Part 4 of the *Student Worksheet — Estuary*

Check for Understanding

1. Discuss the following:
- ❑ How do agricultural areas, industrial sites, landfills, and sewage treatment plants affect water quality in a watershed?
- ❑ Explain how an estuary can act as a filtration system for runoff in a watershed.

2. Supply students with a road map of the eastern U.S. and project a satellite image of the Chesapeake Bay watershed. <http://education.usgs.gov/common/resources/mapcatalog/images/image/chesapeake_satellite.jpg>

Ask students to identify major urban areas around Chesapeake Bay and major rivers that drain the watershed. Ask students to predict where they would expect areas in the most danger of contamination and pollution if a major storm event such as a hurricane struck the region.

Optional Extension Inquiries

1. Investigate the National Estuarine Research Reserve closest to the location of your school. If possible, arrange to take your students on a field trip to the reserve.
2. Have your students construct a map of the watershed for the reserve using a topographic map of the region.
3. Have students locate possible sources of pollution and contamination in the watershed.
4. Establish a water-monitoring program at a stream or river near your school.
5. Report the results of your monitoring program to your town council or other governing body (water company).

Teacher Worksheet with Answers
Activity 3: Estuary and Watershed

Part 1 — Exploring the San Francisco Watershed

1a. Fly around the bay in a clockwise direction, identify the rivers that empty into the bay, and list them.

Answer: The Pentaluma River, Napa River, San Joaquin River, Sacramento River, and several streams and creeks empty into San Francisco Bay.

1b. Where is the source of the Sacramento River?

Answer: The source is in the Sierra Nevada Mountains.

1c. Where is the source of the San Joaquin River located?

Answer: *The source is in the Sierra Nevada Mountains.*

1d. Describe what kinds of human activity you see along sequence of bays and channels from San Pablo Bay to the junction of the Sacramento and San Joaquin Rivers.

Answer: There is widespread industrial activity, as well as golf courses, farmland, housing developments, parks, and other commercial enterprises along this stretch of the bay complex/estuary. Many ships and docks can be seen as well.

1e. Describe how the terrain up the rivers differs from the types of terrain along the coast. Can you detect any geologic landforms or features that might be a source for salts, minerals, or materials that would affect water quality in the estuary?

Answer: The terrain upriver is mostly farmland until the rivers enter more urban areas such as the cities of Sacramento and San Joaquin. Sewage treatment plants can be seen at the junction of the two rivers.

Part 2 — What's Upstream Comes Downstream

2a. List ten possible sources of pollutants or contaminants along the river. Record the source and a place name or latitude and longitude coordinates for each site.

Answer: Student responses will vary. Students may find factories, sewage treatment plants, farm fields (sources of fertilizer), golf courses (also a source of nitrates and phosphate fertilizer), parks, housing developments, and parking lots along both rivers' banks.

2b. What do you think is the most likely source of pollution and contamination along the river you investigated?

Answer: Most of the land is composed of fields upriver. Runoff from farms carries fertilizer and animal wastes into the river and subsequently into the estuary and bay complex.

2c. Can you see any evidence that contaminants are being released in the estuary and San Francisco Bay?

Answer: Students should be able to see sediment plumes in evidence at various places where the rivers enter Suisun and San Pablo Bays.

Part 3 — Water Quality at the Mouth of a Watershed

3a. Predict how this event would affect these water quality factors in the estuary:

Answer: Student answers will vary.

3b. Consult the *Student Data Sheet 2 — Water Quality Data* to look for evidence of a major storm event that occurred in 2006 and list its approximate dates.

Answer: A major rain and storm event appears to have taken place in October between the 12th and the 16th based on the enormous increase in turbidity and drop in salinity.

3c. What happened to each of the water quality indicators during and immediately following this event?

Answer:

•water surface temperature:	*temperature dropped almost 2°F*
•pH :	*changes slightly, drops .1 to .2 of a unit*
•dissolved oxygen:	*stays about the same*
•Salinity:	*salinity decreased due to the influx of fresh water and stayed low for many days*
•Turbidity:	*quadrupled (200 to 800 NTUs)*

3d. How well did your predictions match what actually happened during the storm event?

Answer: Student answers will vary.

3e. What geologic landforms, features, farming, or industrial concerns affect the quality of water at the mouth of your local watershed?

Answer: Student answers will vary.

Part 4 — Mapping Your Local Watershed

4a. Compare the watershed model you made with the watershed formed by the Sacramento and San Joaquin Rivers. How are they similar? How are they different?

Answer: Answers will depend on your watershed and its characteristics.

4b. What geologic landforms, features, farming, or industrial concerns affect the quality of water in the estuary or mouth of your local watershed?

Answer: Answers will depend on your watershed and its characteristics.

Student Reading—1
Activity 3: Estuary and Watershed

A watershed, also called a drainage basin, is the area in which all water, sediments, and dissolved materials drain from the land into a common body of water, such as a river, lake, estuary, or ocean. A watershed encompasses not only the water but also the surrounding land from which the water drains. Watersheds range in size from huge areas like the Mississippi River drainage basin to small areas like your backyard.

Whether large or small, a watershed's characteristics can greatly affect how water flows through it. Heavy storms may cause streams to rise rapidly. Human-made features of the watershed like dams or large paved areas can change stream flow and alter the watershed. If the terrain is steep, changes in stream flow due to runoff can be significant.

In some watersheds, stream flow may take a long time to respond to rainfall runoff. On heavily vegetated, relatively flat terrain, much of the rainfall is absorbed by the soil and the vegetation slows runoff. In these areas, stream flow will rise slowly, but also recede slowly. On steep terrain with a scarcity of vegetation, heavy rain can cause rapid stream flow and runoff with very little absorption by the ground. These grade changes create different habitats in the stream that support different forms of life and change the quality of water in the watershed.

Water quality is critically impacted by everything that goes on within the watershed. Mining, forestry, agriculture, and construction practices, urban runoff from streets, parking lots, chemically-treated lawns and gardens, failing septic systems, and improperly treated municipal sewage discharges all affect water quality. Reducing pollution and protecting water quality requires identifying, regulating, monitoring, and controlling potential sources of pollution. Some examples of control practices include protecting stream banks and shorelines by maintaining vegetated buffer strips, treating all wastes to remove harmful pollutants, or using grass-lined catchment basins in urban areas to trap sediment and pollutants. Also, protecting wetlands is essential since they are important in slowing runoff, absorbing floodwaters, and cleaning storm water.

Estuaries lie at the mouth of watersheds. San Francisco Bay is a shallow, extremely large estuary that drains about forty percent of California. Nearly ninety percent of the fresh water flowing into the bay comes from the Sacramento and San Joaquin rivers. Technically, both rivers flow into Suisun Bay, which flows through the Carquinez Strait to meet with the Napa River at the entrance to San Pablo Bay, which then connects at its south end to San Francisco Bay. This entire group of interconnected bays is referred to as San Francisco Bay.

San Francisco Bay has lost approximately *80-90%* of its historic tidal wetlands due to human and industrial activities within and around the bay. Tidal wetlands are critical for flood prevention; sediment management; and habitats for small mammals, migratory birds and fish species, many of which are threatened and endangered.

What happens upstream can affect the quality of water and the living conditions for organisms that live in the tidal estuary. In this activity, you will investigate the San Francisco Bay watershed and estuary.
The North or San Pablo Bay receives he waters of the Sacramento and San Joaquin rivers via Suisun Bay and the Carquinez Strait on its east end, and it connects to San Francisco Bay on its south end.

Student Reading—1
Continues.... Activity 3: Estuary and Watershed

San Pablo Bay is a primary wintering stop for the canvasback duck population on the Pacific Flyway, as well as a migratory staging ground for numerous species of waterfowl. Endangered species that are found in the bay include the salt marsh harvest mouse. Endangered saltwater fishes found in the bay include striped bass, sturgeon, starry flounder, leopard shark, and anchovy. The southwestern end, near the town of San Rafael, was the site of a Chinese shrimp-fishing village where some 500 people lived in the 1880s, sending some 90% of their catch of bay shrimp back to China. The location is now part of China Camp State Park, which is part of the San Francisco Bay National Estuarine Research Reserve (NERR). The water quality data you will examine in Part 3 of this activity was taken at this site.

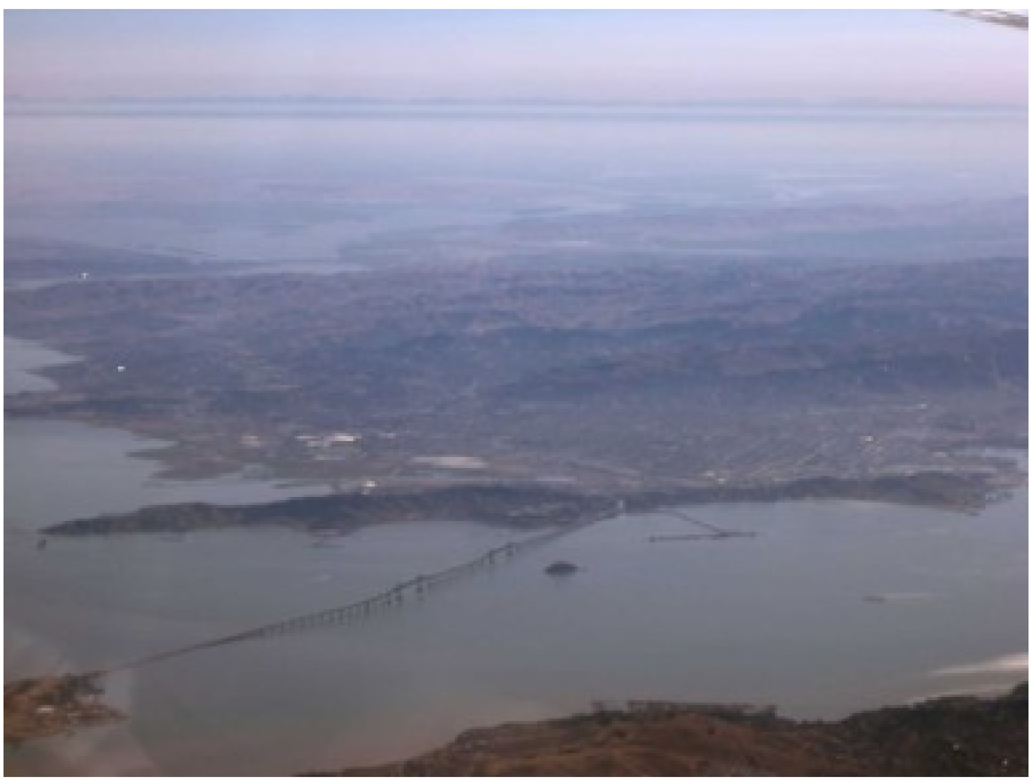


Figure 1. San Pablo Bay or North Bay

Student Worksheet
Activity 3: Estuary and Watershed

Part 1 — Exploring the San Francisco Watershed

In this part of the activity, you will examine the San Francisco Bay watershed and then investigate the impact of the natural and man-made features that cause materials to be carried down river into parts of the estuary.

Obtain a piece of plastic overlay and put it over the Oblique View of the San Francisco area on *Student Data Sheet 1 — Orienting Yourself to the San Francisco Estuary and Watershed*.

Use a marker and outline any high ridges or mountains you see surrounding low basin areas.

Use a map of California to label cities and the names of mountains present in the image.

Sketch the path of the Sacramento and San Joaquin Rivers as far as you can. (The lines marking the tops of the mountains outline the huge watershed of San Francisco Bay.)

Figure 2. South Bay is the large bay at the bottom of this image.
South Bay has very little fresh water flowing into it.
(Image courtesy of US Geological Survey)

Take a closer look at both the estuary and the nature of the watershed using Google Earth.

If you are unfamiliar with Google Earth, your teacher will give you a short demonstration on how to navigate and change your viewing altitude using the software.

If San Francisco Bay is not preset, enter 37° 48' 53.12 N, 122° 28' 38.26 W, the coordinates of the Golden Gate Bridge, into the Search box.

Press the Go button (magnifying glass).

Consult the Road Map on *Student Data Sheet* to orient yourself to the series of bays in the estuary and to the location of the city of San Francisco.

After taking a look at the bridge, increase your viewing altitude to 20 km.

Fly straight north by pressing the "up" arrow until you reach North Bay (San Pablo Bay). You should see the town of Gallinas on the western shore of the bay.

1a. Fly around the bay in a clockwise direction, identify the rivers that empty into the bay, and list them.

As you reach the eastern side of the bay, notice a large channel heading towards the right side of the screen. Follow it past Grizzly and Suisun Bay to Sherman Island. Two major rivers intersect here—the Sacramento and San Joaquin Rivers.

Follow the northern river (Sacramento) along its course. When it branches, keep taking the northern branch until you can no longer observe its course. This point is the river's source or headwater.

1b. Where is the source of the Sacramento River?

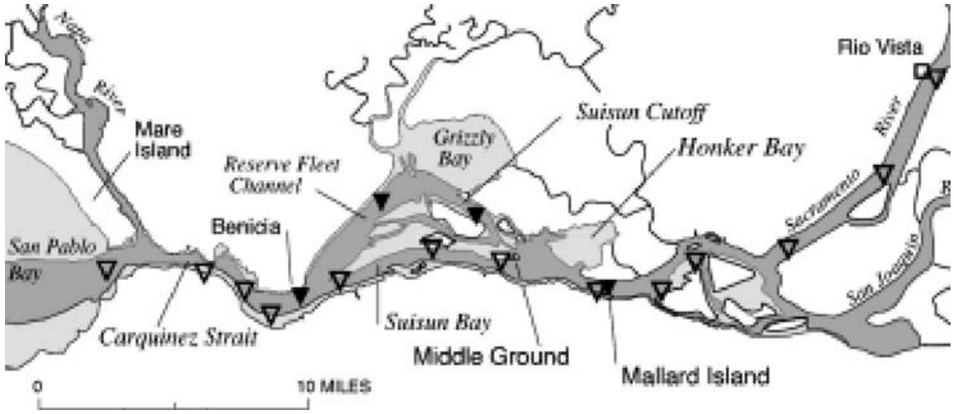


Figure 3. Most of the fresh water that mixes with ocean water
in the estuary comes from two sources —the Sacramento and San Joaquin Rivers.

Figure 4. An oblique satellite image of the same scene.
The vertical scale of this image is enhanced 5 times.

Travel back to the junction of the two rivers and trace the path of the San Joaquin River and locate its headwaters.

1c. Where is the source of the San Joaquin located?

Travel back to the Golden Gate Bridge and explore the rest of the estuary, including South Bay. List any additional sources of fresh water flowing into the estuary.

1d. Describe what kinds of human activity you see along the sequence of bays and channels from San Pablo Bay to the junction of the Sacramento and San Joaquin Rivers.

1e. Describe how the terrain up the rivers differs from the types of terrain along the coast. Can you detect any geologic landforms or features that might be a source for salts, minerals, or materials that would affect water quality in the estuary?

Part 2 — What's Upstream Comes Downstream

You will now take a closer look at the watershed and try to determine the nature of the pollutants and contaminants that might be washed downstream into the estuary by heavy rain and floods.

Pick one of the two major rivers (Sacramento or San Joaquin) flowing into San Pablo Bay to follow upstream. Fly low—one kilometer or less—to see features like chemical or other industrial plants, sewage treatment plants, golf courses, and other possible sources of contaminants.

Selected River (circle one): Sacramento River San Joaquin River

2a. List ten possible sources of pollutants or contaminants along the river. Record the source and a place name or latitude and longitude coordinates for each site.

Possible Source of Pollution/Contaminants	Name or Location
1. ____________________	____________________
2. ____________________	____________________
3. ____________________	____________________
4. ____________________	____________________
5. ____________________	____________________
6. ____________________	____________________
7. ____________________	____________________
8. ____________________	____________________

9. ______________________________ ______________________________

10. ______________________________ ______________________________

2b. What do you think is the most likely source of pollution and contamination along the river you investigated?

2c. Can you see any evidence that contaminants are being released in the estuary and San Francisco Bay?

Part 3 — Water Quality at the Mouth of a Watershed

You will attempt to determine how a major weather event might affect water quality near the mouth of a watershed, in this case, in the San Pablo Bay region of the estuary at China Camp State Park.

Imagine the following: A major storm dumps several inches of rain in the Sierra Nevada mountains and the cities of Sacramento and San Joaquin. Regional flooding occurs along the banks of both rivers and the runoff increases the volume of fresh water running into the bay and estuary system.

3a. Predict how this event would affect these water quality factors in the estuary:

water surface temperature ______________________________

pH ______________________________

dissolved oxygen ______________________________

salinity ______________________________

turbidity ______________________________

3b. Consult the *Student Data Sheet 2 — Water Quality Data*, look for evidence of a major storm event that occurred in 2006, and list its approximate dates.

3c. What happened to each of the water quality indicators during and immediately following this event?

water surface temperature ______________________________

pH ______________________________

dissolved oxygen ______________________________

salinity ______________________________

turbidity ______________________________

3d. How well did your predictions match what actually happened during the storm event?

3e. What geologic landforms, features, farming, or industrial concerns affect the quality of water at the mouth of your local watershed?

Part 4 — Mapping Your Local Watershed

Cover the topographic map of a watershed supplied by your teacher with a piece of clear plastic.

Find, mark, and label with blue pen the following items on the map:

- streams
- ditches
- ponds
- rivers
- lakes
- ocean
- water wells
- water treatment plant
- water storage tanks
- schools
- sewage lagoon or catchment ponds

Find the highest and lowest points in the watershed. Mark all the high points (hilltops) with a black "H." Mark the lowest spot with a red "L."

From the black "H" high points, draw arrows on your map to show the flow of runoff. Where does water flow into ponds, lakes, streams, rivers, or ocean?

Draw a black line around the perimeter of the watershed. To do this, start at the lowest point (the mouth of a stream or river where it drains into another body of water) and start clockwise up the nearest ridge. Connect the "Hs" on the ridge until you have completely enclosed the stream and end up back at the starting point.

4a. Compare the watershed model you made with the watershed formed by the Sacramento and San Joaquin Rivers. How are they similar? How are they different?

4b. What geologic landforms, features, farming, or industrial concerns affect the quality of water in the estuary or mouth of your local watershed?

Student Data Sheet - 1
Activity 3: Orienting Yourself to the San Francisco Estuary and Watershed

Oblique View

Figure 5. An oblique view of the San Francisco Bay area showing the outer margins of the large watershed drained by the San Joaquin and Sacramento Rivers. The Sierra Nevada Mountains are on the top right edge of the image. The vertical scale has been exaggerated by a factor of 5.

Road Map

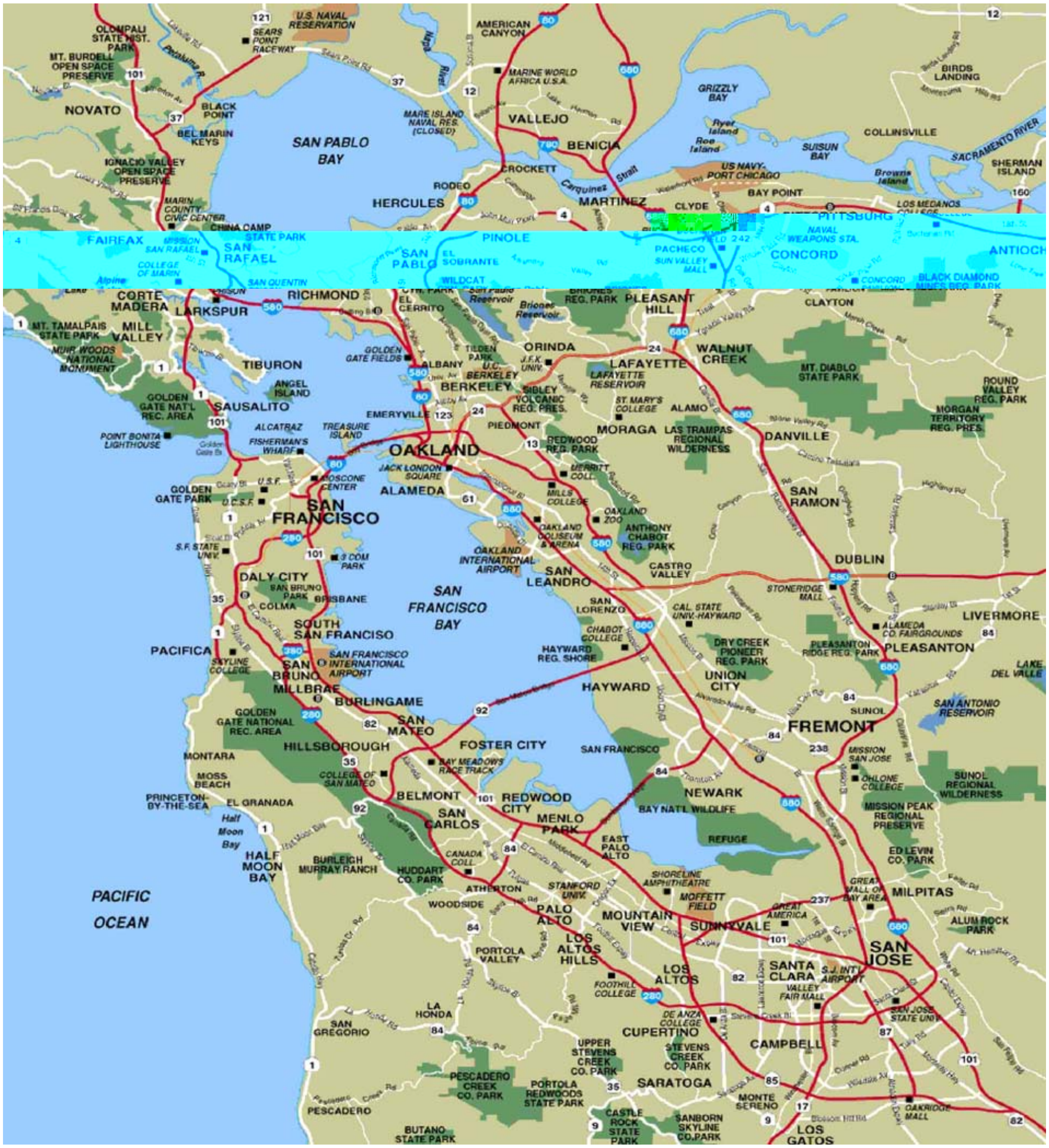


Figure 6. Road map of the San Francisco Bay area

Satellite View

Figure 7. A satellite view of the San Francisco Bay area. Your tour of the rivers that drain the San Francisco Bay watershed begins in the upper-right portion of this image.

View of the Estuary

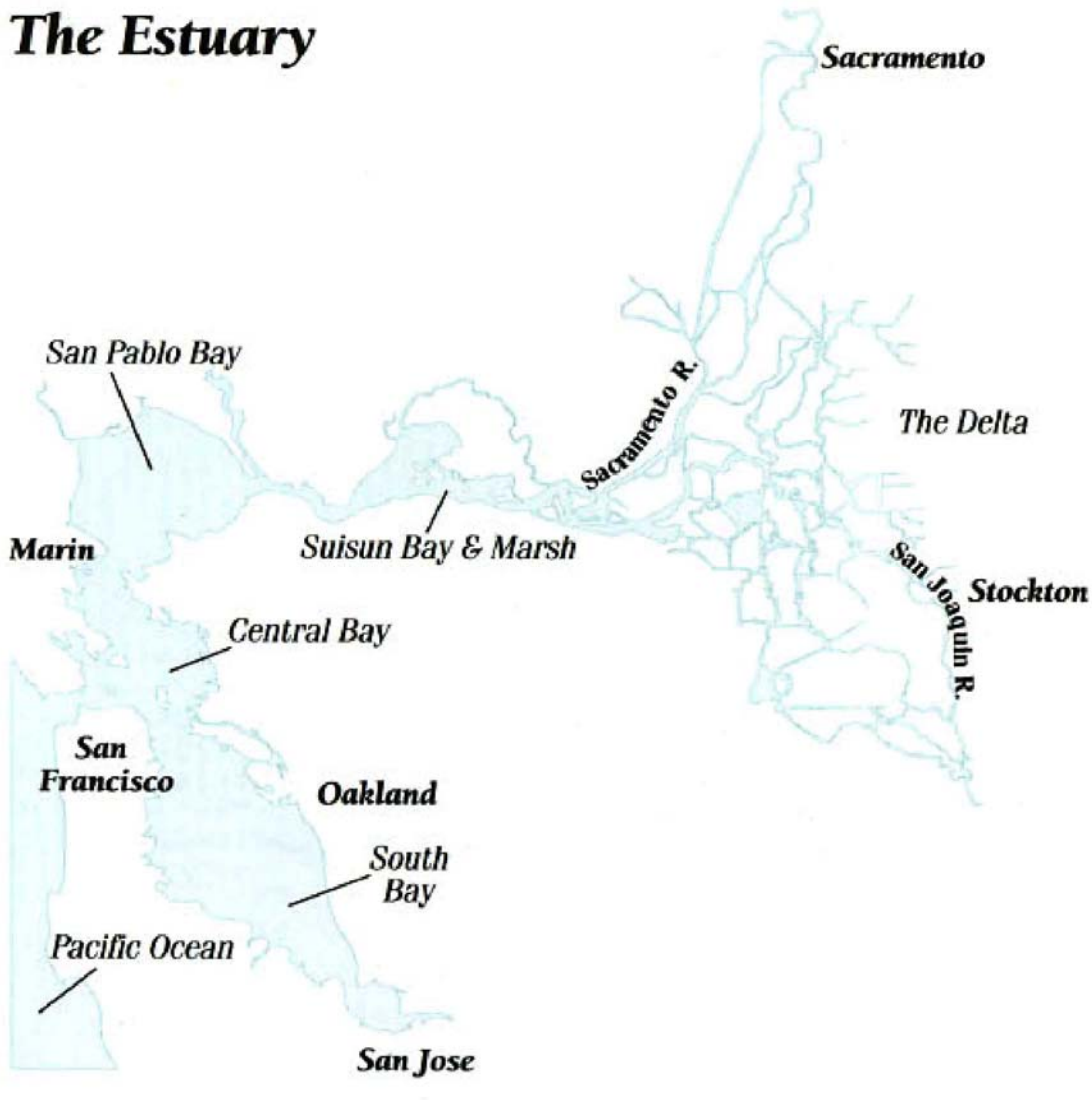


Figure 8. The San Francisco estuary has many parts.

Student Data Sheet - 2
Activity 3: Water Quality Data

China Camp, San Pablo Bay

All data from the China Camp Monitoring Station in San Pablo Bay, Dec 20, 2005 to Jan 19, 2006

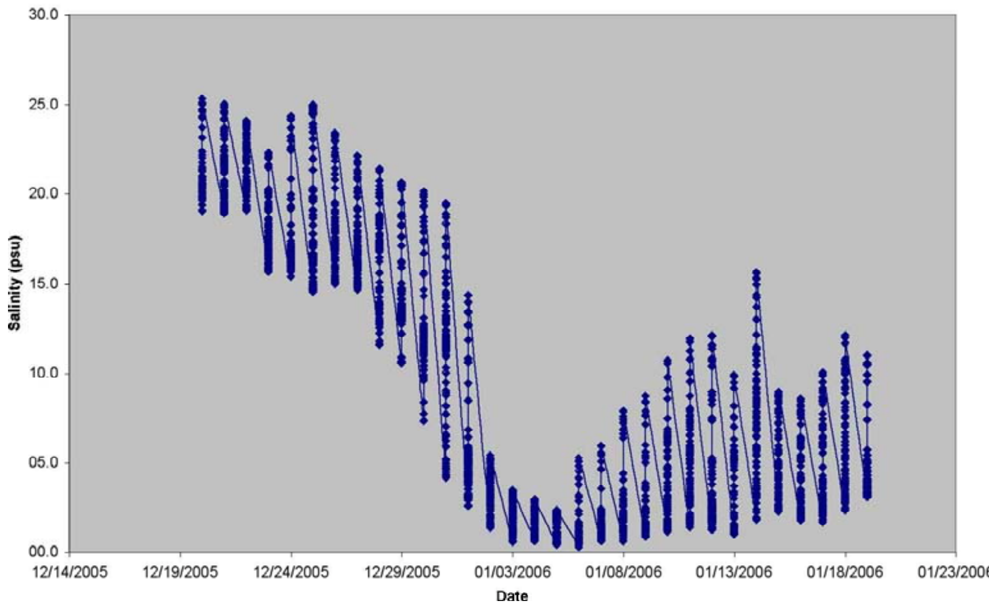


Figure 9. Salinity Drop with Storm

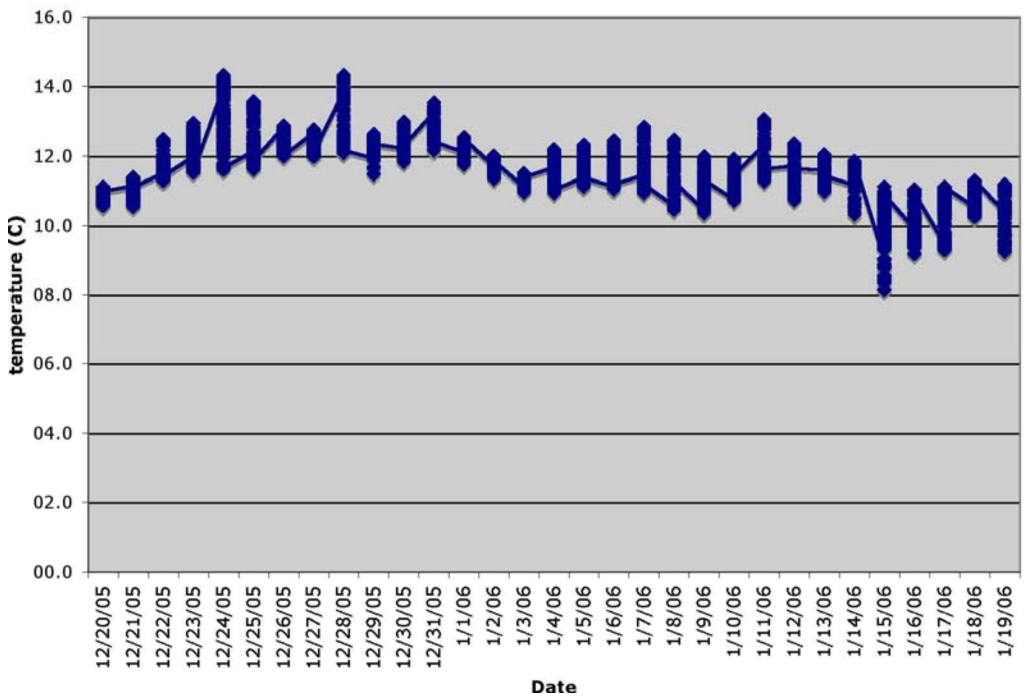


Figure 10 . Water Temperature

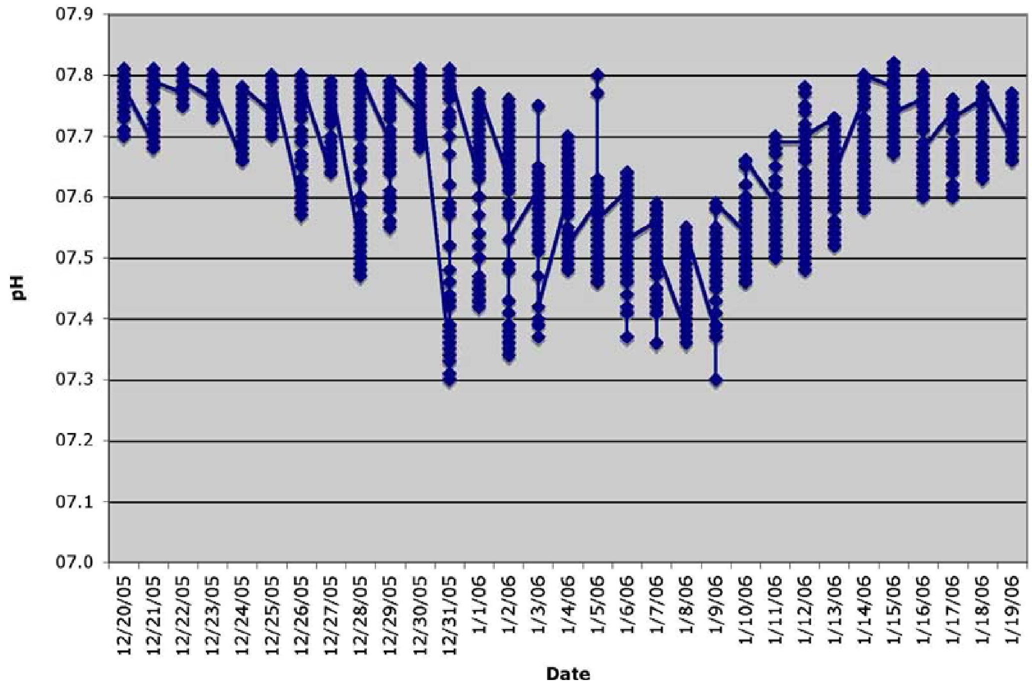


Figure 11. pH

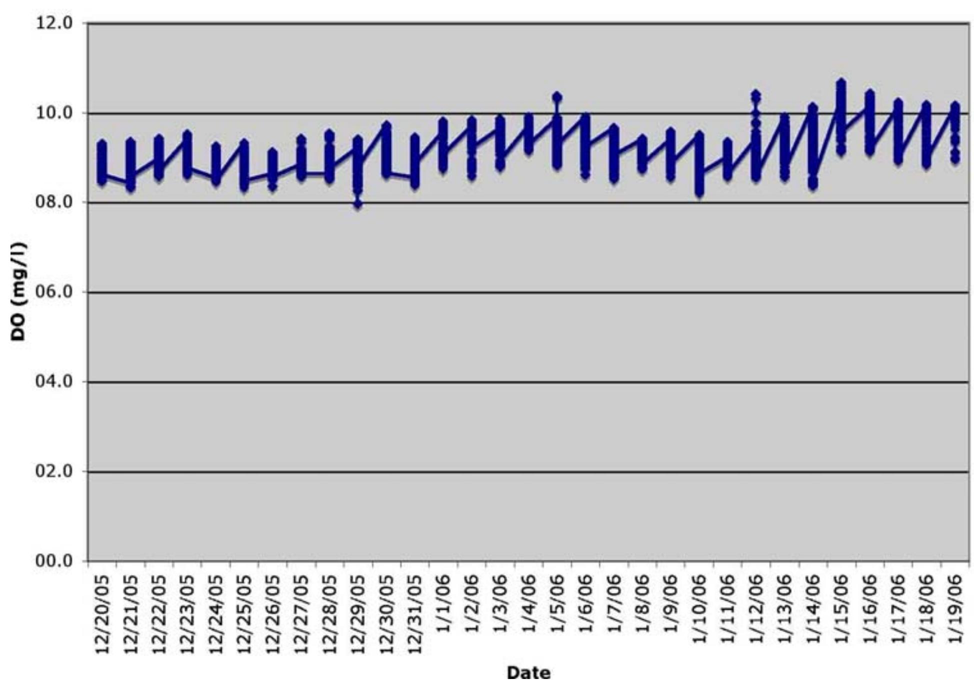


Figure 12. Dissolved Oxygen

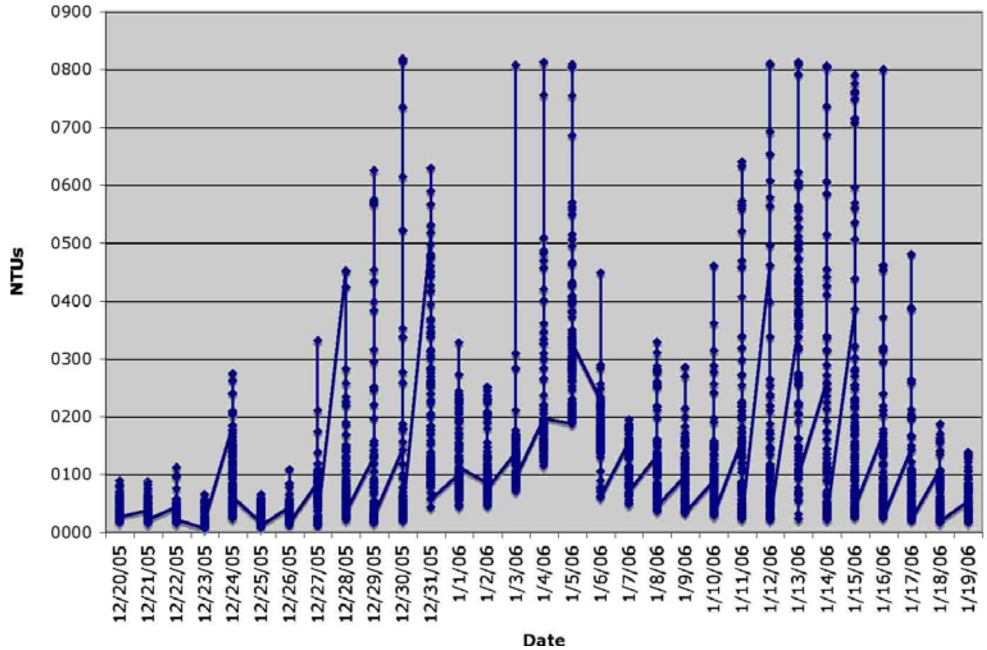


Figure 13. Turbidity

Teacher Guide—Earth Science Module
Activity 4: Extreme Weather and Estuaries

Featured NERRS Estuary:
North Carolina National Estuarine Research Reserve

http://www.nerrs.noaa.gov/

Activity Summary

Students investigate how hurricanes can affect NERRS estuaries. Students begin by studying the North Carolina National Estuarine Research Reserve (NCNERR) in the Cape Fear area with Google Earth and predict which areas of the reserve might be more vulnerable to the onslaught of high winds, heavy rain and storm surge than others. Then students monitor and interpret the changes in water quality factors day by day as a severe storm approaches, strikes the estuary, and then dissipates.

Learning Objectives

Students will be able to:

1. Describe the features and landforms associated with a coastal estuary.
2. Predict how major storm events affect NERRS reserves in the United States.
3. Investigate and interpret changes in water quality in an estuary due to a severe weather event.
4. Determine the relationship between the characteristics of an extreme weather event (heavy wind, torrential rains and storm surge) and the subsequent change in water quality over time.

Grade Levels

9-12

Teaching Time

3 (55 minute) class sessions + homework

Organization of the Activity

This activity consists of 3 parts which help deepen understanding of estuarine systems:

Investigating an Estuary

Which NERRS are Affected by Hurricanes?

Impact of Extreme Weather on an Estuary

Background

The activity focuses on a portion of the North Carolina NERR centered on Zeke's Island, which is a little north of Cape Fear. Zeke's Island is located in Brunswick and New Hanover counties, approximately four miles south of Kure Beach. This component of the North Carolina NERR is bounded by

Federal Point to the north, Smith Island to the south, the Atlantic Ocean to the east, and the Cape Fear River to the west. The lagoon-like complex at the Zeke's Island site is one of the most unusual areas of the North Carolina coast. There are three main islands within the component of the reserve—Zeke's Island covering 42 acres of high ground, North Island encompassing 138 upland acres, No Name Island covering about three acres, and the beach barrier spit of 64 acres. The islands are fringed with extensive marshes and tidal flats.

Habitat and communities in the reserve include tidal flats, intertidal salt marshes, supratidal salt marshes, shrub thicket, maritime forest, dune areas, sandy beach, and rock jetty.

Zeke's Island is part of the lower Cape Fear region, an area whose outstanding estuarine and ocean resources have long-supported an important commercial fishing industry. The Cape Fear estuary drains the largest watershed in North Carolina, containing 27 percent of the state's population. The Cape Fear River itself (about 320 km in length) is formed in the Piedmont province by the confluence of the Haw and Deep Rivers in Chatham County. Two tributaries join it just upstream of Wilmington, the Black River and the Northeast Cape Fear River. The Black River drainage represents about 17 percent of the Cape Fear drainage system and the Northeast Cape Fear River about 18 percent. (Adapted from the North Carolina NERR site.)

Preparation

Download Google Earth and install it on your classroom computer(s) or computer lab machines. To find a tutorial for using Google Earth, please read the box below.

Google Earth

This activity *requires* the use of Google Earth. If students have computer access, the use of Google Earth (http://earth.google.com/) can help them develop spatial skills.

Find Tutorial "*Using Google Earth to Explore Estuaries*" in estuaries.gov, click under Teachers, Classroom Activities and find the tutorial.

Materials

Students

- Need to work in a computer lab or with a computer and projector
- Copy of *Student Worksheet — Extreme Weather in an Estuary*.
- Copy of *Student Reading — Extreme Weather in an Estuary.*
- Copy of *Student Data Sheet 1 — Which NERRs Are Affected by Hurricanes?*
- Copy of *Student Worksheet — Extreme Weather in an Estuary.*
- Copy of *Student Data Sheet 2 — Impact on an Estuary by an Extreme Weather Event.*
- Copy of *Using Google Earth to Explore Estuaries*

Teachers

Bookmark the following sites:

- nerrs.noaa.gov/NorthCarolina/Component_Zekes.html
- http://www.nasa.gov/vision/earth/lookingatearth/2005hurricane_recap.html
- Download Google Earth <*http://earth.google.com/*>.
- If you don't want to use Google Earth, supply topographic and road maps of the area to students instead.

Equipment:

- Computer lab or
- Computer and Projector

Procedure

Part 1 — Investigating an Estuary

1. Ask students if they have lived through a hurricane event. Ask what kind of damage the storm did their homes, community, or to their environment in general.

2. Have your students use the NERRS web site to learn basic information about the North Carolina NERR and Zeke's Island <*nerrs.noaa.gov/NorthCarolina/Component_Zekes.html*>.

3. Have them use Google Earth to explore it further, by entering 33° 56" 41.39" N, 77° 56" 40.78" W in the Search Box. You may want to project the image to lead the tour of the area. Or supply the coordinates to your students and have them take the tour individually or in small groups. If you don't want to use Google Earth, supply topographic and road maps of the area to students instead.

   If this is the first time students have used Google Earth, give a short tutorial and review how to navigate and change viewing altitude. (If necessary, refer to *Using Google Earth to Explore Estuaries*)

4. Have students explore the estuarine environment and complete Part 1 of the *Student Worksheet — Extreme Weather in an Estuary*.

5. Review and discuss the Part 1 tasks and questions.

6. Have students read *Student Reading — Extreme Weather in an Estuary*.

Part 2 — Which NERRs Are Affected by Hurricanes?

7. Supply students with copies of *Student Data Sheet 1 — Which NERRs Are Affected by Hurricanes?*, and after they study the map of the 2005 hurricanes, go over the keys and answer any questions students may have.

8. Show the animation of the tracks of the 2005 hurricanes by clicking on the map at <*http://www.nasa.gov/vision/earth/lookingatearth/2005hurricane_recap.html*>. Or allow students to go to the site themselves. Have students try to match the tracks on the Student Data Sheet 1 map with the movements of the storms shown in the animation.

9. Have students complete Part 2 of the *Student Worksheet — Extreme Weather in an Estuary*.

10. Review and discuss the Part 2 tasks and questions.

Part 3 — Impact of Extreme Weather on an Estuary

11. Ask students what effects they would expect a hurricane to have on an estuarine environment.

    - How might the effects of the storm combine with normal changes in water levels and quality such as tides?

    - What would happen to the temperature, salinity,

National Science Education Standards

Content Standard A: Science as Inquiry

A3. Use technology and mathematics to improve investigations and communications.

A4. Formulate and revise scientific explanations using logic and evidence.

A6. Communicate and defend a scientific argument.

Content Standard D: Earth and Space Science

D1. Structure of the Earth System

D2. Geochemical cycles

Content Standard E: Science and Technology

E2. Apply and adapt a variety of appropriate strategies to solve problems

Content Standard F: Science in Personal and Social Perspectives

F4. Environmental quality

F5. Natural and human-induced hazards

dissolved oxygen, and pH of the water in the estuary if the hurricane dumped 6 inches of rain into the surrounding watershed?

- What impact would a high storm surge have?

12. Have students complete Part 3 of the *Student Worksheet — Extreme Weather in an Estuary*, using the *Student Data Sheet 2 — Impact on an Estuary by an Extreme Weather Event.*

13. Review and discuss the Part 3 tasks and questions.

Check for Understanding

Discuss the following with students:

- ❑ What were the effects of a major storm event in the North Carolina NERR?
- ❑ What caused the change in each of the four abiotic parameters studied in this activity?
- ❑ Why is there a difference in the time it takes for the different parameters to return to normal?
- ❑ What effects do you think the storm might have had on different plants and animals in the estuary?

Optional Extension Inquiries

Hurricane Katrina struck the southern coast of the United States in late August 2005. Show an image of Katrina as it hit the US on Aug. 29.

- ❑ Locate the Weeks Bay NERR on a map for students or take a screen shot of Weeks Bay with Google Earth. Ask students to sketch what the salinity, pH, DO, and turbidity graphs might be look like for the Weeks Bay NERR for the period of August 29 to September 4.

- ❑ Download data from the SWMP Web site for a station in Weeks Bay during the given time period and give or project the graphs so students to compare their predictions with the actual data.

Teacher Worksheet with Answers
Activity 4: Extreme Weather in an Estuary

Part 1 — Investigating an Estuary

1a. Adjust your Eye altitude to 3 km to get a good bird's-eye view of the island. Describe the estuary and features of landforms around the island.

Answer: Students will see barrier beaches, salt marshes and swamps, sand bars, coves, inlets, and a large lagoon.

1b. "Fly" slowly down the coast and explore the region from Zeke's Island to Cape Fear. Can you identify any of the following estuary and coastal features in the region? Write the name and/or the coordinates of any features you find—salt marshes, a headland, a bay, inlets, a slough, barrier beaches, sediment plumes, a lagoon, sand bars, and tidal flats

Answer: Students should find each of these features as they travel between Zeke's Island and Cape Fear.

1c. Predict which areas in the region might be most liable to be damaged during a severe storm event. Explain your reasoning.

Answer: The outer beaches east of Zeke's Island and the entire strip of land south to Cape Fear lie unprotected in the path of any major storm. It is a high-risk area for beach erosion and flooding.

1d. Which areas in the region do think are protected somewhat from high winds and higher than normal tides? Explain your reasoning.

Answer: Zeke's Island and the coast just west of it are protected from large storm waves by barrier beaches and the intervening lagoon.

Part 2 — Which NERRs Are Affected by Hurricanes?

2a.Which NERRS site or sites would be hardest hit by a hurricane in 2005?

Answer: Student answers will vary. Grand Bay took a direct hit from at least two hurricanes including Katrina.

2b.Which NERRS sites had more than one major weather event impact them in 2005?

Answer: Grand Bay and Weeks Bay seem to have had at least four encounters with severe weather events in 2005.

Part 3 — Impact of Extreme Weather on an Estuary

3a. What do you think caused the severe drop in salinity on August 26?

Answer: The hurricane dumped many inches of fresh water into the estuary. After the storm passed, runoff from rivers and streams increased dramatically, adding to the proportion of fresh water to salt water that remained high (low salinity) for weeks after landfall.

3b. Why do you think the salinity of the water in the reserve continued to fall and then remain at such low levels for weeks after the storm event?

Answer: Runoff from streams and rivers continued to flow into the salt water of the estuary.

3c. What was the change in water temperature caused by the storm?

Answer: The water temperature in the estuary dropped about 5 °C, but rose to previous levels three days later.

3d. How was the pH of the water in the estuary affected by the storm?

Answer: The pH of the estuary water became slightly more basic due to the influx of waste products from upstream.

3e. What caused the huge increase in turbidity around Zeke's Island during the storm?

Answer: Immense quantities of natural particulates (clay, mud, sand, etc.) enter the estuary from runoff of streams and rivers.

3f. How long did it take for each of the water qualities to return to normal? Why do you think it took longer for some factors to return to normal than others?

Answer: The temperature, pH, and turbidity of the estuary water were restored to normal in just 2 to 4 days. The salinity, however, remained low for a month as runoff from streams and rivers continued to inundate the estuary with fresh water. Dissolved oxygen remained low for several weeks since so much raw sewage and pig farm residue were washed into it.

Student Reading
Activity 4: Extreme Weather in an Estuary

Usually, when extreme weather occurs, the damage caused by it is categorized in dollars and lives lost. However, the tremendous damage on animal and plant species is rarely addressed. Estuaries are places of transition, a zone of constant change in which physical and chemical properties of water constantly shift and move in response to tides, daily cycles, and seasonal variations. Storm events have the power to alter conditions in an estuary in a dramatic and sometimes catastrophic way that threatens the survival of thousands of organisms that live there.

Estuaries are in one sense resilient. After a major storm, water in estuaries can act as a buffer, absorbing large quantities of excess precipitation and floodwater brought in by streams and rivers. However, toxins such as fertilizers, animal and human wastes, and other chemical products washed into the estuary during and after a storm can make water quality such that numerous animal and plant species face destruction.

After a major storm event, water quality slowly returns to normal. As sediment settles to the bottom, plant growth is renewed, dissolved oxygen rises, and the pH of the water returns to normal levels. The time required to return to normalcy is dependent on the amount of toxic materials carried into the estuary by the floodwaters produced by the storm.

The focus of this activity is the North Carolina National Estuarine Research Reserve (NCNERR). North Carolina's estuarine system is the third largest in the country, encompassing more the two million acres. This system is of prime economic importance to the coastal area—90 percent of the commercial seafood species caught in the state spend at least part of their lives in an estuary. The North Carolina NERR was established to preserve these fragile natural areas and the variety of life they support.

In this activity, you will investigate the features of the North Carolina NERR, and then study the effect of severe weather on NERRS sites. Then, you will investigate what happened to this estuarine area as a hurricane approached, struck the coast with 100 mph winds, and then moved into the Atlantic Ocean.

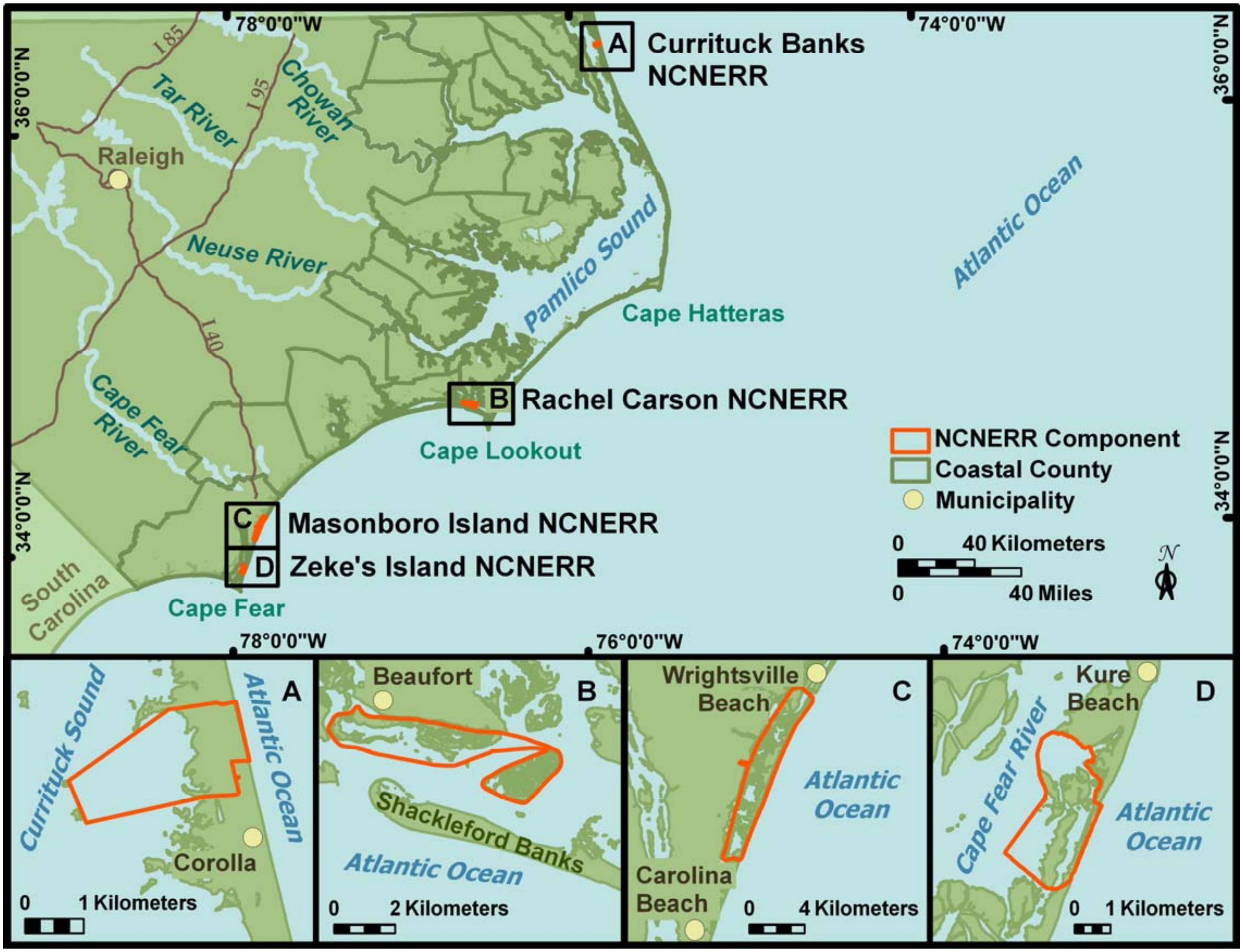


Figure 1. The four major portions of the North Carolina NERR

Student Worksheet
Activity 4: Extreme Weather in an Estuary

Student Name:____

Part 1 — Investigating an Estuary

The North Carolina NERR consists of four different regions; in this activity, we will focus on just one of them—Zeke's Island.

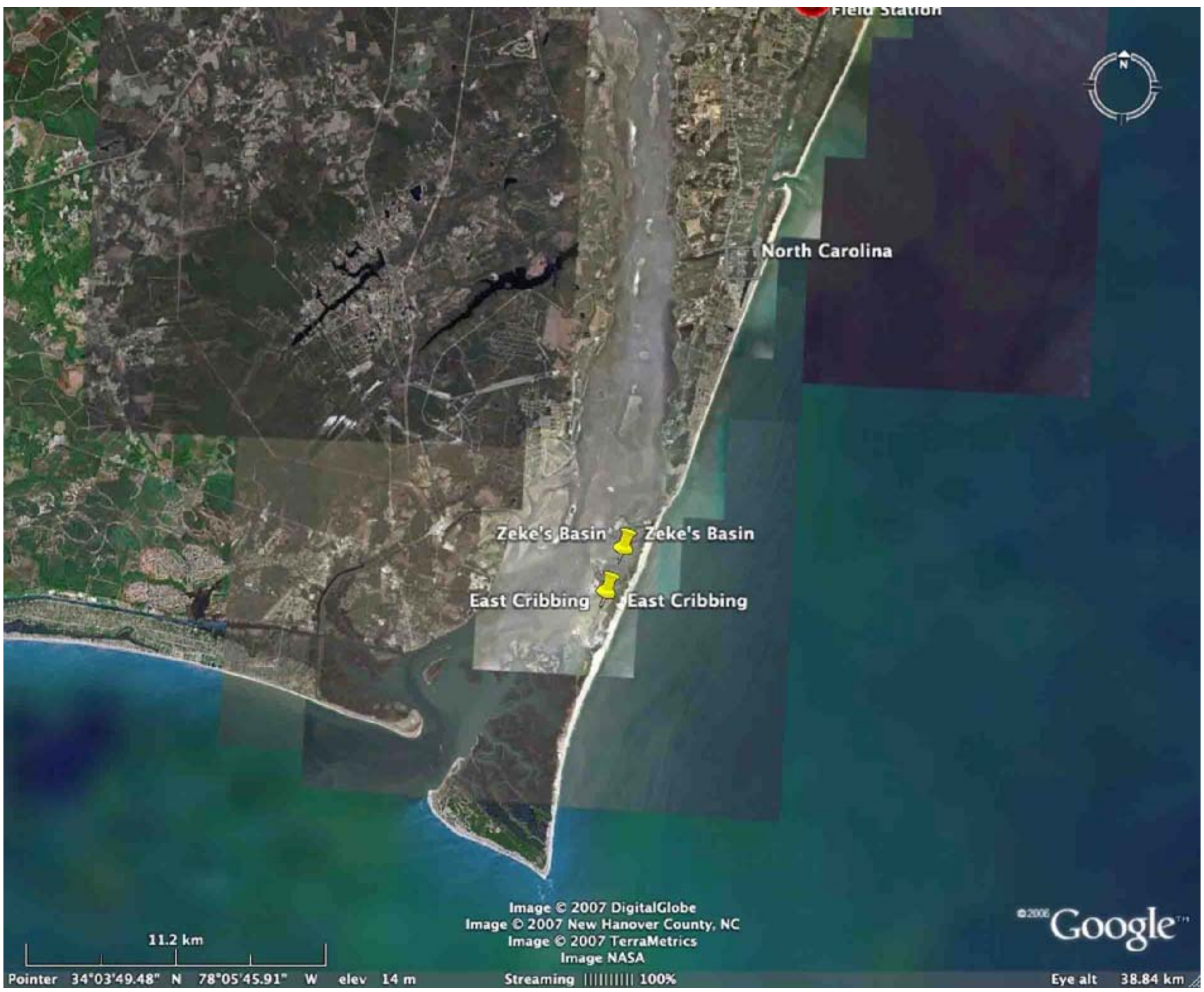


Figure 2. Region between the North Carolina NERR
and Cape Fear (bottom of page) showing several monitoring stations.

Use Google Earth to investigate the North Carolina NERR. Open the Google Earth program and insert the coordinates for Zeke's Island into the "Fly To" box (33° 56' 43.19", 77° 56' 45.82").

1a.Adjust your Eye altitude to 3 km to get a good bird's-eye view of the island. Describe the estuary and features of landforms around the island.

1b."Fly" slowly down the coast and explore the region from Zeke's Island to Cape Fear. Can you identify any of the following estuary and coastal features in the region? Write the name and/or the coordinates of any features you find.

salt marshes ____

a headland ____

a bay ____

inlets ____

a slough ____

barrier beaches ____

sediment plumes ____

a lagoon ____

sand bars ____

tidal flats ____

1c. Predict which areas in the region might be most liable to be damaged during a severe storm event. Explain your reasoning.

1d. Which areas in the region do think are protected somewhat from high winds and higher than normal tides? Explain your reasoning.

Part 2 — Which NERRs Are Affected by Hurricanes?

You will find a chart of all hurricanes and major tropical storm events that occurred during 2005 in the Atlantic Ocean on *Student Data Sheet 1 — Which NERRs Are Affected by Hurricanes?*. To get an idea of how these major storms traveled through the Atlantic, your teacher will show you an animation. Or, open up http://www.nasa.gov/vision/earth/lookingatearth/2005hurricane_recap.html and click on the small map on the right side of the home page.

Which NERRS sites were affected by these storms and to what degree? To answer this question, refer to the charts and images on your data sheet and fill out the Impact on Estuaries table. Predict the severity of the impact of each storm on each estuary by considering the extent of the average major storm. Winds are highest near the center of hurricanes while bands of rain may extend a hundred miles from the center of a large storm.

2a. Which NERRS site or sites were hardest hit by a hurricane(s) in 2005?

2b. Which NERRS sites had more than one major weather event impact them in 2005?

Part 3 — Impact of Extreme Weather on an Estuary

Severe weather has profound effects on coastal areas, tearing down trees, and washing beaches and houses away. Estuaries are particularly sensitive to severe weather since the organisms that live in them are already in a delicately balanced environment of a salt and fresh water transition zone.

You will investigate the effect of a large storm on the North Carolina Estuarine Research Reserve. Hurricane Bonnie formed off the coast of western Africa on August 14th, 1998.

Although slow to develop, Bonnie grew in intensity and became a tropical storm with winds of about 40 mph a week later. While moving more quickly, Bonnie achieved hurricane status with winds over 60 mph as the storm passes north of Puerto Rico on August 22nd.

On August 26th, Hurricane Bonnie weakens a little before she strikes the coast just east of Cape Fear near midnight with winds around 110 mph.

Bonnie was the first major hurricane (Category 3) of the 1998 season. The winds and flooding rains damaged buildings and cut off power to nearly a half-million people. The storm was nearly 400 miles wide as it crossed the coast.

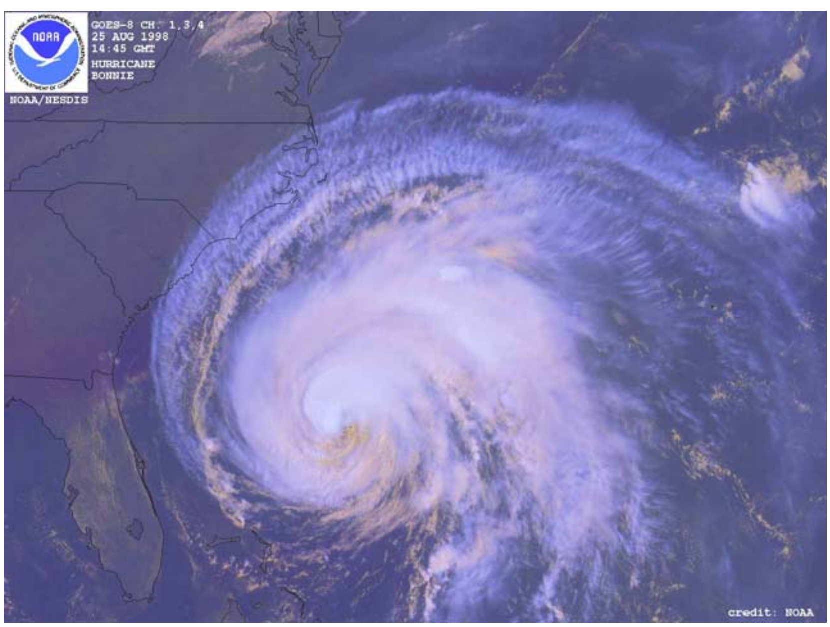


Figure 3.
Hurricane Bonnie making landfall on the eastern coast of the United States.

To understand the effects of a major storm on an estuary, refer to *Student Data Sheet 2 — Impact on an Estuary by an Extreme Weather Event: A Case Study*. Study the graphs of precipitation and water quality for the Zeke's Island reporting station for August 1 to September 17, 1998. As you review the data, remember that Hurricane Bonnie made landfall on August 26.

3a. What do you think caused the severe drop in salinity on August 26?

3b. Why do you think the salinity of the water in the reserve continued to fall and then remain as such low levels for weeks after the storm event?

3c. What was the change in water temperature caused by the storm?

3d. How was the pH of the water in the estuary affected by the storm?

3e. What caused the huge increase in turbidity around Zeke's Island during the storm?

3f. How long did it take for each of the water qualities to return to normal? Why do you think it took longer for some factors to return to normal than others?

Student Data Sheet—1
Activity 4: Which National Estuarine Research Reserves Are Affected by Hurricanes?

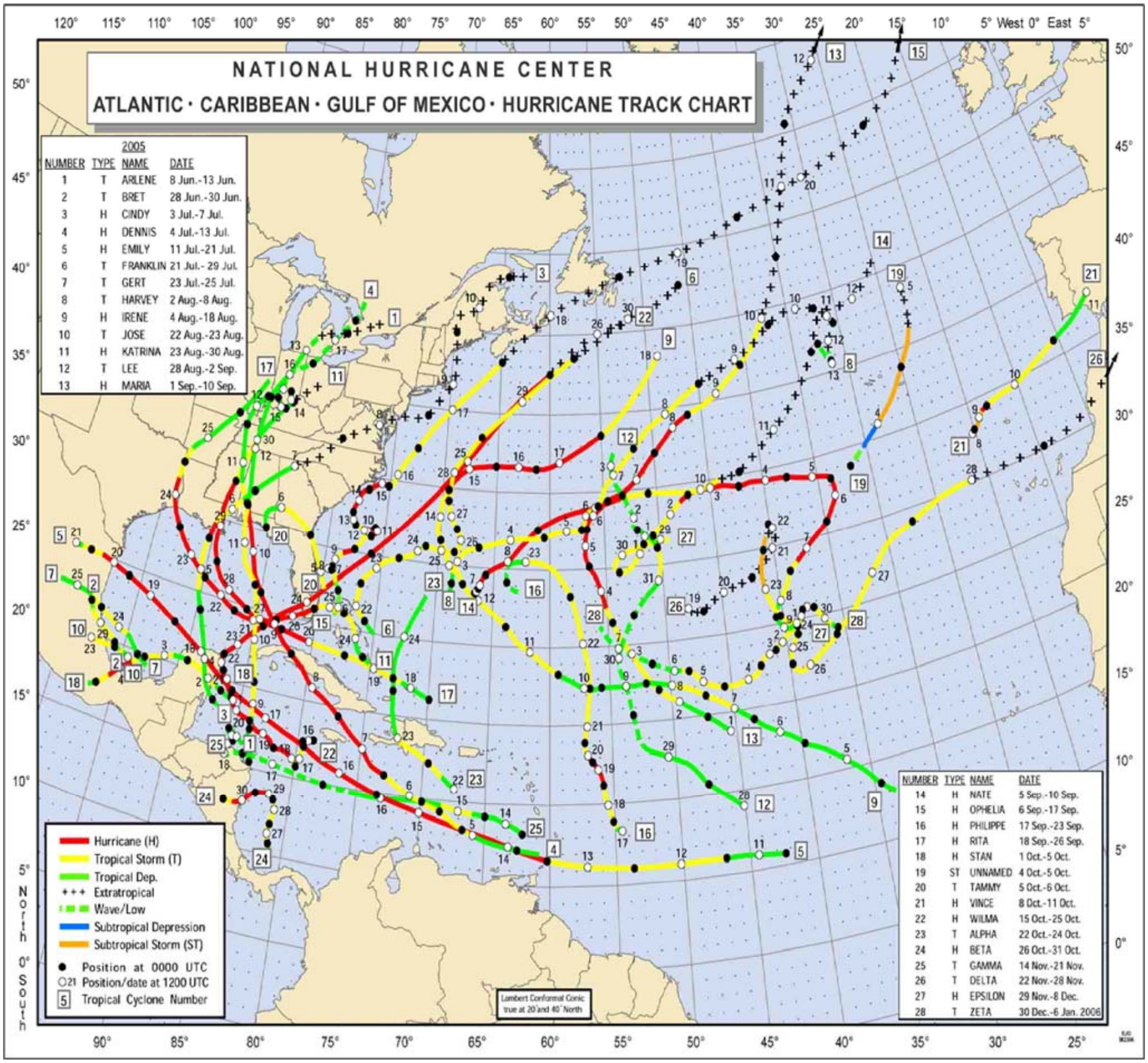


Figure 4. The hurricanes are numbered and named in the order of their appearance during the 2005 hurricane season. The change in color and pattern indicate the change in the intensity of the storm.

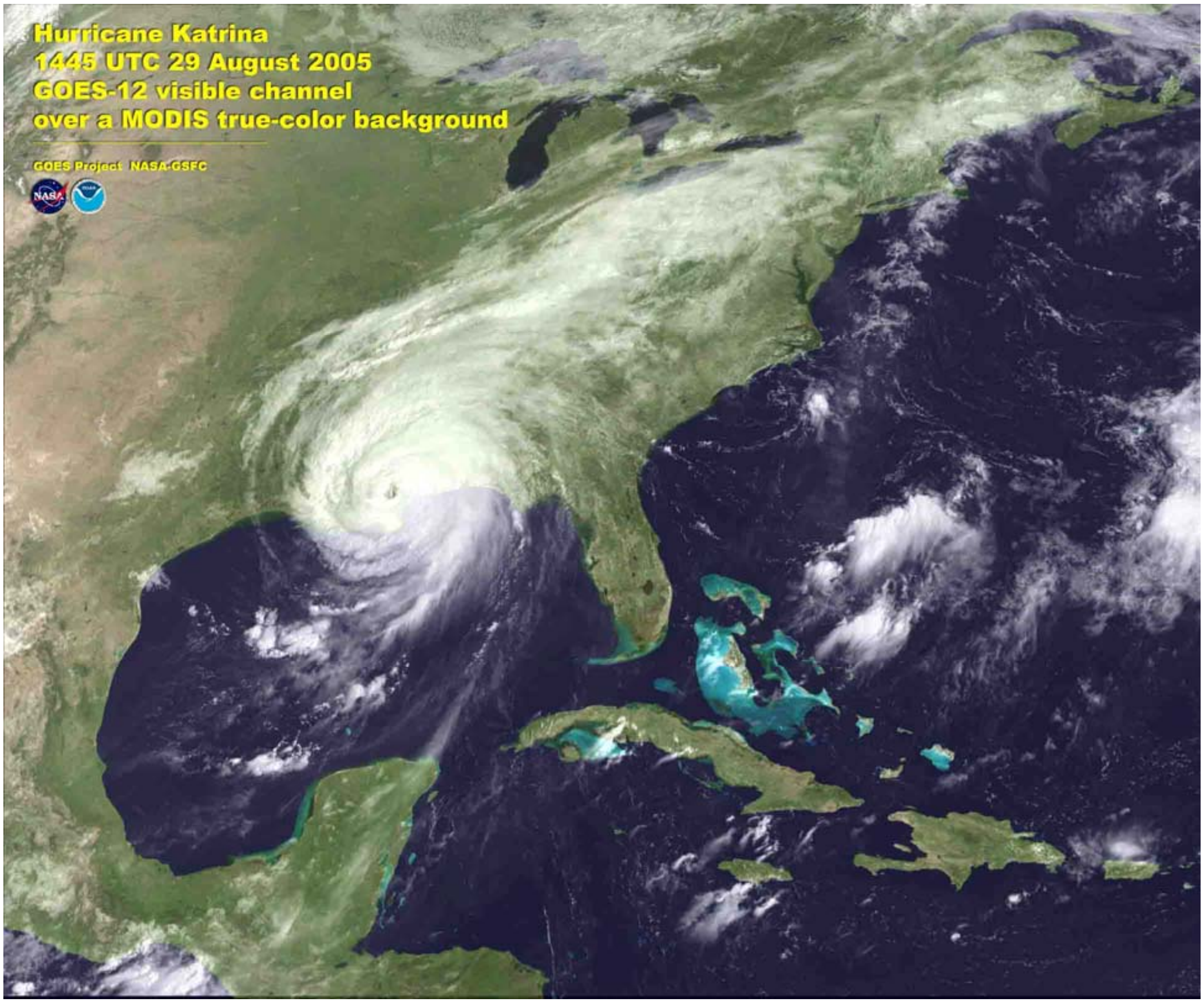
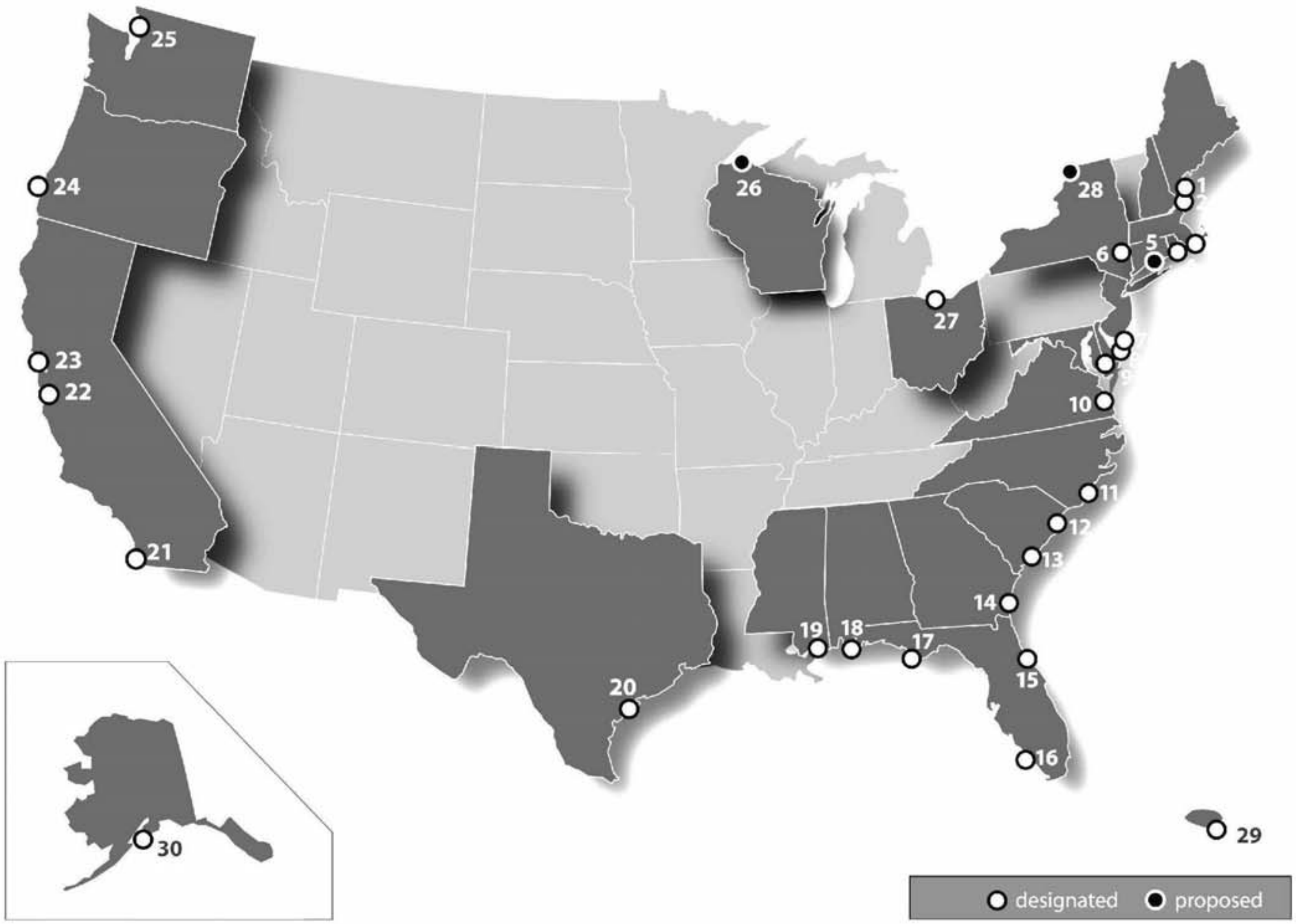


Figure 5. Keep in mind that hurricanes are truly huge objects, sometimes hundreds of miles across.

The National Estuarine Research Reserve System (NERRS)



1. Wells, Maine
2. Great Bay, New Hampshire
3. Waquoit Bay, Massachusetts
4. Narragansett Bay, Rhode Island
5. Connecticut*
6. Hudson River, New York
7. Jacques Cousteau, New Jersey
8. Delaware
9. Chesapeake Bay, Maryland
10. Chesapeake Bay, Virginia
11. North Carolina
12. North Inlet-Winyah Bay, South Carolina
13. ACE Basin, South Carolina
14. Sapelo Island, Georgia
15. Guana Tolomato Matanzas, Florida
16. Rookery Bay, Florida
17. Apalachicola, Florida
18. Weeks Bay, Alabama
19. Grand Bay, Mississippi
20. Mission-Aransas, Texas
21. Tijuana River, California
22. Elkhorn Slough, California
23. San Francisco Bay, California
24. South Slough, Oregon
25. Padilla Bay, Washington
26. Wisconsin*
27. Old Woman Creek, Ohio
28. St. Lawrence River, New York*
29. Jobos Bay, Puerto Rico
30. Kachemak Bay, Alaska

* Proposed Reserve

Figure 6 — Twenty-seven sites compose the National Estuarine Research Reserve System

Table of Estuaries Affected by Severe Storm Events in 2005

Site Name	Storm(s)	Predicted Impact (severe, moderate, mild)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
9)		
10)		

Student Data Sheet—2
Activity 4: Impact on an Estuary by an Extreme Weather Event: A Case Study

Water Quality — Zeke's Island Aug 1- Sept 17, 1998

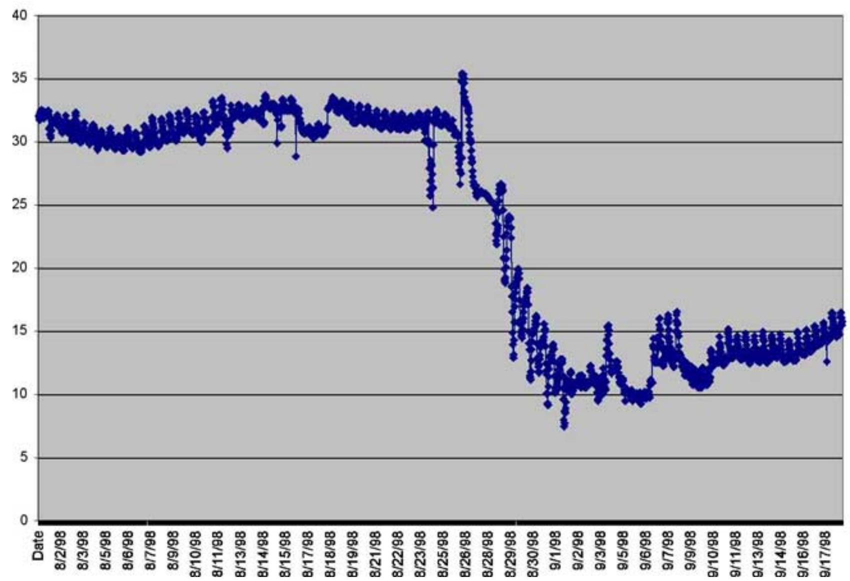


Figure 7 — Salinity in parts per thousand (ppt)

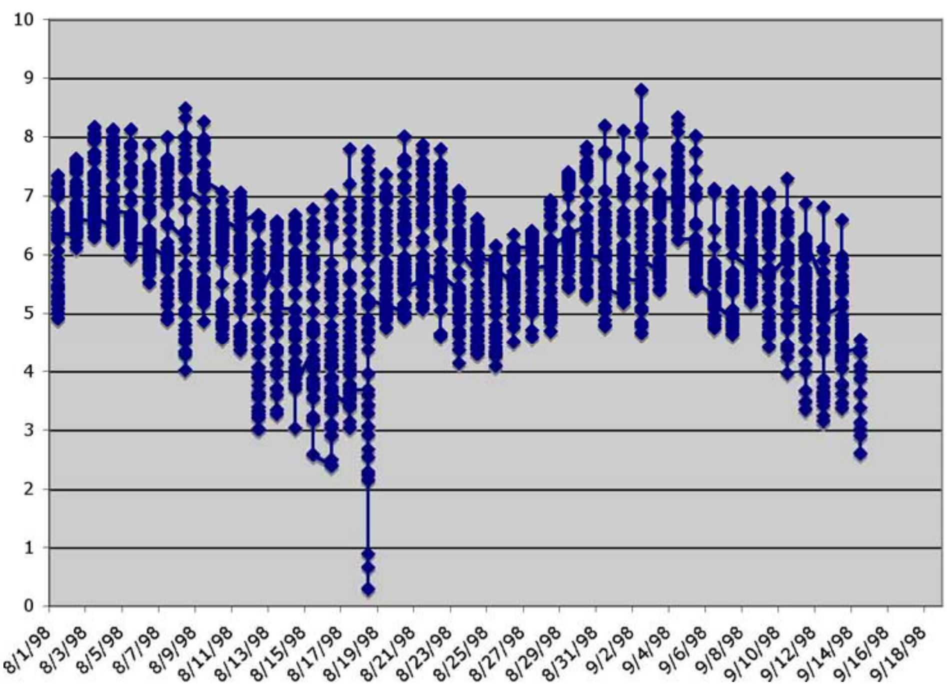


Figure 8 — Dissolved Oxygen in mg/l

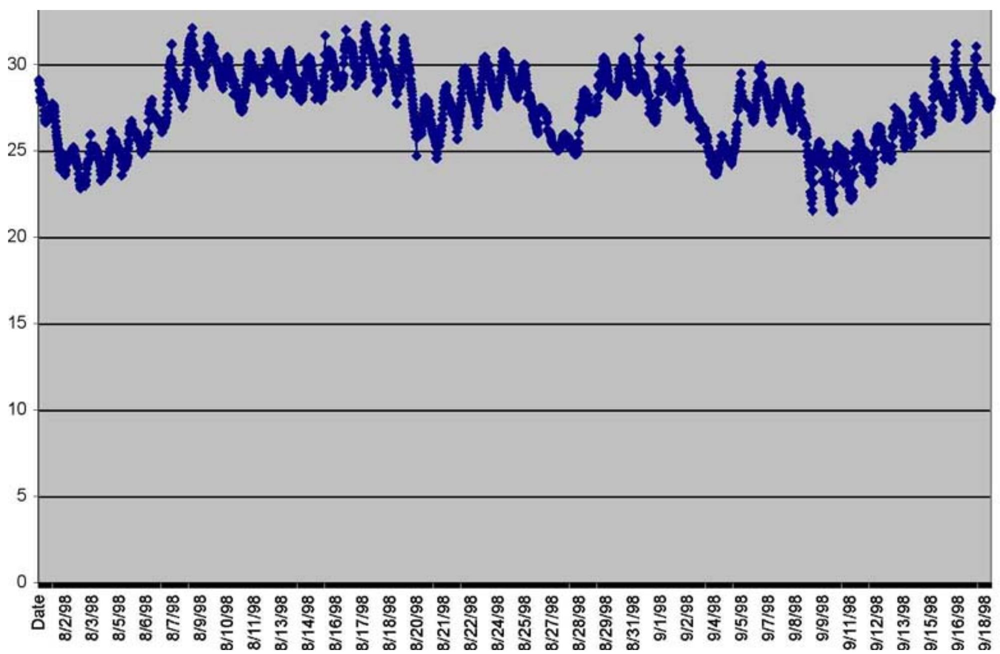


Figure 9 — Water Temperature in °C

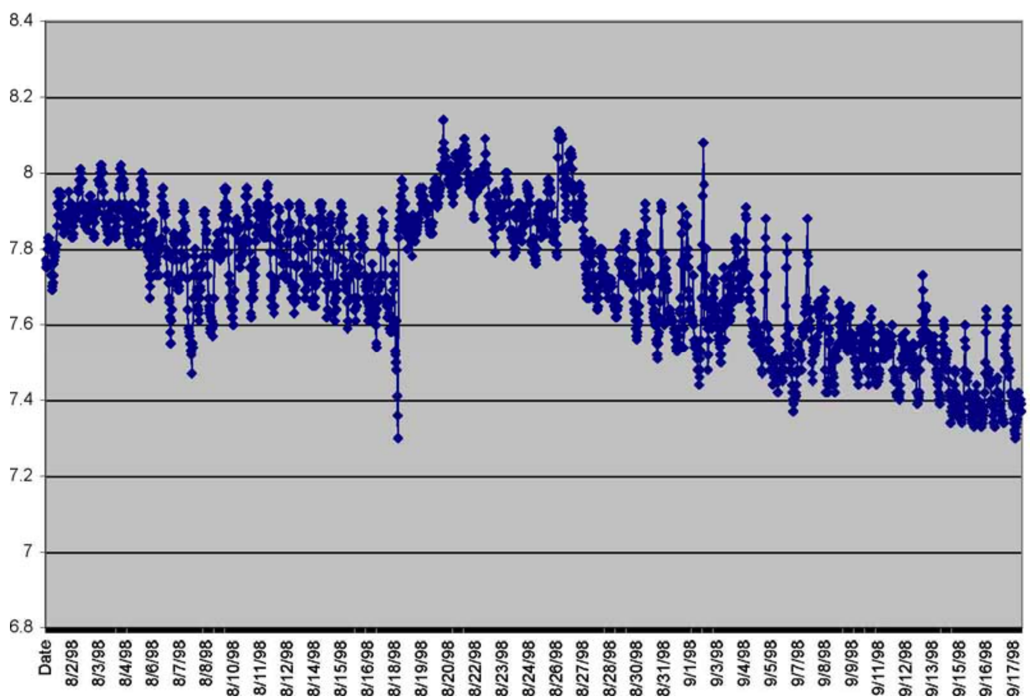


Figure 10 — Water pH

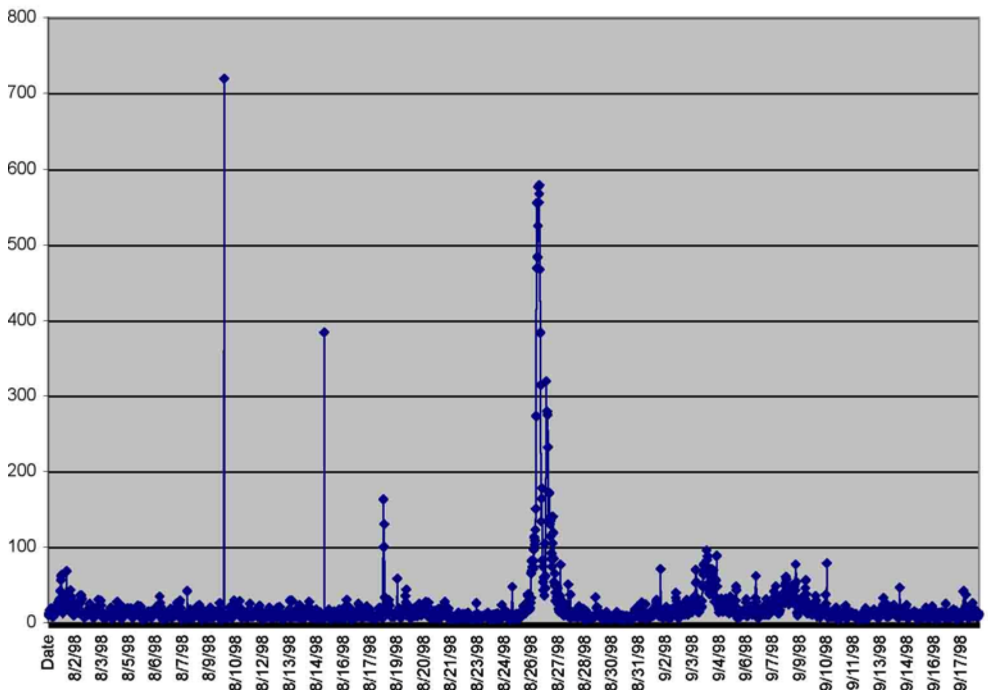


Figure 11 — Water Turbidity in NTU units

Teacher Guide—Earth Science Module
Final Assessment

1. Have students download 2005 CDMO abiotic and biotic data from several stations within Grand Bay NERR and examine the changes wrought by the severe storm events they identified in their data table in Part 2. Or, download the data yourself, print and copy it for students. <*http://cdmo.baruch.sc.edu/QueryPages/viewstations.cfm?Site_ID=gnd*>

2. Have students use Google Earth to explore the terrain around Grand Bay NERR. In general, what landforms and estuary features can you identify around Grand Bay NERR?

   Answer: Bayous, bays, headlands, coastal beaches, and extensive wetlands lie east and north of Grand Bay NERR.

3. Are there specific areas (natural, suburban, or urban) areas that seem particularly vulnerable in the midst of a severe storm event?

   Answer: The Chevron refinery and the entire city of Pascagoula seem to be in the direct path of the storm. The bayou areas north of Bangs Lake seem to be vulnerable to storm surges and flooding.

Figure 1. A Google Earth view of the
Grand Bay NERR region and monitoring stations.

3. Download 2005 data from the Point Aux Chenes Bay and the Bayou Herron monitoring stations in Grand Bay NERR.

a. Describe the general pattern of values at both stations for the week that Katrina struck the estuary.
b. What is the range of values for each parameter at each station? If data is missing, offer an explanation to why no data exists for that time period.
c. How long did it take for the parameter values to return to normal at each station? Explain any differences you find between the two stations.
d. What impacts might the storm have had on organisms, habitats, or human life in the estuary?
e. Do an Internet search to find the actual damage suffered by the Grand Bay area, particularly the Pascagoula area.
f. Can you suggest strategies that could be employed by towns and cities in the area to decrease the damage to both the suburban and estuarine environment?