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.

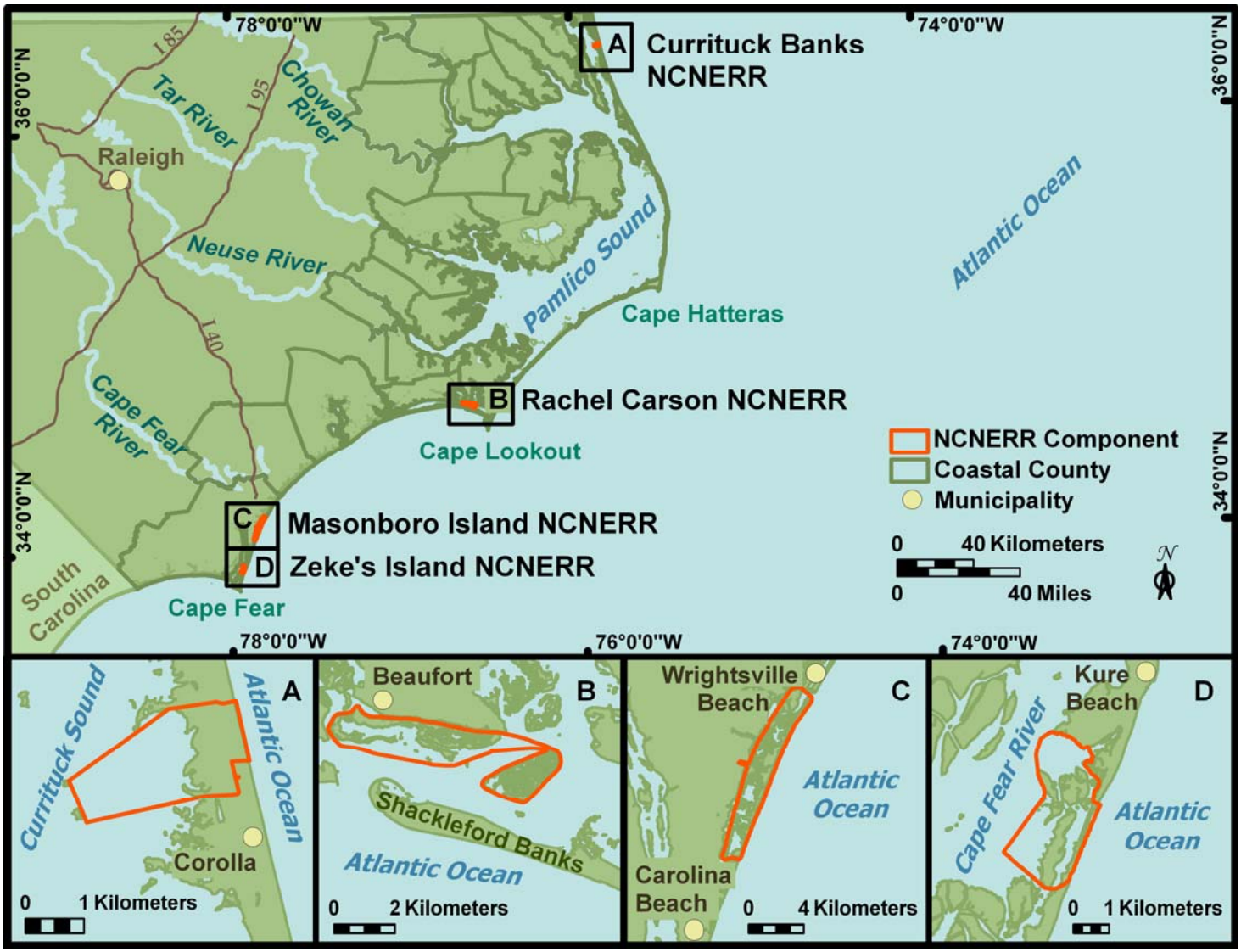

Figure 1. The four major portions of the North Carolina NERR

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.

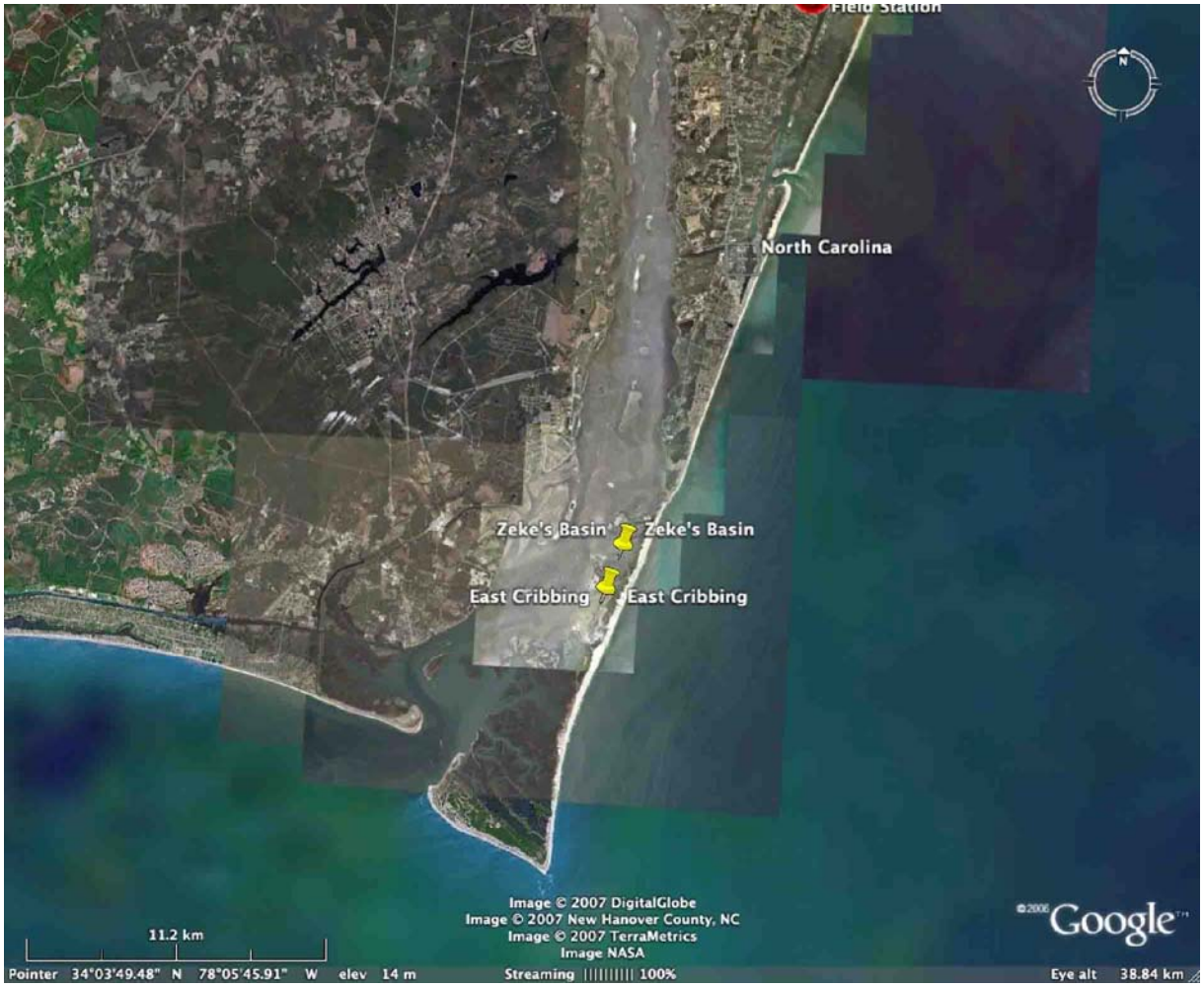

Figure 2. Region between the North Carolina NERR and Cape Fear (bottom of page) showing several monitoring stations.

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.

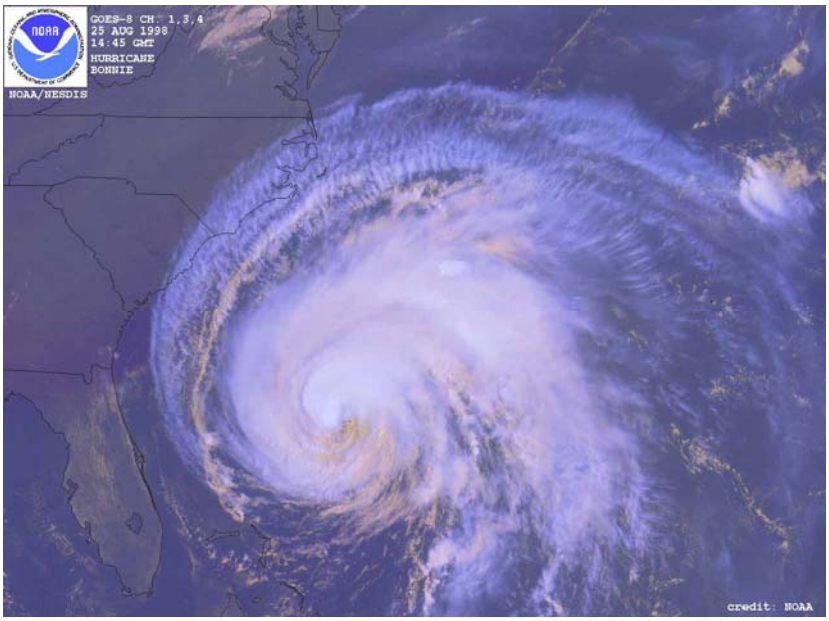

Figure 3.
Hurricane Bonnie making landfall on the eastern coast of the United States.

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?

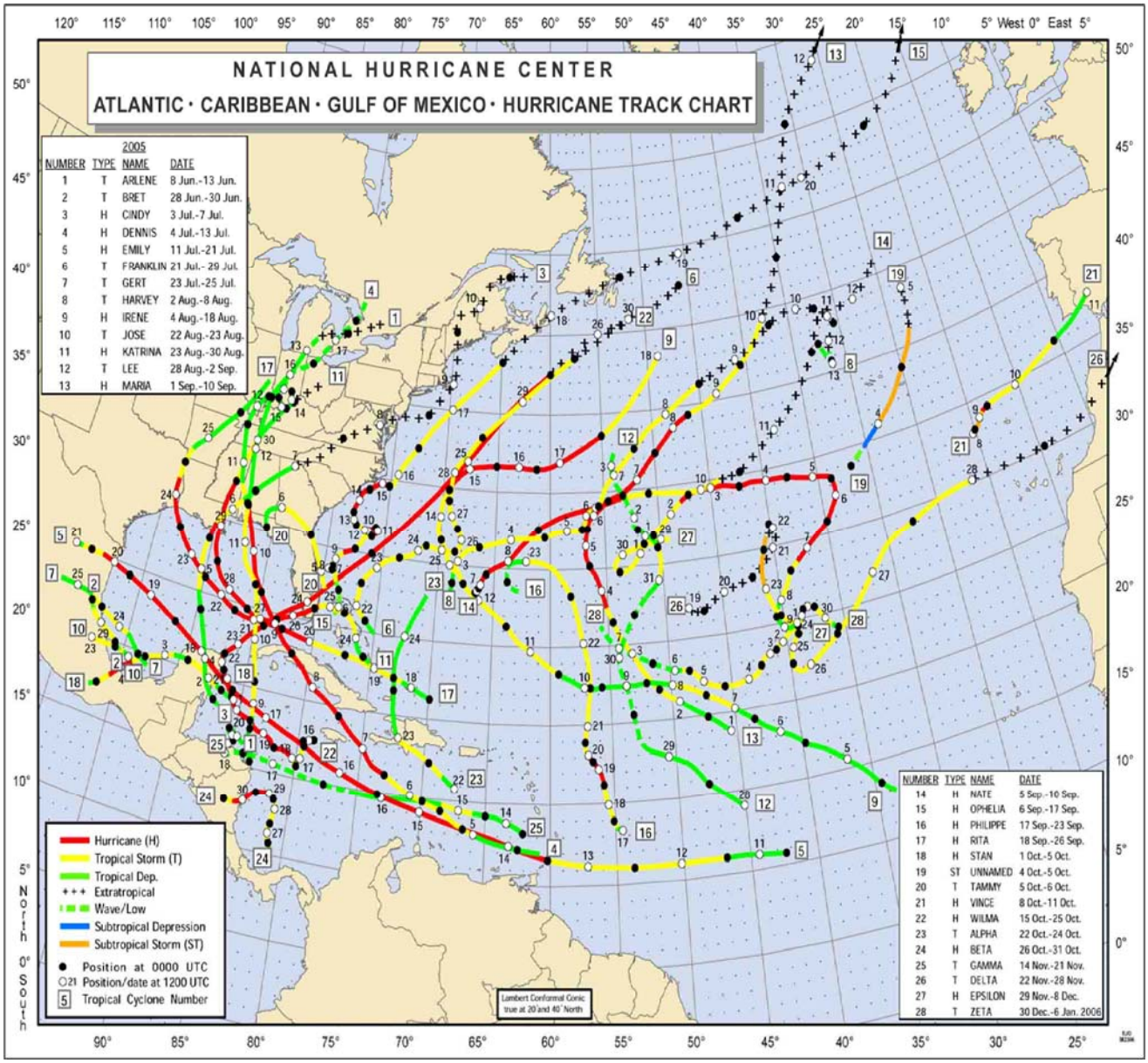

Figure 4. The hurricanes are numbered and named in the order of their appearance during the 2005 hurricane season. The change in color and pattern indicate the change in the intensity of the storm.

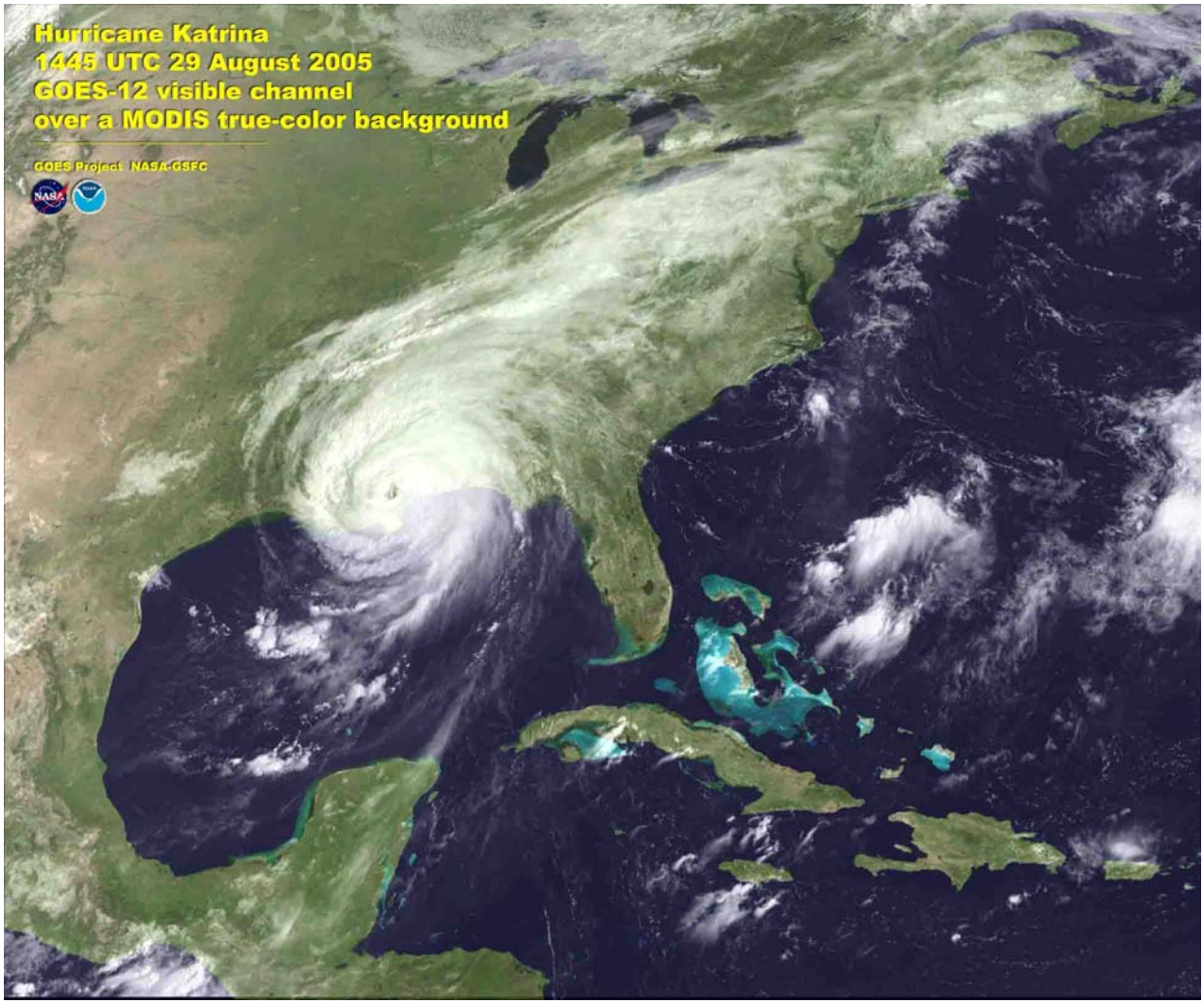

Figure 5. Keep in mind that hurricanes are truly huge objects, sometimes hundreds of miles across.

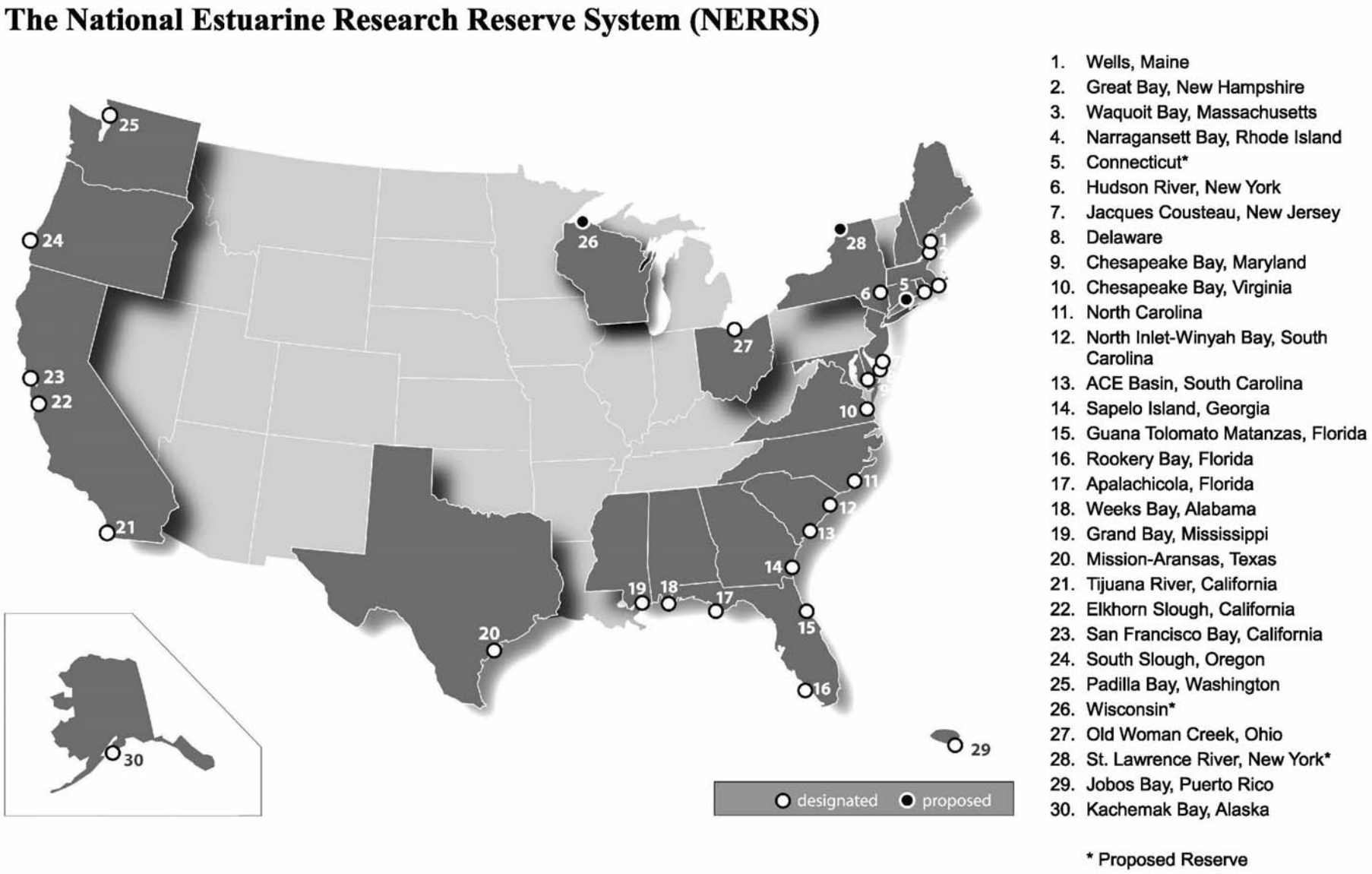

Figure 6 — Twenty-seven sites compose the National Estuarine Research Reserve System

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

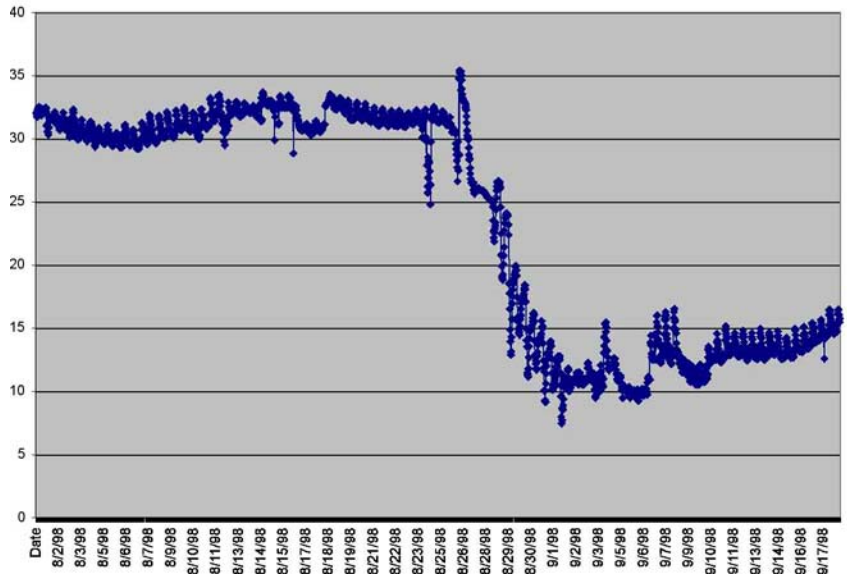

Figure 7 — Salinity in parts per thousand (ppt)

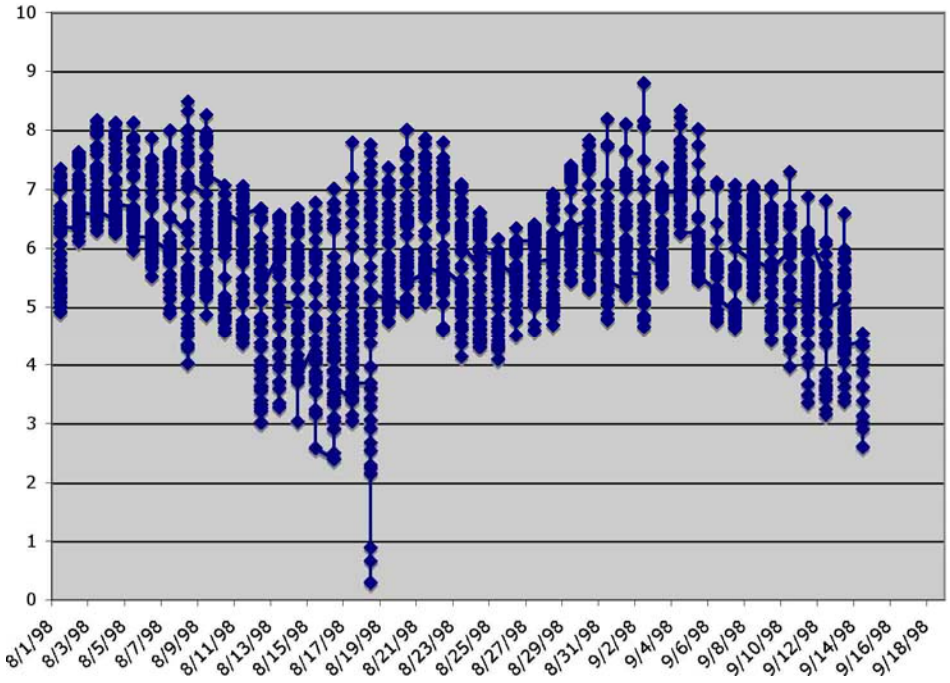

Figure 8 — Dissolved Oxygen in mg/l

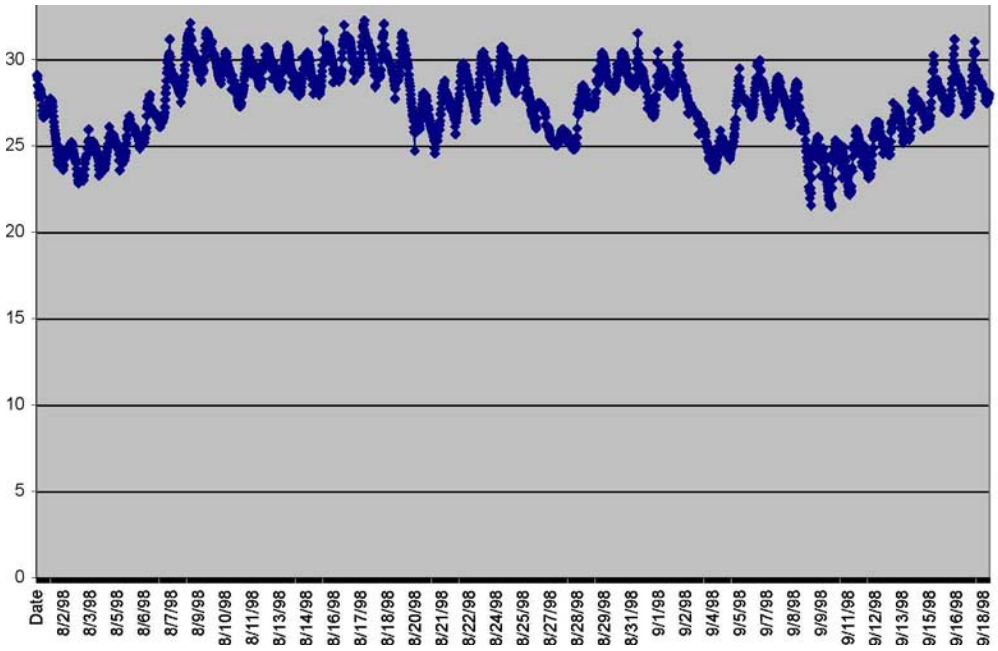

Figure 9 — Water Temperature in °C

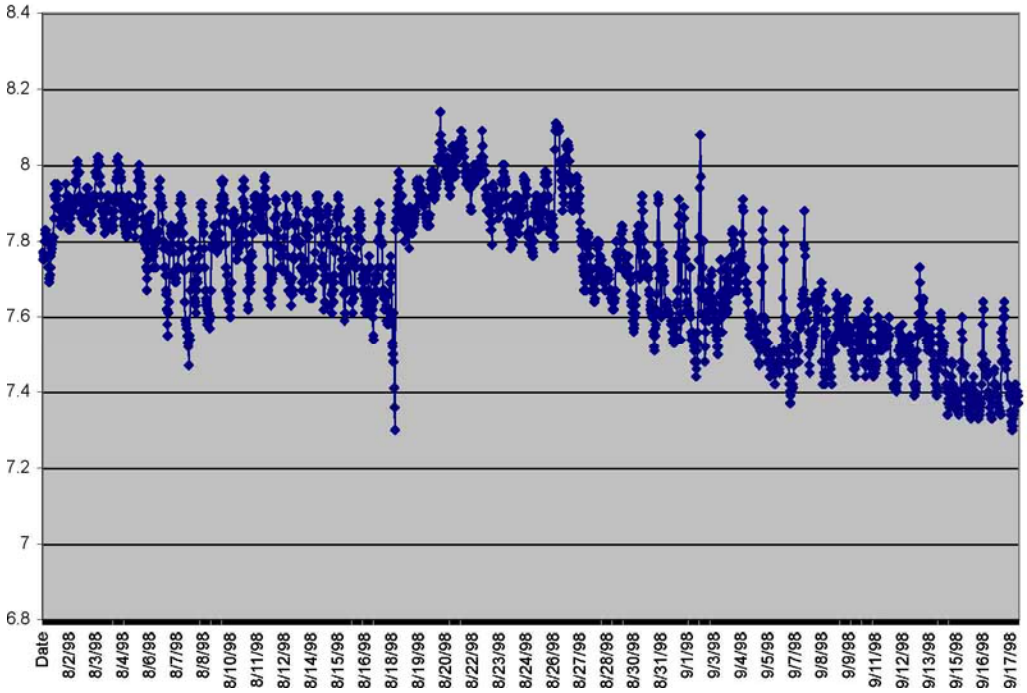

Figure 10 — Water pH

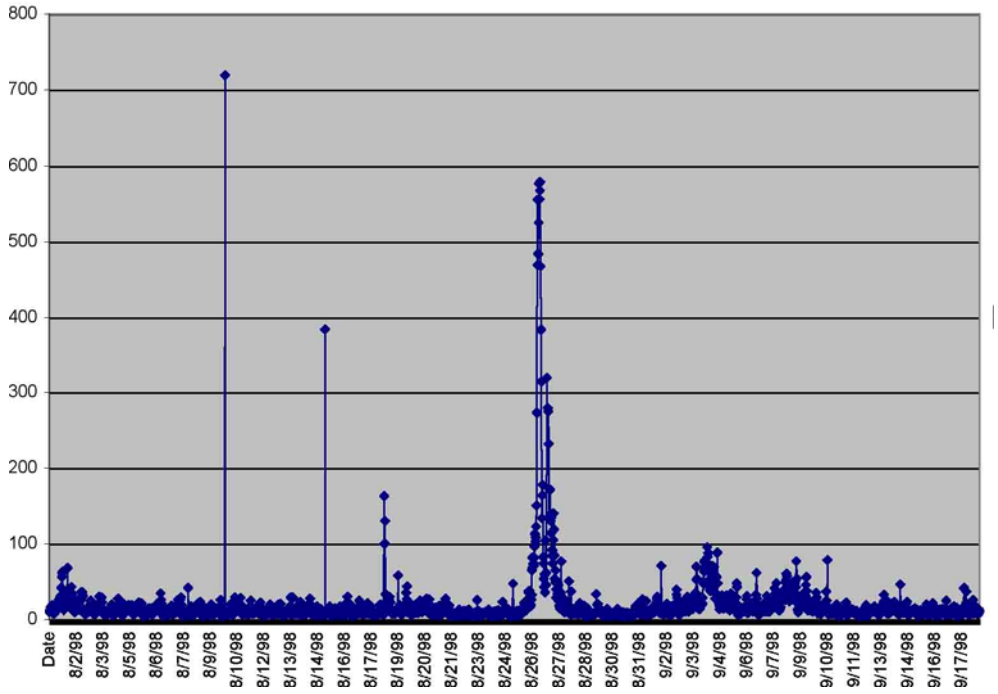

Figure 11 — Water Turbidity in NTU units