Student Reading—1
Activity 1: A Tale of Three Estuaries

An estuary is a partially enclosed body of water where two different bodies of water meet and mix e.g. fresh water from rivers or streams meets and mixes with salt water from the ocean or fresh water from rivers or streams meets and mixes with chemically distinct water of a large lake. In estuaries, water levels are affected by lunar or storm-driven tides.

Each estuarine environment is unique and is characterized by a set of biotic and abiotic factors determined by the nature of the physical setting. You will be comparing the water quality factors from estuaries separated by 3,000 miles. One, the South Slough NERR, is in Oregon on the west coast. Second is the Delaware NERR is located on the east coast. The third is the Old Woman Creek NERR, a freshwater estuary located on Lake Erie in Ohio. (A freshwater estuary such as Old Woman Creek occurs when water from an inland source [stream or river] mixes with a much larger body of water such as one of the Great Lakes.) As you investigate the water chemistry of these estuaries, note the difference in their proximity to the ocean, their physical make-up, and other characteristics that make them dynamic transition zones for life.

South Slough National Estuarine Research Reserve

The South Slough NERR contains upland forests, freshwater wetlands and ponds, salt marshes, mud flats, eelgrass meadows and open water habitats. The reserve is located five miles south of Charleston, OR, on the South Slough of the Coos Bay estuary.

The Coos estuary is an example of a drowned river mouth estuary. The formation of such estuaries along

Figure 1. Mudflats in the South Slough NERR

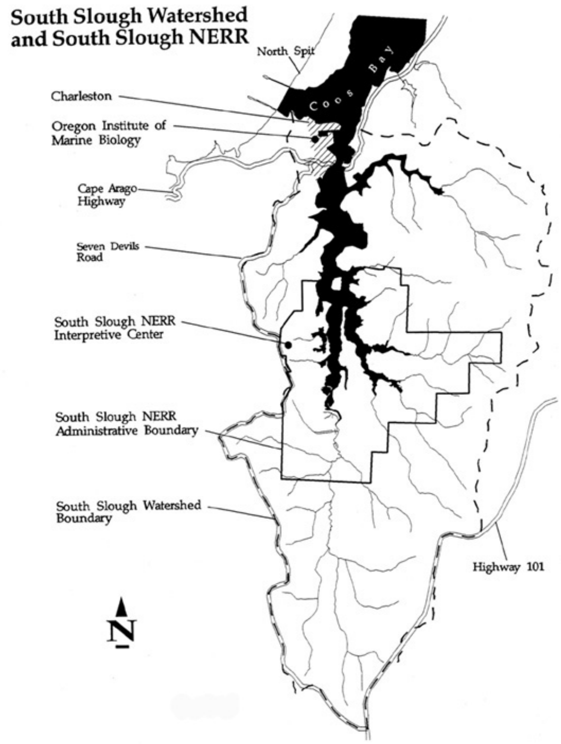

Figure 2. South Slough Watershed and South Slough NERR

the Oregon coast began 20,000 years ago as glaciers melted and sea level began to rise, flooding river valleys.

South Slough is important habitat for many animals, including several that are rare, threatened, or endangered, like the Coho salmon and the western snowy plover. The bald eagle and peregrine falcon, both of which were endangered but are making a comeback, also use the estuary. These species survive at South Slough because of the diverse habitats and plentiful food resources that the estuary provides.

Delaware National Estuarine Research Reserve

The Delaware NERR consists of two unique components, one on Blackbird Creek and the other on the St. Jones River. The St. Jones Reserve component is located six miles southeast of Dover. The Blackbird Creek component is located in southern New Castle County.

The Blackbird Creek component consists of non-tidal wetlands, tidal freshwater marshes, and tidal brackishwater marshes. Saltmarsh cordgrass and common reed are among the most common wetland plants. The uplands surrounding the marshes are a mixture of shrub and tree species, including both hardwoods and softwoods.

The Blackbird Creek watershed drains a portion of southern New Castle County, Delaware. This is a predominantly rural area, consisting of wetlands, forests and agricultural lands. Blackbird Creek flows into the Delaware River just upstream from Delaware Bay.

The St. Jones River component features tidal brackishwater and saltwater marshes dominated by saltmarsh cordgrass and salt hay. The marshes are bordered by open water habitats of the river and bay and upland habitats like meadows, woodlands, and farmlands.

The St. Jones River watershed drains a portion of the coastal plain in central Kent County, Delaware, including the city of Dover, the surrounding suburbs, industrial areas, agricultural areas and Dover Air Force Base. A dam impounds the upper St. Jones 10.5 miles upstream from the bay to form Silver Lake, a municipal recreation area. Some other headwater streams are also impounded. Much of the eastern portion (bayward) of the watershed consists of wetlands and forests, including lands and waters managed for waterfowl, wild turkey, deer and other wildlife.

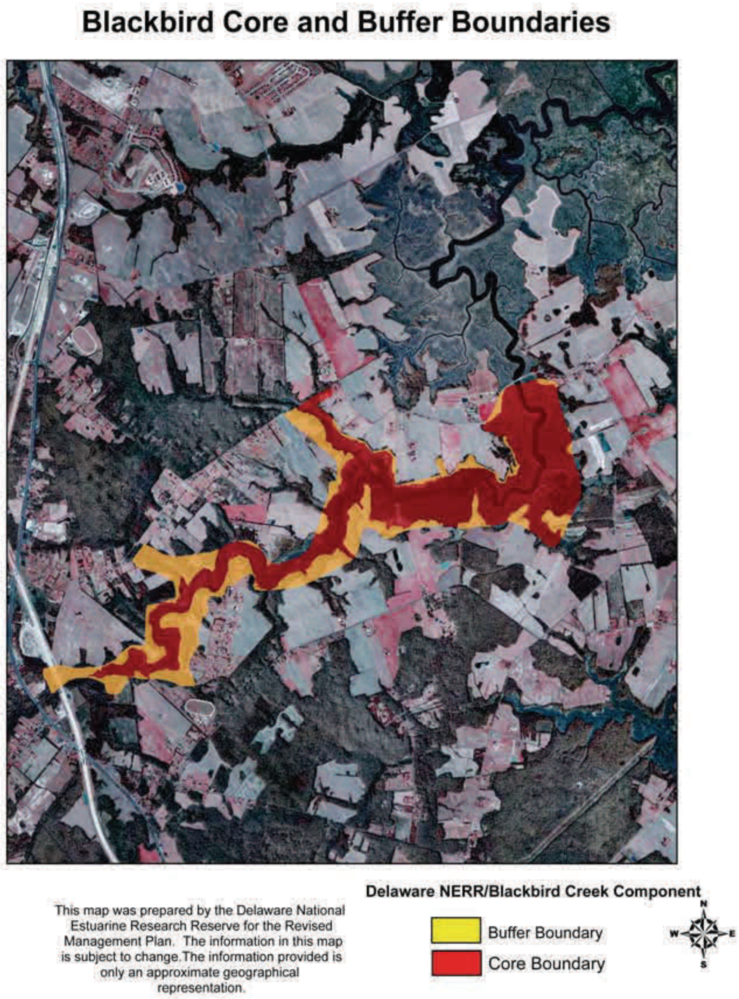

Figure 3. Delaware NERR, Blackbird Creek Component.

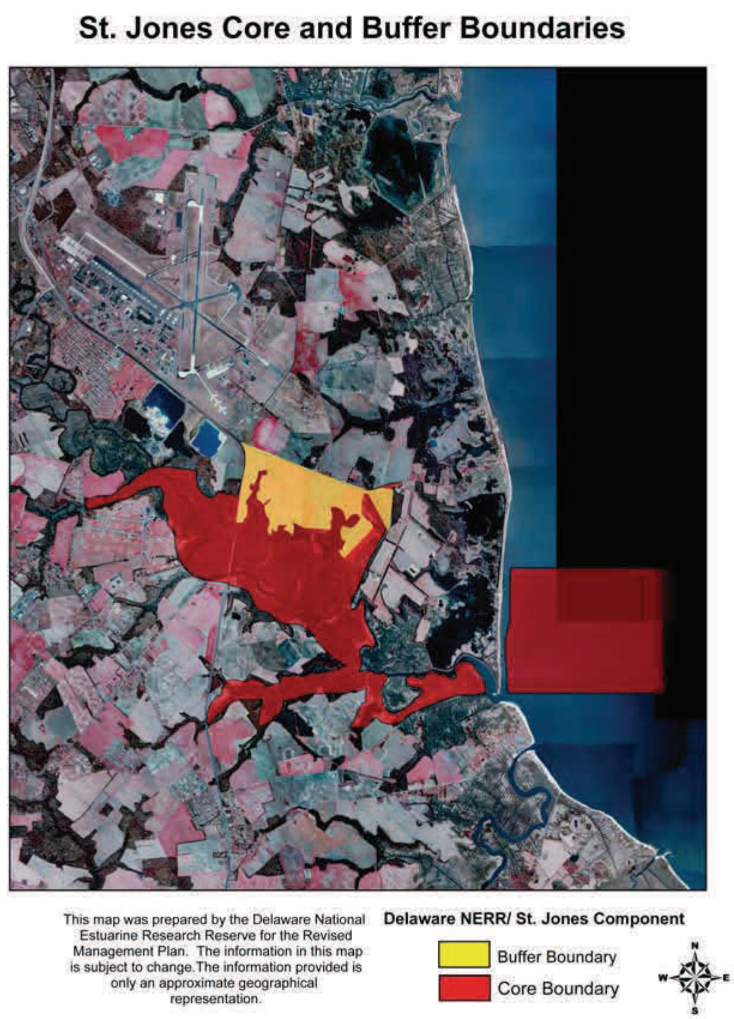

Figure 4. Delaware NERR, St. Jones Component

Old Woman Creek National Estuarine Research Reserve

Located near Huron, Ohio on the south-central shore of Lake Erie, the Old Woman Creek estuary is the drowned mouth of a small Lake Erie tributary. Since the retreat of mile-thick glaciers from the eastern United States and Canada, the land around the Great Lakes gradually rebounded, causing water levels to rise and flood the mouths of the rivers and streams flowing into them and creating the conditions for freshwater estuaries to develop. Today these estuaries are characterized by:

- drowned river mouths
- areas where stream and lake water meet and mix
- water levels that are regulated by changing lake levels (including wind-driven storm surges and resulting seiche events).

Figure 5. Barrier beach closed

Figure 6. Barrier beach open

Like water sloshing in a bathtub, seiches are tide-like rises and drops in Great Lakes coastal water levels caused by prolonged strong winds that push water toward one side of the lake, causing the water level to rise on the downwind side of the lake and to drop on the upwind side. When the wind stops, the water sloshes back and forth, with the near-shore water level rising and falling in decreasingly small amounts on both sides of the lake until it reaches equilibrium. In large bodies of water such as Lake Erie, the magnitude and timing of the seiches cause them to affect the coast much like lunar tides.

A barrier beach formed by waves and other forces within the lake isolates the estuary from the Lake Erie proper for extended periods. The barrier is normally opened by storm runoff from the watershed, but occasionally Lake Erie storm surges spill over the bar and into the estuary.

Like salt marshes, the emergent wetland plant communities of freshwater estuaries are among the most biologically productive areas on earth. Old Woman Creek NERR contains a variety of habitats including marshes and swamps, upland forests, open waters, bays and mudflats, tributary streams, a barrier beach and near shore Lake Erie. The estuary and surrounding environment support over 40 species of fish at some time during their life cycles, serve as a way station for over 300 species of migratory birds, and provide habitat for many species of mammals, reptiles, and amphibians.

Old Woman Creek flows 15 miles through portions of Huron and Erie counties including Townsend, Berlin and neighboring townships and the Village of Berlin Heights before entering Lake Erie 3 miles east of the city of Huron. Over 67% of the land within the creek's 27 square mile watershed is used for agriculture and the population is approximately 3,200. Although the estuary has remained relatively undisturbed, water quality is still negatively impacted by siltation, habitat alteration, and organic and nutrient enrichment stemming from agriculture and other land uses.

Figure 7. Old Woman Creek estuary photo (Credit: Gene Wright)

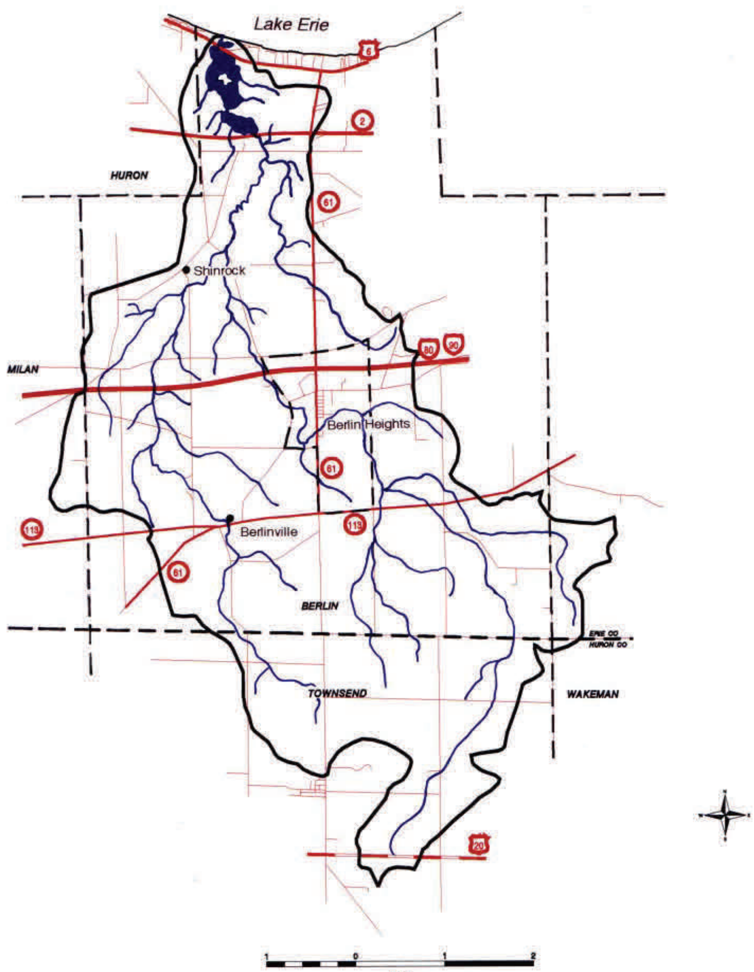

Figure 8. Old Woman Creek NERR, Ohio

Student Reading – 2
Activity 1: Chemistry in an Estuary

Estuaries are partially enclosed body of water and surrounding coastal habitats, where saltwater from the ocean mixes with fresh water from rivers, streams, or groundwater and where water levels are affected by lunar tides. In Great Lakes estuaries, fresh water from rivers or streams mixes with the chemically-distinct fresh water of the Great Lakes and water levels are influenced by wind-driven rather than lunar tides.

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, or areas in which a source of fresh water such as a stream or river flows into a much larger body of water like one of the Great Lakes. 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. In enclosed, non-marine location such as Lake Superior, the change in water levels due to lunar tides is measured in centimeters instead of meters. Although the lunar-driven tide is small on the Great Lakes, estuaries there are influenced by changes in water level resulting from wind-driven storm surges and resulting seiches.

Like water sloshing in a bathtub, seiches are tide-like rises and drops in Great Lakes coastal water levels caused by prolonged strong winds that push water toward one side of the lake, causing the water level to rise on the downwind side of the lake and to drop on the upwind side. When the wind stops, the water sloshes back and forth, with the near shore water level rising and falling in decreasingly small amounts on both sides of the lake until it reaches equilibrium.

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, the Bay of Fundy, which is located off the northern coast of Maine extending up to Canada, can be found at the end of a long, narrow inlet. In this Bay, tides are heightened because a large volume of water is being forced into a very small space. The tide there is in excess of 40 feet!

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.

Monitoring the environment of an estuary by measuring critical factors such as pH, dissolved oxygen, salinity, and temperature is vital to ensure that animals and plants thrive. It is important to know what these parameters are measuring.

pH

Scientists use pH as an indicator of whether water is acidic or basic. pH is measured on a scale of 1 to 14, where numbers less than 7 are increasingly acidic and numbers greater than 7 are increasingly basic. Distilled water has a pH of 7 and is said to be neutral. Water on the surface of Earth is usually a little acidic or basic due to both geological and biological influences.

pH is actually a measure of the amount of hydrogen ions in solution. In fact, some people think of pH as being the "power of hydrogen". A lower pH indicates that there are more free hydrogen ions, which creates acidic conditions, and a higher pH indicates there are fewer free hydrogen ions, which creates basic conditions. pH is equal to the negative logarithm of the hydrogen ion activity, meaning that the hydrogen ion concentration changes tenfold for each number change in pH unit.

All aquatic organisms have a pH range to which they are adapted. Outside of this range, critical biological processes may be disrupted, leading to stress and death. Most organisms cannot live below a pH of 5 or above a pH of 9. Additionally, pH is used to monitor safe water conditions. Once the background range of pH has been established, a rise or fall in pH may indicate the release of a chemical pollutant or an increase in acid rain. Additionally, pH affects the solubility, biological availability, and toxicity of many substances. For example, most metals are more soluble, and often more toxic, at lower pH values.

Temperature

Temperature is a measure of kinetic energy, or energy of motion. Increasing water temperature indicates increasing energy, or motion of water molecules and substances dissolved in the water. Temperature is a critical factor for survival in any environment. Organisms that live in water are particularly sensitive to sudden changes in temperature.

The Celsius temperature scale is used worldwide to measure temperature. Temperature has a significant impact on water density. Water density is greatest at 4 degrees Celsius, meaning that water at higher or lower temperatures will float on top of water at or near 4 º C. This is why ice floats on water, and warm water floats over cooler water. Differences in water temperature can cause the formation of distinct, non-mixing layers in water, otherwise known as stratification. This stratification leads to chemically and biologically different regions in water.

Salinity and Conductivity

Salinity and conductivity are measures of the dissolved salts in water. Salinity is usually described using units of parts per thousand or ppt. A salinity of 20 ppt means that there are 20 grams of salt in each 1000 grams of water. Because it is impractical to routinely determine the total amount of salts dissolved in water, a surrogate measure—the ability of the water to conduct electricity—is made for determining both conductivity and salinity.

Salinity and conductivity are closely related. Pure water is a very poor conductor of electrical current, but salts dissolved in the water are in ionic (charged) form and conduct electrical current. Conductivity, which is the opposite of resistance, measures the ability of water to conduct current. A higher conductivity indicates less resistance, and means that electrical current can flow more easily through the solution. Because dissolved salts conduct current, conductivity increases as salinity increases. Common salts in water that conduct electrical current include sodium, chloride, calcium, and magnesium.

All aquatic life in an estuary must be able to survive changes in salinity. All plants and animals have a range of salinity to which they are adapted. Outside of this range, they will be unable to function and may die. Salinity affects the ability of water to hold oxygen, and seawater holds approximately 20% less oxygen than freshwater. Many chemical reactions that determine the concentration of nutrients and metals in the water are influenced by salinity. The conductivity and salinity of seawater is very high while these parameters are comparatively low in tributaries and rivers. Freshwater lakes typically have conductivities and salinities even lower than those of inland streams. This is because inland streams pick up salts from rocks, soils, and roads as they flow over the landscape.

Many chemical reactions that determine the concentration of nutrients and metals in the water are influenced by salinity. For instance, salinity and conductivity affect the ability of particles to flocculate, or stick together, which is important in determining turbidity levels and sedimentation rates. Salinity also increases the density of water, with seawater being heavier than freshwater. This density difference inhibits mixing. In fact, conductivity and salinity serve as excellent indicators of mixing between inland water and sea or lake water, and they are particularly useful in indicating pollution events or trends in freshwater. For example, an overdose of fertilizers or the application of road salt will cause spikes in conductivity and salinity.

Conductivity and salinity are dependent on many factors, including geology, precipitation, surface runoff and evaporation. Since conductivity is a much more sensitive measurement than salinity, it is more impacted by changes in temperature. Conductivity increases as water temperature increases because water becomes less viscous and ions can move more easily at higher temperatures. Because of this, most reports of conductivity reference specific conductivity. Specific conductivity adjusts the conductivity reading to what it would be if the water was 25°C. This is important for comparing conductivities from waters with different temperatures.

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen gas that is dissolved in a sample of water. DO is usually measured in units of milligrams per liter (mg/L). Just as we need air to breathe, aquatic plants and animals need dissolved oxygen to live. Dissolved oxygen is used for respiration, which is the process by which organisms gain energy by breaking down carbon compounds, such as sugars. Dissolved oxygen is also essential for decomposition, which is a type of respiration in which bacteria break down organic materials for energy. Decomposition is an important process that recycles nutrients and removes organic materials such as dead vegetation from our waterways. Because dissolved oxygen is required for aquatic life, balancing the sources and sinks of dissolved oxygen is essential in maintaining a healthy ecosystem.

The concentration of dissolved oxygen in water depends on a number of interrelated factors, including biological factors, such as the rates of photosynthesis and respiration, and physical and chemical factors, such as temperature, salinity, and air pressure.

Dissolved oxygen enters the water by diffusion from the air and as a byproduct of photosynthesis. Diffusion from the air occurs very quickly in turbulent, shallow water or under windy conditions.

The amount of oxygen that can dissolve in water depends on water temperature, salinity, and air pressure. As temperature and salinity increase, and pressure decreases, the amount of oxygen that can be dissolved in water decreases. Cold water holds more dissolved oxygen than warm water, and water at sea level holds more dissolved oxygen than water at high altitudes. Seawater holds approximately 20% less oxygen than freshwater at the same temperature and altitude.

Student Worksheet
Activity 1: Chemistry in an Estuary

Student Name:____

Part 1 — What is an Estuary?

As you are shown various images in the *Monitoring Tutorial*, take notes on the nature of estuaries and record any ideas you have about what factors would cause changes in water quality in an estuary over the course of a day, a season or a year.

1a. What is an estuary?

1b. List the types of habitats shown in the *Monitoring Tutorial*.

1c. What features do estuaries have in common?

1d. List some of the water quality parameters that are important in determining the suitability of the water for different species of plants and animals.

Part 2 — Investigating Water Quality in an Estuary

You will study four of the water quality parameters in the South Slough NERR in Oregon. You will look at how pH, dissolved oxygen, salinity, and water temperature are measured by one of the four monitoring stations comprising the estuary reserve—Charleston Bridge.

Look at the satellite image below to see the location of the site and its general position with respect to the ocean. If time permits, investigate this area more fully by using Google Earth.

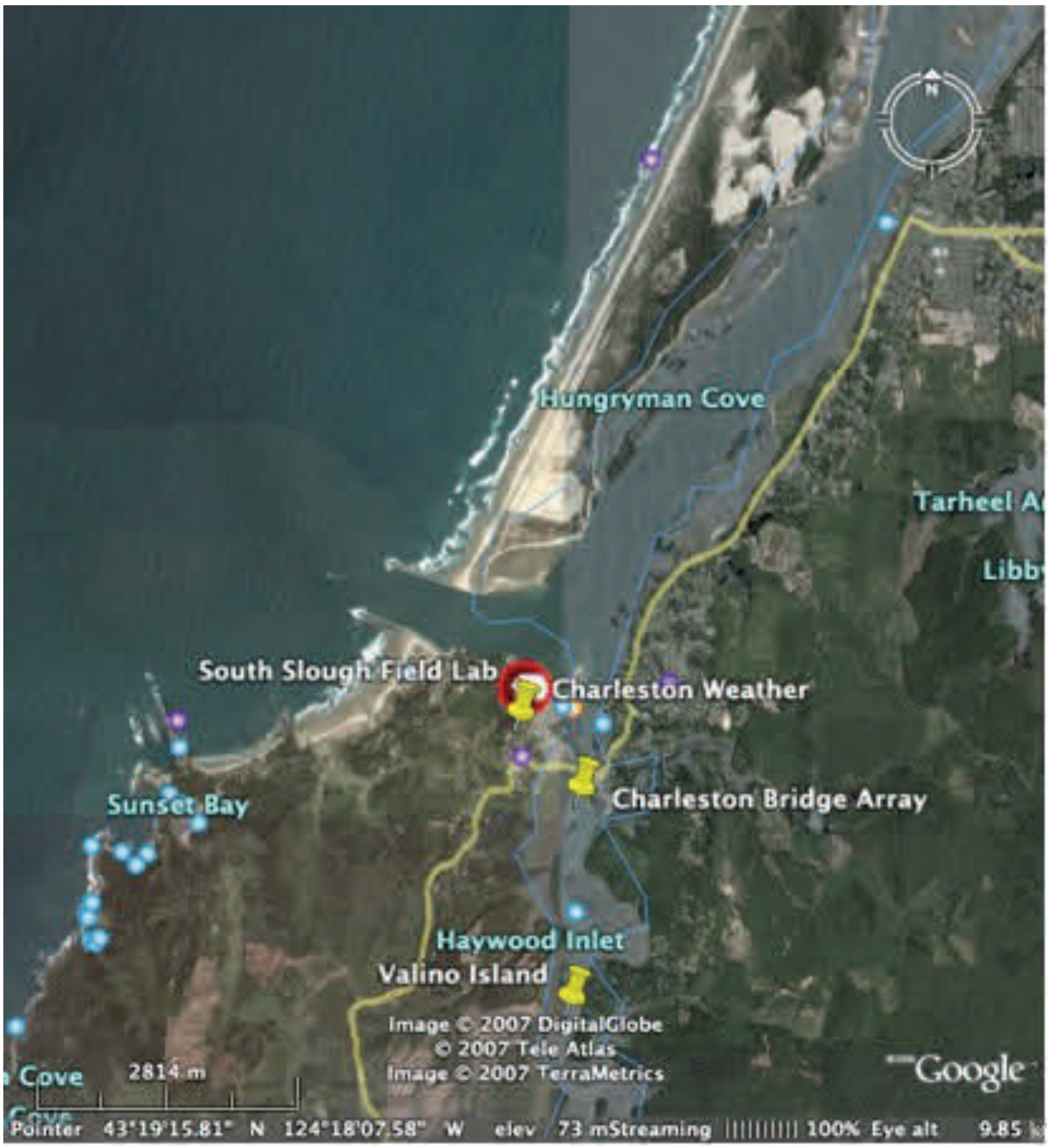

Figure 9. South Slough NERR with monitoring stations.

Study the sets of gauge data (Gauge Data for 9/5/07 at 11 AM EDT—Charleston Bridge) from the *Student Data Sheet—Chemistry in an Estuary*.

2a. Write down the difference between the maximum and minimum value for each water quality parameter (this number is called the range of values).

2b. What do you think causes the changes in each parameter over the course of one day?

Part 3 — Investigating Water Quality Over a Day

You will now study the same water quality parameters over a 24-hour period using a graphical display. Each graph (Graphical Data: Midnight 9/4 to 11 AM 9/5/07—South Slough, OR—Charleston Bridge) from the *Student Data Sheet* begins at midnight on Sept. 4 and ends at 11 AM on Sept. 5.

3a. Describe the pattern of change for each parameter.

3b. Give a reason to explain what is causing the variation of each parameter over a 24-hour period.

3c. Use the graphs to complete the following sentences:

i. When the temperature of the water in an estuary increases, the ________________________ decreases.

ii. The water in the South Slough estuary is slightly ______________________ (acidic or basic) on average during this 24-hour period.

Part 4 — Investigating Water Quality Over a Year

Now you will study the same four parameters as they vary over an entire calendar year, using the graphs (Graphical Data for the year 2006—South Slough, OR—Charleston Bridge) from the *Student Data Sheet*.

Compute the range for each water quality parameter for each site over the course of a year (high value - low value).

4a. Describe the pattern of change of each water quality factor over the course of a year.

4b. Explain what you believe is causing the variation of each factor over the course of a year.

Part 5 — Comparing Water Quality Data Between Three Different Estuarine Environments

You will now compare the ranges of water quality factors for South Slough, OR with two very different estuaries—Blackbird Landing, a monitoring station in the Delaware NERR, and Lower Estuary, a monitoring station in Old Woman Creek, Ohio, the only freshwater estuary in the National Estuarine Research Reserve System.

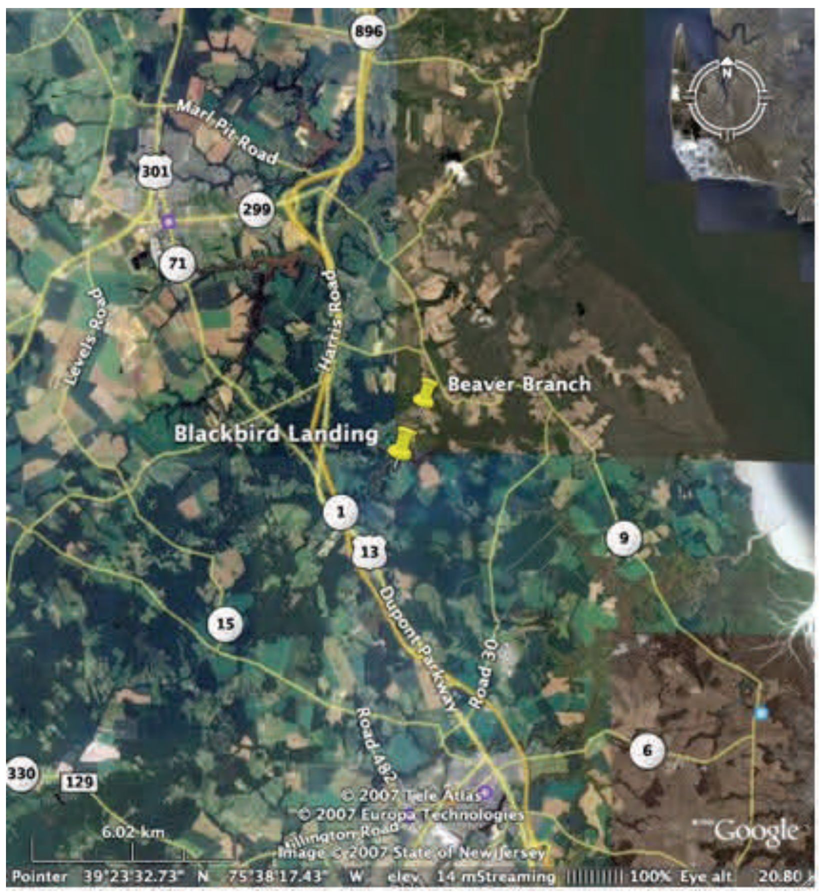

Figure 10. The Delaware NERR showing the location of Blackbird Landing

Figure 11. Aerial image of Old Woman Creek NERR showing the location of the Lower Estuary monitoring station

Study the 2006 data graphs (Graphical Data for the year 2006—Old Woman Creek, OH) from the *Student Data Sheet* and compute the yearly ranges for each of the four parameters.

Then study the 2006 data graphs for the Lower Estuary monitoring station in the Old Woman Creek NERR and compute the yearly ranges for each of the four parameters.

5a. Compare the ranges of the water quality parameters between the three sites: South Slough, Blackbird Landing, and Old Woman Creek Lower Estuary. Which parameter ranges are about the same? Which ones are different?

5b. Compare the time of year for the maximum and minimum pH, dissolved oxygen, salinity and water temperatures at each of the sites. Are they the same or different? Give one reason for any differences between them.

5c. Does the pattern of change for any of the four water quality factors vary appreciably between sites? If so, explain why the patterns are different.

Student Data Sheet
Activity 1: Chemistry in an Estuary

Part 2 — Investigating Water Quality in an Estuary

Gauge Data for 9/5/07 at 11 AM EDT — Charleston Bridge

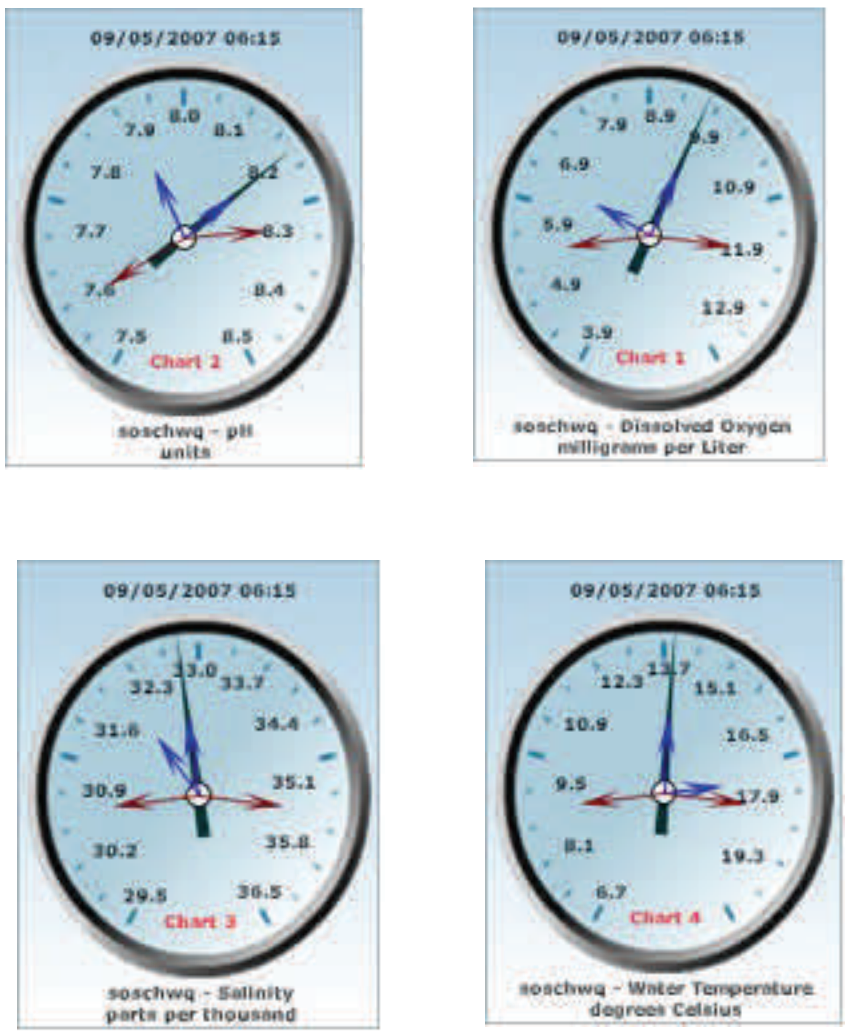

Figure 12. Gauge Data for 9/05/07 at 11 AM EDT—Charleston, Bridge

Part 3 — Investigating Water Quality Over a Day

Graphical Data: Midnight 9/4 to 11 AM 9/5/07—South Slough, OR—Charleston Bridge

NOTE: The vertical and horizontal scales differ somewhat from graph to graph.

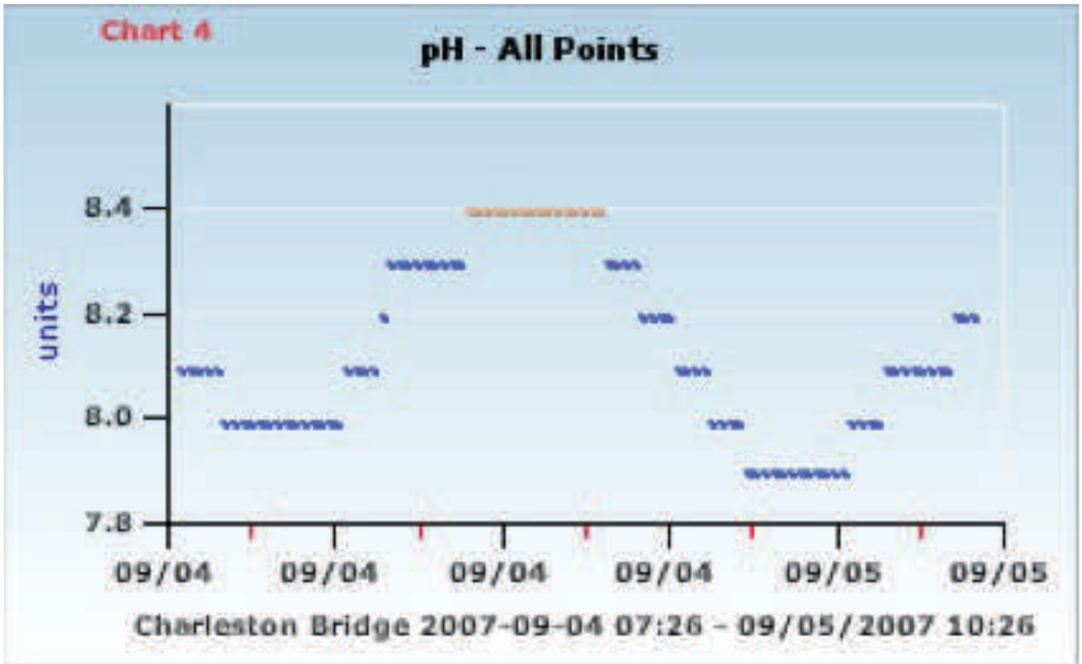

Figure 13. Daily pH: South Slough, OR—Charleston Bridge

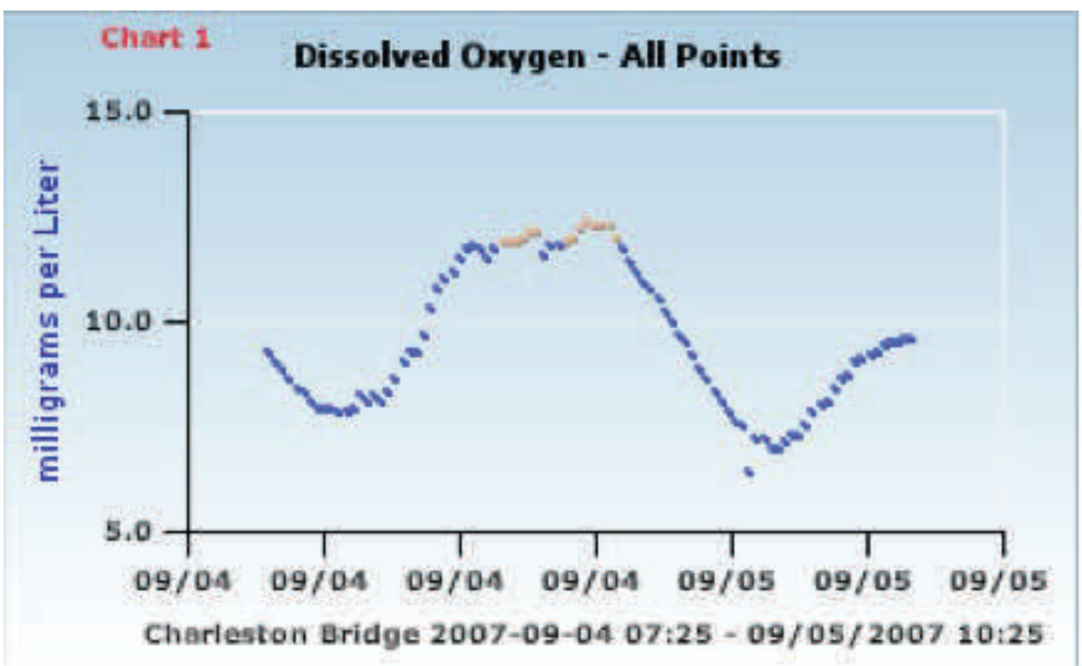

Figure 14. Daily DO: South Slough, OR—Charleston Bridge

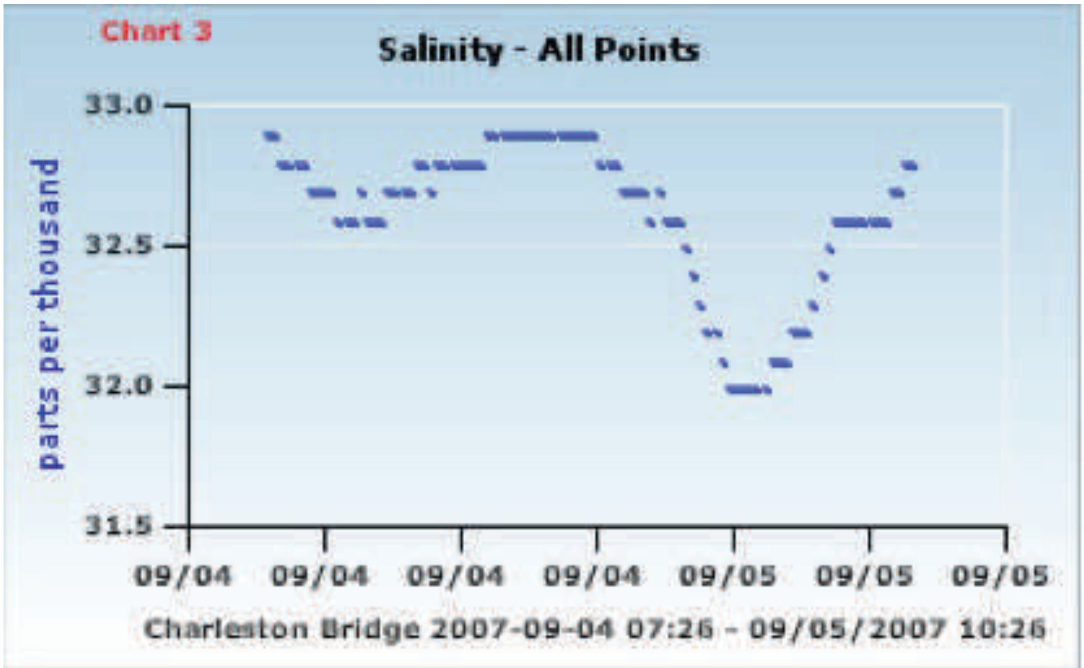

Figure 15. Daily Salinity: South Slough, OR—Charleston Bridge

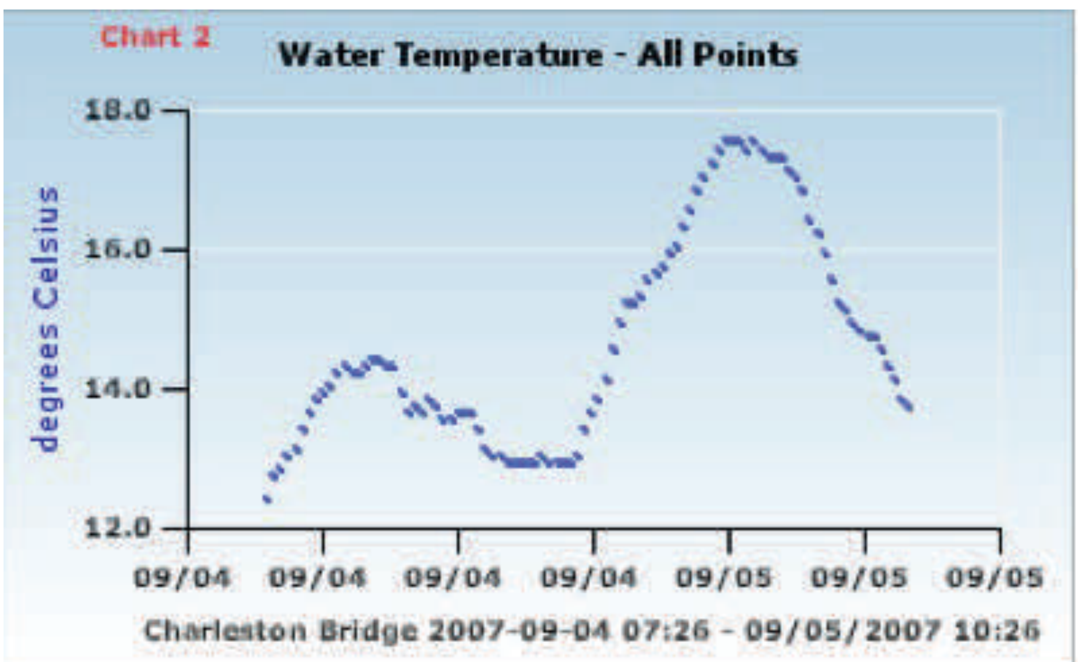

Figure 16. Daily Water Temperature: South Slough, OR—Charleston Bridge

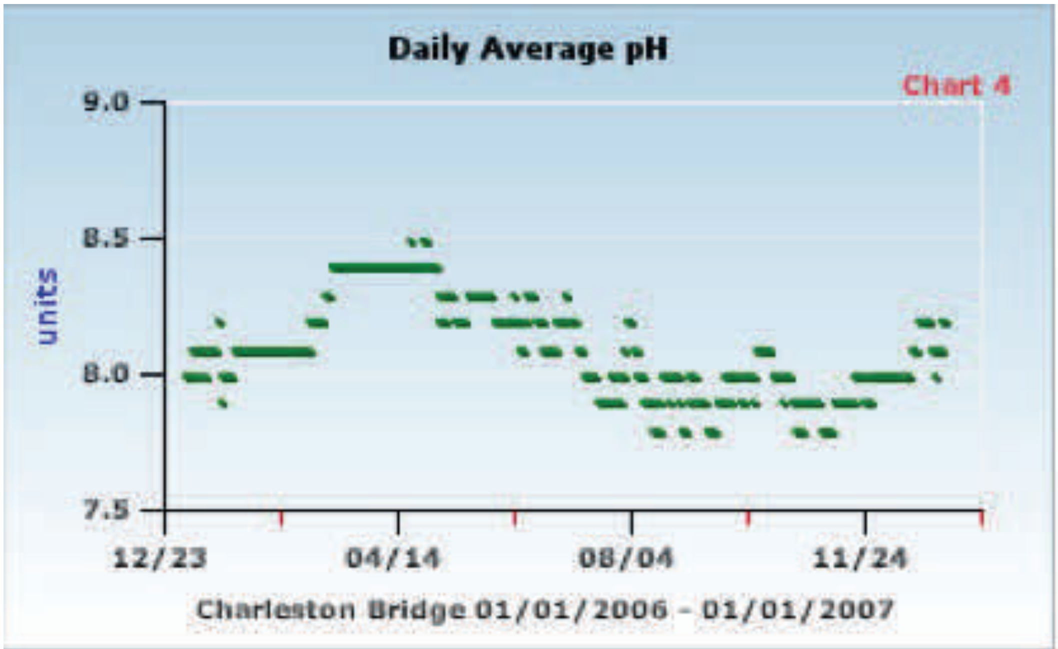

Figure 17. Annual pH: South Slough, OR—Charleston Bridge

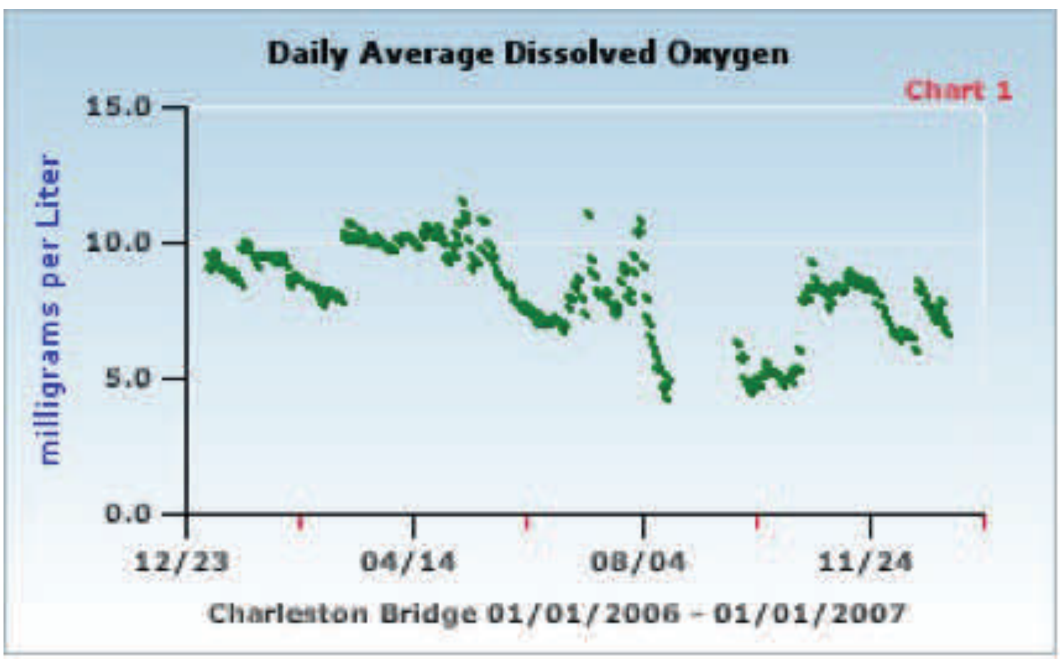

Figure 18. Annual DO: South Slough, OR—Charleston Bridge

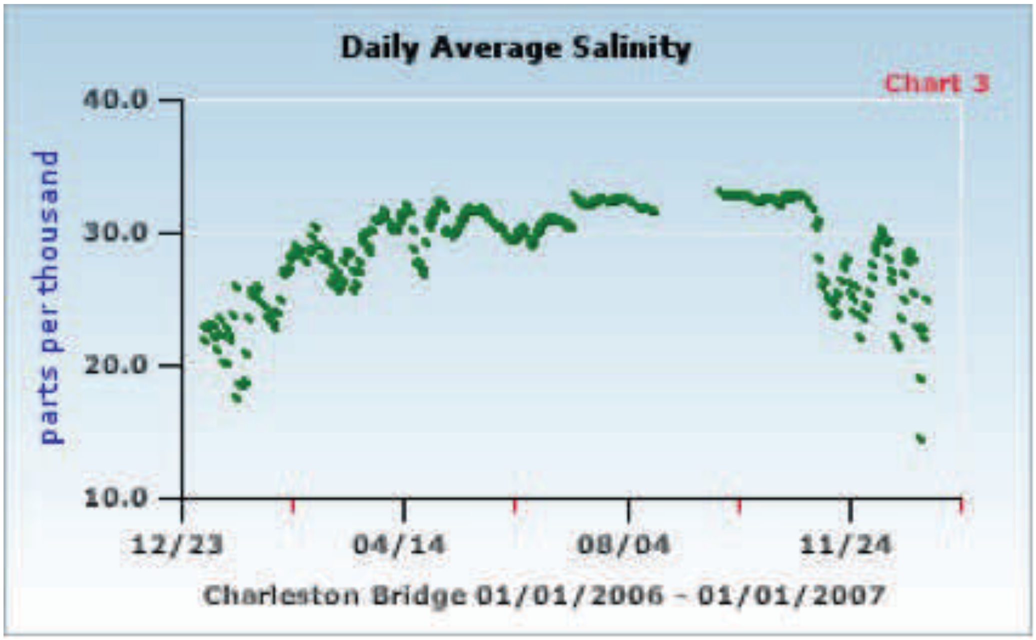

Figure 19. Annual Salinity: South Slough, OR—Charleston Bridge

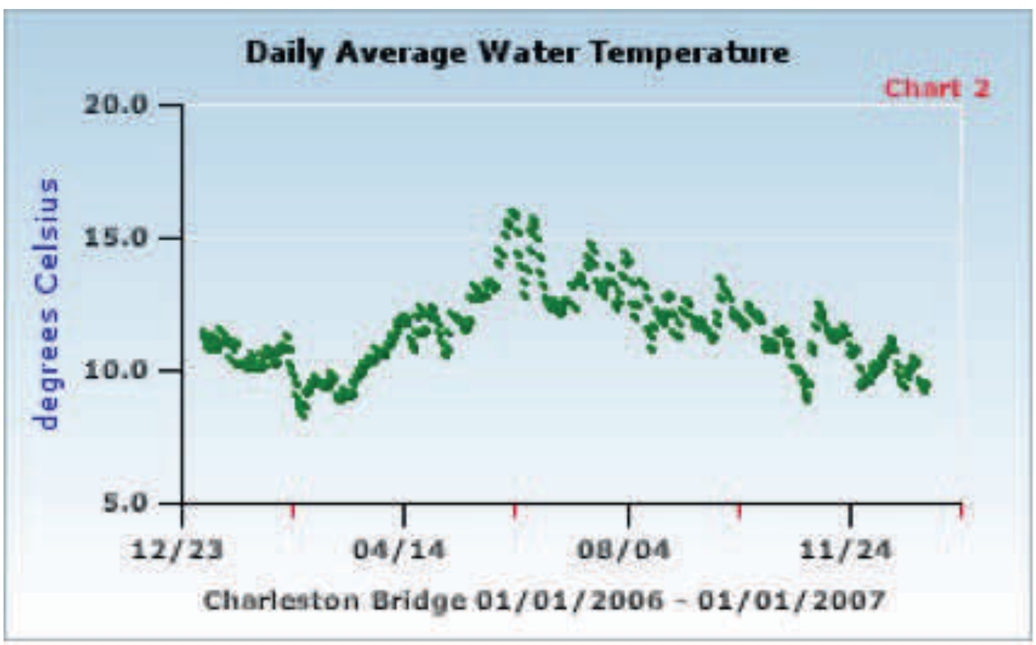

Figure 20. Annual Water Temperature: South Slough, OR—Charleston Bridge

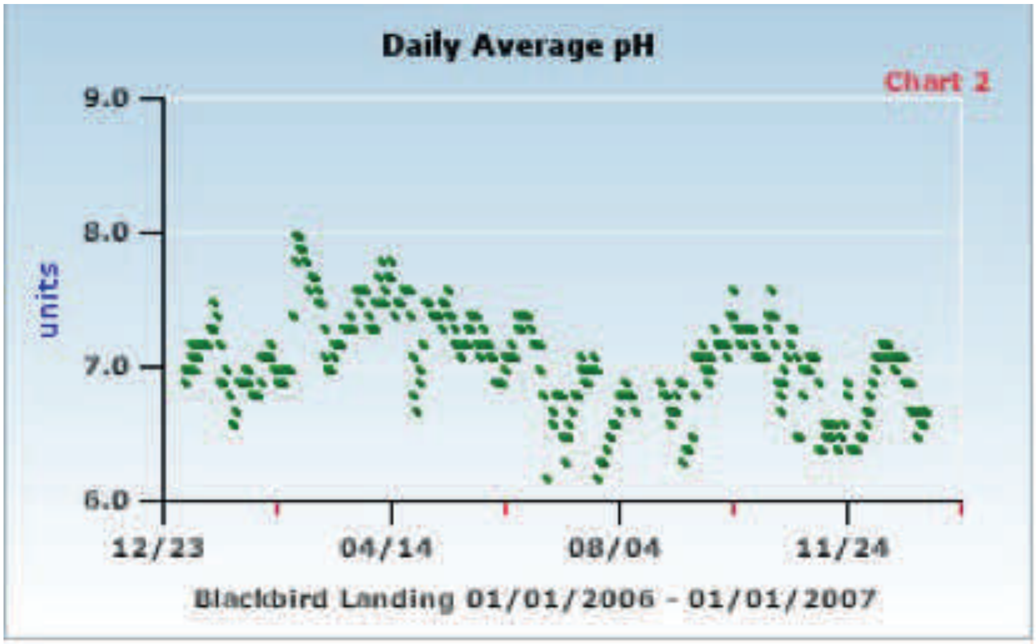

Figure 21. Annual pH: Blackbird Landing, DE

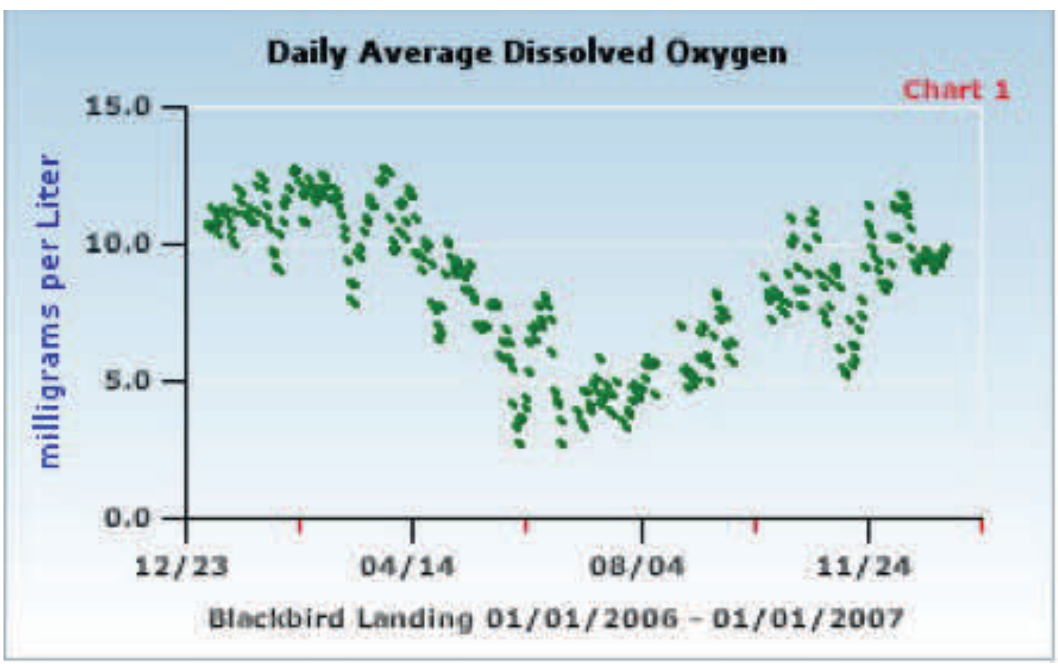

Figure 22 Annual DO: Blackbird Landing, DE

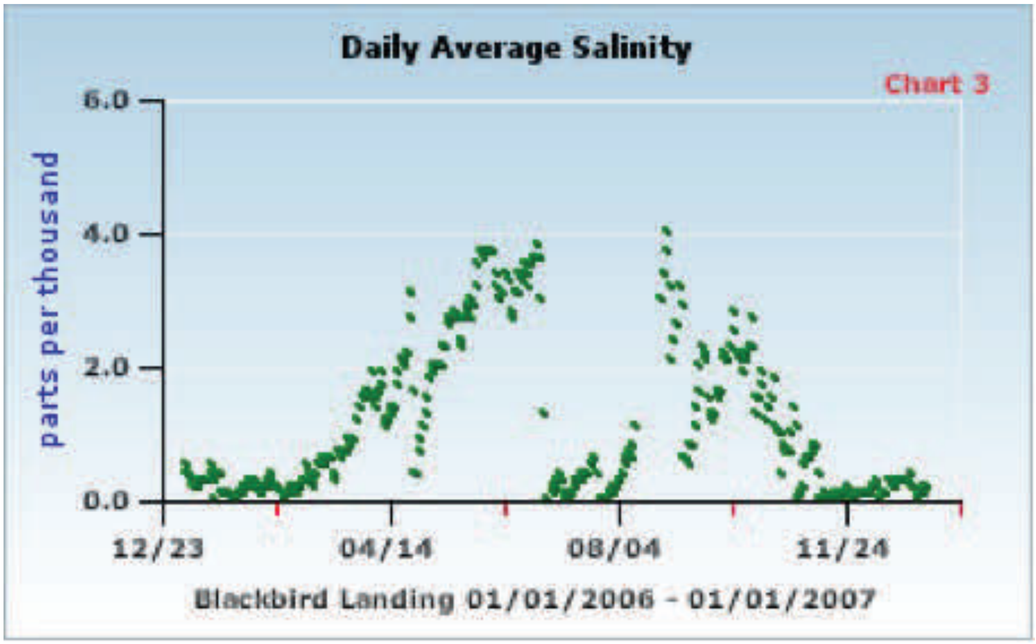

Figure 23. Annual Salinity: Blackbird Landing, DE

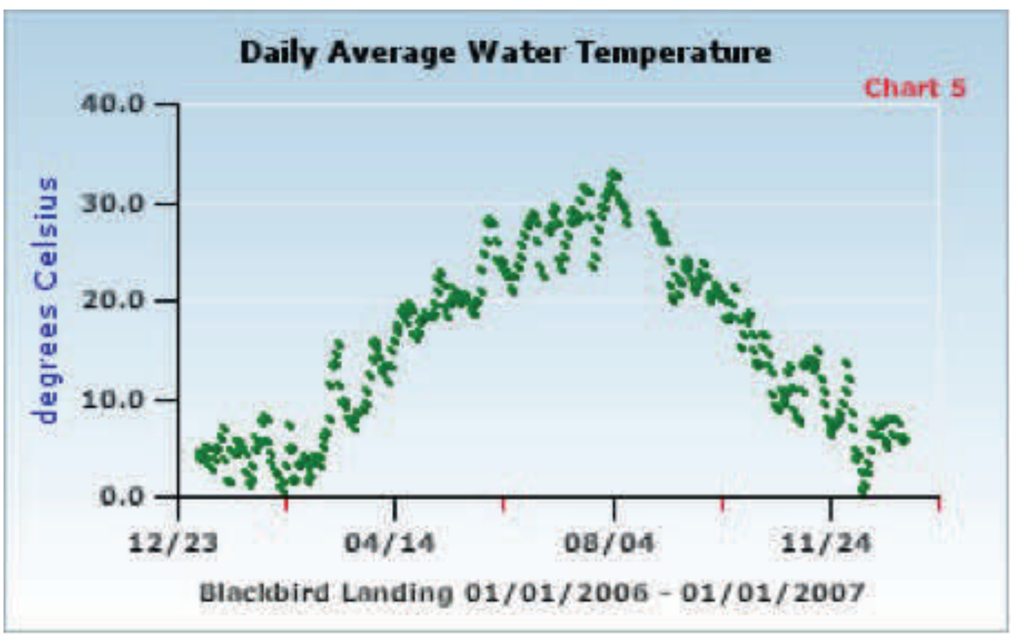

Figure 24. Annual Water Temperature: Blackbird Landing, DE

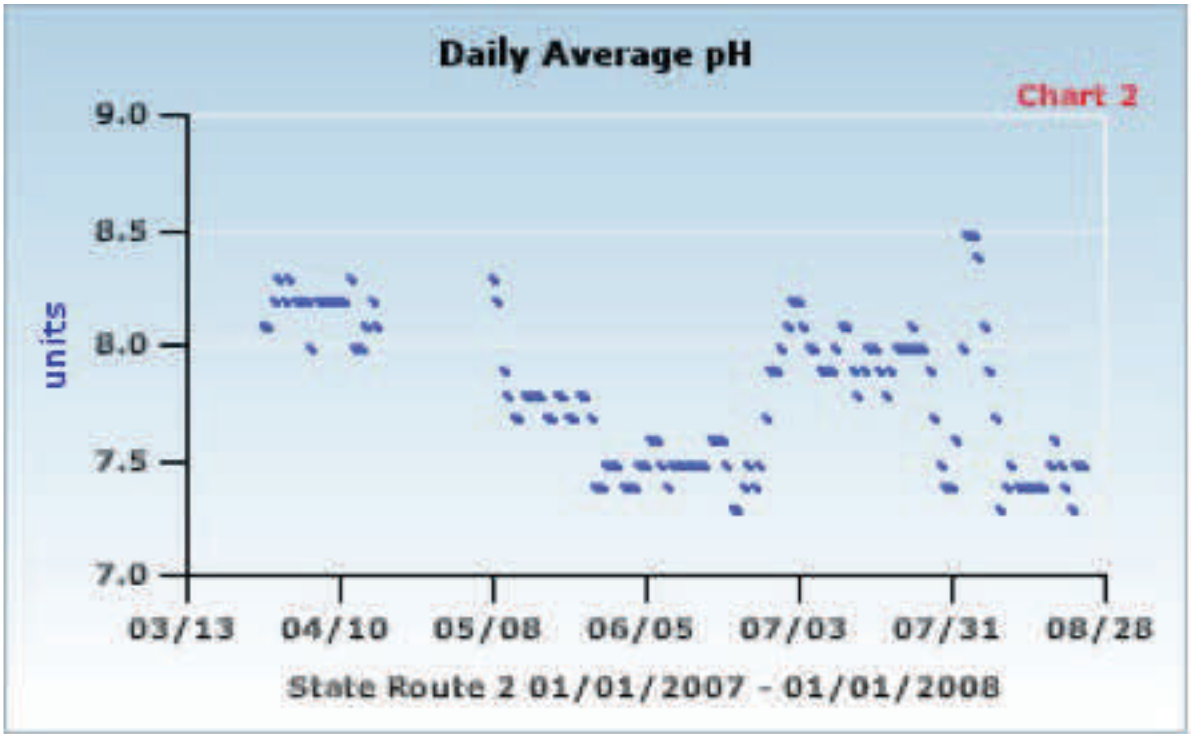

Figure 25. Annual pH: Old Woman Creek, OH—Lower Estuary

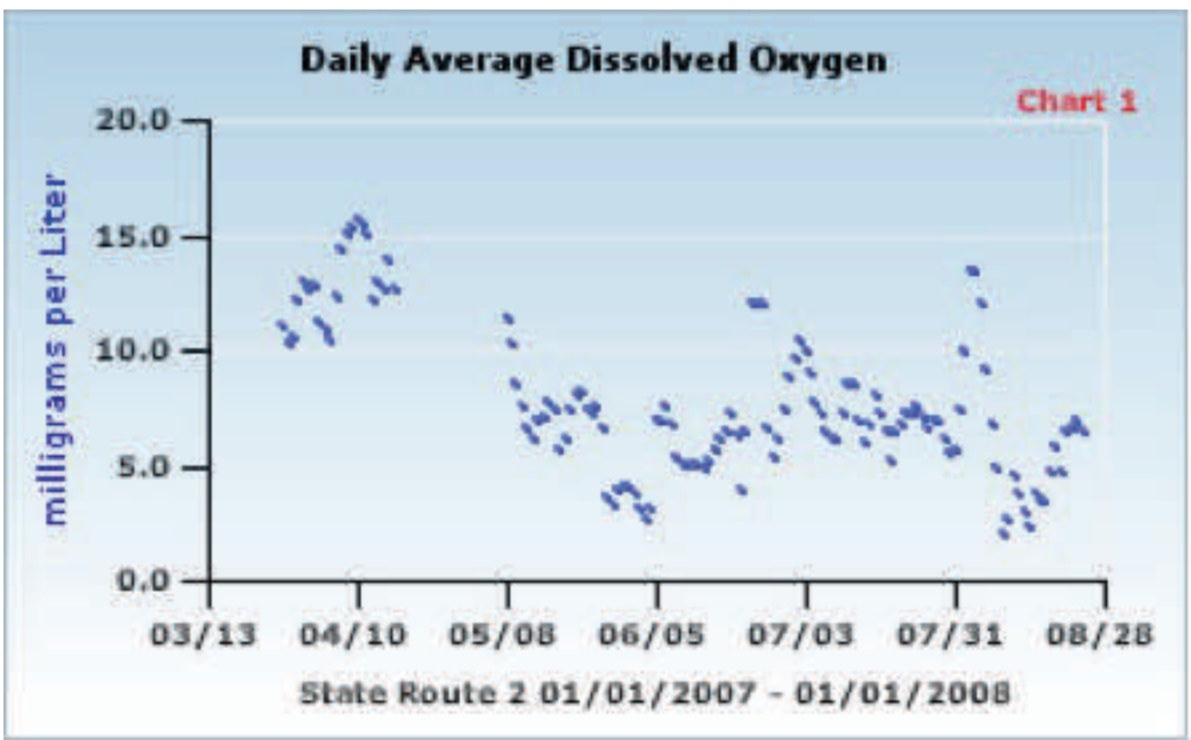

Figure 26. Annual DO: Old Woman Creek, OH—Lower Estuary

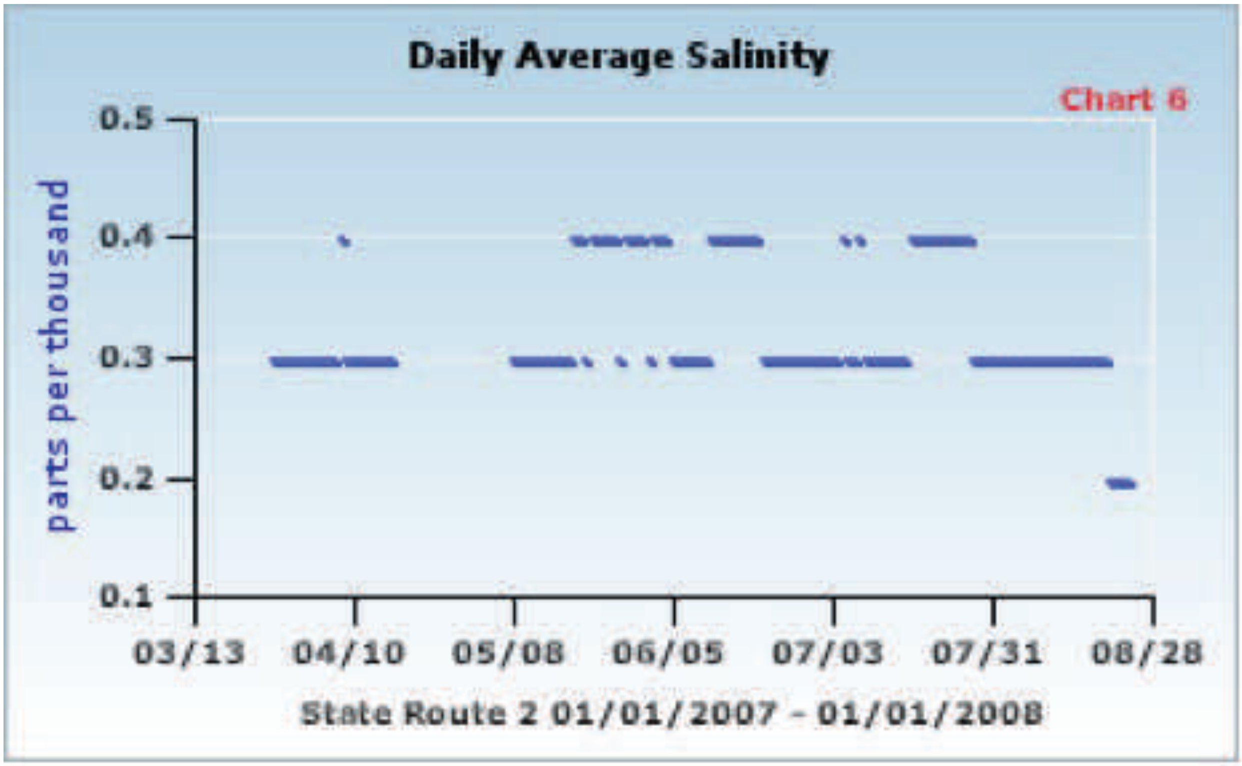

Figure 27. Annual Salinity: Old Woman Creek, OH—Lower Estuary

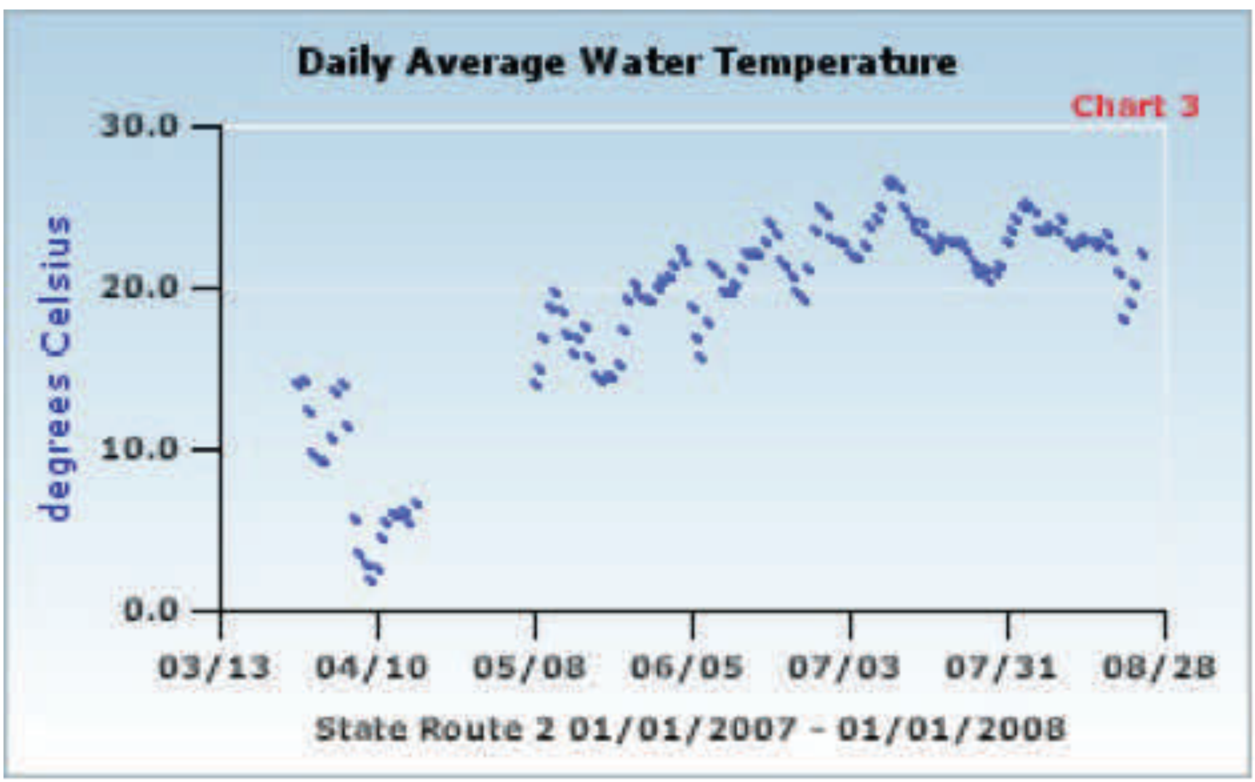

Figure 28. Annual Water Temperature: Old Woman Creek, OH—Lower Estuary