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

Featured NERRS Estuary:
San Francisco Bay
National Estuarine Research Reserve
http://nerrs.noaa.gov/Reserve.aspx?ResID=SFB

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.

To find the Tutorial "*Using Google Earth to Explore Estuaries*" go to Estuaries.noaa.gov, click the tab titled Curriculum and then the sub-tab titled Tutorials.

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.

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

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

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 and Watershed.*

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://gallery.usgs.gov/photos/03_08_2010_bFVi0MLyx6_03_08_2010_0

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.

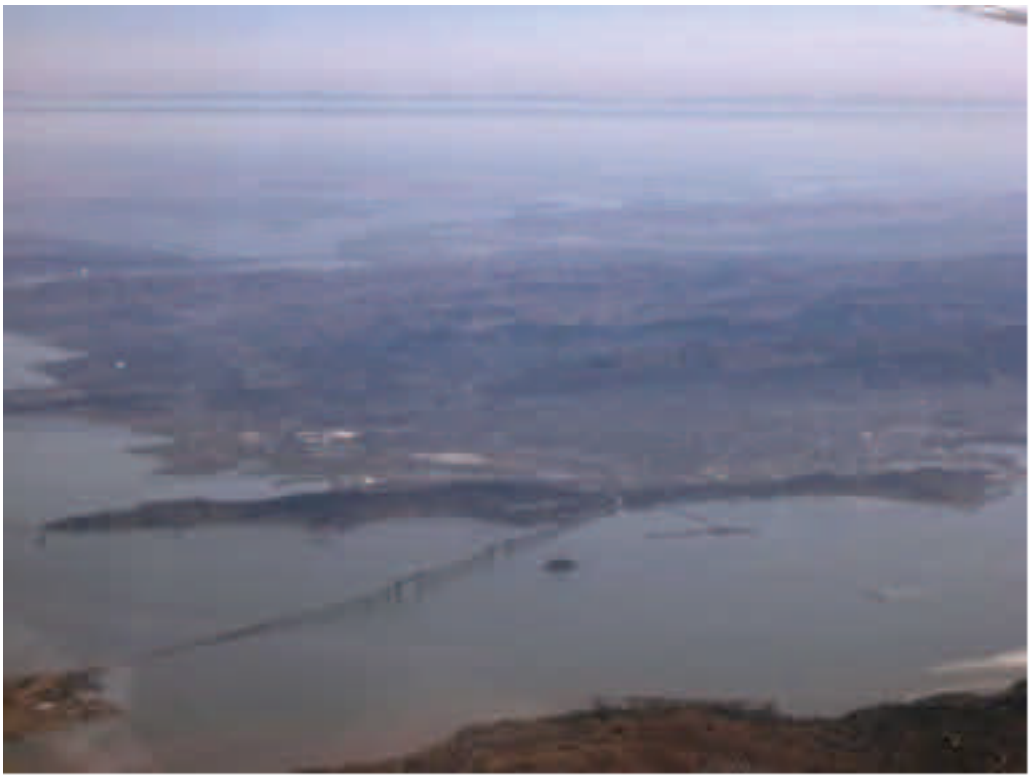

Figure 1. San Pablo Bay or North Bay

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?

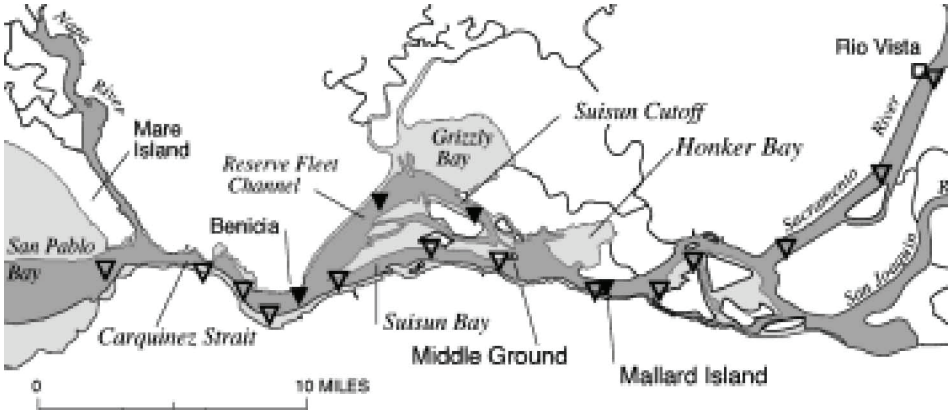

Figure 3. Most of the fresh water that mixes with ocean water in the estuary comes from two sources —the Sacramento and San Joaquin Rivers.

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

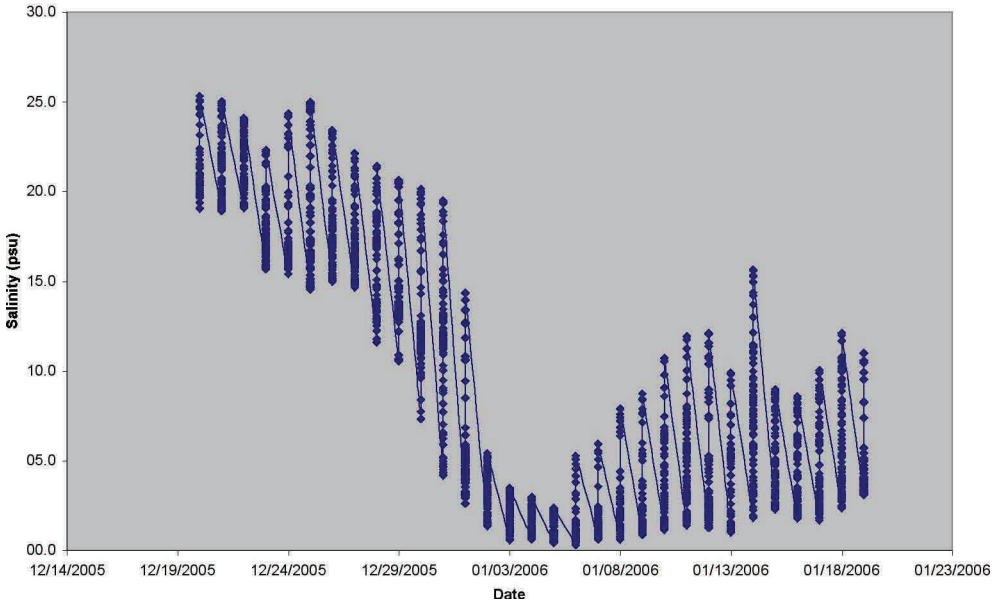

Figure 9. Salinity Drop with Storm

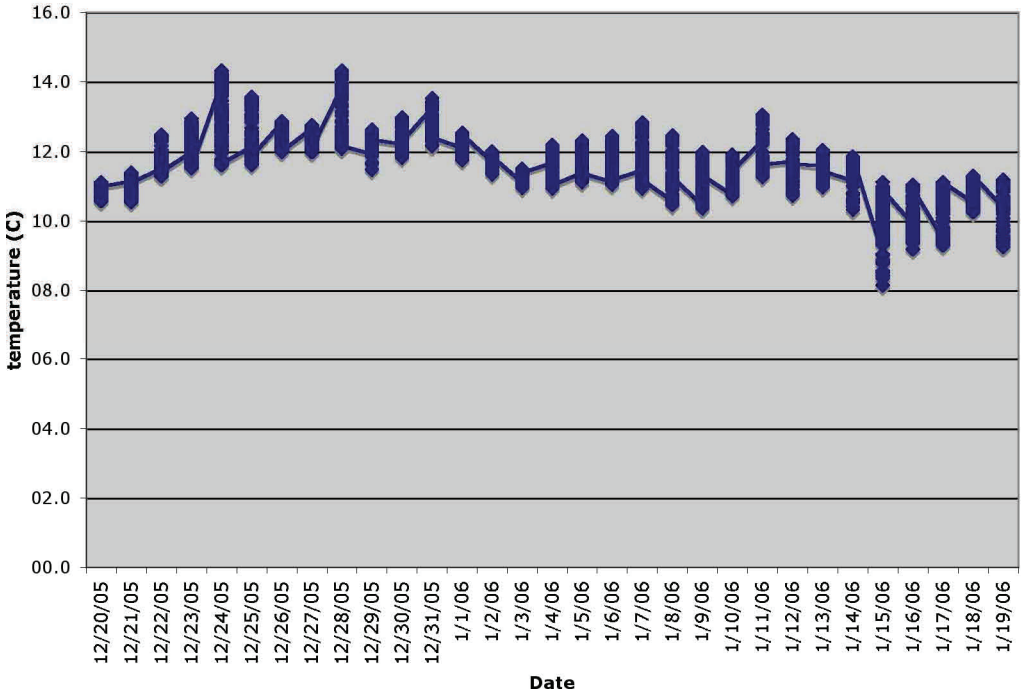

Figure 10 . Water Temperature

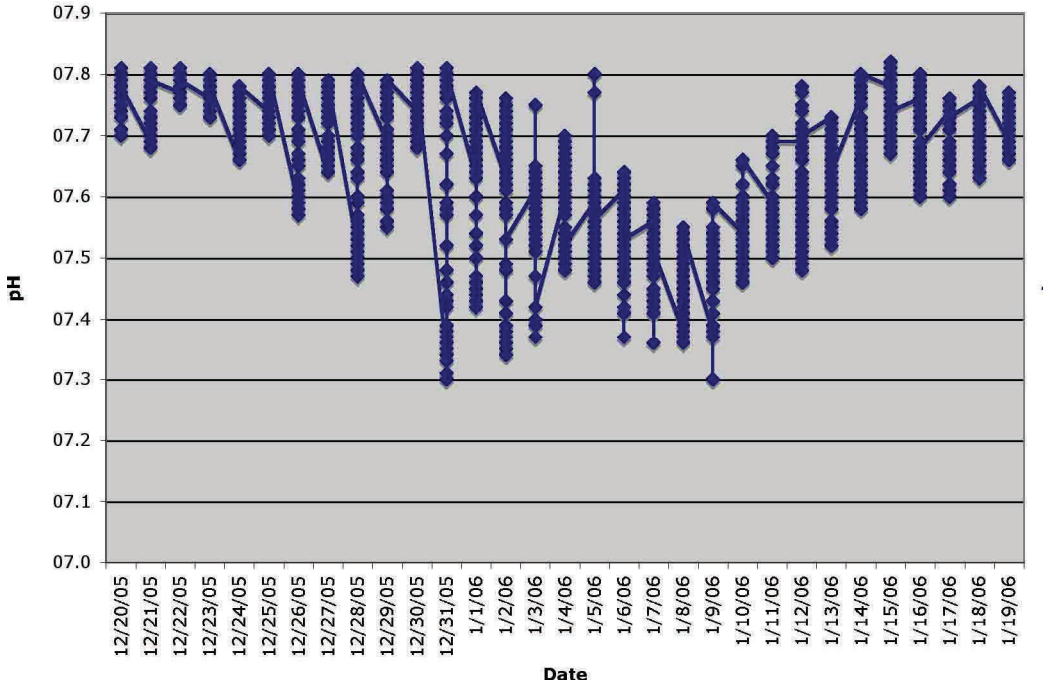

Figure 11. pH

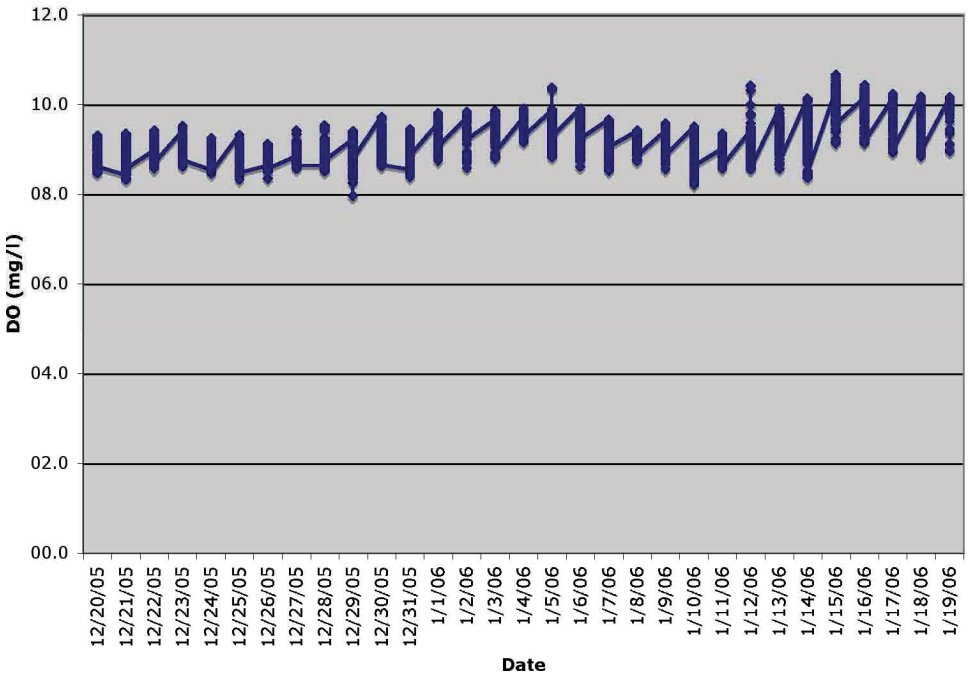

Figure 12. Dissolved Oxygen

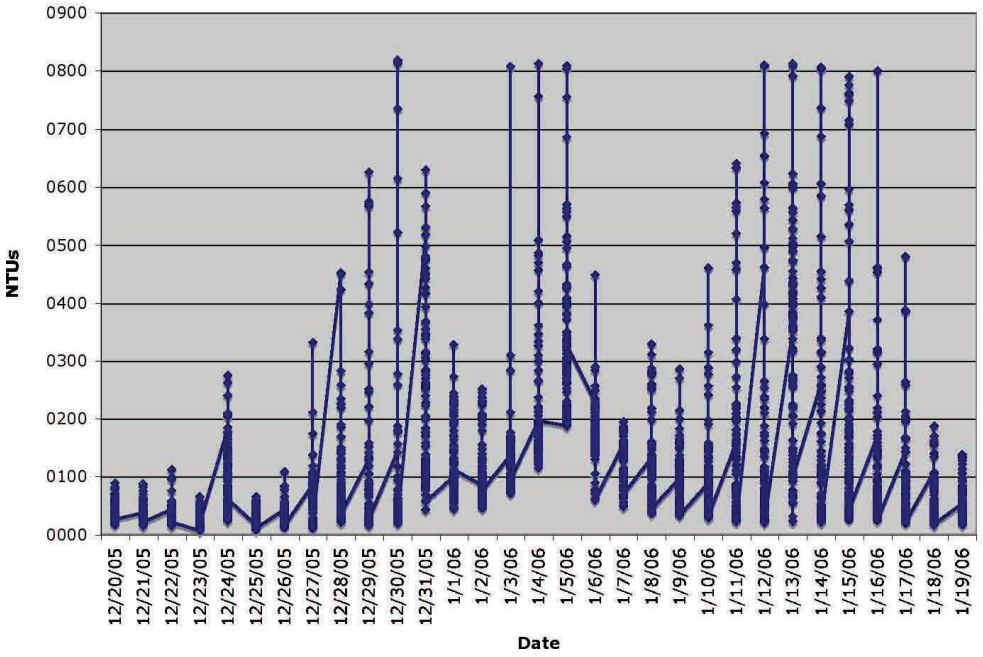

Figure 13. Turbidity