

# 2 San Francisco Bay

## Overview

San Francisco Bay is a large coastal embayment located on the Pacific Coast of the State of California. It consists of 5 major water bodies - Suisun Bay, Carquinez Strait, San Pablo Bay, Central Bay (northern San Francisco Bay) and South Bay (southern San Francisco Bay). East of San Francisco Bay lies the Sacramento-San Joaquin Delta, where two major rivers the Sacramento and San Joaquin Rivers meet. Freshwater from the Sacramento-San Joaquin Delta merges with the incoming ocean water from the Golden Gate to form an estuary.

For this report Suisun Bay, Carquinez Strait, San Pablo Bay and Central Bay will be referred as the northern region, and South Bay as the southern region. The entire San Francisco Bay will be referred to as the Bay.

## Location



### Basic information

Surface area : 1,222 km<sup>2</sup>

Volume : 6 km<sup>3</sup>

Average depth : 5 m

Maximum depth : 109 m

## Nature

### < Background >

San Francisco Bay has a catchment area of approximately 156,000 km<sup>2</sup>, covering about 40 per cent of California and receiving roughly 47 per cent of the state's runoff. It provides drinking water to over 22 million Californians and irrigates 18,000 km<sup>2</sup> of farmland.<sup>1</sup>

Before human intervention, extensive wetlands surrounded the Bay, but now much of the shoreline has been turned into residential, industrial, agricultural and commercial areas. As a consequence of this, the Bay is facing various environmental problems. However, the Bay still supports vast ranges of plant and animal species, and also continues to play a vital role for the people of California.

### Climate

The Bay catchment area has a Mediterranean climate, characterized by cool, wet winters and warm, dry summers. In the inland area, the average temperature is about 6 °C in winter and 26 °C in summer. Temperatures in the coastal area show less variation, with mean monthly temperatures ranging from 10 °C to 16 °C.<sup>2</sup>

Precipitation varies greatly within the catchment area. In the wettest area, annual precipitation is around 1,500 mm.<sup>2</sup>

### Topography

A relatively deep channel runs throughout the San Francisco Bay, but the Bay is mostly shallow, with an average depth of only 6 m. Most of the coastline has a shallow slope, except along Carquinez Strait and part of Central Bay where the coastline is steep. At the Golden Gate, the entrance to the Bay, the water is at its maximum water depth of approximately 109 m.<sup>3</sup>

### Hydrology

The Bay receives the majority of its freshwater from the Sacramento and San Joaquin Rivers. Freshwater from these two rivers influences the salinity and water circulation patterns of the Bay, especially in the northern region. Salinity in the north of the Bay varies considerably and increases along a gradient from the Sacramento-San Joaquin Delta to Central Bay. The mean annual salinity at the mouth of the Sacramento River is slightly less than 2; in Suisun Bay it is about 7; and in Central Bay it increases to about 30. However, large inflows from the above rivers dramatically drop the average salinity of the Bay. For example, the average salinity of the Bay dropped from 26.1 to 9.0 during the 1997 floods, reducing the salinity of the Bay from 79 per cent seawater to only 27 per cent seawater.<sup>2,4</sup>

The southern region receives only minor amounts of freshwater from the surrounding watershed. Thus circulation patterns and salinity are regulated by a combination of oceanic and northern-region waters that enter from Central Bay. Since there is no significant freshwater input, the salinity levels are usually higher and more uniform in the southern region. However, as in the above example, salinity in the southern region can be altered by large floods in the northern region.<sup>2</sup>

The water temperature of the Bay varies geographically and seasonally, ranging from 10 to 20 °C. During the summer, water in the northern region is usually warmer than the ocean, due to atmospheric heating and river input, whereas in winter the Bay is usually cooler than the ocean. The water temperature of the southern region is intermediate between the ocean and river temperatures.<sup>2</sup>

## < Surrounding environment >

### Wetlands

Before human intervention in the 1800's, the Bay was surrounded by extensive tidal mudflats and marshlands. Since then, to fulfill the human needs approximately 800 km<sup>2</sup> of these natural wetlands have been artificially filled, diked, drained and converted into diked marshes, agricultural land, salt ponds and urban land. Nowadays less than 20 per cent of the original wetland remains in its original state.

Currently, wetlands are distributed in parts of South Bay, San Pablo Bay and Suisun Bay, totaling to approximately 1,000 km<sup>2</sup>. North of Suisun Bay lies the Suisun Marsh. It is the largest wetland in California, with an area of about 280 km<sup>2</sup>. The area is dominated by diked salt and brackish marshes. In South Bay, intertidal mudflats, salt ponds, and seasonal wetlands predominate. In San Pablo Bay, intertidal mudflats and agricultural wetlands are most common.<sup>2,3</sup>

Although these wetlands are largely artificial, they still support a wide range of plant and animal life and provide valuable open space and recreational opportunities. Over 480 km<sup>2</sup> of these wetlands are protected by governmental and private entities, as parks, recreational areas, wildlife refuges and reserves.<sup>2</sup>



< <http://www.nrdc.org/greengate/wildlife/wetlands.html> >

### Wildlife

A wide variety of freshwater, brackish, marine and anadromous fish species are found in the Bay, which is consistent with a brackish environment, totaling more than 130 species. Freshwater species include Threadfin shad, bluegill and carp. Brackish species include delta smelt, starry flounder and yellowfin goby. Marine species include Pacific herring, English sole and white croaker. Anadromous species include Chinook salmon, white sturgeon and striped bass. Many of the fish species in the Bay are endemic.<sup>2</sup>

Marine mammals, such as California sea lion and harbor seals, are also found in the Bay. Sometimes harbor seals come ashore to rest and give birth and are seen in Central Bay and the southern region of South Bay. The population of harbor seals is estimated to be around 700.<sup>5</sup>

The wetlands surrounding the Bay support a vast range of bird species. Over half of the birds that migrate along the Pacific Flyway are known to stop-over to rest and feed.<sup>5</sup>



**Harbor seal**

< <http://www.dfg.ca.gov/watchable/seals.html> >

## History and Culture

San Francisco Bay did not exist twenty thousand years ago. It was formed by the drowning of a large river valley at the end of the last ice age when melting continental ice sheets caused the sea level to rise. About 10,000 years ago, the ocean penetrated the Coast Range through the Golden Gate and began to fill the Bay. The Golden Gate was widened by the powerful tidal currents that still occur today. Over the last 6,000 years, sediment deposition has built mudflats and marshes, creating an amazing and intricate ecosystem. Starting with the 1849 Gold Rush, human use and development in and around the estuary has led to its degradation and the decline of many important native species.

< <http://www.calacademy.org/research/izg/SFBay2K/sfbayfacts.htm> >

## Social Environment

### < Population >

The population of the San Francisco Bay area has increased rapidly, from about 3 million in 1950 to about 7 million in 2000. The catchment area has approximately 10 million people, one-third of California's population. It is expected to reach 12 million by 2005. The population density is high in the counties surrounding South Bay, such as San Francisco, San Mateo and Santa Clara.<sup>2</sup>

### < Land use >

The 12 Bay counties (Alameda, Contra Costa, Marin, Napa, Sacramento, San Francisco, San Joaquin, San Mateo, Santa Clara, Solano, Sonoma and Yolo) in the San Francisco Bay catchment area contain almost 3,600 km<sup>2</sup> of urban land. Of this total, residential development occupies almost 2,400 km<sup>2</sup>, commercial properties and light industry about 600 km<sup>2</sup>, and heavy industry over 640 km<sup>2</sup>. In addition, the region encompasses over 7,200 km<sup>2</sup> of intensive agricultural land and over 15,200 km<sup>2</sup> of other agricultural and rural lands. Until recently, almost all of the people, jobs and housing were located on the flatlands immediately surrounding San Francisco and San Pablo Bays, and in a few major centers along the principal rivers in the Delta. However, during the last two decades, population growth has begun to shift away from these urban centers, following the development of state and interstate highways farther inland. Urbanization of these once rural lands threatens the balance of the estuarine ecosystem by eliminating or modifying sensitive wetlands, altering stream courses and watershed lands, and polluting the waters that flow into the Estuary.<sup>6</sup>

< **Industry** >

Major industries in the Bay region include shipping, tourism, commercial fishing, agriculture and manufacturing. Many of these industries are heavily dependent on the Bay environment.<sup>2</sup>

**Shipping**

The Bay is a major west coast shipping center, with millions of tons of cargo passing through the Golden Gate each year. There are six public ports in the Bay, and the annual tonnage handled at these ports has increased at a dramatic rate over the past decades. In contrast, the number of ships arriving has decreased because of the trend towards large ships. This, in turn, has increased the need for more frequent dredging.<sup>2</sup>

**Fisheries**

The Bay supports commercial bait shrimp, herring, and dungeness crab fisheries and is the only commercial urban fishery in the nation. The herring fishery is, by far, the largest commercial fishery in the Bay with landings of around 4,000 tons per year over the past ten years. Herring are mostly fished for their high priced eggs that are exported to the Japanese market.

< [http://www.bay.org/about\\_the\\_bay.htm](http://www.bay.org/about_the_bay.htm) >

< [http://www.dfg.ca.gov/mrd/herring/sf\\_bay.html](http://www.dfg.ca.gov/mrd/herring/sf_bay.html) >

**Tourism**

The Bay region is famous for its scenic beauty and attracts millions of tourists every year. The most popular tourist attractions are closely tied to the Bay's scenic values and productivity - the Golden Gate Bridge and Fisherman's Wharf.<sup>2</sup>

**Manufacturing**

Salt production is perhaps the most visible industrial activity in the Bay, with over 145 km<sup>2</sup> of land converted into salt ponds, primarily in South Bay. In recent years, approximately 1.3 million tons of salt have been produced annually.<sup>2</sup>

Other major industries include the production and refining of petroleum and high-tech computer manufacturing.<sup>7</sup>



**Golden Gate Bridge**

< <http://elib.cs.berkeley.edu/photos/> >

***Environmental Problems***< **Water and sediment quality** >

While the pollution levels of some contaminants have been reduced from peak levels of earlier decades, high levels of certain pollutants are still prevalent in some areas. Major sources of pollution are municipal wastewater, industrial facilities, urban runoff, rural runoff, pesticides from agriculture and other human activities.<sup>1</sup>

**Water Quality**

According to a survey conducted by the San Francisco Estuary Institute in 2001, the biggest concerns regarding water quality in the Bay are over the concentrations of mercury, PCBs, pesticides and PAHs. These contaminants were frequently detected in the Bay above their regulated levels. Overall, contamination levels were high in the lower South Bay, Petaluma River mouth and San Pablo Bay. Contamination levels in Central Bay were low, primarily due to mixing with relatively clean ocean water.<sup>1,4</sup>

Mercury concentration is high near the mouth of Guadalupe River of South Bay (maximum concentration of 0.15 µg/L) and Petaluma River of San Pablo Bay. The high mercury concentration in Guadalupe River is thought to be due to the historic mining in the upper watershed. Also, bioassays of striped bass showed that

mercury concentrations have not changed much since the 1970s, indicating that high mercury levels are persistent in the food web as well.<sup>1</sup>

The total PCB concentration is especially high at the southern end of South Bay, with values of 6,500 pg/L measured in Guadalupe River in 2001.

< [http://www.sfei.org/rmp/2001/RMP\\_2001\\_water.pdf](http://www.sfei.org/rmp/2001/RMP_2001_water.pdf) >

### **Sedimentation**

Much of the Bay's sediment is contaminated and is likely to remain so for many years. The most common contaminants are pesticides, such as chlordanes and DDT's, and trace elements, including arsenic, chromium, copper, nickel and mercury. Major contaminant sites are in the lower South Bay, the Petaluma and Napa River mouths, San Pablo Bay and Grizzly Bay.<sup>4</sup>

### < **Other Environmental Problems** >

#### **Decline of biological resources**

There are currently 105 federally-listed endangered or threatened plant and animal species in the Bay-Delta area. The list includes 11 fish species, including winter-run Chinook salmon, delta smelt and splittail. The primary factors that have driven these species towards extinction are habitat loss through development, introduction of invasive species, water diversions, agriculture and water pollution. For example, dam construction has drastically reduced spawning populations of Chinook salmon by blocking their upstream migration route. Its spawning population in the Bay's tributaries has declined by nearly 70 percent, compared to levels in the early 1900s.<sup>2</sup>



**Female Chinook salmon**

< <http://www.pac.dfo-mpo.gc.ca/ops/fm/Salmon/chinook.htm> >

< <http://www.nrdc.org/greengate/wildlife/salmonf.asp> >

#### **Introduced species**

Many of the benthic species in the Bay are either accidentally or intentionally introduced. During the past 140 years, more than 100 introduced species have become established. Most of the large invertebrates in the Bay's shallows are now dominated by introduced species. Species of great concern are the green crab, Chinese mitten crab and Asian clam. Green crabs have reduced the abundance of 20 invertebrate species, including native species. Chinese mitten crabs have clogged power-plant cooling systems and are thought to weaken levees and banks through burrowing. The Asian clam is now the dominant benthic organism in many parts of the Bay and is suspected of being the main cause for the reduction of zooplankton abundance.<sup>1,2</sup>



**Chinese Mitten Crabs**

< <http://www.nhm.ac.uk/zoology/crab/> >

### < **Environmental Protection Measures** >

#### **Comprehensive Conservation and Management Plan (CCMP)**

Growing public concern for the health of the Bay and Delta led the U.S. Environmental Protection Agency (U.S. EPA) to establish the San Francisco Estuary Project (SFEP) in 1987. The SFEP, part of the U.S. EPA's National Estuary Program, is a five-year cooperative effort to promote more effective management of the San Francisco Bay-Delta Estuary and to restore and maintain the Estuary's water quality and natural resources. The Project is jointly sponsored by the U.S. EPA and the State of California.<sup>7</sup>

In order to prepare a management plan for the Bay and Delta, the Project brought together over one hundred representatives from the private and public sectors, including government, industry, business and environmental interests, as well as elected officials from all 12 Bay-Delta counties. After five years, the

Project's cooperative public-private partnership reached its goal of developing a Comprehensive Conservation and Management Plan (CCMP) for the Bay and Delta. The CCMP was implemented in 1993 after gaining approval from the EPA. The CCMP primarily focuses on the following five key management issues.<sup>7</sup>

- Intensified Land Use
- Decline of Biological Resources
- Freshwater Diversion and Altered Flow Regime
- Increased Pollutants
- Dredging and Waterway Modification

### **Regional Monitoring**

In the San Francisco Bay-Delta Estuary, more than 70 estuary monitoring programs are being conducted for a number of diverse applications, such as the number and health of the fish residing in the Estuary, the quality and quantity of fresh-water flowing into the Estuary system, and the types and amounts of pollutants. These monitoring programs are centered on the five key management issues identified in the CCMP.<sup>7</sup>

### **Related organizations and NGOs**

- San Francisco Bay Conservation and Development Commission - California state commission charged with the protection and enhancement of San Francisco Bay < <http://www.bcdc.ca.gov/index.html> >
- Friends of the San Francisco Estuary - Non profit California cooperation dedicated to protecting the San Francisco Bay-Delta Estuary < <http://www.abag.ca.gov/bayarea/sfep/about/friends.html> >
- San Francisco Estuary Institute - NPO dedicated to the scientific understanding of the Bay < <http://www.sfei.org/> >
- Natural Resources Defense Council - National environmental organization dedicated to protecting the environment < <http://www.nrdc.org/greengate/default.asp> >
- Save San Francisco Bay Association - Seeks to preserve, restore and protect the San Francisco Bay and Sacramento/San Joaquin Delta Estuary < <http://www.savesfbay.org/> >
- Audubon's San Francisco Bay Restoration Program - Dedicated in protecting the fish and wildlife populations and water quality < <http://www.audubonsfbay.org/> >

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