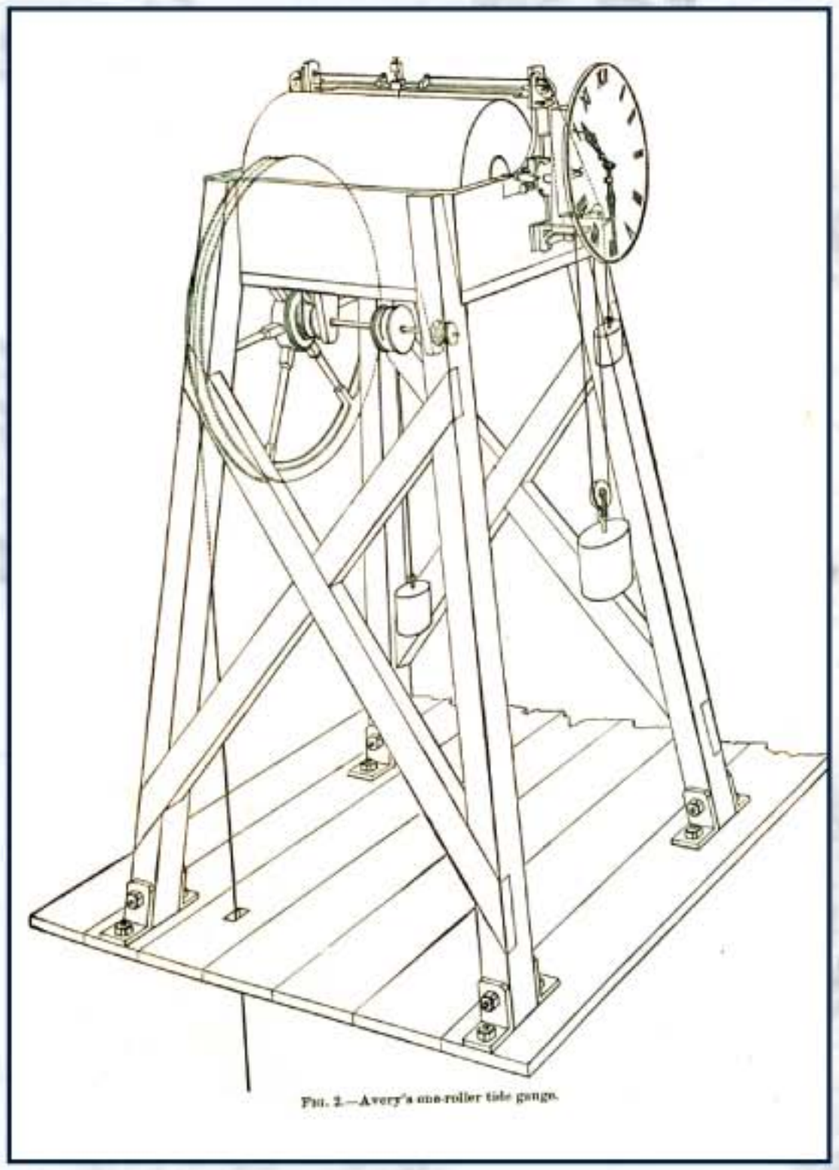
# Recording the Tides in San Francisco Bay

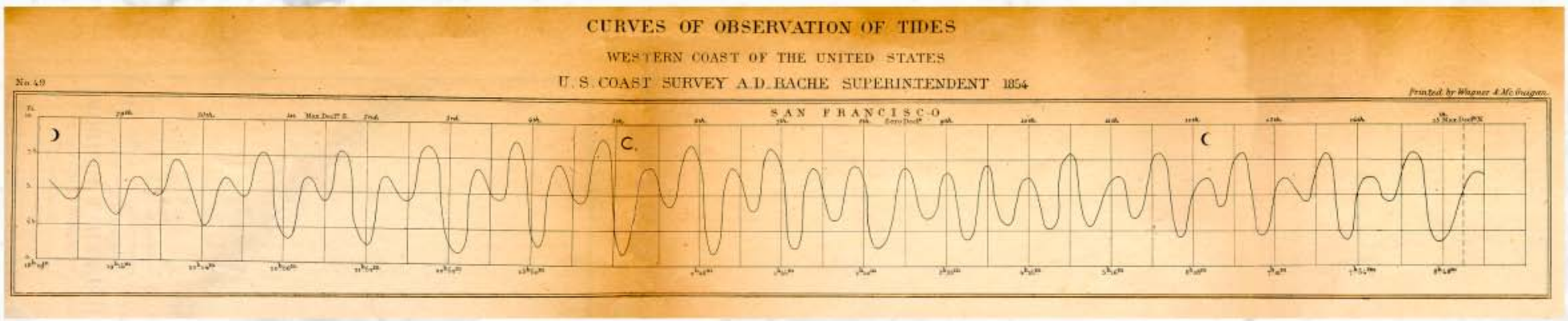
- What are Tides?
- Why Are Tide Records Important?
- Tide Gauges Past and Present
- Nautical Charts—Why Are They Important?
- Charting the West Coast
- Sea Level Rise
- El Niño and Tsunamis

# Recording the Tides in San Francisco Bay




A U.S. Coast Survey recording tide gauge was installed at Rincon Point in San Francisco on June 30, 1854.

Since that day, tide gauges at San Francisco have provided the longest unbroken tide record in the Western Hemisphere.




Tide gauge readout from 1854

Safely navigating the Bay requires accurate tide records.

Biologists depend on tide records for wetlands restoration projects.

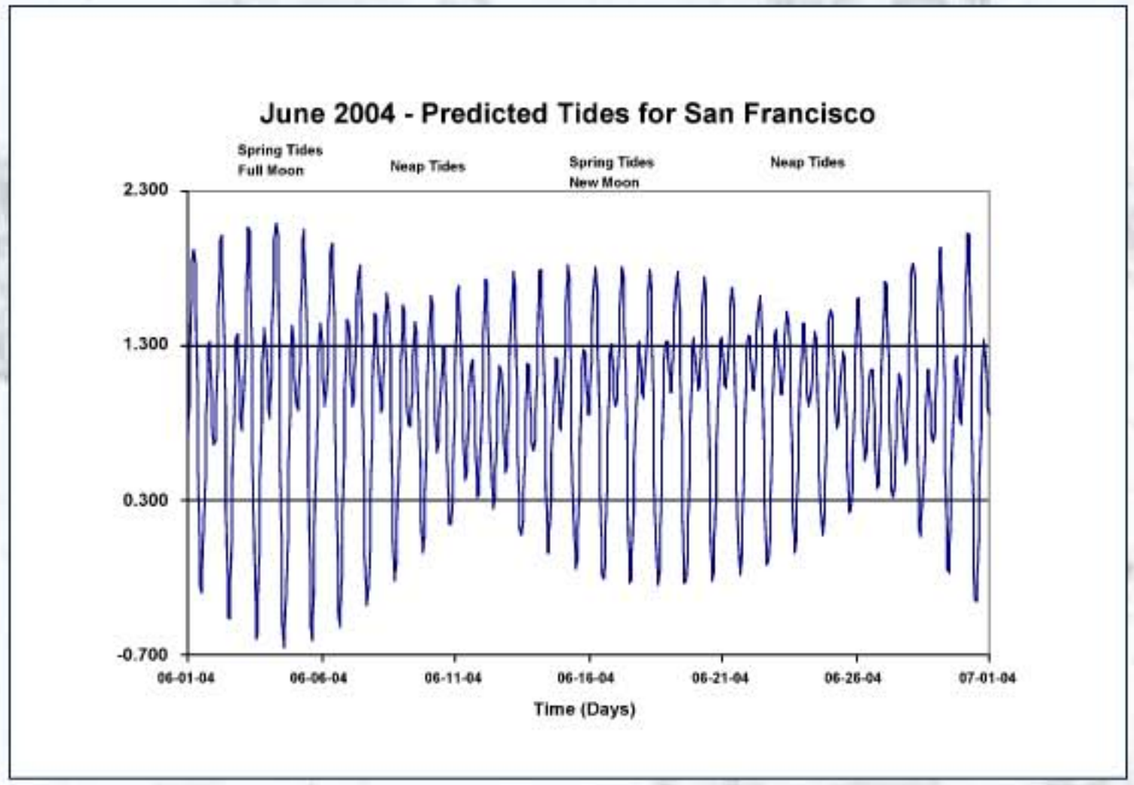
Accurate tide records are important for many reasons. They help keep big ships and small craft safe. They help engineers design coastal construction projects and biologists plan wetland restoration sites. They provide a record of natural phenomena such as earthquakes and tsunamis. And they give proof that world sea levels have been rising over the last century.

- **What Are Tides?**
- **Why Are Tide Records Important?**
- **Tide Gauges Past and Present**

# What are Tides?

Tides are the regular rise and fall of the sea.

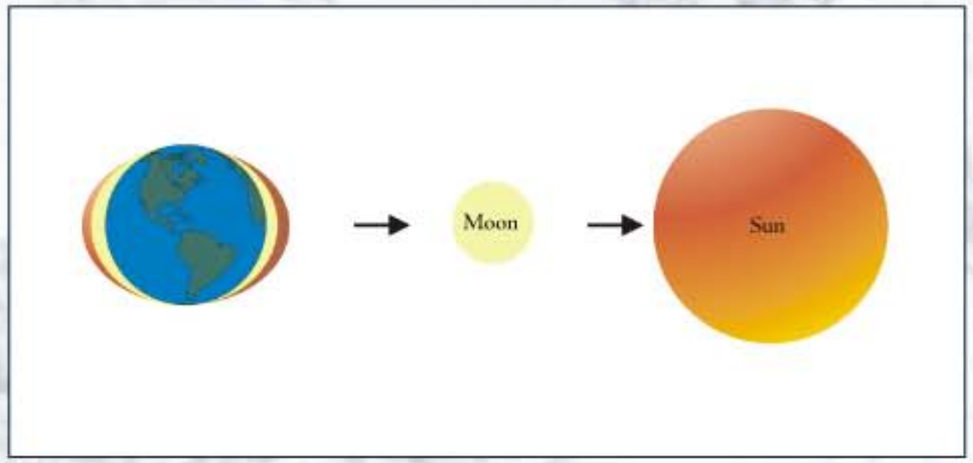
Tides are caused by the combined influences of the moon's gravity and the sun's gravity on the earth and its oceans.




In most places on earth, the tides go in and out every 12.42 hours—a little more than twice a day.

When the tide is rising,
it is called a **flood tide**.

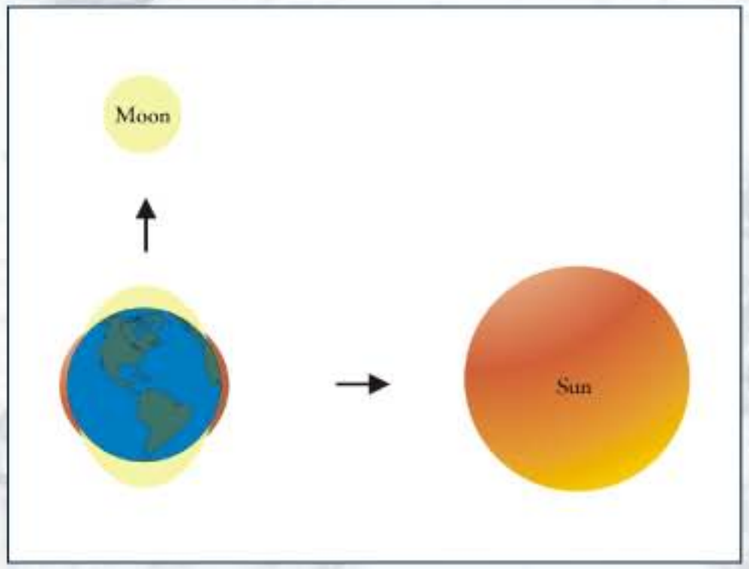
When falling, it is called
an **ebb tide**.




Spring Tides

Tides are at their most extreme —highest and lowest— during full and new moons, when the moon and sun are in a straight line with the earth and their combined gravity fields are strongest. These extreme tides are called spring tides.

The rotation of the earth causes a "bulge" on both sides – the water "swings" with the motion of the earth.

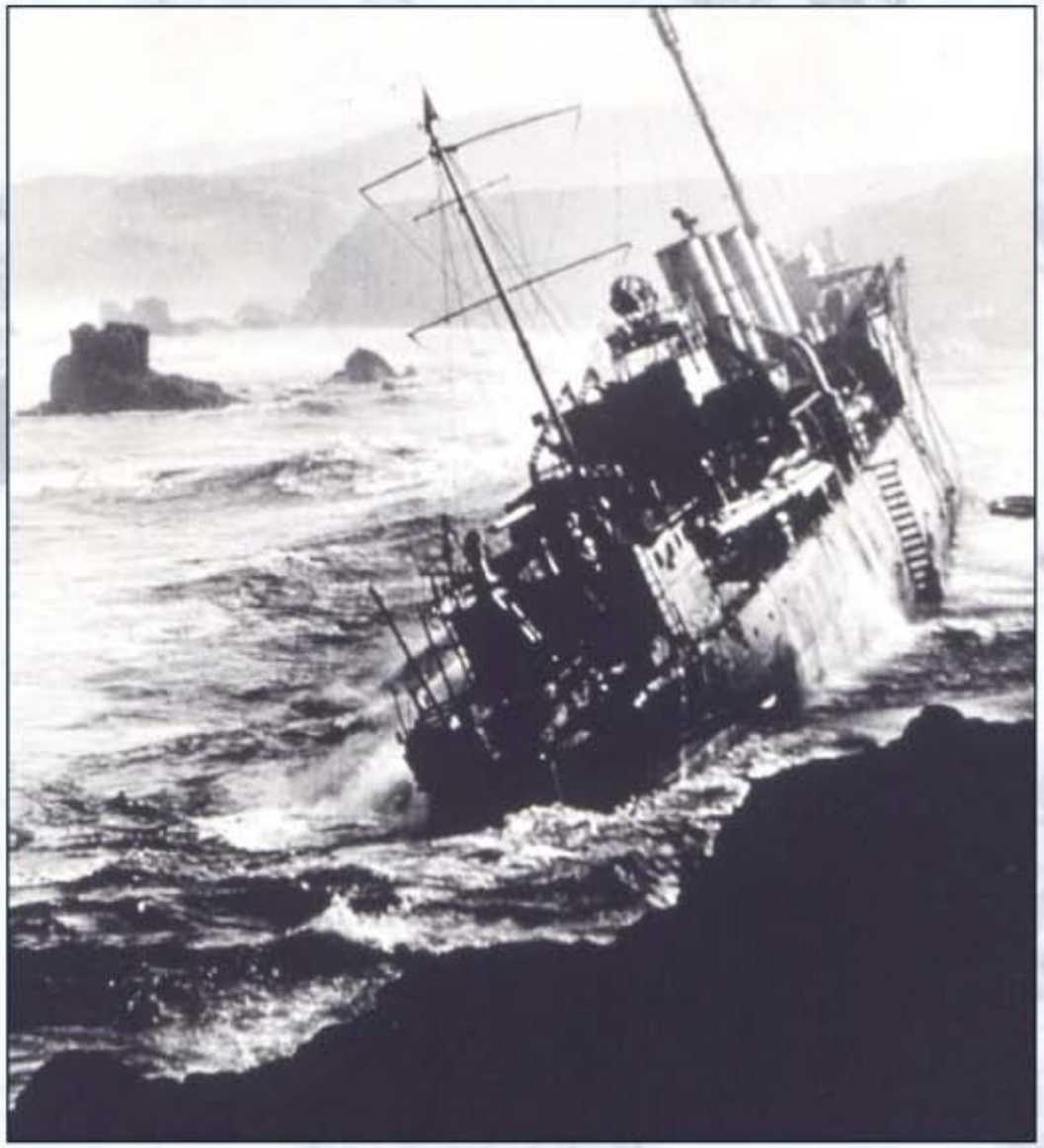



Neap Tides

Less extreme tides occur during half moons. These are called neap tides.

- **Why Are Tide Records Important?**
- **Tide Gauges Past and Present**

# Why Are Tide Records Important?



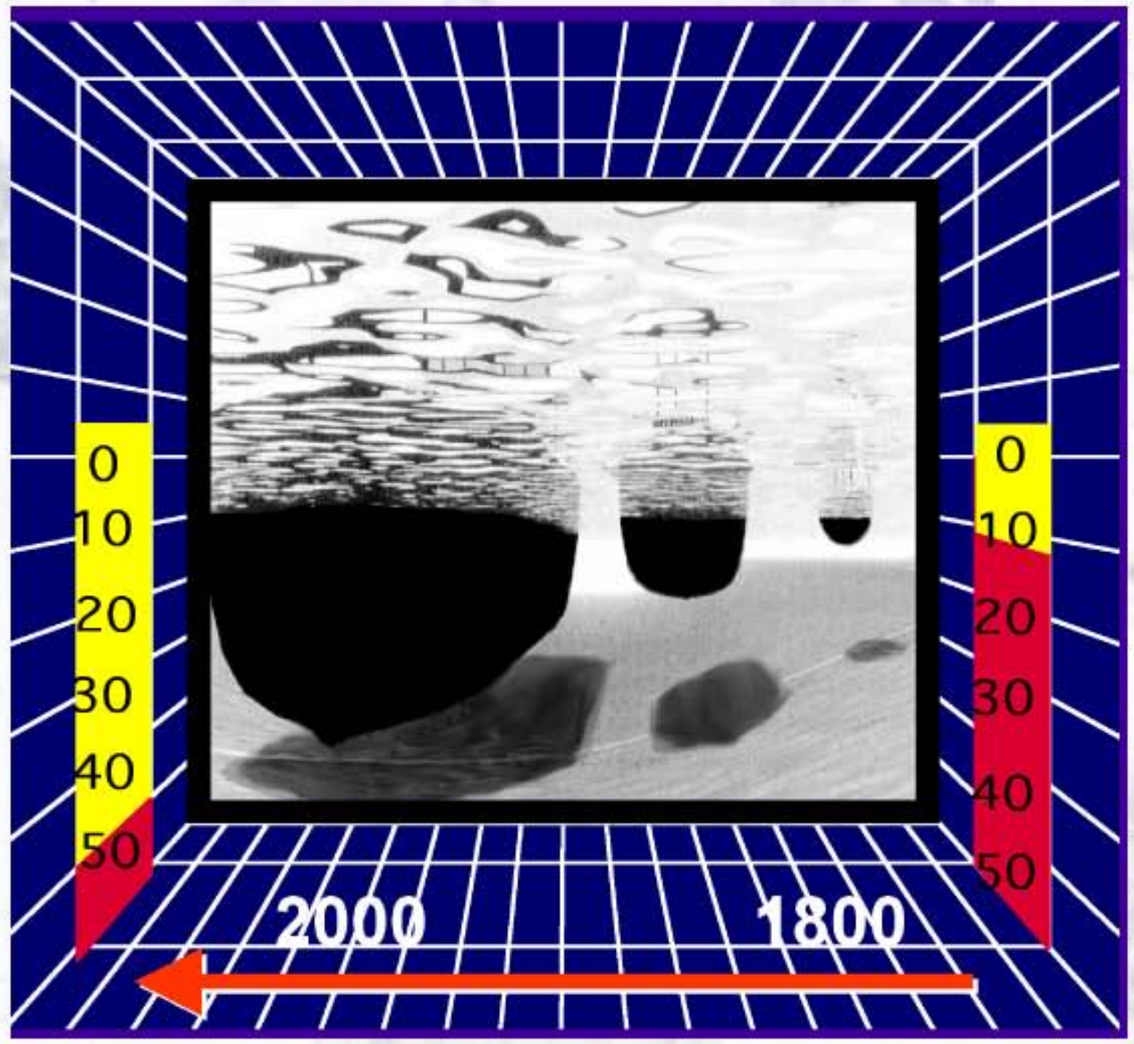
In a word, safety.

The tidal currents are visible as "chop" in this photo of a hazy day on San Francisco Bay.

In San Francisco Bay, rising and falling tides cause strong water currents to rush in and out of the Golden Gate.

In the days of sail, ship captains depended upon tide predictions to tell them when they could ride these currents in and out of port.

Today, small motorized craft and sailboats need tide information for the same reason.




Today's ships have a radically deeper draft than earlier vessels.

Today's huge tankers and freighters sit very deeply in the water. In some ports, they clear the bottom by a foot or less.

In a port like San Francisco Bay, tides raise and lower the depth of the water several feet in a day, increasing the chance that even a minor error in navigation could run a ship aground.

A large container ship can only travel along a narrow channel in the Bay.

Accurate tide information tells harbor pilots and ship captains when shipping channels are deep enough to drive their ships through.

This photo shows giant cranes clearing the San Francisco Bay Bridge by inches. Pilots used real-time tide information to plan this journey under the bridge precisely when the tide was lowest.

Construction of a new wetland.

On shore, tide information is used to help plan coastal construction and wetland restoration projects, as well as to assist emergency managers.

Evacuation route flooded from storm surge.

- **Sea Level Rise**
- **El Niño and Tsunamis**

# Tide Gauges
# Past and Present

Joseph Saxton, inventor

The first tide gauge used in the Americas that automatically made its own printed records was invented in 1851 by Joseph Saxton of the Office of U.S. Weights and Measures.

This was the same type of gauge installed in San Francisco in 1854.

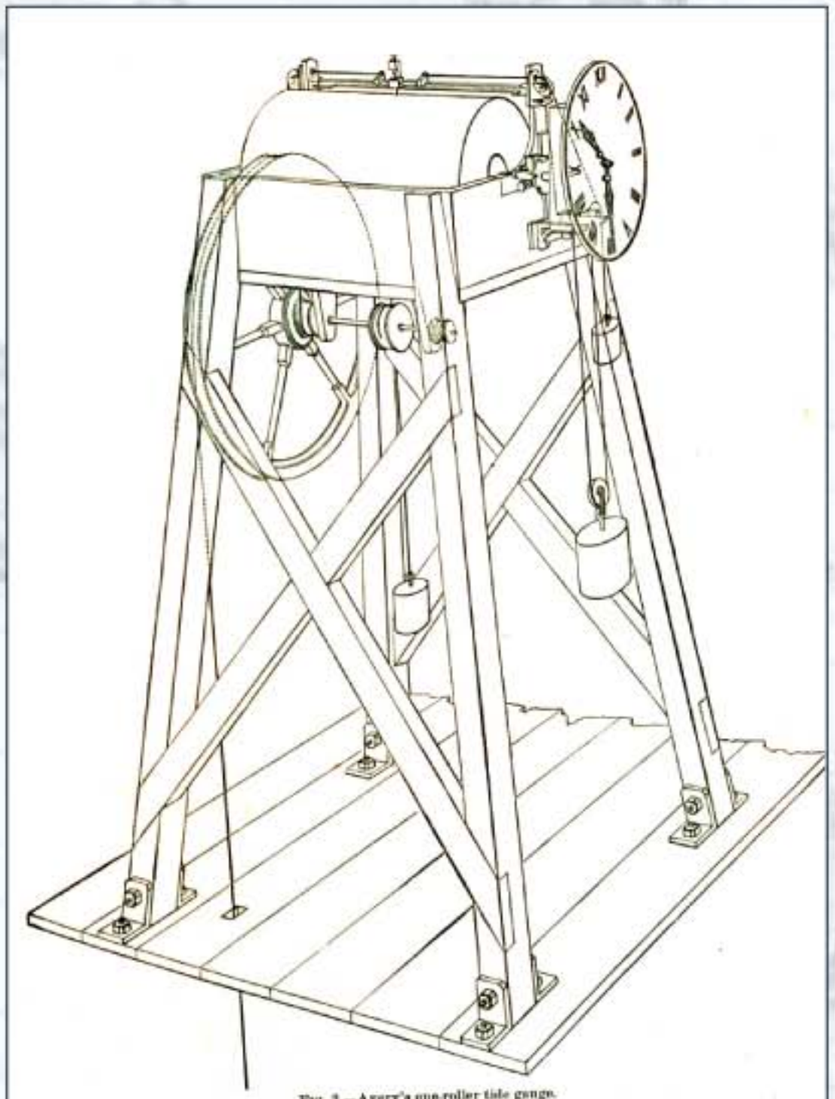
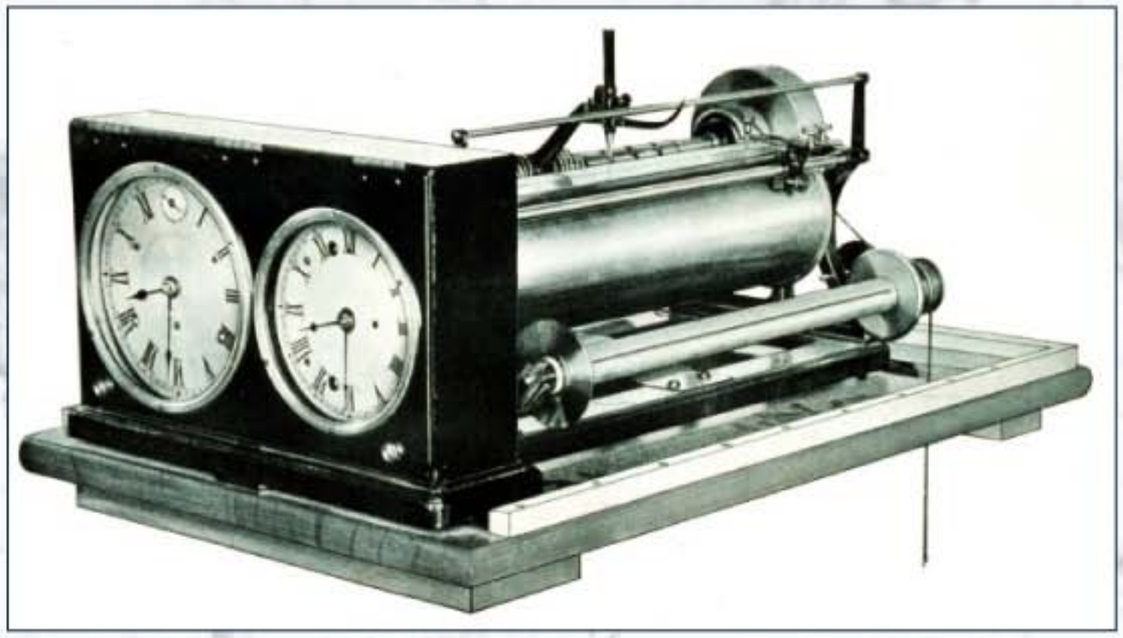
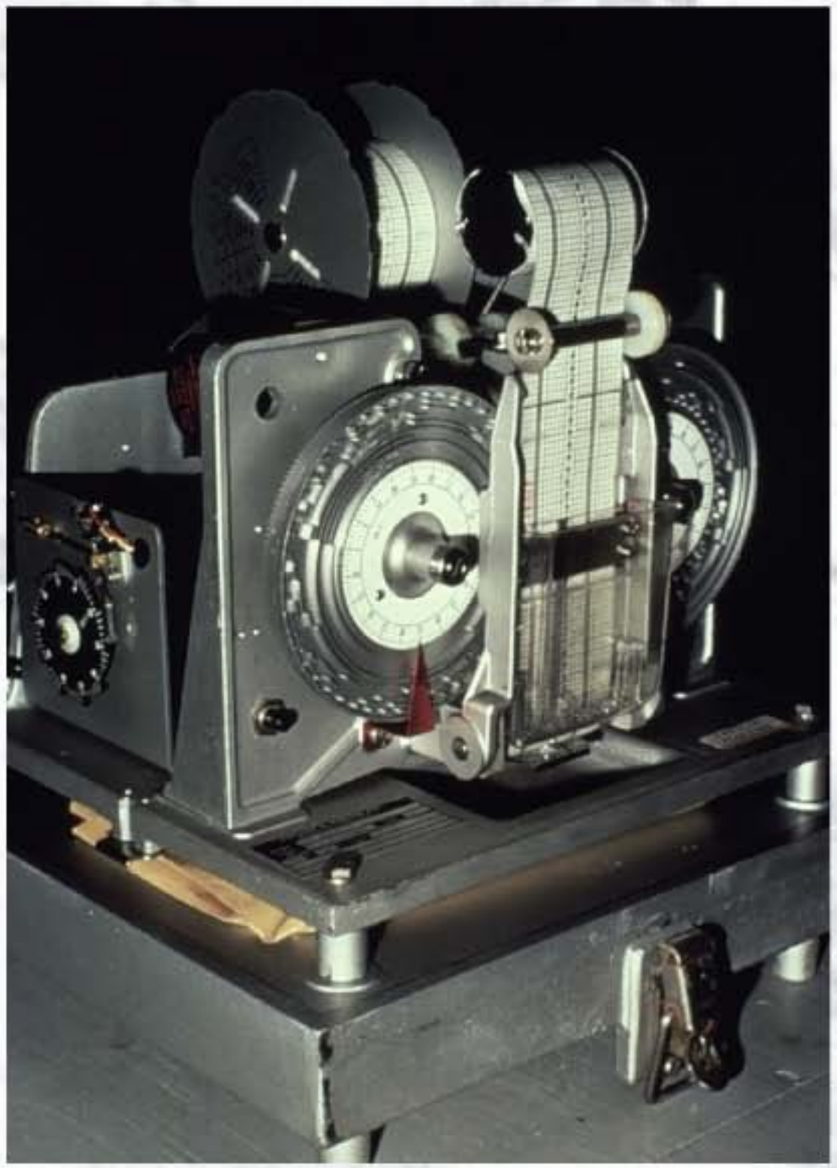


FIG. 2.—Avery's one-roller tide gauge.

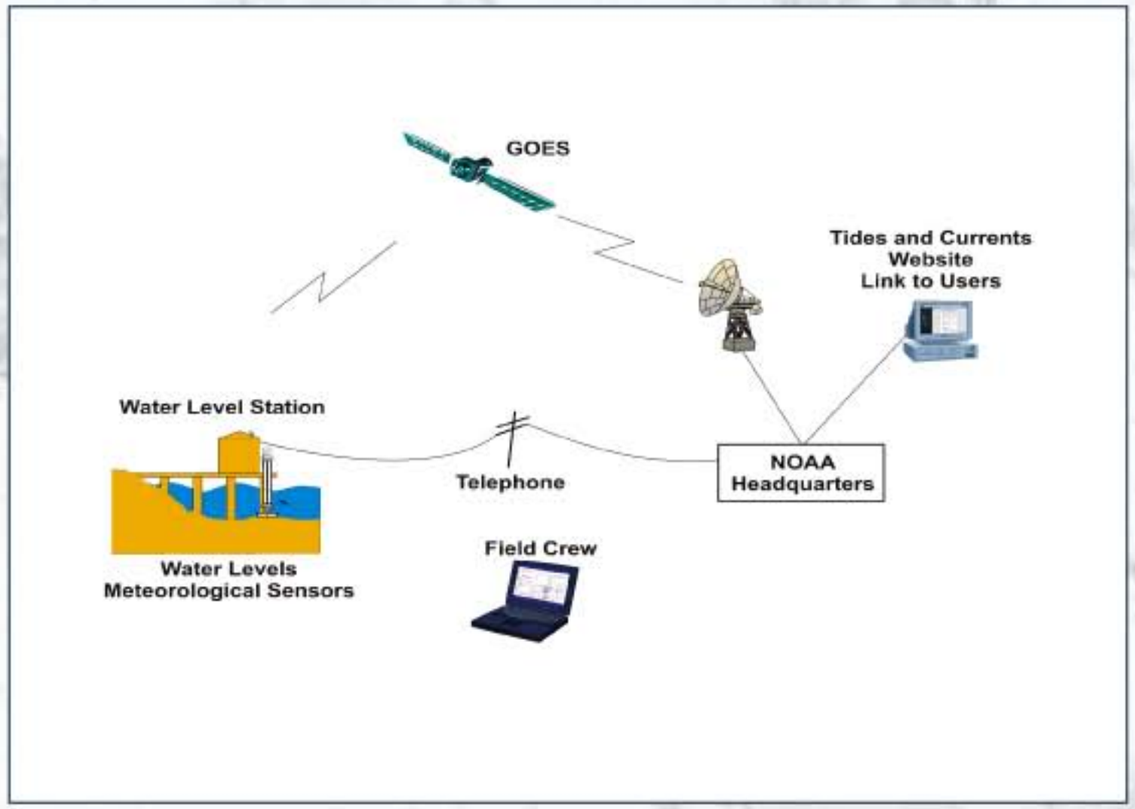
Saxton's gauge used a clock, a rotating drum, and a pencil to record changing water levels. It was used at tide stations around the country for over 40 years.



In the 1890s, it was replaced by the standard automatic tide gauge like the one on display in this exhibit. Invented in 1890, it is a mechanical work of art. A time clock recorded hour marks on a moving paper chart. A motor clock moved the chart.



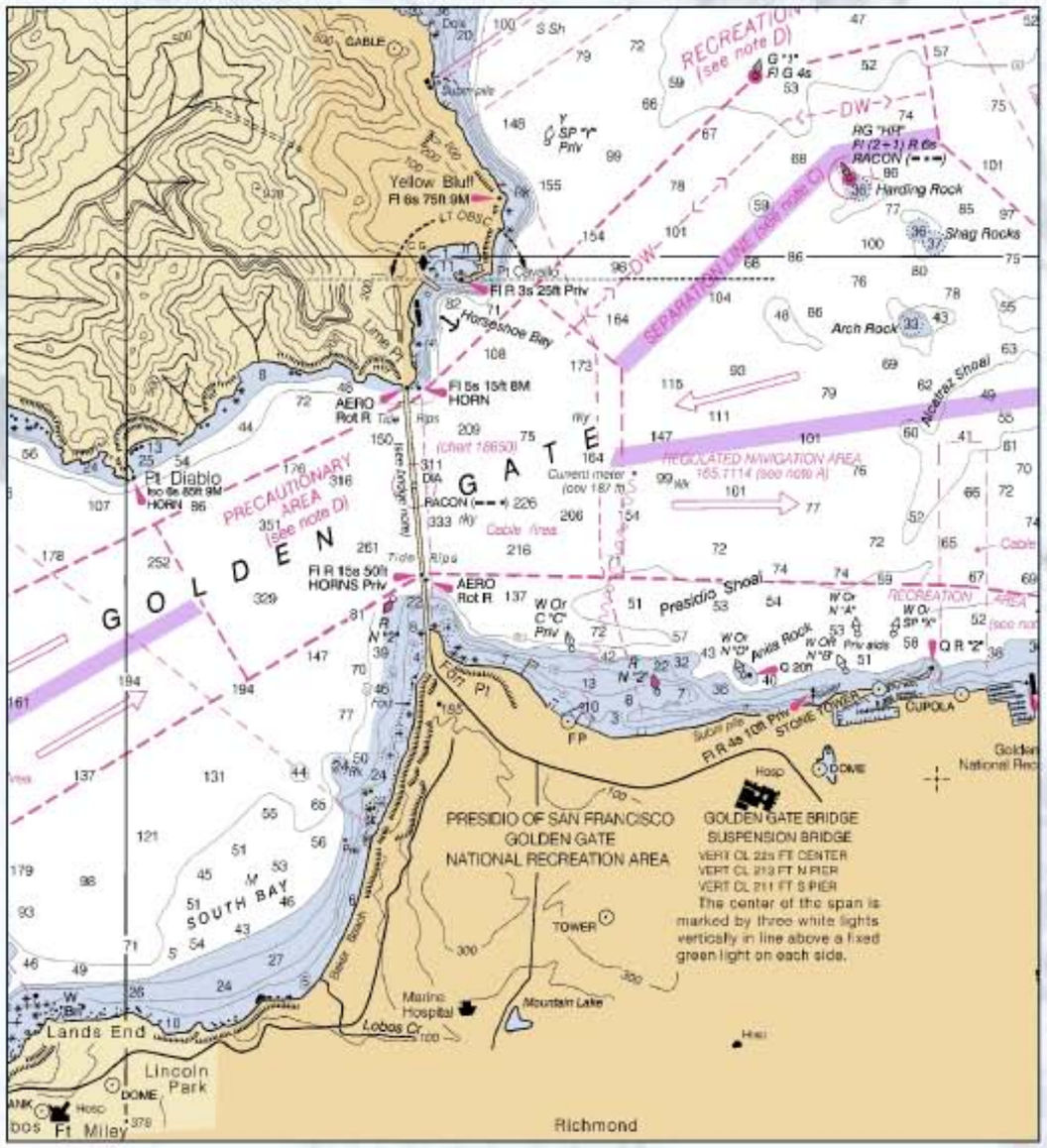
The mechanical punch recorder, or Analog to Digital Recorder (ADR), was brought into service in the 1960s. Every six minutes, a wheel punched holes representing water level in a paper tape. This technology enabled data to be easily fed into computers. The tape was removed every month and mailed to the Washington, D.C. headquarters of the Coast and Geodetic Survey (one of NOAA's predecessor organizations) for computer processing.




Today's tide gauges are part of a nationwide network of self-contained, accurate instruments that need little maintenance. Tide measurements are sent via satellite to NOAA headquarters, analyzed, and posted immediately to a web site, where anyone can see them at **www.tidesandcurrents.noaa.gov**.

- **Nautical Charts —Why Are They Important?**

# Nautical Charts–
# Why Are They Important?



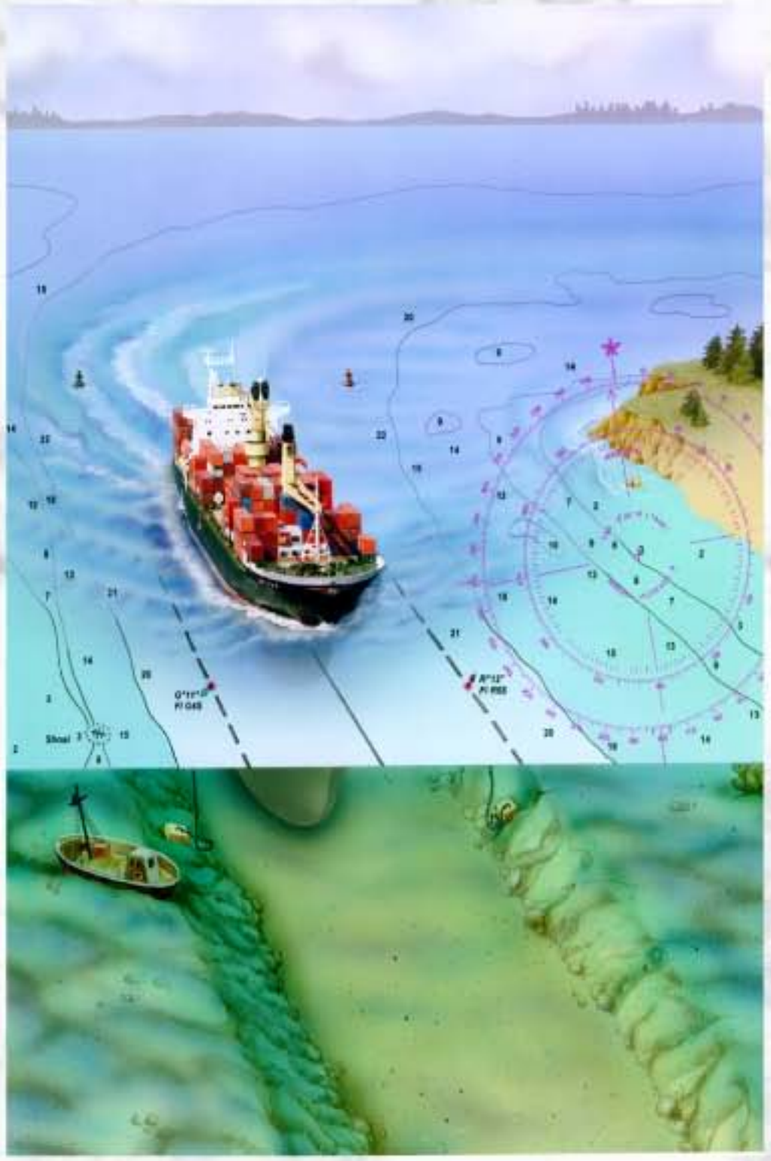

A nautical chart is a map that helps vessels navigate on the water. A chart identifies water depths, channels, landmarks, beacons, buoys, lighthouses, fog signals, and other navigation aids.

Understanding the tides is essential for making and using nautical charts whose depths are based on low tide.

Charts also point out hazards such as rocks, shoals, and shipwrecks.

Why do we need charts?

Because America depends on maritime commerce, and that commerce depends on charts.

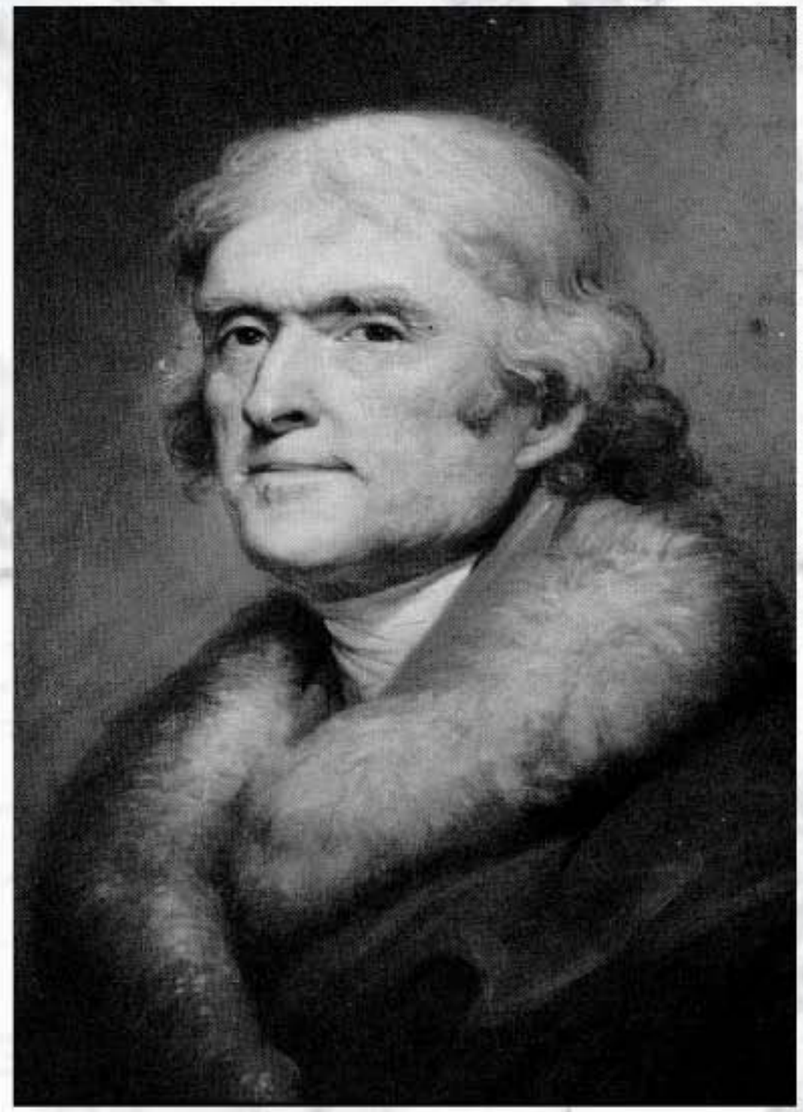


Each month, more than 260 deep draft ships enter the San Francisco Bay.

Almost everything we need and use arrives by ship: food, clothing, appliances, cars, oil. Pilots use charts and tide information to navigate the ships that carry those goods in and out of port safely and efficiently.

- **Charting the West Coast**

# Charting the West Coast



Thomas Jefferson helped to create the U.S. Coast Survey.

In 1807, President Thomas Jefferson signed into law a bill creating the U.S. Coast Survey, whose mission was to "carry out a survey of the coast."

This organization later became the Coast Survey, then the U.S. Coast and Geodetic Survey, then the Coast and Geodetic Survey, and today the National Oceanic and Atmospheric Administration (NOAA).

MORRO ROCK, IN COAST VIEW ACCOMPANYING THE CHART.

Coast Survey charts pointed out dangers such as Morro Rock.

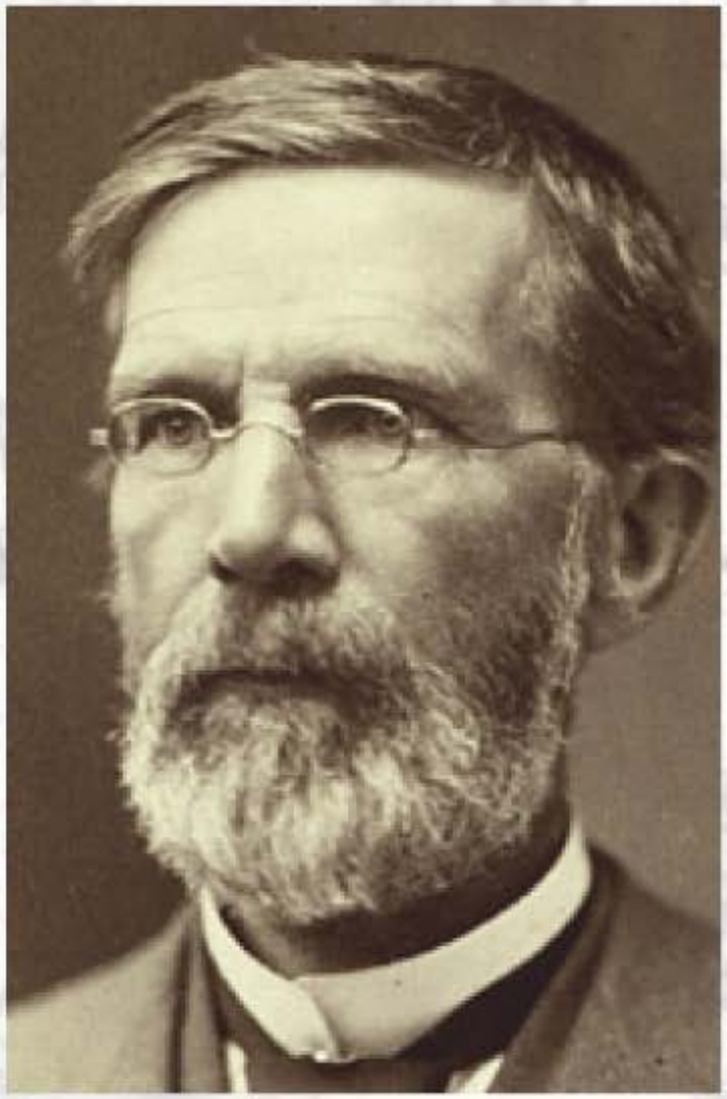
MORRO ROCK, IN COAST SURVEY CHART.

Our young country certainly needed such a survey. Ship captains had to know if there were rocks, sandbars, shipwrecks, or other hazards along our coasts that might put their ships in danger.

Before cameras, artists had to sketch the perils of the coast for mariners.

Surveyors, artists, hydrographers, and tide observers gathered information about a section of the coast and sent letters and sketches to Coast Survey headquarters in Washington, D.C.

The first survey of the rocky, fog-bound coast of California was carried out in 1852 by the Coast Survey Steamer *Active*, Lt. James Alden commanding. Lead lines were used to measure the depth to the sea bottom, but often missed large rocks and other obstructions.



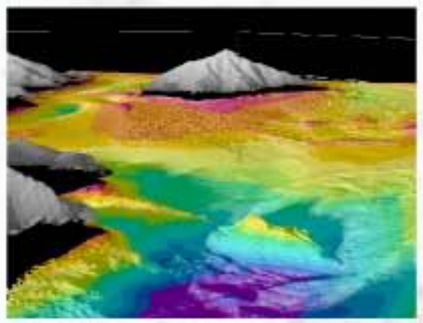
George Davidson, surveyor & scientist

Much of the difficult survey work was done by George Davidson (1825-1911), who would go on to have a long career as a prominent scientist in California. Mount Davidson in San Francisco and the underwater Davidson Seamount south-west of Monterey are named for him.

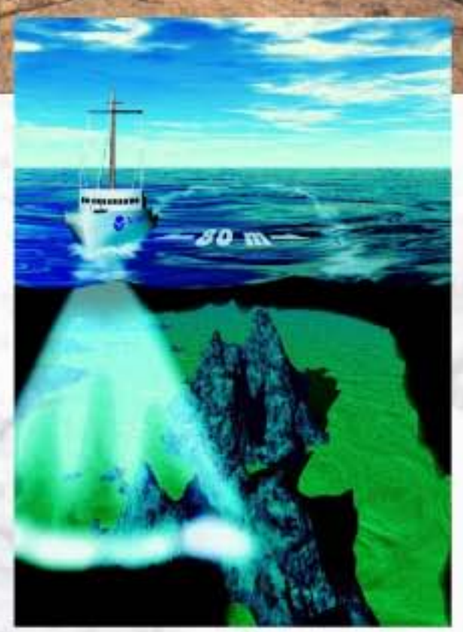
It was important to survey the shore as well as the sea, in order to determine correct elevations and positions of land features. Mariners used land features to navigate by, and a small error could be fatal. Drawing the shoreline accurately on a chart was a slow, difficult process.

multi-beam scanning

Today, precise chart information is gathered electronically through multi-beam and side scan sonar systems, Global Position System (GPS) satellite data, and other methods.



3D imaging

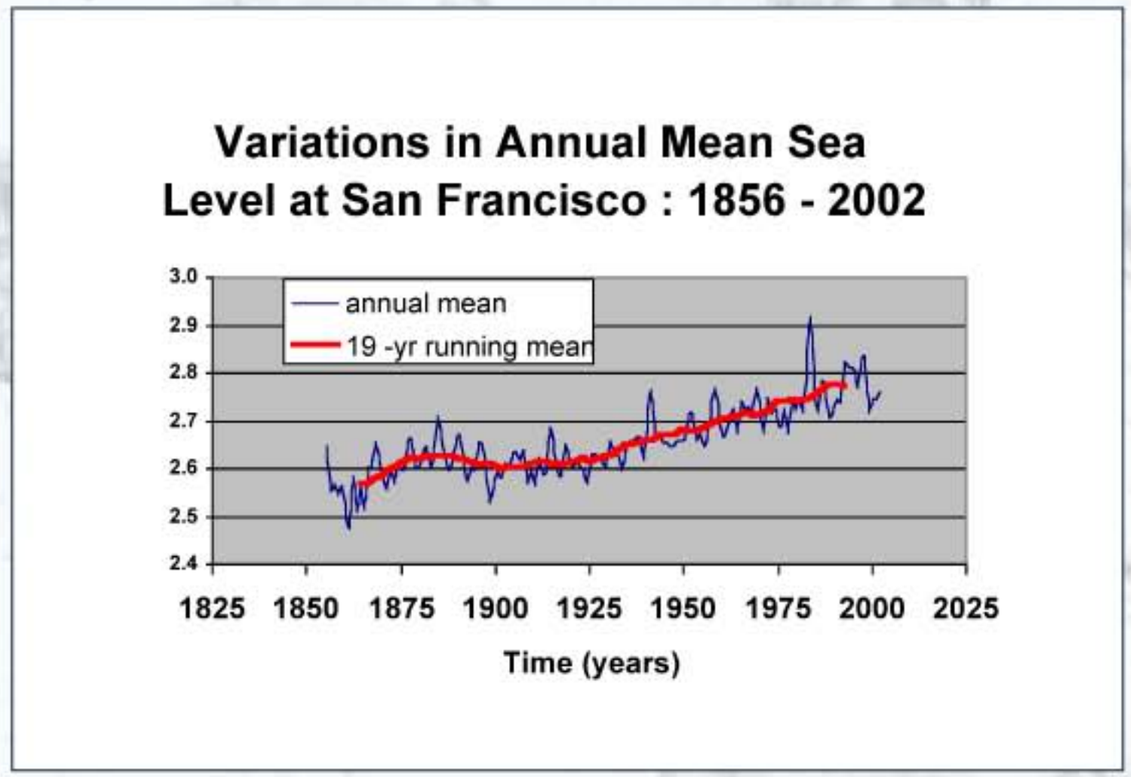



sonar scanning

- **Sea Level Rise**

# Sea Level Rise

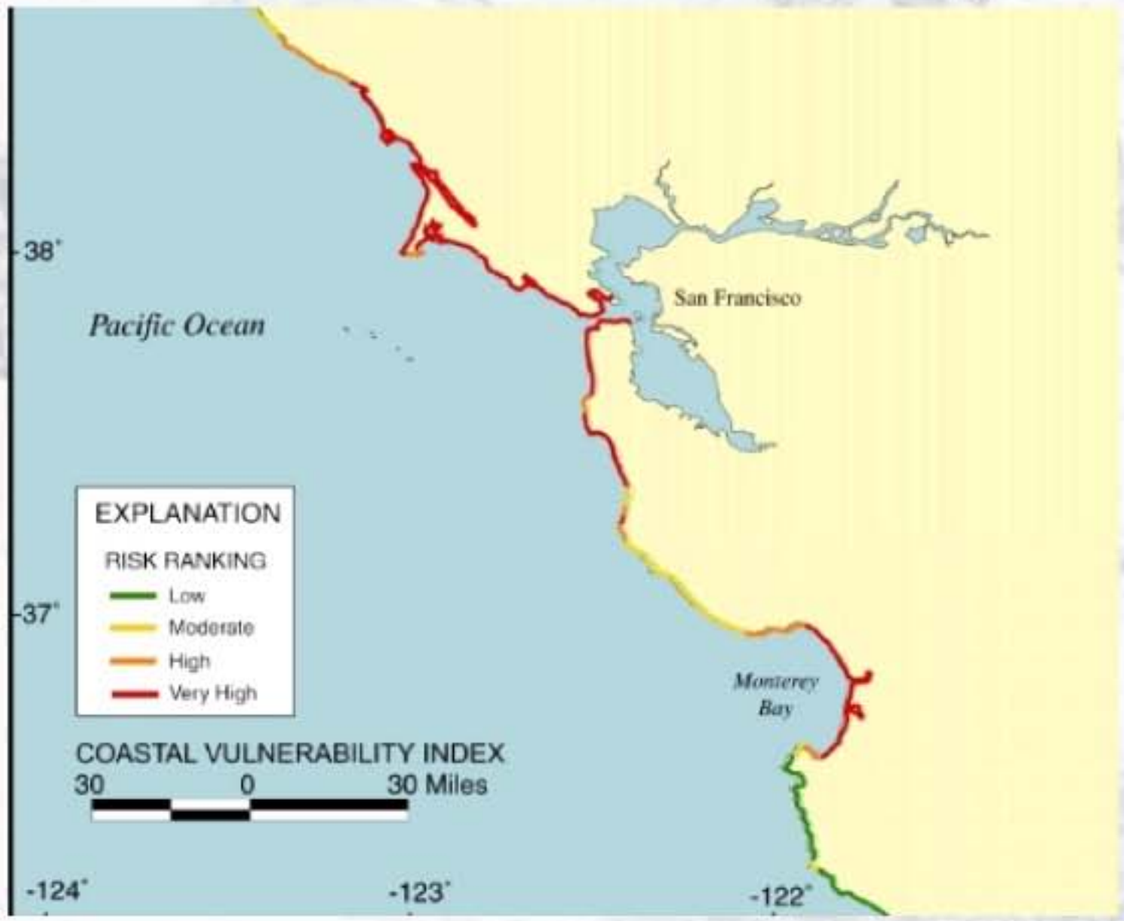
San Francisco has the longest unbroken tide record in the Western Hemisphere, dating back to June 30, 1854. This huge mass of data reveals something very interesting about sea level: it has been rising since 1900.




As measured at San Francisco, the ocean level has been rising at a rate of 2.13 millimeters a year, or over eight inches per century.

More coastal areas will see increased damage due to storm surges during severe storms.

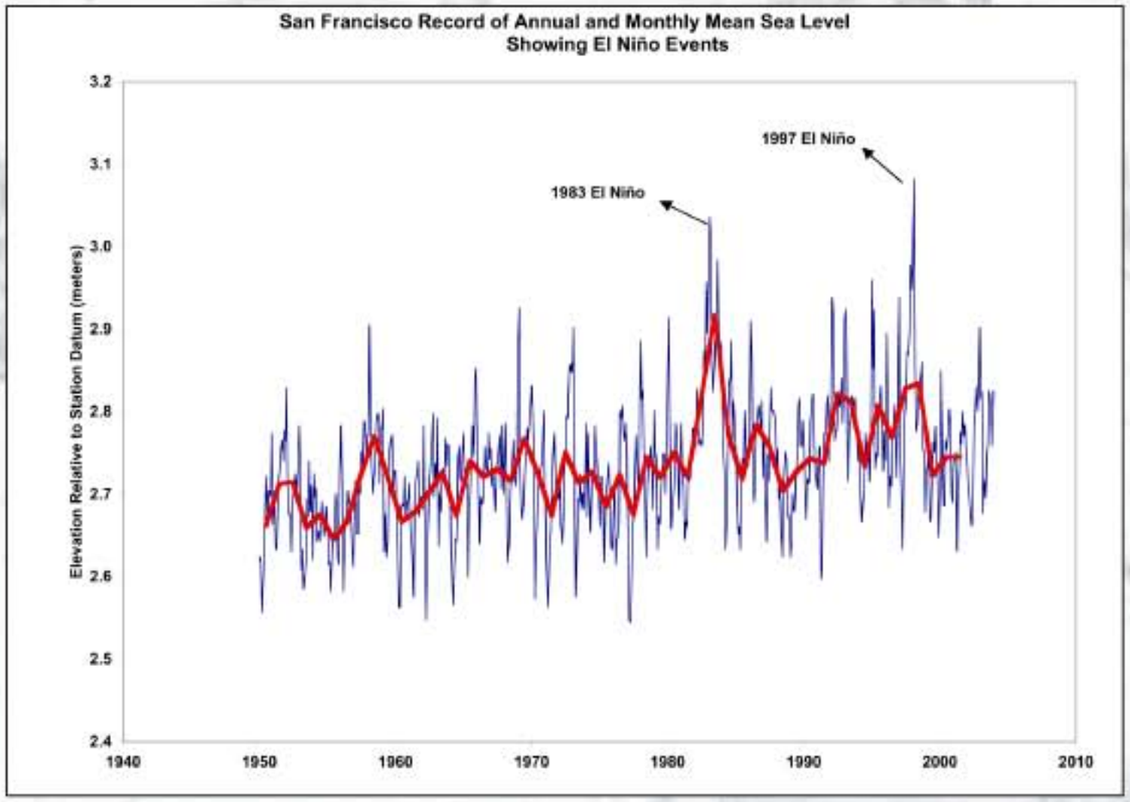
This rise might be significant. If it continues, coastal erosion will increase. Engineering works such as bridges and wharves will have to be rebuilt or modified. Wetlands, and the creatures that live in them, will be threatened. Low-lying islands will be submerged.




The central coast of California is especially vulnerable to sea level rise. Coastal erosion is already a serious problem in many communities.

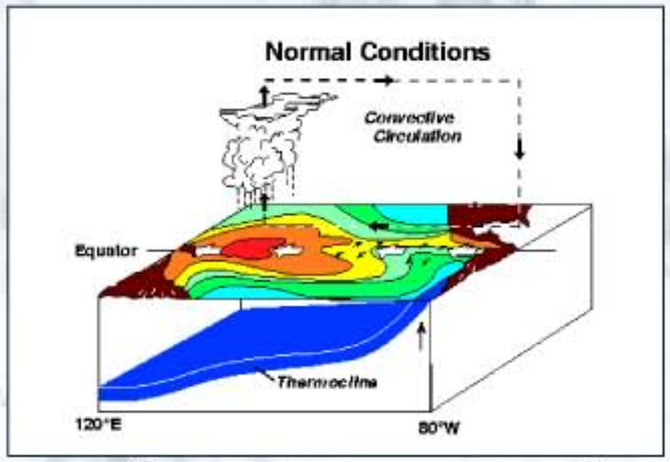
- **El Niño and Tsunamis**

# El Niño and Tsunamis

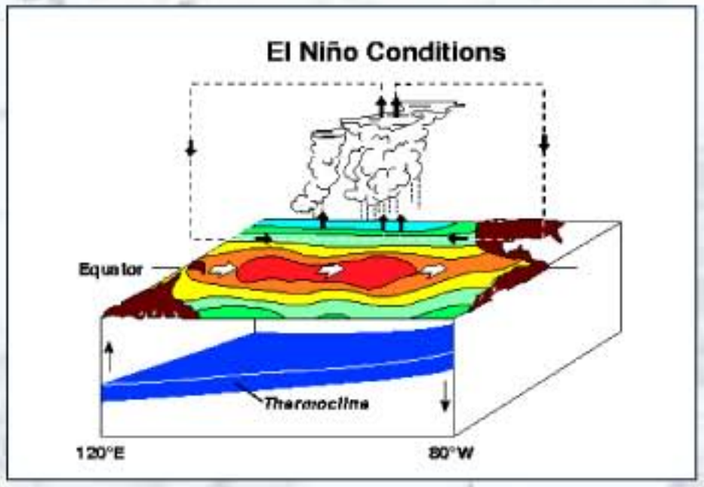



El Niño events appear as spikes in the tide records.

San Francisco's long tide record helps us measure a major natural phenomenon: El Niño.



sea surface temperature: normal



sea surface temperature: high

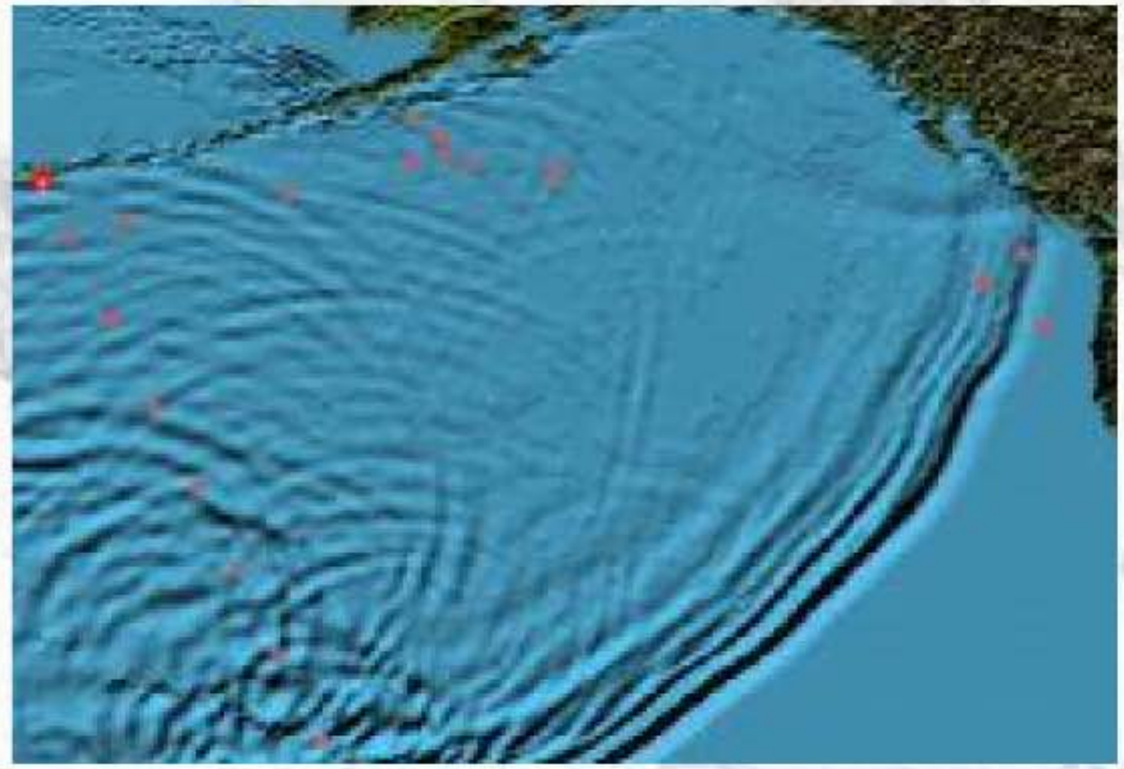
Every two to seven years, for reasons we don't yet completely understand, the surface of the western Pacific ocean gets warmer than normal. The heat causes the water to expand, and Pacific sea levels rise slightly. This rise is recorded in the San Francisco tide observations.

High winds, heavy rains, and abnormally high tides wreak havoc in the Bay Area.

In addition, El Niño brings increased storms, which cause greater tides and bigger waves breaking on shore.

A huge wave breaks over the seawall at Fort Point and drenches a parked car during an El Niño event in February 1998.

The tide record also shows us another type of global event: tsunamis.

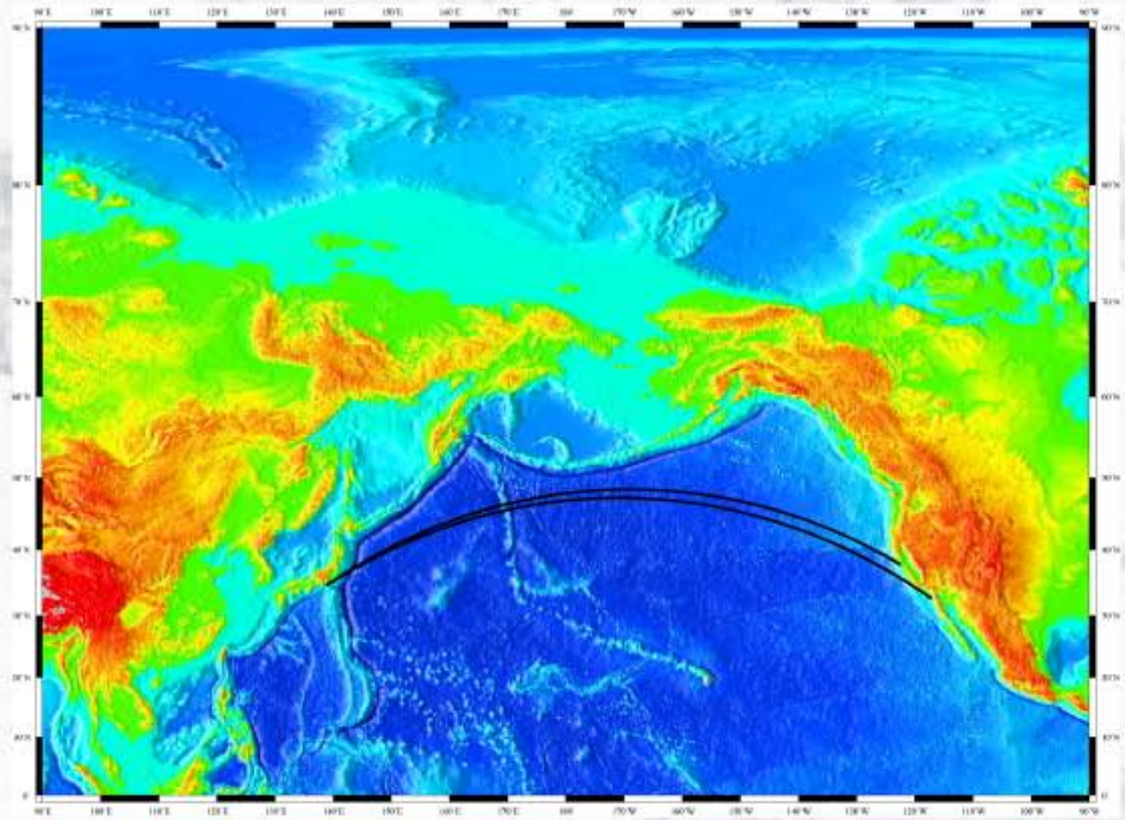


This 3D image shows an enormous swell traveling across the Pacific after a tsunami.

A tsunami, sometimes incorrectly called a tidal wave, is a series of large waves generally caused by an earthquake under the sea or along the shore. At sea, the waves move fast but are not very high. As they approach the shore, they slow down and get higher.

Aftermath of a tsunami.

When they hit the shore, tsunamis can reach as high as 100 feet. In the past, they hit without warning, causing many deaths and immense destruction. Today, we can track them with tide gauges around the world and warn coastal residents. The San Francisco tide gauge is part of the U.S.Tsunami Warning System.



San Francisco's tide gauge has recorded tsunami waves from as far away as Japan.

Over the years, the San Francisco tide gauge has recorded many of the great Pacific Ocean tsunamis—even those that happened thousands of miles away on the other side of the planet. In fact, tsunami waves from an earthquake in Japan in 1854 were recorded by the San Francisco tide gauge and used to make one of the first accurate estimates of the average depth of the Pacific Ocean.

- **Tide Gauges Past and Present**
- **Why Are Tide Records Important?**