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Integrated Natural Resource Science Program

San Francisco Bay

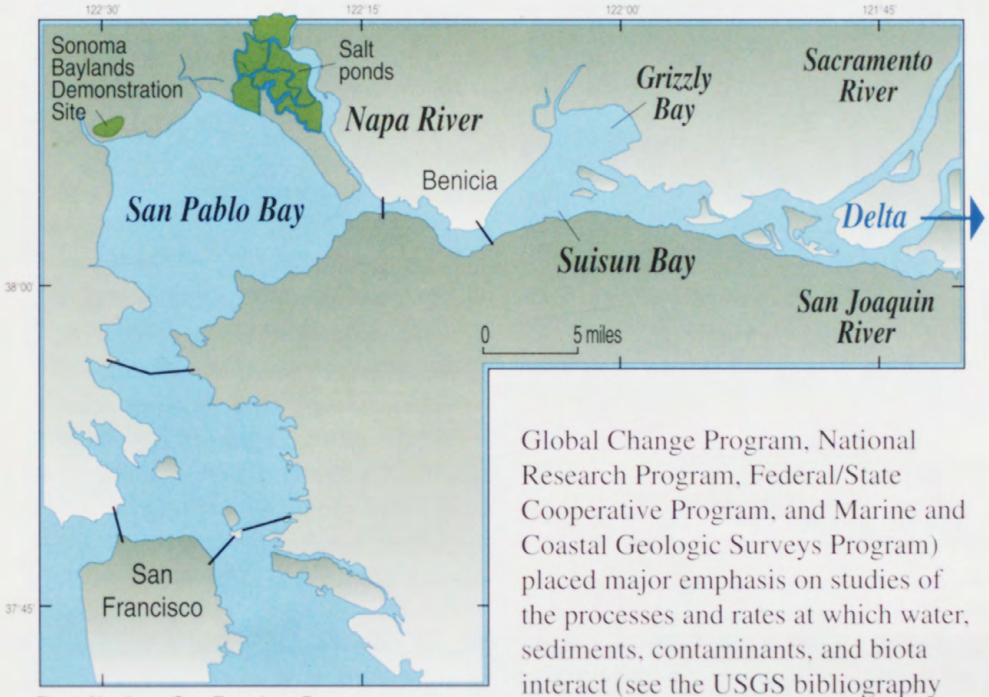

Fig 1. Northern San Francisco Bay.

Introduction

The San Francisco Bay-Delta estuary and its watershed have been a focus of intense human activity and environmental impact since 1848 when gold was discovered in the foothills of California's Sierra Nevada mountains. As the estuary and its watershed continue to be changed by human activities, resource managers, environmental regulators, elected officials, and the public seek credible, unbiased scientific information about the factors related to observed changes in order to restore impaired species, habitats and ecological functions.

For many years the U.S. Geological Survey (USGS) has maintained a broad program of interdisciplinary studies of the San Francisco Bay estuary. These programs (Toxic Substances Hydrology Program, Global Change Program, National Research Program, Federal/State Cooperative Program, and Marine and Coastal Geologic Surveys Program) placed major emphasis on studies of the processes and rates at which water, sediments, contaminants, and biota interact (see the USGS bibliography on the World Wide Web at http://sfbay.wr.usgs.gov/access).

In recognition of the need to support the management of the natural resources of the San Francisco Bay and Delta, the USGS has designated the San Francisco Bay estuary as one of the "critical ecosystem" study sites in its Integrated Natural Resource Science (INATURES) Program. With the creation of this program (formerly the Ecosystem Program), the USGS augmented and integrated its hydrologic, biologic and geologic investigations in the estuary and Delta in order to develop technical information that is directly relevant to problems faced by state and federal resource managers. Particular emphasis has been placed on increasing our understanding of linkages among the physical, chemical, and biological components of this estuarine ecosystem, and improving the availability of the information.

Beginning in FY1999, the San Francisco Bay Estuary INATURES Program will focus on two areas relevant to restoring ecosystem health and improving water management, and on continuing to make its new information available on the World Wide Web.

Background

The San Francisco Bay estuary, at the confluence of the Sacramento and San Joaquin Rivers in central California (Fig. 1), is renowned for its natural beauty, international commerce, recreation and sports fishing. However, the estuary and its watershed have been greatly modified by 150 years of intensifying human activity. Most of its historic tidal marshes have been leveed and filled, including use for the production of salt in evaporation ponds. The flow of freshwater into the estuary has been greatly reduced by water diversions to support irrigated agriculture and growing urban populations. Harbor and channel dredging have altered both the dredged and disposal sites, and changed water flow patterns and salinity. Contaminants enter the estuary in municipal and industrial sewage, and urban and agricultural runoff. These changes have had marked influences on the estuary's biological resources, particularly evident in the declining abundance of some fish species and elevated contaminant levels in recreationally important fish and wildlife species (San Francisco Estuary Project Management Committee, 1994).

U.S. Department of Interior
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USGS Fact Sheet 138-98
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DEPOSITORY

Water Flow Management

Population increases, agriculture, and industrial activities have altered the quantity and quality of freshwater entering the Delta and Bay, causing changes in both flow patterns and salinity distributions. These changes are perceived to be responsible for observed changes in the bay's biological populations, most notably in the declines in the abundance of some important fish species. In 1994, the U.S. Environmental Protection Agency reached an agreement with California water agencies, water contractors, and environmental groups establishing a salinity standard (the "X2 standard"; Jassby et al., 1995) that requires the salt content of the water in ecologically sensitive regions of the estuary to be maintained at specified levels. Significant scientific uncertainty remains, however, about the specific linkages between salinity and fish species abundance and about how the aquatic ecosystem within the Delta and Suisun Bay might respond to changes in water flow management. Information is also needed about the relationships between river flow and fate and effects of contaminants both in the water, and associated with suspended and bottom sediments.

Freshwater Flows, Sediments and Contaminants

The USGS is studying the relationships between freshwater inflow to the estuary, and the movement and fate of sediments and associated contaminants over a range of temporal and spatial scales. The USGS has linked atmospheric conditions, river basin water availability, and estuarine chemistry in order to quantify long-term patterns of freshwater inflow to the estuary and salinity responses within the estuary. By incorporating simple models of the daily air temperature-streamflow relation with NOAA 14-day forecasts of air temperatures, the USGS can now predict by up to a week or more the initiation of spring snowmelt surges in the Merced River (Dettinger et al. 1997). Water flow data are being collected within Delta channels, in cooperation with the California State Department of Water Resources, to calibrate and validate a new numerical model of water flow in the Delta that will be used in the operation of the State and Federal water export facilities to meet salinity standards. By establishing a critical water-flow monitoring station in one of the Delta channels, USGS completed a network of stations needed to provide the first true measure of the freshwater flow from the Delta into the estuary.

The USGS collects and analyzes data to explain the influence of variations in river flow on the distribution of salt and suspended sediments. Recent results (Burau, 1998) have demonstrated that the transport of salt, suspended sediment particles, and biota in the Suisun Bay area is not, as previously assumed, strongly controlled by the commonly invoked gravitational circulation process (Fig. 2a; seaward-flowing river water on the surface balanced by landward-flowing saline water at the bottom). Instead, landward flowing salty bottom-water is arrested by the abrupt shallowing of Suisun Bay east of the Benicia Bridge (Fig. 2b). This finding is critical to decisions about how to manage freshwater flow to meet the X2 salinity standard and for decisions about the proposed deepening of the ship channel near Benicia. Deepening of the channel to accommodate the passage of deeper draft vessels could result in elevated salinities in Suisun Bay and the western Delta (Burau, 1998), thus requiring increased freshwater outflows to meet the X2 salinity standard.

To better characterize the sources and impacts of contaminants on the Bay's biota, USGS scientists have documented the timing and amounts of agricultural pesticides flushed into the

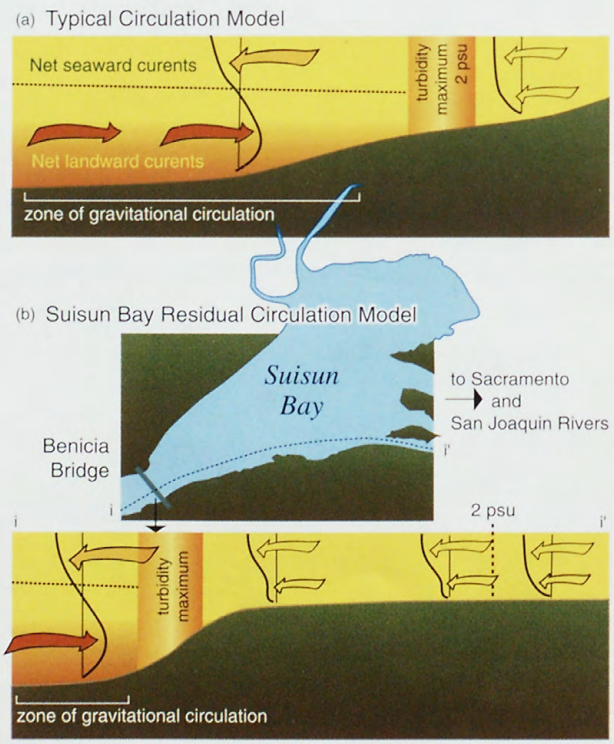

Fig.2. Comparison of a typical estuarine circulation model (a) with the proposed conceptual model of circulation and salt transport in the Suisun Bay region (b). The red color denotes the upstream-moving higher salinity water; the yellow color denotes the downstream-moving lower salinity water (psu = practical salinity units).

Delta that are toxic to aquatic organisms (Kuivila and Foe, 1995). Additional studies have shown that trace metals (from waste treatment plants, refineries, chemical plants, and urban runoff) can affect two measures (reproductive organ development and tissue condition) of the health of the *Potamocorbula amurensis*, a common clam in the bay (Brown and Luoma, 1998). The contaminants disrupt normal reproductive cycles in parts of the estuary where metals concentrations are high.

In a study that may be very useful in predicting the distribution of mercury buried in Bay and Delta sediments, data from hydrographic and topographic surveys from the 1850s to the 1990s (Jaffe et al. 1998) have been compared with historical trends of metal contamination found in sediment cores (Hornberger et al. 1998). This study shows that sediment accumulation occurred on a very large scale during the period of hydraulic gold mining (1853-1884), with large accumulations of sediment in San Pablo Bay (Fig. 3, lower right panel). The concentrations of mercury (used in gold extraction) found in these accumulated sediments were 3-4 times higher than the regional background (Fig. 3, left panel). The bathymetric survey data also explained a hiatus within the sediment core between 1888 and 1951 when erosion predominated in San Pablo Bay, thus causing the removal of sediments and associated contaminants. After 1951, sediment deposition continued only in parts of San Pablo Bay, particularly along the margins of the deep mid-bay channel where the sediment core was collected (Fig 3, upper right panel). Here, mercury concentrations remain elevated.

Wetland Processes

Past INATURES studies of the wetlands of San Francisco Bay have included measurements of historic and recent changes in wetland margins, wetland morphology, and sediment distribution patterns within and adjacent to the Sonoma Baylands Demonstration site (Fig 1) where dredge spoils were used to create proper elevations for wetland habitat. Another investigation focused on comparing the level of organic contamination (e.g., PCBs and DDT) in both the newly created wetland and an adjacent pristine marsh. The study found that polycyclic aromatic hydrocarbons and chlorinated pesticides, while present in the sediments and the dredge spoil fill materials, were in concentrations below accepted toxicity standards (Pereira et al. 1998).

Wetland Restoration

The conversion of 90 percent of San Francisco Bay's tidal wetlands to urban and agricultural uses since 1850 represents a huge loss of habitat for wildlife and fish species that use the wetlands during breeding and maturing stages. The remaining 50 mi² of wetlands are threatened by development and by natural processes of destruction from wave action and rising sea level. Efforts to restore wetlands have included conversion of subsided diked areas into tidal marsh using dredge spoils from harbors and ship channels to restore land elevations.

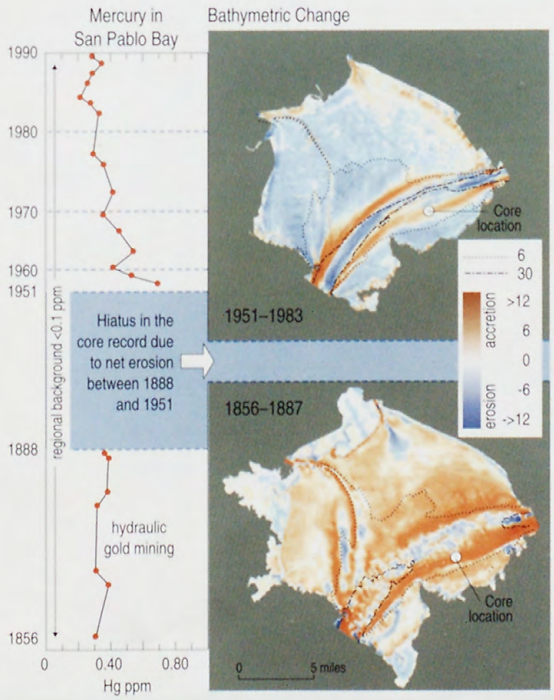

Fig 3. Changes in the bathymetry of San Pablo Bay during two periods (1856-87, 1951-83), and the accumulation of mercury in the sediments deposited at the edge of the mid-bay channel, as shown in a chronologically dated sediment core sample. Any sediment that accumulated at this site during the period 1887-1951 is missing from the core sample because of erosion (ppm = parts per million; erosion and accretion are in feet).

Data Accessibility

To provide resource management agencies and the public with ready access to USGS data and reports, the USGS is using World Wide Web protocols to develop and join various USGS databases. The "Access USGS" Home Page (http://sfbay.wr.usgs.gov/access) provides information on USGS work related to its San Francisco Bay ecosystem studies. For example, the "Water Quality of San Francisco Bay" page (http:// sfbay.wr.usgs.gov/access/wqdata) provides visual and download access to nearly three decades of USGS measurements of water quality along a 90-mile transect spanning the length of the entire estuarine system, from the South Bay to the Sacramento River.

This website describes the measurement program, displays results of water quality measurements, and makes the full data set available to all interested users.

New Studies

In FY1999 and beyond, the San Francisco Bay-Delta INATURES study will focus on two integrated project elements: (1) the interrelations among water flow, sediment transport, and contaminant movement and effects, and (2) a comparison of the physical and biological attributes of an abandoned salt evaporating pond system with those of an adjacent tidal marsh.

Flow, sediments, and contaminants

USGS scientists will examine the linkages between local hydrodynamics, bathymetry, sediment and pollutant transport, and pollutant exposure of the dominant benthic organism, *Potamocorbula amurensis*. The study will seek to determine how the transport and fate of suspended sediments and associated contaminants might influence the life history and cycles of reproduction in this species. A specific goal is to support the development of pollutant regulations that are based on field studies. The Grizzly Bay region of Suisun Bay (Fig. 1) has been chosen as the study site because of the importance of this region as a habitat for some of the Bay's threatened and endangered species, and because this is the geographic region most influenced by the management of freshwater inflows to maintain the X2 salinity standard.

Napa salt ponds

Beginning in the late 1800s, the shallow shorelines of San Francisco Bay were diked off and used as solar evaporation ponds for the production of salt. The ponds served as wetland habitat for migratory and resident birds. As the salt industry has reduced its operations here, the abandoned ponds have become the focus of interest regarding their possible conversion to tidal wetlands. Prior to and during conversion to a tidal wetland system, USGS scientists will examine the hydrological and ecological attributes and functioning of the Napa River salt pond system in northern San Francisco Bay (Fig. 1) in order to establish a baseline of information. The study will encompass investigations of the hydrology, geomorphology, and ecology of existing salt ponds and a former salt pond within the same complex that has recently reverted to a tidal marsh through natural causes. USGS scientists will examine the use of these ponds by resident plant, invertebrate, fish and waterbird communities. The goal is to document the relative importance of abandoned ponds versus tidal marshes to the region's fish and wildlife species.

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Additional Information

More detailed information about the INATURES Program in San Francisco Bay can be found at: http://sfbay.wr.usgs.gov/access