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Monitoring and Managing Water Quality in the San Francisco Estuary

35 Years After the Clean Water Act

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Management Update

Recent developments in water quality management in the Estuary

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The History of Municipal Wastewater Treatment: 35 Years of POTWs Protecting the Bay

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Highlights

As the Bay Area population grew through the 1900s, Bay water quality suffered.

By the 1950s, many communities had built primary sewage treatment plants, but water quality problems persisted or became worse into the early 1970s.

California's Porter-Cologne Water Quality Control Act of 1969 and the federal Clean Water Act of 1972 together provided a major impetus to cleaning up San Francisco Bay. The Clean Water Act provided clear goals and over a billion dollars toward construction of Bay Area wastewater treatment facilities.

Beginning in the late 1960s and continuing through the 1980s, Bay Area communities built secondary or tertiary level treatment facilities and improved wastewater outfalls, while controlling industrial inflows.

The Bay Area population has continued to increase, but pollutant inputs to the Bay from publicly-owned treatment works (POTWs) have plummeted, in some cases by 99%.

East Bay Municipal Utility District wastewater treatment plant. Photograph by Greg Keller.

Terms in **Blue** defined in Glossary on Inside Back Cover

Introduction

In 1972, Congress passed the Federal Water Pollution Control Act Amendments. This Act, which later became known as the Clean Water Act, set in motion a nation-wide effort to clean up our waterways. In the 1970s and 1980s, in response to the Clean Water Act, cities and utility districts around the Bay completed a massive public works campaign that built sewage treatment facilities. In a short span of time, these new and upgraded publicly-owned treatment works (POTWs) dramatically reduced the amount of pollutants released to the Bay. In the following decades POTWs continued to decrease the quantities of pollutants discharged to the Bay even as the population increased. Future reductions of pollutant discharge from POTWs are unlikely to be as dramatic as those following the initial construction program and wastewater agencies increasingly focus on preventing pollutants from entering wastewater collection systems. Today, roughly $500 million per year is spent in operating the facilities. This ongoing public investment is essential to the health of the Bay.

What The Bay Was Like – Pollution Problems

Bay Area residents are now accustomed to a Bay with no readily apparent water quality problems. Some problems remain, but the gross pollution of the mid-1900s is gone. Before cleanup efforts began, the Bay was plagued with poor water quality that frequently caused large die-offs of fish and threatened the health of swimmers and consumers of shellfish from the Bay. Key water quality issues of these early years are described below.

"The Big Stench." Until the first treatment facilities were built - mostly after 1950 – raw sewage entered the Bay via streams or sewers. A 1941 study reported "because of this bad practice the shores and shore waters of the East Bay cities have become obnoxiously and notoriously foul and an affront to civic pride and common decency" (Hyde 1941) (**Figure 1**).

Low Dissolved Oxygen and High Biochemical Oxygen Demand. Dissolved oxygen (DO) is vital to aquatic organisms. In 1969, researchers noted that there were significant dissolved oxygen depletions in the Lower South Bay and that oxygen concentrations in Coyote Creek (near Milpitas) sometimes fell to zero (Kaiser Engineers 1969). As late as 1975, the San Francisco Bay Regional Water Quality Control Board (Water Board) reported that, in the lower extremity of South San Francisco Bay, biochemical oxygen demand (BOD – a measure of organic waste that causes oxygen depletion) had been observed to be as high as 48 milligrams per liter (mg/L) (essentially that of partially treated wastewater), while DO had been as low as 0.7 mg/L. Such low oxygen levels preclude the survival of most fishes. The Basin Plan minimum is 5 mg/L.

Figure 1
The Strawberry Creek Outfall carried the University of California and City of Berkeley's wastes directly into the Bay, contributing to the "Big Stench." A report (Hyde et al. 1941) pointed out the sludge bank to the right of the outlet.

Shellfish Contamination. A shellfish study in 1972 noted that the Bay was "ringed by numerous discharge points which daily spew forth millions of gallons of polluting effluent" (Breslaw 1972a). The same study found that 14 out of 16 shellfish beds exceeded bacteria standards, and detected *Salmonella* in two of them. The Bay's oysters once supported the most lucrative fishery in California and were made famous by the writer Jack London. But by 1940 (according to Breslaw (1972a)), the fishery was decimated as a result of bacterial contamination.

Fish Kills. In 1971, the State Water Resources Control Board sent a report to Governor Reagan and the Legislature (SWRCB 1971) stating that "toxic materials and nutrients are discharged in virtually all municipal and industrial wastewaters; these toxic materials and nutrients cause fish kills and excessive algae blooms, particularly in the nearshore areas." The report listed fish kills that had occurred between 1965 and 1970; several of those kills involved over 10,000 fish (**Figure 2**).

Early Wastewater Treatment Facilities

Palo Alto began operating a primary treatment (**Sidebar, next page**) plant in 1934. This was the first treatment facility in the South Bay and perhaps in the Bay Area. Most communities constructed primary plants during the 1950s (**Table 1**).

In 1963, a report from UC Berkeley estimated that $200 million had been spent on wastewater treatment facilities since 1950 but noted that "the problem of

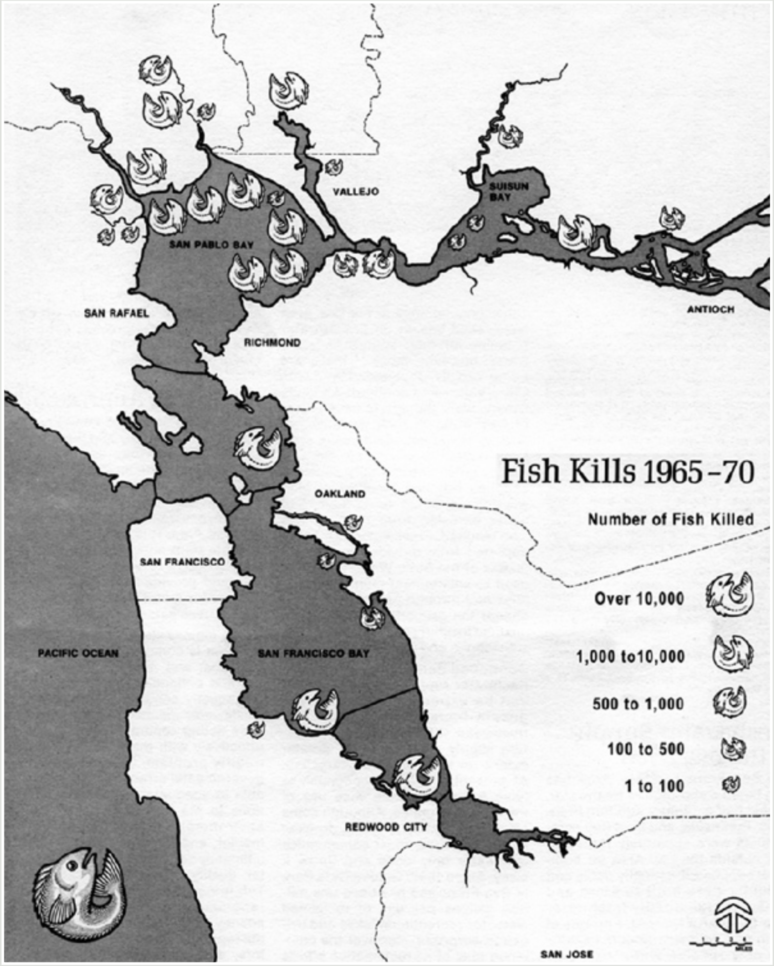


Figure 2

In 1971, the State Water Resources Control Board sent a report (SWRCB 1971) to Governor Reagan and the State Legislature concluding that in spite of "great strides … the Bay water system continues to suffer marked deterioration in quality." The report used graphics like the one above to illustrate the water quality problems and proposed an overall agency to construct and manage the needed treatment, reclamation, and disposal facilities.

pollution stubbornly defies solution" (Scott 1963). A few facilities, including those of San Jose/Santa Clara, Oro Loma, and Dublin-San Ramon, were providing secondary treatment (**Sidebar**) by the late 1960s. However, most secondary treatment facilities were not built until funds became available through the Clean Water Act. Many of the early and smaller facilities were eventually abandoned as flows were consolidated and treatment upgraded.

By the early 1970s, the total municipal and industrial wastewater flow to the Bay was 786 million gallons per day (mgd) (Breslaw 1972a). Municipal dischargers accounted for 452 mgd, or 58% of the total wastewater flow (the current municipal discharge volume to the Bay is approximately 617 mgd, an increase of 37%). A report on industrial waste discharges in the Bay Area, including the Sacramento/San Joaquin Delta, noted that most of the industrial inputs came from a few facilities: one paperboard mill in Antioch contributed 45% of the total industrial loading of BOD to the Bay and Delta and 20% of the suspended solids (Breslaw 1972b).

Table 1.
Representative early primary treatment facilities on San Francisco Bay

Facility	Online
Palo Alto	1934
Petaluma (discharge to river)	1938
Central Contra Costa San. Dist.	1948
Oro Loma Sanitary District	1950
San Francisco–North Point	1951
East Bay Municipal Utility District	1951
Mountain View	1951
San Francisco–Southeast	1952
Hayward	1954
San Jose/Santa Clara	1956
Sunnyvale	1956
Los Altos	1957

Levels of Wastewater Treatment

Primary Treatment. The first stage of the wastewater treatment process where mechanical methods, such as filters and scrapers, are used to remove pollutants. Solid material in sewage also settles out in this process.

Secondary Treatment. The second stage of the wastewater treatment process (following primary treatment) involving the biological process of reducing organic matter through bacterial metabolism. This process generally removes 80 to 90 percent of the BOD and suspended solids.

Tertiary Treatment. The third stage of wastewater treatment removes nutrients or other pollutants that resist conventional treatment practices. This can be accomplished by a variety of biological, physical, and chemical separation processes.

Laws, Regulations, and Planning

For over a century, federal and state legislators have attempted to put controls on water pollution. Major progress did not occur, however, until the Clean Water Act introduced mandated treatment levels and substantial federal funding. Key steps in the history of regulation of Bay water quality are described below.

1899. Refuse Act. Federal water quality protection efforts began in 1899 with the Refuse Act, which prohibited the discharge or deposit of "any refuse of any kind" into any navigable water of the United States. Sewage and street runoff were excluded from the prohibition. This Act was resurrected in 1970 by President Nixon, who directed the newly created Environmental Protection Agency (USEPA) to implement a permit program based on this law.

1948. Water Pollution Control. Federal Authority Given to Surgeon General. The first federal Water Pollution Control Act authorized the Surgeon General to prepare plans and programs to eliminate or reduce the pollution of interstate waters and tributaries.

1949. Dickey Water Pollution Act in California. State and Regional Water Boards Formed. The Dickey Water Pollution Act created the California State Water Pollution Control Board (later the State Water Quality Control Board) to set statewide policy and to coordinate with other agencies. The Act also established the nine regional boards that still exist today. Staffing was an issue: in 1958, the San Francisco Regional Water Board had five employees and a budget of approximately $74,000 (Scott 1963).

1956 to the 1960s. Some Federal Funding for Treatment Plants. Federal amendments to the Water Pollution Control Law in 1956 started a grant program for sewage treatment plants which continued into the 1960s, providing up to 30 percent of facility cost or $250,000, whichever was less. Although this level of funding now seems trivial, Palo Alto's first treatment plant only cost about $63,000 to construct. The 1956 amendments also strengthened enforcement provisions by providing for an abatement suit where health was being endangered.

1965. State Water Pollution Control Law. Water Quality Standards Developed. The State Water Quality Control Board (the predecessor of the current State Water Resources Control Board) adopted water quality objectives in 1967. Also in 1967, the Central Valley and San Francisco Regional Water Boards identified a list of beneficial uses for the waters within the Bay-Delta system (Kaiser Engineers 1969). These beneficial uses included the familiar ones still part of the current San Francisco Basin Plan, such as domestic water supply, recreation (whole body water contact and limited contact), fish and wildlife propagation and sustenance, and esthetic appeal.

The 1965 law also directed the State Water Board to assess the feasibility of a comprehensive, multi-purpose waste collection and disposal system that would serve the entire area. This plan, completed in 1969, recommended eventual (2005) implementation of a Reclamation-Marine Disposal System, with most Bay Area treated waste flows directed to the ocean along with a substantial reclamation component (Kaiser Engineers 1969).

1969. Porter-Cologne Act: Key State Law. The Porter-Cologne Act of 1969 rewrote existing state law and created the state requirements in their current form. The Act introduced waste discharge requirements as part of a permit system for all discharges with the potential to adversely affect water bodies.

1972. Clean Water Act: The Modern Era. The Federal Water Pollution Control Law Amendments of 1972, Public Law 92-500, later known as the Clean Water Act, built on the experiences of California and other states that had pre-existing permit programs. Key components included a permitting program called the National Pollutant Discharge Elimination System (NPDES). This program implemented "technology-based" minimum limits applicable to all dischargers as well as "water quality-based" limitations to address local water quality standards.

The mandatory technology-based standards avoided the problem of previous state-based permitting efforts, which had floundered because of the difficulty of linking water quality problems to specific dischargers. Thus, all POTWs were required to achieve secondary treatment as defined in the regulations, regardless of which dischargers were most responsible for the problems.

Probably most importantly, the Clean Water Act brought with it substantial funding; by 1987, the Clean Water Act had provided $1.2 billion in federal funds to the Bay Area (U.S. 1987). This initial grant funding was supplemented by requirements that wastewater agencies develop equitable self-funding revenue programs to pay for the local share of construction and ongoing operation and maintenance costs.

1975. Updated Basin Plans, Increased Enforcement. In 1972, the Regional Water Boards began an effort to update the Basin Plans and bring them into compliance with the Clean Water Act (SFBRWQCB 1975). These plans were due in July 1975 and constituted the first Basin Plans as we currently know them. They were intended to create a management scheme for the next 20 to 30 years, with revisions "at least annually" (**Figure 3**). Regional Water Board enforcement efforts also increased. For example, the San Francisco Board issued 113 "cease and desist" orders in year 1976-77, a third of all such orders issued in the state (SWRCB 1978).

1986. Congressional Hearings: "Contamination of the San Francisco Bay." In 1986, a congressional subcommittee met in San Francisco to discuss pollution of the Bay. Representative George Miller presided and cited the "large number of recent reports, some public and some not yet released, which document that the future of San Francisco Bay is threatened."

Don Anderson, Chairman of the San Francisco Regional Water Board, testified that the Bay had gone from 80 percent noncompliance with bacteria standards in the early 1960s to 80 percent compliance 20 years later. He also pointed to improvements in fisheries, including the re-establishment of the commercial bait fishery for native Bay shrimp. A representative from the POTWs, Walter Bishop of East Bay Municipal Utility District, testified that municipal dischargers had realized a 96% reduction in the quantity of heavy metals released to the Bay. Representatives of environmental groups continued to point to POTWs and industry as significant sources of metals and other toxic pollutants but also identified hazardous waste sites and stormwater as contributors to Bay pollution.

Subsequent Developments. Both the Porter-Cologne Act and the Clean Water Act have been amended since their original passage, but the basic framework they developed remains in place. One significant change came in 1987, when the Clean Water Act was amended to include specific requirements for the control of municipal and industrial stormwater.

What Was Built

Although limited federal funding was available up through the 1960s, the Clean Water Act provided a huge jump in funding beginning in 1973. The Federal Construction Grant Program became the largest nonmilitary public works program since the Interstate Highway System. Bay Area facilities were early and active participants in the Program, which originally provided 75% of project costs from federal sources, with the state contributing another 12.5%. The local share of project costs was thus only 12.5%, which made the construction of wastewater facilities viable for most communities. California was the first state in which USEPA authorized state management of the Program. Governor Jerry Brown promoted an accelerated construction program, and between 1975 and 1977, the state processed over $2 billion in grant applications from municipalities.

The federal contribution to facility construction costs was reduced to 55 percent in 1981, and the Construction Grant Program was eventually phased out in 1982. The federal Water Quality Act of 1987 authorized the current State Revolving Fund program, which continues to provide low-interest loans for wastewater facilities.

The federal and state funding helped implement Water Board plans, which included consolidating facilities; upgrading secondary treatment facilities for all

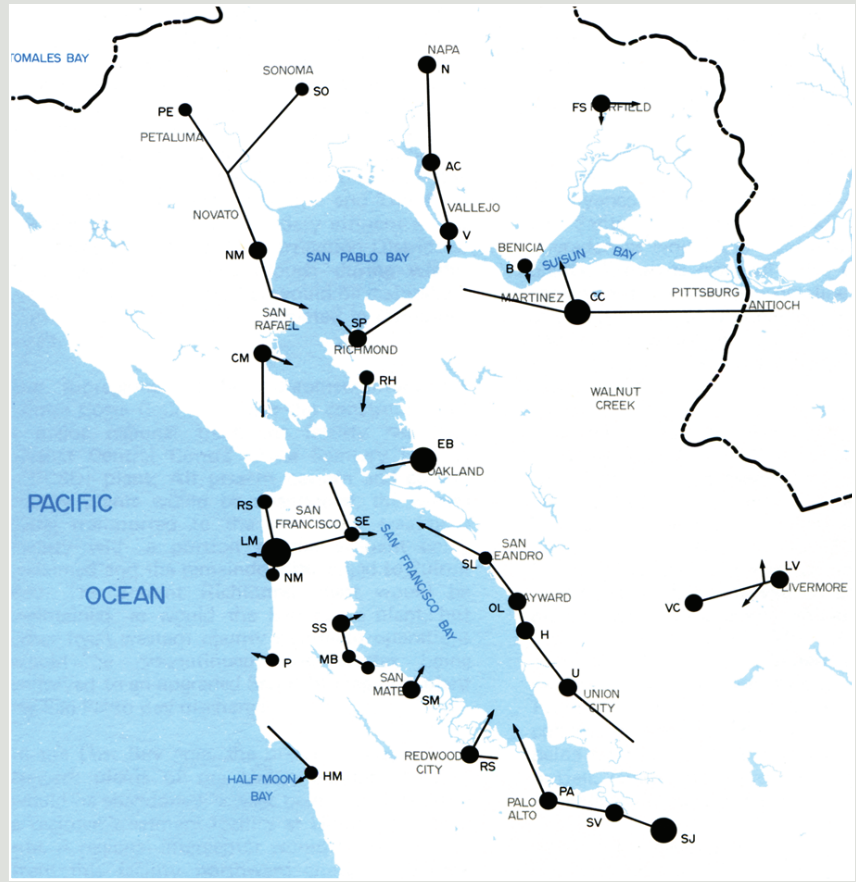


Figure 3
In the 1975 San Francisco Basin Plan, the Water Board opted for regional consolidation of wastewater treatment facilities. The first Basin Plan in 1969 proposed taking almost all treated wastewater to the ocean in combination with eventual reclamation of much of the flow (Kaiser Engineers 1969). The Kaiser authors stated that "for any given level of wastewater treatment the effects would be less adverse for discharge to the ocean than they would be for discharge in a confined "estuary". In the 1975 Basin Plan, as shown in the figure, the Board proposed a lower-cost, moderate consolidation program that would also be compatible with future reclamation. Upgrades to at least secondary treatment were also part of the plan.

POTWs; and nutrient removal or bans on dry-weather discharges to critical waterways. By the time the Basin Plan was approved in 1975, many of the needed secondary facilities were under construction or completed. The implementation schedule in the 1975 Basin Plan provided for all treatment plants to be under construction by 1977, with completion no later than 1980.

In 1987, the Water Board reported that between 1960 and 1985, over $3 billion had been spent in the Bay Area to upgrade and construct wastewater treatment plants and to move outfalls into deeper water. By 1987, all but one POTW discharging to the Bay were providing at least secondary treatment. Between 1960 and 1985, the number of POTWs in the region had been reduced from 82 to 58 (with 46 discharging directly or indirectly into the Bay) to allow for better treatment and more dilution in the Bay. Many of those phased out were inefficient and inadequate in terms of capacity and effluent quality.

Population Growth and Changes in Wastewater Volume

From 1955 to 1975, wastewater flows increased faster than population growth in the wastewater service areas. It is not clear why this occurred, but perhaps post-war industrialization increased flows into the collection systems. However, after 1975, this pattern changed, and population increased faster than wastewater flows due to water conservation and the closure or relocation of heavy water-using industries, such as canneries. California's 1987-1992 drought, in particular, spurred water conservation practices (**Figure 4**).

The Bay Area is highly rated for water conservation practices. The State Water Code requires the preparation of Urban Water Management Plans that must include conservation measures. Ongoing conservation efforts have reduced the volume of flows to treatment plants, although influent pollutant concentrations to POTWs may increase.

What Was Achieved

Within 15 years of the adoption of the Clean Water Act in 1972, Bay water quality had improved substantially. This improvement included greatly reduced discharge of the "conventional pollutants" total suspended solids (TSS) and BOD, as well as of bacteria. Discharges of toxic metals were also reduced during this period, since they are often associated with TSS. However, determining exact reductions of some pollutants is difficult because of imprecise analytical methods in the early years. Acceptable data for metals in effluents were not generally available until the mid-1980s, and data on long-term trends are limited to certain metals.

Conventional Pollutants

In 1987, the Water Board completed a comprehensive review of the status of pollutant inputs to the Bay based on 30 years of TSS and BOD data. These two pollutants are important because USEPA uses them to define the expected performance of secondary treatment facilities. The Water Board review included loadings from 1955 to 1985 and documented major reductions in the Bay (SFBRWQCB 1987). These early data have been extended to bring the record up to date (**Figure 5**). The decreases in

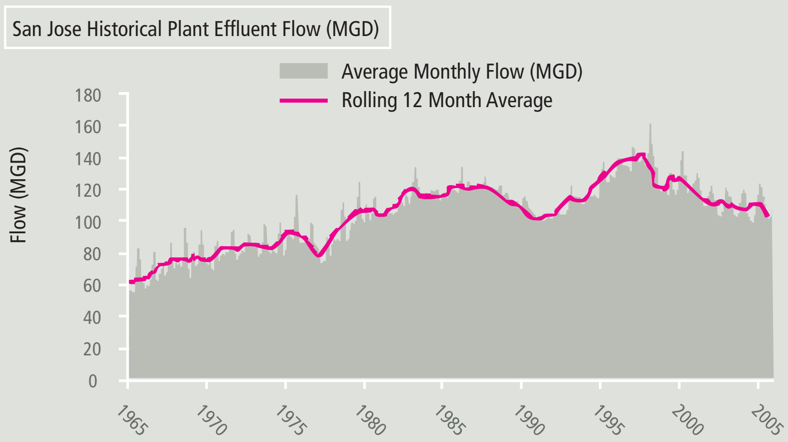


Figure 4
The service area population of the San Jose/Santa Clara Wastewater Treatment Plant is one of the fastest-growing in the state, but wastewater flows have decreased in recent years. Flows decreased during California's 1987-1992 drought and then again beginning about 1998. Local communities and the Santa Clara Valley Water District have aggressive water conservation programs. One goal of these plans is to decrease the volume of treated freshwater discharged to South Bay salt marshes during the drier months in order to protect endangered species.

TSS and BOD loading resulted from upgrading primary treatment facilities to secondary or, in some cases, tertiary (**Sidebar, page 9**). Palo Alto and Sunnyvale upgraded to tertiary treatment in 1978; San Jose/Santa Clara in 1979. Currently, more than 30 percent of Bay Area flows receive advanced (tertiary) treatment.

The Lower South Bay has been particularly challenged, because these waters are shallow and poorly flushed. Before the Clean Water Act and the Construction Grant Program, this segment of the Bay was the most stressed. However, by 1985, dischargers to this region had decreased their BOD loading by 99% even though wastewater flows had more than doubled since 1955 (**Figure 6**).

Toxic Pollutants

Even more striking than BOD and TSS reductions are the decreases in toxic metals loading to the Bay that occurred after facility construction began. Because of shortcomings in early chemical analysis techniques, long-term assessment of changes in toxic concentrations is limited to a few metals. As one example, the East Bay Municipal Utility District (EBMUD) began partial secondary treatment in mid-1977 and had full secondary in operation by late 1978. The new facilities reduced metals loadings by over 70% percent. In the following years, pretreatment controls (limits on industrial and commercial releases into the sewage collection system) resulted in additional substantial reductions (**Figure 7**).

It is particularly remarkable that significant reductions in metal loadings continued after the major construction era ended in about 1985. More extensive data on metal loadings are available beginning in the mid-1980s and illustrate the effectiveness of the pretreatment controls imposed by wastewater agencies on industrial and commercial facilities discharging into the collection systems (**Figures 8 and 9**). The intent of these controls is to ensure that commercial and industrial discharges do not disrupt treatment systems or pass through pollutants that may cause water quality problems. In addition, the agencies implemented pollution prevention programs targeting the general public and businesses.

Effluent Toxicity Reduced

POTWs conduct toxicity tests on their effluents, in which test organisms are exposed to effluent. There are two types of tests: 1) acute, which measures mortality of the test organisms; and 2) chronic, which measures impacts on reproduction or growth. Tests are conducted using the most sensitive organisms possible, which are usually juvenile fish, shellfish, crustaceans, or algae. POTW effluents rarely show any acute toxicity, and with only a few exceptions, there is very little chronic toxicity in POTW effluents (SFBRWQCB 2007).

Bacteria

Disinfection with chlorine became common with the first primary treatment facilities constructed in the 1950s. However, chlorination is less effective on only partially-treated wastewater, since suspended solids can “shelter” bacteria that can remain viable. The implementation of full secondary treatment at all facilities and additional tertiary treatment at some facilities meant that chlorination became increasingly effective.

By the late 1970s, the Water Board had noted the rapid changes in Bay water quality: “the bacteriological conditions in the Bay improved 5 to 16 fold between 1973 and 1976, and swimming is now safe in most areas of the Bay during summer” (SFBRWQCB 1987) (**Figure 10**).

The Benefits

By 1987, improvements in Bay water quality were dramatic (**Sidebar page 16**).

Despite these improvements, Luoma and Cloern (1982) noted that some major problems continued into the 1980s. Localized instances of accumulation of toxic metals and trace organics in the food web equalled those anywhere in the world. Indications of physiological stress in animals contaminated with these pollutants had also been observed. Later studies concluded that clam reproduction was significantly reduced due to metal contamination through the 1980s and into the 1990s.

Improvement in Bay water quality continued in the 1980s and 1990s. Metals concentrations in the food web declined considerably during this period in response to load reductions, and recent findings indicate that they are no longer affecting clam populations in the Bay (**page 61**).

Although loadings of many pollutants from POTWs have declined substantially since the 1950s, some other sources have not been reduced in a comparable manner. These sources include urban runoff and the legacy pollutants in Bay sediments such as mercury left over from gold-mining days. Water quality problems in the Bay also persist (**page 59**).

What’s Next For POTWs?

Beginning in the late 1960s, the clean water agencies of the Bay Area dramatically reduced pollutant loading to the Bay. Ongoing monitoring, however, has identified new problems that need to be addressed.

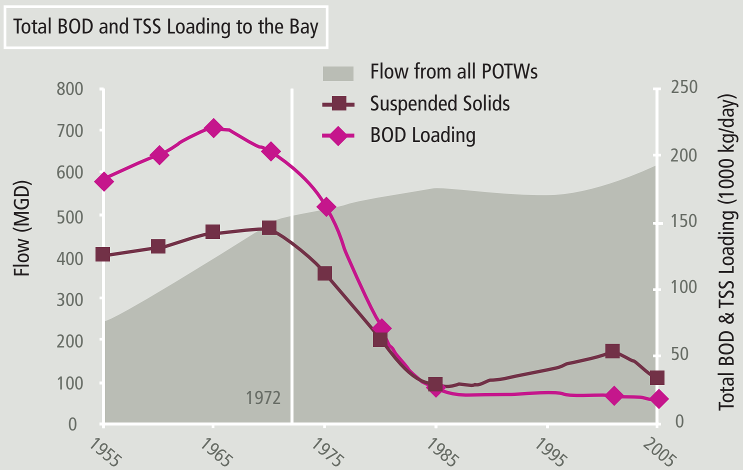


Figure 5

Funding for the construction of treatment facilities provided by the 1972 Clean Water Act produced a sharp drop in pollutants released to the Bay. By 1985, Bay Area POTWs had reduced TSS by 80% and BOD by 88% from the high values recorded two decades earlier, while the service area population increased by 52% over the same period.

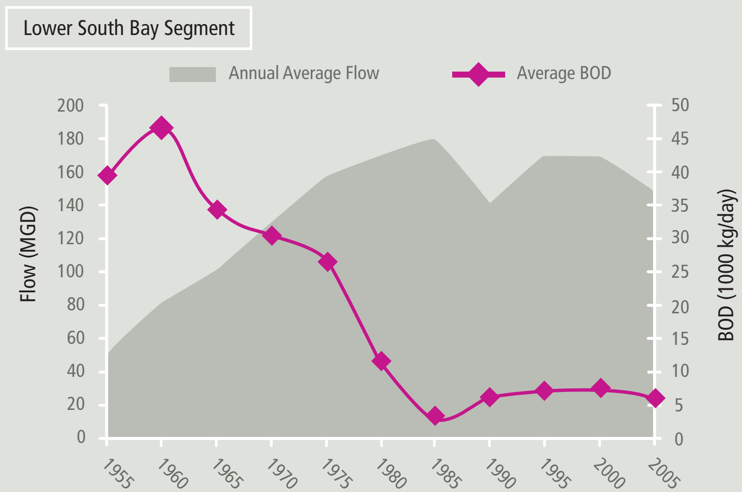
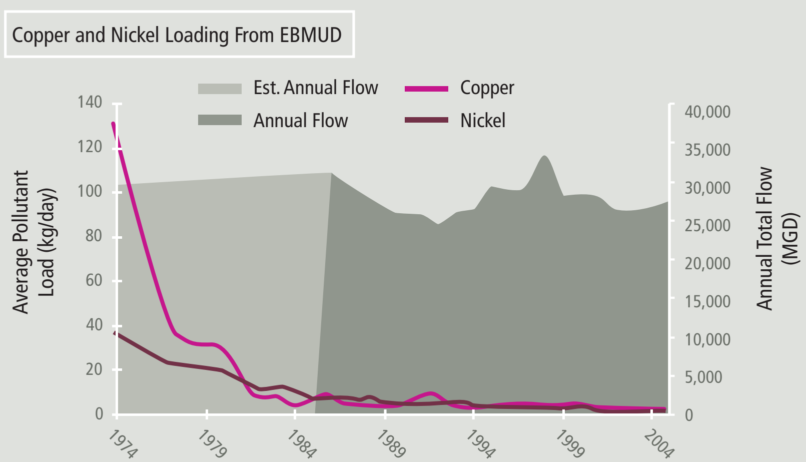


Figure 6

An extraordinary decrease in pollutant inputs has benefited the highly-stressed Lower South Bay. The 1955 to 1985 effluent BOD data were collected by the Water Board and combined with recent data from dischargers.



Footnote: This graph combines historical data from EBMUD with subsequent data (1986–2005) from the Regional Water Board (Lam 2007). (Flow between 1974 and 1986 is estimated as a straight line)

Figure 7

Discharges of metals declined even more than BOD and TSS. The extraordinary reduction in East Bay Municipal Utility District (EBMUD) copper and nickel loadings resulted from the construction of secondary treatment facilities followed by aggressive pretreatment and pollution prevention programs.

Copper and Nickel Loading from Large Dischargers

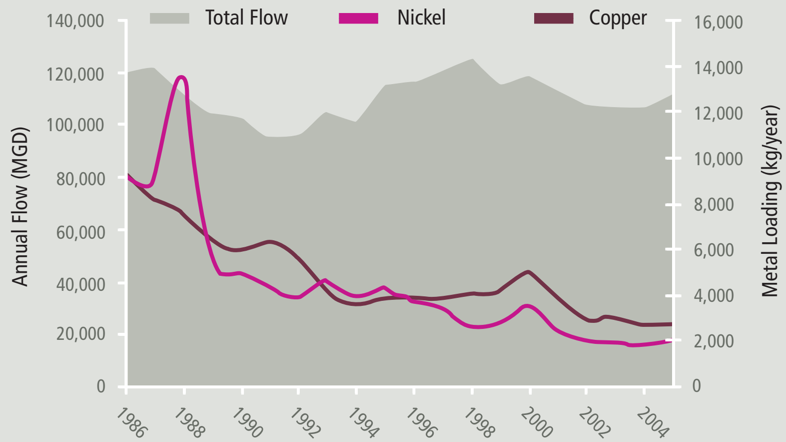


Figure 8

Due to pretreatment and pollution prevention programs, metal loadings continued to decrease after treatment plant construction was completed. Four treatment plants (San Jose/Santa Clara, San Francisco, EBMUD, and Central Contra Costa Sanitary District) discharge 53% of the total volume of treated wastewater flowing to the Bay. Most reductions in metal loadings likely took place when the secondary or tertiary facilities were built in the 1960s and 70s. Nevertheless, loadings of copper and nickel have decreased by an additional 75% since 1986.

Copper Loadings from San Jose/Santa Clara

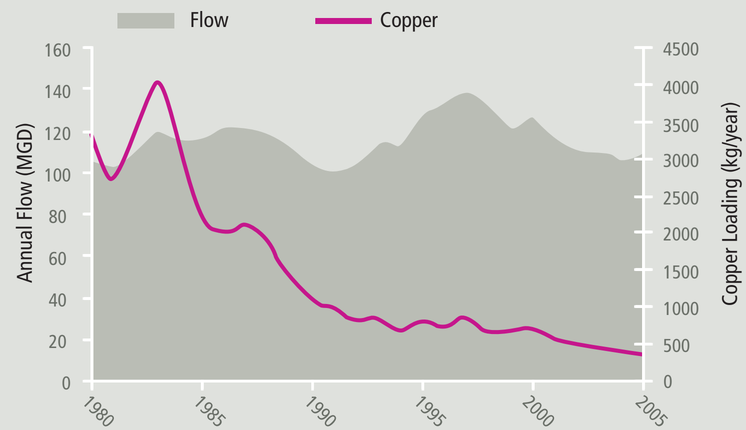


Figure 9

The San Jose/Santa Clara POTW was able to reduce its copper loading to the Bay by over 90% in the period after its tertiary treatment facility came online in 1979. The Bay Area has benefited from copper pollution prevention programs, including legislation that prompted the California Department of Pesticide Regulation (DPR) to prohibit copper-based root control products in 1995, an action that was urged by POTW groups such as BACWA and Tri-TAC. In addition, the San Jose/Santa Clara facility has implemented an In-plant Copper Reduction and Treatment Processes Optimization Program.

Bacteria in Offshore Waters

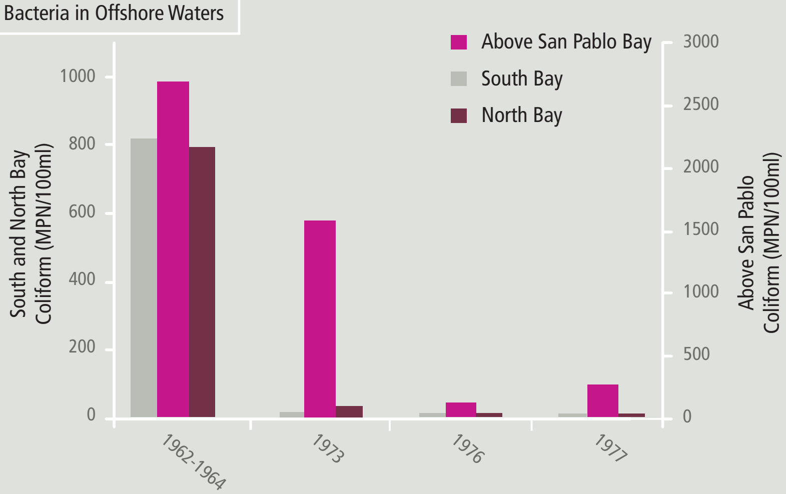


Figure 10

Data collected by the Water Board in 1977 showed rapid improvement in the bacterial quality of Bay water. Coliform bacteria are typically used as indicators of the possible presence of pathogenic (disease-causing) organisms in wastewater or the Bay.

Clean Water Act Section 305(b) requires each state to prepare a biennial report on the condition of waters within state boundaries. Referencing the Regional Monitoring Program, California's 2006 report (California Water Boards 2006) indicates that the two main contaminants of concern in the Bay are mercury and polychlorinated biphenyls (PCBs). The report also mentions the toxicity of storm-water runoff and contaminated sediments as concerns, as well as emerging contaminants such as polybrominated diphenyl ethers (PBDEs). Mercury and PCBs are targeted by cleanup plans known as total maximum daily loads (TMDLs) (Sidebar, next page).

New Challenges

Compounds of Potential Concern. Water quality managers are concerned about newly emerging pollutants termed Compounds of Potential Concern (CPC). CPCs include PBDEs, endocrine disruptors, and residues from medicines and personal care products. Many of these are present in POTW wastewater, generally at low levels, and may present a threat to Bay water quality, as they do to many water bodies in the country and the industrialized world.

Our ability to detect these emerging pollutants in the waters of the Bay and in other waterways is partly due to improved technical capabilities. Unfortunately, very little is known about these substances, and we are far from clearly understanding the level of risk associated with them. At this point, Bay Area clean water agencies are attempting to reduce these compounds in their discharges through public education campaigns and other pollution prevention efforts. CPCs are a societal issue, and preventing them from becoming the legacy pollutants of the future will take the concerted effort of all stakeholders.

Reclamation. Some POTWs currently reclaim some wastewater for reuse for irrigation or other needs. The need for wastewater reclamation will likely increase in the future due to constraints on water supplies. Most reclamation uses require higher levels of treatment.

Improved Water Quality

In a 1987 report, the Water Board summarized the benefits and changes in pollutant loadings to the Bay.

- Swimming is now safe in most areas of the Bay during summer.
- Bay water quality has improved to the point that public harvesting of shellfish in San Mateo County was approved in 1982 (for the first time in 50 years) and subsequently in 1983 and 1985.
- As a result of a dramatic improvement in DO south of Dumbarton Bridge and the low salinity regime created by tertiary effluents, Bay shrimp (*Crangon franciscorum*) were once again abundant re-establishing a viable commercial bait fishery) (SFBRWQCB 1987).

Hydromodification. Hydromodification refers to changes in a waterway resulting either in an increase or decrease in the volume of water flowing or changes in the shape of the waterway. Hydromodification has greatly impacted the Bay in the past. In the future, global climate change will likely result in additional hydromodification that could affect POTWs. Sea level rise (page 50) will increase the infiltration of salt water into some low-lying collection system sewers and thereby increase wastewater salinity, making reclamation less viable and possibly harming the biological processes involved in the wastewater treatment process. The dynamics of the Bay will also change in ways that are difficult to forecast, due to changes in patterns of runoff from the Sierra Nevada, changes in tidal action due to the increased depth of the Bay, and other factors.

Chlorination. The potential need to address byproducts resulting from chlorination and dechlorination of wastewater is another water quality concern. Recent work has shown chlorination reacts with pollutants such as some pharmaceutical residues and may increase the toxicity of some of these compounds. In the 1980s, the Water Board and POTWs conducted studies on the Bay and concluded that alternative limits for bacteria could reduce the amount of chlorine used for disinfection of effluent. These alternative limits allowed many agencies to reduce their chlorine use by 50% or more. This cooperative effort between the Water Board and POTWs greatly reduced the quantity of disinfection byproducts that reach the Bay.

Infrastructure Replacement. Much of the existing wastewater infrastructure was constructed in the 1970s and is now reaching the point that replacement and upgrades to meet new requirements are beginning to occur. One of the major responsibilities of POTWs is to collect revenues adequate to fund future replacements. Bay Area agencies are in the process of spending hundreds of millions of dollars in the next 5 to 10 years to meet this challenge.

Ongoing Efforts by POTWs

The daily activities at POTWs are directed at achieving continued reductions in pollutant loading to the Bay.

Enforcement of "Local Limits." Every reissued POTW discharge permit requires a reassessment of the numeric discharge limitations that are imposed by the POTWs on industries and other regulated facilities discharging to the municipal collection system. Municipal agencies monitor dischargers as well as influent to the treatment plant to track performance.

Implementation of Pollutant Minimization Programs. The permits also require specific control efforts to address pollutants suspected of exceeding limitations.

Optimizing treatment. Treatment plant operators continue to look for opportunities to fine-tune treatment operations and improve the performance of existing facilities.

Support for research and monitoring. Wastewater agencies are major supporters of the Regional Monitoring Program and financially support the collection of technical data for TMDL development for the Bay. The agencies also contribute to national efforts such as the Water Environment Research Foundation, whose work includes a current research project on Estimation of Mercury Bioaccumulation Potential from Wastewater Treatment Plants in Receiving Waters. This research will attempt to clarify the relationship between mercury levels in wastewater treatment plant discharges and mercury accumulation in the food web.

Recent Initiatives

While the initial pollution control efforts in the 1970s and 1980s focused on building treatment facilities, many of the newer programs are directed at controlling original sources, that is, keeping problem pollutants out of wastewater collection systems altogether.

Collecting Discarded Medicines. In May 2006, the Bay Area Pollution Prevention Group, composed mostly of Bay Area clean water agencies, collected 3,500 pounds of unused or expired medications at 32 locations. Some agencies currently provide ongoing collection services or facilities.

Controlling Dental Mercury. In 2004, San Francisco began the state's first regulatory program to capture the mercury released during the preparation, placement, and removal of silver fillings. Other Bay Area agencies have now implemented or are planning to implement similar efforts.

Comprehensive Pollution Prevention. Palo Alto's Regional Water Quality Control Plant has developed a Clean Bay Campaign targeting pollution prevention efforts not only for toxic wastes going into the collection system but also pollutants, such as pesticides used on lawns, which are carried into the Bay by stormwater.

Thermometer Exchange, Fluorescent Light Bulb Recycling, and Related Efforts. Many wastewater agencies provide facilities and financial support for recycling household products containing mercury and other toxics (see http://www.baywise.info/).

Wastewater agencies view their primary mission as protecting the Bay and will continue to implement the programs needed to achieve this goal.

TMDLs and POTWs

TMDLs are being prepared for both mercury and PCBs. The TMDLs are required for polluted waterways and result in the allocation of "safe" loadings of pollutants to dischargers and other sources as a means of bringing pollutant concentrations to acceptable levels. Currently, mercury loading to the Bay from POTWs is estimated at 17 kg/yr, which is 1.4% of the estimated 1,200 kg/yr that enters the Bay. The TMDL calls for a reduction of the POTW load to 11 kg/yr. For comparison, urban storm water is estimated to contribute about 160 kg/yr (about 13% of the total load) and will receive an allocation of 82 kg/yr.

For PCBs, the estimate of current total loading is 84 kg/year, with 2.3 kg/year coming from POTWs (about 2.7%) and 40 kg/year from urban runoff (about 48%). As currently planned, both POTWs and urban runoff management agencies will need to reduce loading to 2.0 kg/yr. Pollution prevention efforts, rather than additional treatment, will likely be used to achieve the necessary load reductions from POTWs.

Glossary

303(d) List
Official list of water bodies that do not meet water quality standards, required by Section 303(d) of the Clean Water Act.

Acute toxicity tests
Toxicity tests that measure mortality in a relatively short exposure period.

Atmospheric deposition
The transfer of pollutants from the atmosphere to the water or land surface.

Basin Plan
Water Quality Control Plan for the San Francisco Bay Basin The Water Board's master water quality control planning document for the Bay. It designates beneficial uses and water quality objectives, and includes programs of implementation to achieve water quality objectives.

Beneficial uses
Specific benefits derived from a water body that water quality managers strive to protect. Some important uses of the Bay are fishing, habitat for aquatic life, contact and non-contact water recreation, and shellfish harvesting.

Best practicable technology
A level of treatment based on available technology established by USEPA under the Clean Water Act for each class of industry emitting pollution.

Bioaccumulation
The accumulation of pollutants by living organisms.

Bioaccumulative
Describes pollutants with a tendency to accumulate in living organisms.

Biosolids
Nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility.

BOD Biochemical Oxygen Demand
A measure of the amount of organic matter in water that consumes and depletes dissolved oxygen.

California Toxics Rule
Rule promulgated by USEPA in 2000 that made federal water quality criteria legally applicable to California waters (i.e., equivalent to water quality objectives).

Capping
Covering contaminated sediment with cleaner sediment in a manner that keeps the contaminants out of circulation.

Central Bay
See Figure 2, page 82.

Chlordane
A persistent, chlorine-based organic chemical widely used as an insecticide until it was banned in 1988.

Chronic toxicity tests
Toxicity tests that measure sublethal responses such as growth or reproduction in a relatively long exposure period.

Coliform bacteria
Bacteria found in the intestinal tract of humans and animals. Their presence in water indicates fecal pollution and potentially adverse contamination by pathogens.

Conservative
A substance that does not become degraded in the Bay.

Copper
A heavy metal used in many products, including brake pads and pesticides, that is highly toxic to aquatic life, especially bivalves and algae.

Cyanide
General term for a group of compounds containing carbon and nitrogen, some of which are toxic. Small amounts of cyanide are formed in municipal wastewater treatment plants as a by-product of disinfection processes, such as chlorination.

DDT
A ubiquitous, persistent, chlorine-based organic chemical widely used as an insecticide until it was banned in 1972.

Delta outflow
Water and associated sediment and pollutants that flow from the Sacramento-San Joaquin Delta into the Bay.

Diazinon
An organophosphate insecticide commonly used in agriculture and residential pest control through the 1990s. Residential use was banned in 2004.

Dieldrin
A persistent, chlorine-based organic chemical widely used as an insecticide until it was banned in 1988.

Dilution credit
Mechanism by which discharges to waters with greater dilution are granted more lenient effluent limits.

Dioxins
Highly toxic, persistent organic chemicals that are primarily by-products of combustion and accumulate in food chains.

Dissolved concentrations in water
The fraction of a pollutant concentration that is not associated with sediment particles suspended in a water sample.

DO Dissolved oxygen
Oxygen that is dissolved in water. DO is vital to aquatic organisms.

Dredging windows
Limited periods of time in which dredging and disposal of dredged material are allowed because impacts on aquatic species such as migratory fish are unlikely.

Emerging pollutants
Pollutants where water quality objectives are not in place, but limited information available suggests possible ecological or human health risks.

Exotic species
Non-native aquatic species introduced to the Bay.

Impairment
Interference with a beneficial use.

Implementation
Carrying out plans to improve water quality and restore beneficial uses.

Legacy pesticides Includes DDT, Dieldrin, and Chlordane
Persistent insecticides widely used in the 1950s and 1960s, banned in the 1970s and 1980s, but still accumulate in the food chain.

Legacy pollutants
Persistent pollutants that entered the Bay as a result of historical activities no longer practiced.

Loading
The release or transport of a mass of pollutant into the Bay.

Lower South Bay
The portion of the Bay south of the Dumbarton Bridge. See Figure 2, page 82.

Mercury
A heavy metal that accumulates in the food chain and is highly toxic.

Seal lions at Fisherman's Wharf. Photograph by Jay Davis.

Methylmercury
The problematic form of mercury that comprises only about 1% of total mercury in aquatic ecosystems, but accumulates in the food chain and is highly toxic.

Narrative water quality objective
A water quality objective that does not specify numeric limits.

Nickel
A heavy metal used in many products that is moderately toxic to aquatic life.

NPDES Program
National Pollutant Discharge Elimination System - A provision of the Clean Water Act which prohibits discharge of pollutants into waters of the United States unless a special permit is issued by USEPA, a state, or tribal government.

Nonpoint source
Diffuse pollution sources without a single point of origin. The pollutants are generally carried off the land by storm water.

Nonurban runoff
Runoff from nonurban lands, such as agricultural lands, pastures, and open space.

North Bay
See Figure 2, Segments 1 & 2, page 82.

Nutrients
Nitrogen, phosphorus, and other elements that stimulate growth of algae.

Organophosphates
A class of insecticides that contain phosphorus. Diazinon and chlorpyrifos are prominent examples.

PAHs
Polycyclic Aromatic Hydrocarbons
Organic chemicals that are found in petroleum and are formed in petroleum combustion, and are toxic to aquatic organisms.

Pathogen
Bacteria or viruses that can cause illness.

Pathways
The routes through which contaminants enter the Bay, such as urban runoff, streams and rivers, deposition from the atmosphere, or wastewater discharge. Pathways are sometimes misconstrued as sources.

PBDEs
Polybrominated diphenyl ethers
A class of flame retardant chemicals that contain bromine and accumulate in aquatic food chains.

PCBs
Polychlorinated biphenyls
Persistent, toxic organic chemicals that were widely used by electrical utilities and industry, banned in 1979, but still accumulate in the food chain today.

Petroleum hydrocarbons
Organic chemicals, including PAHs and others, that are found in petroleum and are toxic to aquatic organisms.

Pollution prevention
Reducing or eliminating pollutants at the source by modifying production processes, the use of non-toxic or less-toxic substances, conservation, and re-use of materials.

POTW
Publicly-owned treatment works
A facility that treats sewage and wastewater from homes, businesses, and industry prior to discharge of the water into the Bay or other water body.

ppb
parts per billion
A unit describing concentrations. For example, 1 ppb is equivalent to 1 milligram of pollutant in 1000 kilograms of sediment.

ppm
parts per million
A unit describing concentrations. For example, 1 ppm is equivalent to 1 milligram of pollutant in 1 kilogram of sediment.

Pretreatment
Treatment to reduce the level of pollutants discharged by industry and other non-domestic wastewater sources into municipal sewer systems.

Primary treatment
The first stage of the wastewater treatment process where mechanical methods, such as filters and scrapers, are used to remove pollutants.

Pyrethroids
Insecticides that are currently heavily used and are highly toxic to fish and aquatic invertebrates.

San Pablo Bay
See Figure 2, page 82.

Secondary treatment
A wastewater treatment process involving the biological process of reducing organic matter through bacterial metabolism.

Sediment quality objectives
Guidelines for the protection of sediment quality, similar to water quality objectives.

Sediment Toxicity
An index of sediment pollution derived from exposure of test organisms to sediment from the Bay.

Selenium
An element that enters the Bay from agricultural runoff and wastewater effluent, accumulates in the food chain, and is toxic to aquatic life.

Silver
A heavy metal formerly used in photo processing that is highly toxic to aquatic life.

Site-specific objectives
Water quality objectives developed for a specific water body that are adjusted due to local water quality factors that affect the risks posed by a pollutant.

Sources
Activities leading to the release of pollutants into the environment, such as combustion of gasoline in a car engine or application of a pesticide to an agricultural crop.

South Bay
See Figure 2, page 82.

Suisun Bay
See Figure 2, page 82.

Suspended solids
Particles of solid material suspended in water.

Technology-based effluent limit
Effluent limits based on application of the best available treatment technology.

Tertiary
A third stage of wastewater treatment that removes nutrients or other pollutants that resist conventional treatment practices.

TMDL
Total maximum daily load
A cleanup plan called for by the Clean Water Act, based on determining the maximum load that an aquatic ecosystem can receive without adverse impacts.

Total concentrations in water
The sum of the dissolved fraction and the particle-associated fraction of pollutants in a water sample.

Total mercury
The overall sum of all forms of mercury.

Toxicity
The observation of a significant toxic response in a toxicity test.

Toxicity test
A laboratory procedure in which test organisms are exposed to pollutants under controlled conditions.

TSS
Total suspended solids
A measure of the amount of sediment particles in water.

Ultra-clean techniques
Chemical analysis techniques that take extreme precautions to avoid sample contamination. Necessary for measuring minute amounts of pollutants in environmental samples.

Urban runoff
Runoff from urban areas driven primarily by rainstorms but also by irrigation.

Water Board
The San Francisco Bay Regional Water Quality Control Board. The agency with primary responsibility for managing water quality in the Bay.

Water column
The volume of water between the surface of the Bay and the bottom sediment of the Bay.

Water quality based effluent limit
Effluent limits applied to discharges when application of technology-based limitations would still cause violations of water quality standards.

Water quality criteria
A numerical value for a pollutant set by the USEPA to protect aquatic life, wildlife, or human health. Water quality criteria are not binding until adopted as water quality objectives by the state via a regulatory action.

Water quality objectives
Legally enforceable numerical or narrative guidelines, usually based on federal water quality criteria, established to protect beneficial uses of a water body.

Water quality standards
Collectively the beneficial uses of a water body, the water quality objectives (which can be numerical or narrative) established to protect the beneficial uses, and the antidegradation policy.

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