A REVIEW OF WASTEWATER PROBLEMS and WASTEWATER MANAGEMENT PLANNING in the SAN FRANCISCO BAY REGION, CALIFORNIA

OPEN—FILE REPORT

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

Menlo Park, California, 1973
PREPARED IN COOPERATION WITH THE
U.S. DEPARTMENT OF HOUSING AND
URBAN DEVELOPMENT

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

A REVIEW OF WASTEWATER PROBLEMS AND WASTEWATER-MANAGEMENT PLANNING IN THE SAN FRANCISCO BAY REGION, CALIFORNIA

By

W. G. Hines

Prepared in cooperation with the
U.S. Department of Housing and Urban Development

OPEN-FILE REPORT

Menlo Park, California
January 8, 1973

CONTENTS

ILLUSTRATIONS

TABLES

CONTENTS

APPENDIX

A REVIEW OF WASTEWATER PROBLEMS AND WASTEWATER-MANAGEMENT PLANNING IN THE SAN FRANCISCO BAY REGION, CALIFORNIA

By W. G. Hines

ABSTRACT

The San Francisco Bay region has suffered adverse environmental effects related to the discharge of municipal-, industrial-, and agricultural-wastewater and storm-water runoff. Specific pollutional properties of these discharges are not well understood in all cases although the toxic materials and aquatic-plant nutrients (biostimulants) found in municipal and industrial wastewater are considered to be a major cause of regional water-quality problems. Other water-quality problems in the region are commonly attributed to pesticides found in agricultural wastewater and potentially pathogenic bacteria in municipal-wastewater discharges and in storm-water runoff.

The geographical distribution and magnitude of wastewater discharges in the bay region, particularly those from municipalities and industries, is largely a function of population, economic growth, and urban development. As might be expected, the total volume of wastewater has increased in a trend paralleling this growth and development. More significant, perhaps, is the fact that the total volume of pollutants contained in wastewater discharges, as measured by several parameters such as BOD (biochemical oxygen demand), biostimulant concentrations, and toxicity, has increased despite large expenditures on new and improved municipal- and industrial-wastewater-treatment plants. Also, pollutant loadings from other major sources, such as agriculture and storm-water runoff, have increased.

At the time of writing (1972), many Federal, State, regional, and local agencies are engaged in a comprehensive wastewater-management-planning effort for the entire bay region. Initial objectives of this planning effort are: (1) the consolidation and coordination of loosely integrated wastewater-management facilities and (2) the elimination of wastewater discharges to ecologically sensitive areas, such as fresh-water streams and shallow extremities of San Francisco Bay. There has been some investigation of potential long-range wastewater-management alternatives based upon disposal in deep water in the bay, in the Pacific Ocean, or on land. Also, wastewater-reclamation and water-reuse concepts seem to be growing in favor with the public and should become an important part of future wastewater-management plans. Because most wastewater-reclamation and water-reuse systems would involve the use of land (that is, agricultural irrigation, ground-water recharge, recreational reservoirs) local and regional land-use planners can add much to wastewater-management planning by identifying local and subregional wastewater-reclamation and water-reuse possibilities within their jurisdictions and integrating them with future land-use plans. The timely participation of planners is essential because Federal and State planning and funding deadlines for a regional wastewater-management system become effective in July 1973 and July 1974, respectively.

INTRODUCTION

The people of the San Francisco Bay region (fig. 1) utilize the area's fresh and estuarine water, and ultimately the Pacific Ocean, as the final phase of a vast, though poorly planned, wastewater-disposal system. The principal sources of wastewater discharges are municipal and industrial outfalls, agricultural drains, and storm-water runoff; other sources include watercraft, sanitary landfills, and septic tanks.

The quantity of wastewater discharged in the bay region is enormous and continually increasing. Hines and Palmer (1971) reported that in 1971 the volume of identifiable municipal and industrial wastewater discharged directly into San Francisco Bay, or tributary fresh-water streams, was approximately 880 mgd (million gallons per day). Total municipal- and industrial-wastewater discharge will likely increase to more than 2 bgd (billion gallons per day) by 2020 as most projections indicate a 2- to 3-fold increase in the regional population in the next 50 years (Kaiser Engineers, 1969, p. VI-6). Two billion gallons per day of municipal and industrial wastewater would be sufficient to fill more than 40 percent of the present volume of the bay in 1 year's time, if it were not for tidal-exchange and fresh-water flushing processes. Wastewater discharge from sources other than municipalities and industries will also increase substantially as population increases and intensive urbanization and resource development continues.

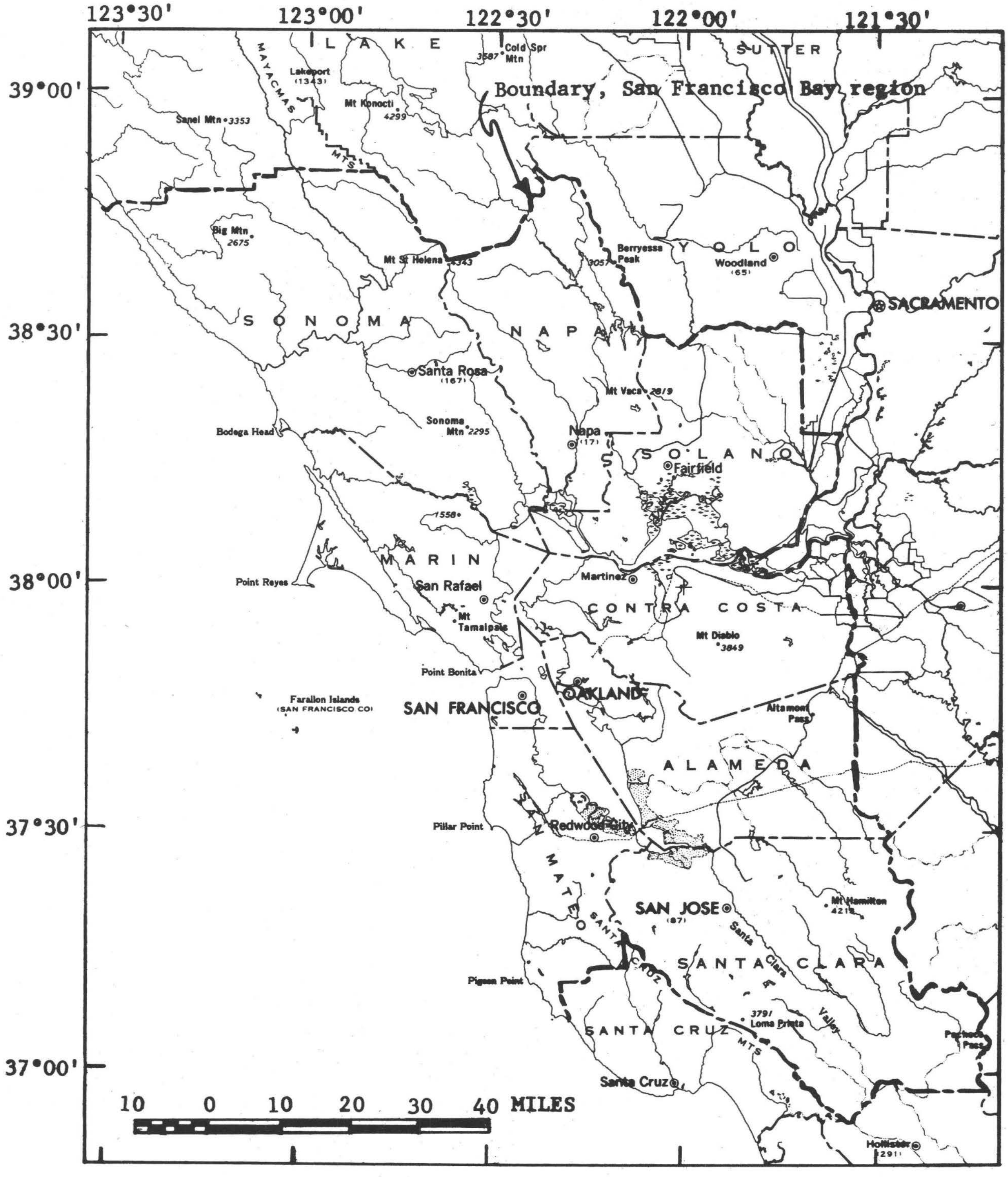


FIGURE 1.--The San Francisco Bay region. Base map from State of California and U.S. Geological Survey, 1:1,000,000, 1971.

An important question now being faced is how best to collect, treat, dispose of, or reuse this tremendous volume of wastewater. If the water of the bay system is to retain the functional and ecological values that are a vital part of the desirable living habitat of the region, practical solutions to wastewater-management problems must be forthcoming. A prerequisite to these solutions is a basic understanding of the source, distribution, and magnitude of wastewater discharged in the bay region.

Purpose and Scope

Planners, government officials, and general citizens have heard much in recent years about the increasingly serious wastewater and water-quality problems in the bay region. Many reports, documents, and newspaper articles have been written about these problems. From the standpoint of the nontechnical reader (indeed for many technical readers) many of the reports and documents are not well known and are often voluminous and difficult to understand. Newspaper articles that have summarized wastewater and water-quality reports and documents have no doubt appeared contradictory and confusing to readers in some cases. This situation is not surprising considering the difficulties involved with studying and reporting on the aspects of an environment as vast and complex as the San Francisco Bay region.

This report reviews the results of past studies, complements findings of current studies related to wastewater and water-quality problems in the bay region; and presents a simple exposition of various plans that have been suggested to cope with such problems. The report is not intended to replace, duplicate, or take issue with current programs being undertaken by Federal, State, regional, and local regulatory or planning agencies.

The report includes a discussion of (1) the major pollutional properties of wastewater, (2) the source, distribution, and magnitude of wastewater discharges in the bay region as referenced to present and predicted future conditions, (3) water-quality problems caused by wastewater discharges, and (4) alternative plans for managing wastewater.

Because of the introduction of many technical terms and concepts, lay readers may find it desirable initially to forego much of the discussion and data presentation given on pages 5 through 33. This is particularly true for those interested primarily in an overview of regional water-quality problems and wastewater-management planning (p. 34 through 43).

This report was prepared by the U.S. Geological Survey, in cooperation with the U.S. Department of Housing and Urban Development as part of the San Francisco Bay Region Environment and Resources Planning Study (SFBRERPS). The work was done during 1971 and 1972 under the general direction of Lee R. Peterson, district chief in charge of water resources investigations in California, and under the immediate supervision of Loren E. Young, chief of the Menlo Park subdistrict office. The author wishes to acknowledge the assistance and encouragement given by Robert C. Averett and David A. Rickert of the Geological Survey during the preparation of this report.

MAJOR POLLUTIONAL CHARACTERISTICS OF WASTEWATER IN THE BAY REGION

Wastewater, whether of municipal, industrial, agricultural, or storm-water origin, is a complex mixture of many different types of pollutants. Several of these pollutants are fairly easy to characterize. Others exhibit extremely complex behavior in aquatic environments and are difficult to accurately monitor and describe with regard to their pollutional effects. To partially overcome this difficulty, engineers and scientists often use a simplified categorization of wastewater parameters. In the bay region, several comprehensive studies have utilized a classification based upon the important pollutional significance of five basic wastewater parameters: (1) toxicants, (2) pesticides, (3) biostimulants, (4) oxygen-consuming substances, and (5) bacteriological contaminants. This classification is generally consistent with the classification used in recent studies published by the Sanitary Engineering Research Laboratory, University of California, Berkeley, Calif. (Pearson, Storrs, and Selleck, 1969), and Kaiser Engineers (1969). Current wastewater and water-quality surveillance and regulatory programs conducted by the California Regional Water Quality Control Board, San Francisco Bay Region, also are based on this classification.

Pollutant Classification

Toxicants

Almost all municipal and industrial wastewater is to some degree toxic to aquatic life. The recommended test for toxicity is a standard laboratory bioassay procedure (American Public Health Association and others, 1971, p. 562). In this test, various dilutions of the wastewater are made, and aquatic organisms of the same species are placed in each of the resulting wastewater solutions. Usually, the test organisms are fish native to the aquatic environment in which the wastewater is discharged. The degree of wastewater toxicity is measured by noting the strength of the solution in which one-half of the test organisms are able to survive for a given time period, usually 48 to 96 hours. This measurement of wastewater toxicity is commonly termed "median tolerance limit" (TL_m) and is expressed as a percentage. Thus, a small percentage, or low TL_m value, indicates a highly toxic wastewater.

In the San Francisco Bay region, municipal and industrial wastewater exhibits a wide range in toxicity, although industrial wastewater that contains substances such as phenols or heavy metals commonly has the lowest TL_m (table 1). The toxic properties of agricultural wastewater usually can be related to pesticide[1] content while the toxic properties of storm-water runoff are largely unknown.

TABLE 1.--*Toxicity of municipal and industrial effluents, San Francisco Bay region*

[From Kaiser Engineers, 1969, p. V-9]

Type of effluent	48-hour median tolerance limit[1] (percent)			Number of discharges sampled
	Minimum	Maximum	Average[2]	
Municipal				
Primary treatment	57	86	76	15
Secondary treatment	72	95	83	9
Industrial				
Chemicals	3	91	68	6
Petroleum refining	12	50	43	2
Paper refining	-	-	[3]99	1

[1]Test fish: Stickleback (Gasterosteus aculeatus)
Dilution water: Brackish
Temperature: 17.1 to 17.9°C
Dissolved oxygen: 5 mg/l or more
[2]Flow-weighted average.
[3]Estimated from test using fresh dilution water.

Obvious shortcomings of the standard toxicity test include the test's inability to indicate long-term (chronic) toxic effects on the test organism or to indicate toxic effects on aquatic organisms other than the test organism. Despite these deficiencies, the toxicity test is presently the only widely recognized means for assessing the acute toxic properties of wastewater. Currently (1972), a wastewater toxicity research program is being concluded by the Sanitary Engineering Research Laboraboty, University of California, Berkeley, in conjunction with several State agencies. Hopefully, the results of this study will lead to better methodology for quantifying the toxic properties of wastewater discharges in the bay region.

The term "relative toxicity" has been developed as a means of quantifying the toxic effects of wastewater discharges and relating the significance of one discharge to another (Armstrong, Storrs, and Pearson, 1970). Relative toxicity can be defined by the following equation:

$$\text{Relative toxicity} = \frac{Q}{48\text{hr-}TL_m}$$

where Q = wastewater flow, in million gallons per day, and
$48\text{hr-}TL_m$ = 48-hour median tolerance limit.

For example, a mildly toxic wastewater discharged in large quantities may have the same relative toxicity as a highly toxic wastewater discharged in lesser quantities. The relative toxicity concept has been used in describing the regional pollutant-loading patterns presented later in this report.

[1]Because of their pollutional significance, pesticides are considered as a separate topic in this report.

Pesticides

Pesticides include a wide spectrum of toxic chemical substances used in the control of plant and animal pests. Insecticides, herbicides, fungicides, fumigants, and other types of biocides commonly are referred to as pesticides. Pesticides usually are classified as either chlorinated hydrocarbons, or phosphorothioates, depending upon the basic chemical composition. Both types of pesticides are complex organic molecules. The chlorinated hydrocarbons contain molecules of carbon, hydrogen, and chlorine atoms, while the phosphorothioates contain molecules of carbon, hydrogen, and phosphorus atoms (other types of atoms may be included in the molecule as well). Most pesticides, particularly the chlorinated hydrocarbons, are long-lived substances with a tendency for accumulation in bottom muds and progressive concentration in the biological food chain of aquatic organisms.

The major source of pesticides in the bay region usually is considered to be agricultural wastewater. There is growing evidence (see table 2), however, that wastewater from municipal and industrial sources and runoff from urban areas are also important sources of pesticides. Table 2 summarizes available data on pesticide concentrations in water and wastewater common to the bay region.

TABLE 2.--*Pesticide concentrations detected in wastewater and in urban storm-water runoff, San Francisco Bay region*

Source of sample	Pesticide type[2]	Concentration (μg/l)
Treated municipal wastewater[1]		
Primary effluent (4 plants)[3]	TICH	2.7
Primary effluent (2 plants)[4]	TICH	4.0
Secondary effluent[5]	TICH	1.3
Industrial effluent[1]		
Industry A	TICH	.9
Industry B	TICH	.1
Agricultural wastewater[6] (Peak concentration, 60-78 samples)		
Subsurface irrigation returns	TICH	1.1
	Phosphorothioates	.9
Surface irrigation returns	TICH	6.2
	Phosphorothioates	5.3
Storm-water runoff[7]		
	Chlordane	.4
	DDT,DDD,DDE	0
	Herbicides[8]	.5

[1]Engineering Science, Inc. (1968). Concentrations are mean values computed from duplicate analyses of 24-hour composite samples of municipal effluent and two grab samples of industrial effluent. All samples were collected during the period May 8-12, 1968. Industries were not identified by Engineering Science, Inc. See figure 4 for explanation of municipal-treatment processes.

[2]TICH (total identifiable chlorinated hydrocarbons) as calculated from summation of DDT, DDD, DDE, Heptachlor epoxide, and Lindane concentrations. Phosphorthioate values calculated from addition of Parathion, Malathion, Baytex, and Ethion concentrations.

[3]Plants operated by the Ora Loma Sanitary District, city and county of San Francisco (North Point); Marin County Sanitary District No. 1, and Central Contra Costa Sanitary District.

[4]Plants operated by the East Bay Municipal Utilities District and by the city and county of San Francisco (southeast). Both plants receive industrial wastewater from pesticide-producing industrial firms.

[5]Plants operated by the city of Vallejo and the city of San Jose.

[6]Federal Water Quality Administration (1967, p. 42).

[7]Data from current Geological Survey-Corps of Engineers storm-water runoff project, Castro Valley Creek, Hayward, Calif. Samples collected during runoff that occurred on November 11, 1971.

[8]Herbicides as calculated from addition of 2,4-D, 2,4,5,-T, and Silvex concentrations determined from a grab sample obtained November 11, 1971.

A group of substances closely related by chemical composition to the chlorinated hydrocarbons are the PCB's (polychlorinated biphenyls). The behavior of PCB's in aquatic environments, although not well understood, is believed similar to that of chlorinated hydrocarbon pesticides. Sources of PCB's are largely industrial in nature, the plastics, petroleum, and paper industries being among known specific sources.

Biostimulants

Biostimulants, or aquatic plant nutrients are commonly believed responsible for excessive aquatic plant growth in the water of the bay system. Compounds of nitrogen and phosphorus (often called primary nutrients) are believed to be the most important aquatic plant nutrients although substances such as carbon, silica, trace elements, and vitamins are also necessary for plant growth. Principal sources of excessive nutrients in the receiving water of the region are municipal and industrial wastewater discharges, and to a lesser extent, return flows from irrigated agriculture, which enter the bay system through the delta of the Sacramento and San Joaquin Rivers (fig. 7). Natural runoff from urban, suburban, and rural areas can contribute significant amounts of nitrogen and phosphorus. Typical nitrogen and phosphorus concentrations found in various types of wastewater common to the bay region are shown in table 3.

TABLE 3.--*Typical nitrogen and phosphorus concentrations in wastewater, San Francisco Bay region*
[Concentrations in milligrams per liter; dash indicates no data available]

Wastewater source	Total nitrogen as *N*	Total phosphate as *P*
Municipal:[1]		
Primary treatment	20-32	5-8
Secondary treatment	10-26	5-12
Industrial:[2]		
Petroleum refining	6.1-27	.04-3.0
Chemicals	1.0-1,200	4-410
Paper and allied products	.09-.8	Nil
Food and kindred products	-	-
Fabricated metals	1.2	.2
Agricultural:[3]		
Irrigation returns	20	.4
Storm-water runoff:[4]		
Urban areas	1.8-3.0	.2-.4
Petaluma and Napa River basins	3.1	2.2
All other basins	1.8-3.1	.2-.9

[1]Pearson, Storrs, and Selleck (1969, p. 50). See figure 4 for description of treatment levels.
[2]Pearson, Storrs, and Selleck (1969, p. 72-74).
[3]Kaiser Engineers (1969, P. VII-15, 16).
[4]Kaiser Engineers (1969, p. VII-20), Federal Water Pollution Control Administration (1967, p. 46).

In addition to biostimulatory properties, large concentrations of unoxidized nitrogen (organic nitrogen and ammonia) in wastewater can represent a significant part of the total oxygen-consuming material present in many municipal and industrial wastewaters.

Oxygen-Consuming Substances

Organic, oxygen-consuming substances are present in all municipal wastewater and, usually, in lesser concentrations, in industrial and agricultural wastewater and storm-water runoff. The oxygen-consuming properties of wastewater have traditionally been measured using the BOD (biochemical oxygen demand) test. The BOD of a wastewater is determined by a standard bioassay procedure that measures the amount of oxygen required by micro-organisms (these organisms are normally abundant in receiving water proximate to wastewater outfalls) to consume the organic substances in wastewater. The normal BOD test is conducted over a 5-day time period (BOD_5) during which approximately two-thirds of the carbonaceous oxygen demand (due to organic carbon) of a typical municipal wastewater will be exerted (fig. 2).

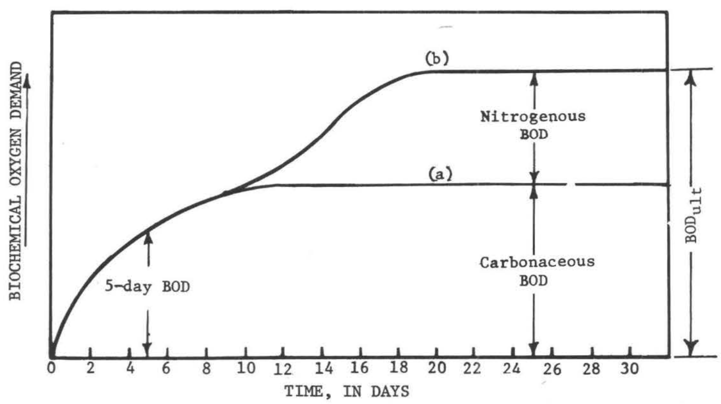


FIGURE 2.--BOD curve, depicting (a) normal carbonaceous oxygen demand, and (b) combined carbonaceous and nitrogenous oxygen demand.

Municipal and industrial wastewater having a high oxygen demand can cause dissolved-oxygen depression in receiving water. Zero or low dissolved oxygen levels, or large daily fluctuations in these levels can lead to many adverse effects including death of aquatic organisms, drastic changes in the types and numbers of indigenous aquatic organisms, obnoxious odors, and other nuisance conditions.

To more accurately describe the regional BOD loading attributable to municipal and industrial wastewater, available BOD_5 data were modified to account for the long pollutant-residence time in certain parts of the bay system. Kaiser Engineers (1969, p. III-3) indicated that pollutants discharged in the northern reaches of the bay may have residence times of 20-400 days, depending upon the magnitude of fresh-water flow carried by the Sacramento and San Joaquin Rivers. Some pollutants in south San Francisco Bay apparently are effectively flushed out of the system only during high fresh-water outflow periods (McCulloch and others, 1970, p. A-17).

The modified BOD_5 parameter, known as BOD_{ult} (ultimate biochemical oxygen demand) is depicted graphically by curve b in figure 2. Note that after about 8 days, the unoxidized nitrogenous component of a typical municipal wastewater begins to exert a significant oxygen demand. The BOD_{ult} curve of many industrial wastewaters is not accurately depicted by figure 2 because of their low nitrogenous content and the presence of toxicants inhibitory to oxygen-consuming micro-organisms. However, the use of the BOD_{ult} parameter still is more generally representative of total oxygen-demanding properties of industrial wastewater than BOD_5, which gives consistently low values. Usually, BOD_{ult} can be expected to be a closer approximation of the oxygen demand of agricultural wastewater and storm-water runoff than the BOD_5. Several of the subregional wastewater-management studies discussed later in this report are making use of BOD_{ult} in designing treatment facilities and outfall locations. Typical BOD_{ult} concentrations calculated for various types of wastewater common to the bay region are shown in table 4.

TABLE 4.—*Typical BOD_{ult} concentrations in wastewater, San Francisco Bay region*
[Concentrations, in milligrams per liter]

Wastewater source	Assumed unoxidized nitrogen concentration as N[1]	Assumed BOD_5 concentration[1]	Calculated[2] BOD_{ult}
Municipal			
Primary treatment	18	140	300
Secondary treatment	12	60	150
Industrial			
Petroleum refining	Individual effluent quality is too variable to allow presentation of average data.		
Chemicals			
Paper and allied products			
Food and kindred products			
Fabricated metals			
Agricultural			
Irrigation returns	Nil	2	3
Storm-water runoff			
Urban basins	1.2	22	36
Petaluma and Napa River basins	1.5	4	13
Other basins (suburban, low development, rural)	1.3	2	10

[1]Unoxidized nitrogen and 5-day BOD values from data presented by Pearson, Storrs, and Selleck (1969), Kaiser Engineers (1969), Federal Water Pollution Control Administration (1967), and California Water Resources Control Board (1971b).

[2]$BOD_{ult} = 1.5(BOD_5) + 5$ (unoxidized nitrogen as N).

[3]Activated sludge and trickling filter plants only.

Bacteriological Contaminants

Disease-causing micro-organisms (pathogens) are potentially present in municipal wastewater and to a lesser extent in industrial and agricultural wastewater and storm-water runoff. Effluent from septic tanks, waste discharges from watercraft, and drainage from sanitary landfills also have relatively high potential for containing pathogens. Normally, public health agencies assess the potential presence of pathogens in water and wastewater by noting the concentration of certain indicator organisms of the coliform bacterial group. Other indicators such as fecal streptococci also are used. High concentrations of these indicator micro-organisms reflect a high potential for the presence of pathogens. In the bay region, the California State Department of Public Health has periodically posted warning notices at certain shellfishing and water-contact sports areas because of high coliform bacteria concentrations (fig. 3).

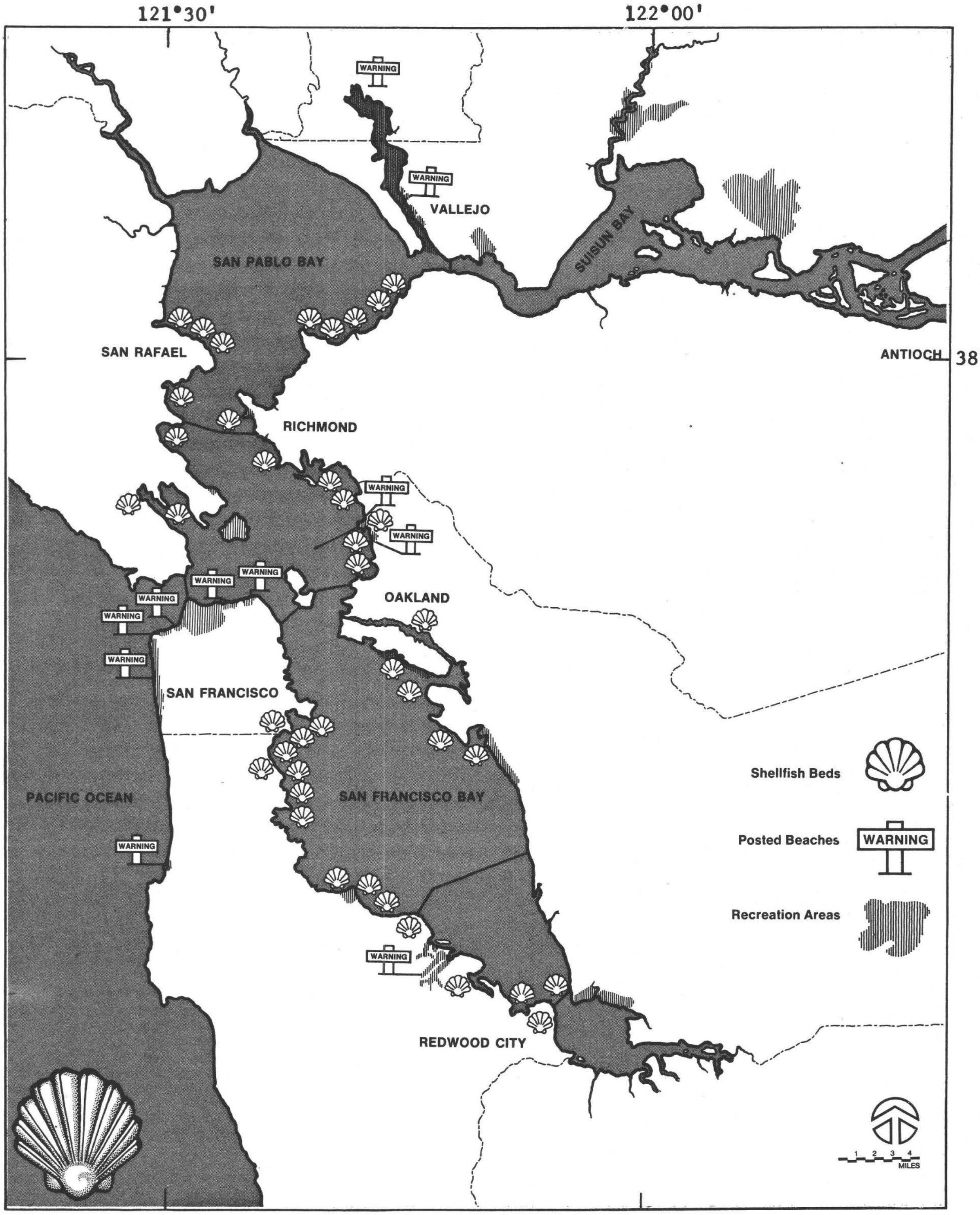


FIGURE 3.--Map showing shellfish beds and water-contact recreational areas in the San Francisco Bay that have been posted because of high coliform bacteria concentrations [adapted from California Water Resources Control Board, 1971a, p. 6].

The concentration of coliform bacteria in wastewater is highly variable. Concentrations in municipal wastewater range from 0 to more than one billion colonies/100 ml depending upon the degree of disinfection. Industrial and agricultural wastewater and storm-water runoff generally exhibit coliform concentrations that are several orders of magnitude less than undisinfected municipal wastewater. The California Regional Water Quality Control Board, San Francisco Bay Region (California Water Resources Control Board, 1971b, p. III-1 to III-2) has prescribed coliform water-quality objectives for wastewater discharges and for receiving water proximate to outfalls in an effort to control the spread of potentially harmful pathogenic organisms.

Other Pollutants

Toxicants, pesticides, biostimulants, oxygen-consuming materials, and bacteriological contaminants are the constituents of most importance in assessing pollutional characteristics of bay region wastewater. There are, however, other constituents that often must be considered in analyzing regional problems associated with water pollution. Among these are: heat, principally from power-generation and industrial-cooling waters; floatable material (including grease and oil) from watercraft, storm-water runoff, and other wastewater discharges; and suspended solids, primarily from man-related activities such as construction, massive landscape alteration, logging, and harbor dredging. Further discussion of these constituents can be found in subsequent sections of this report.

GEOGRAPHICAL DISTRIBUTION AND POLLUTIONAL LOADING OF WASTEWATER DISCHARGES IN THE SAN FRANCISCO BAY REGION

The location and magnitude of wastewater discharges is of great importance to the quality of water in the bay and other receiving waters. Not only do the amounts and types of discharged pollutants vary, but receiving water has a variable capacity to assimilate pollutants without noticeable impairment of aquatic ecosystems or the beneficial uses for which the water is intended.

Although the identification and location of municipal and industrial wastewater discharges in the bay region (app. A) has been fairly well documented by the California Water Resources Control Board, other sources of pollution are more difficult to identify and describe in a quantitative manner. For example, wastewater from agriculture; storm-water runoff; and discharges from watercraft, sanitary landfills, septic tanks, and other sources often occur seasonally or intermittently, and at ill-defined or changing locations.

Despite these difficulties, it is essential to compile information on wastewater loading before undertaking an assessment of the effects of manmade-pollutant emissions on receiving water quality. Such a compilation provides background information that is needed to formulate plans for wastewater-management systems.

The summary of regional wastewater loading presented in subsequent sections of this report was compiled from numerous sources including reports by Kaiser Engineers (1969), Pearson, Storrs, and Selleck (1969), the Federal Water Pollution Control Administration (1967), and Pearson (1958). Current wastewater-loading data were supplied by the California Regional Water Quality Control Boards, San Francisco Bay, Central Valley and North Coast Region, through cooperation with individual wastewater dischargers such as municipalities, sanitary districts, and industries.

Geographical Distribution of Municipal Wastewater Discharges

An inventory completed by the California Water Resources Control Board (1971b) identified 98 major municipal wastewater outfalls in areas tributary to San Francisco Bay. Approximately 70 of these outfalls discharge directly into the bay or into tidal water; the remaining outfalls discharge into the Pacific Ocean, into streams such as the Napa River, or to land-disposal facilities. Approximately 50 percent of the total volume of municipal wastewater discharged in 1971 received primary treatment (fig. 4), about 45 percent received secondary (or equivalent) treatment, and the remaining 5 percent was treated in other facilities such as oxidation ponds, used for crop irrigation, or reclaimed for other uses.

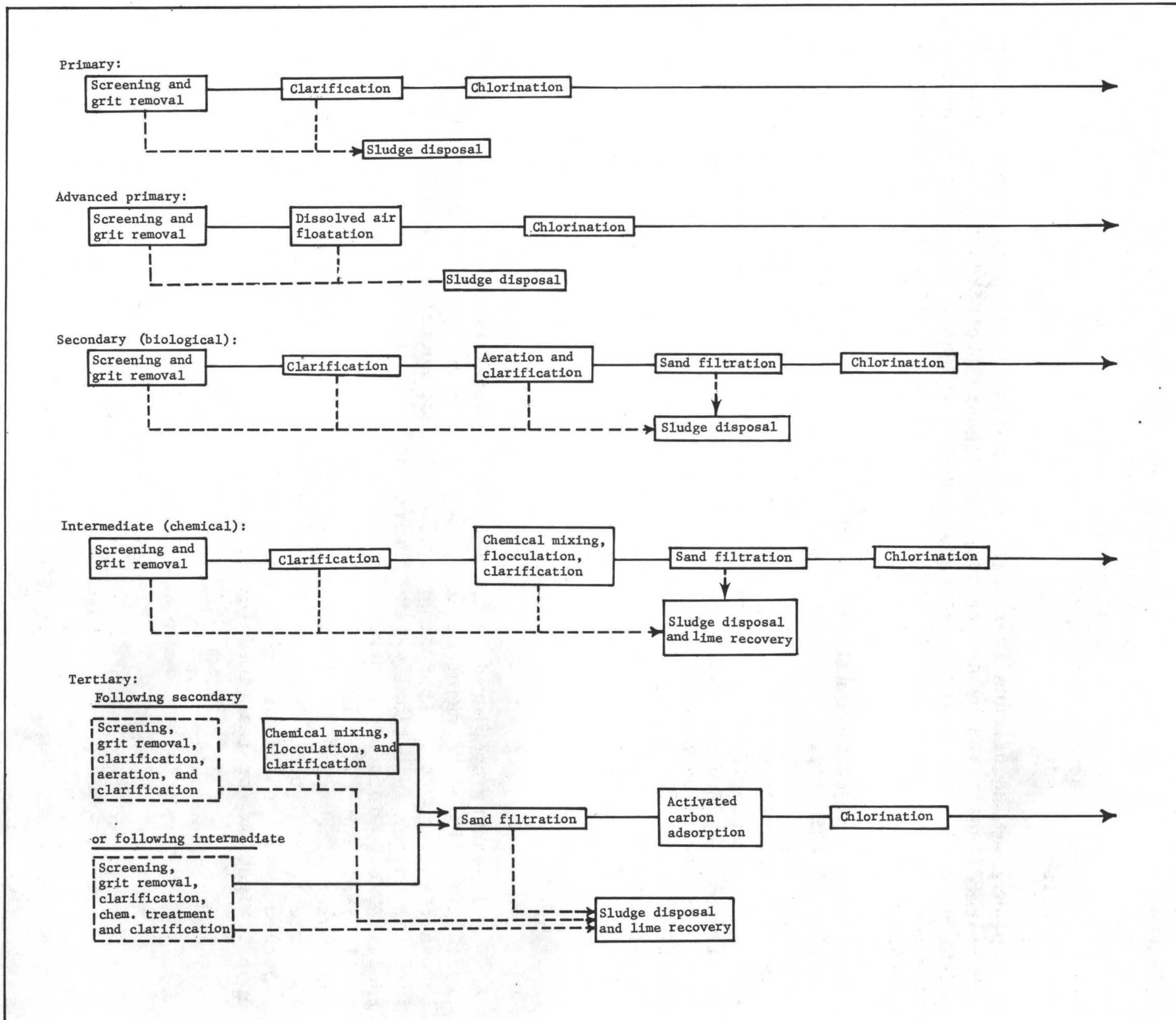


FIGURE 4.--Process diagrams for various types of municipal wastewater-treatment plants.

The location of most of the major municipal and industrial outfalls in the bay region is shown on a map[1] included as appendix A. The map is complemented by data on individual municipal discharges presented in appendix B. Note that major municipal outfalls generally are proximate to the urbanized population centers peripheral to the bay. Municipal wastewater discharged from San Francisco, Oakland, San Jose, lower Alameda County, and eastern San Mateo County account for approximately 70 percent of all municipally-sewered wastewater generated in the bay region.

The location of municipal wastewater outfalls and treatment facilities is largely controlled by the topography of these urbanized areas. Because gravity sewer systems are cheaper and involve less maintenance than pressure systems, almost all municipal-treatment plants and outfalls are located in areas of low elevation adjacent to the bay and other water bodies. Unfortunately, many of these low-lying areas are on manmade fill or other unconsolidated deposits such as bay mud. [Readers wishing to ascertain the location of specific outfalls and treatment facilities relative to manmade fill and the bay mud can examine a map by Nichols and Wright (1971) which shows the historic margins of the bay.] This land is often not well suited for structures because of geologic instability and seismic hazard.

As public investment in treatment facilities continues to increase, wastewater-management systems will be expected to operate for longer periods of time to be economic and effective; therefore, site selection and structural stability of treatment and conveyance systems will become more important in the future.

---

[1]The outfall map does not include the entire SFBRERPS area as previously identified in figure 1, but describes the area within the jurisdiction of the California Regional Water Quality Control Board, San Francisco Bay Region. With the exception of several municipal discharges in the Santa Rosa area of Sonoma County, the eastern part of Solano County, and the southern part of Santa Clara County, the outfall map in appendix A includes all major municipal outfalls in the bay region. Readers wishing information on municipal outfalls in those areas not covered by the outfall map can examine a map prepared by Limerinos and Van Dine (1970) or consult directly with the California Water Resources Control Board in Sacramento. All major industrial outfalls in the bay region are included in appendix A.

Municipal wastewater-treatment levels in the bay region have historically been largely governed by the dilution capacity of local receiving water. For example, in Suisun Bay and in the central parts of San Francisco Bay where fresh-water flow or tidal action is relatively large, municipal-wastewater-treatment plants are typically of the primary type. The wastewater-treatment plants in San Francisco (app. B) are examples. In the shallow extremities of the bay system and in inland areas, municipal wastewater generally receives secondary treatment, the principal advantage over primary treatment being the elimination of a larger fraction of the BOD and suspended-solids load.

Municipal Wastewater Loading

The evaluation of municipal wastewater loading in the San Francisco Bay region involves the compilation of discharge and wastewater-quality data from all major municipal treatment plants. Fortunately, earlier investigations [Pearson, Storrs, and Selleck (1969) and Kaiser Engineers (1969)] included a compilation of these data for the period 1960-64. Municipal wastewater data for the period 1970-71 (Hines and Palmer, 1971) can then be utilized to examine regional wastewater-loading trends that have occurred during the period 1960-71.

Figure 5 depicts six major receiving water regions of the bay system originally identified by Pearson, Storrs, and Selleck (1969). Tables 5 and 6 show municipal wastewater-loading data within each of these water regions for 1960-64 and 1970-71. Table 5 presents total municipal-wastewater loading rates within each receiving water region while table 6 presents per capita rates. All data included in tables 5 and 6 are for treated wastewater. [The 1970-71 total nitrogen- and phosphate-loading data shown in tables 5 and 6 are estimated based upon coefficients developed in a previous report (Hines and Palmer, 1971.]

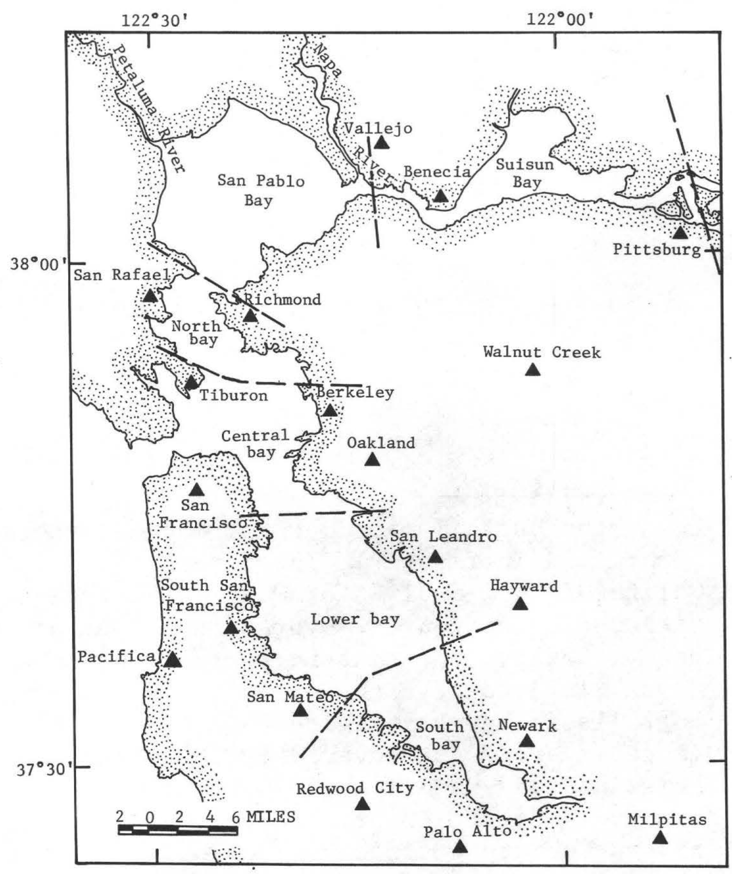


FIGURE 5.--Diagram showing major receiving water regions of the San Francisco Bay system.

TABLE 5.--*Treated municipal-wastewater loads discharged to the San Francisco Bay system, 1960-64 and 1970-71*
[Data compiled from Pearson, Storrs, and Selleck (1969) and public files of the California Regional Water Quality Control Board, San Francisco Bay region, Oakland, Calif.]

Region	1960-64						1970-71					
	Population (millions)	Flow (mgd)	BOD_{ult} (lbs/day)	Total nitrogen (lbs/day)	Total phosphate (lbs/day)	Relative toxicity (mgd)	Population (millions)	Flow (mgd)	BOD_{ult} (lbs/day)	Total nitrogen (lbs/day)	Total phosphate (lbs/day)	Relative toxicity (mgd)
South bay	0.79	85	256,000	18,300	7,400	90	1.32	150	250,000	26,000	11,000	240
Lower bay	.39	45	140,000	11,000	3,600	62	.60	67	136,000	11,000	4,300	104
Central bay	1.20	144	500,000	32,100	8,300	210	1.45	190	487,000	31,000	9,500	235
North bay	.18	19	37,000	3,300	1,200	34	.22	26	34,000	4,100	1,700	42
San Pablo Bay	.27	21	45,000	4,600	2,100	18	.38	41	92,000	8,000	2,900	77
Suisun Bay	.20	18	38,000	4,100	1,600	22	.50	41	102,000	9,900	3,400	47
	3.53	332	1,016,000	73,400	24,200	436	4.47	515	1,101,000	90,000	32,800	745

TABLE 6.--*Treated municipal-wastewater-loading coefficients for 1960-64 and 1970-71, San Francisco Bay system*
[Data compiled from Pearson, Storrs, and Selleck (1969) and public files of the California Regional Water Quality Control Board, San Francisco Bay region, Oakland, Calif.]

Region	1960-64						1970-71					
	Population (millions)	Flow (gal/cap/day)	BOD_{ult} (lbs/cap/day)	Total nitrogen (lbs/cap/day)	Total phosphate as P(lbs/cap/day)	Relative toxicity (gal/cap/day)	Population (millions)	Flow (gal/cap/day)	BOD_{ult} (lbs/cap/day)	Total nitrogen (lbs/cap/day)	Total phosphate as P(lbs/cap/day)	Relative toxicity (gal/cap/day)
South bay	0.79	108	0.32	0.023	0.009	114	1.32	114	0.19	0.020	0.008	181
Lower bay	.39	115	.36	.028	.009	82	.60	112	.23	.019	.009	173
Central bay	1.20	120	.42	.027	.007	75	1.45	131	.34	.021	.007	162
North bay	.18	106	.20	.018	.006	190	.22	118	.16	.019	.008	191
San Pablo Bay	.27	78	.17	.017	.008	70	.38	108	.24	.021	.008	203
Suisun Bay	.20	90	.19	.020	.008	110	.50	82	.20	.020	.007	94
Total	3.03						4.47					
Population-weighted averages		110	0.34	0.024	0.008	144		115	0.25	0.020	0.007	167

Municipal wastewater outfalls in areas more than about 10 miles from the periphery of the bay system are not included in the loading data presented in tables 5 and 6. These areas generally include municipalities discharging wastewater to the Pacific Ocean, to inland reaches of streams tributary to the bay or to streams that are tributary to the Pacific Ocean. Examples are Pacifica (ocean discharge), St. Helena (upper Napa River discharge), and Santa Rosa (Russian River basin discharge).

The regional wastewater-loading data presented in tables 5 and 6 indicate several trends that have been characteristic of wastewater management in the bay region in recent times.

1. Improvements to municipal wastewater-treatment plants between 1960 and 1971 have typically consisted of replacing or upgrading primary treatment plants with secondary treatment plants. These improved treatment facilities have caused a moderate overall reduction in BOD_{ult}, total nitrogen, and total phosphate per capita loading coefficients in several parts of the bay region (table 6). However, reductions in per capita loads for these constituents have been more than offset by increases in total loads (table 5) attributable to population growth, urban development, and other factors. In short, despite increased levels of municipal wastewater treatment between 1960 and 1971, pollutant loads discharged to the bay system continued to increase.

2. The loads of relative toxicity discharged in municipal wastewater indicate that the magnitude of direct pollutional hazard to aquatic life has increased substantially from approximately 436 mgd in 1960-64 to 745 mgd as of 1971. The 16-percent increase in per capita relative-toxicity coefficients in the bay region, 144 to 167 gal/cap/day (gallons per capita per day), apparently reflects a continuing increase in the discharge of toxicants to municipal sewerage systems. This trend should be considered in planning wastewater-management systems. Proposals for future management of toxicants emphasize source-control methods (that is, reduction or management of toxicants at the point of generation, prior to entry into sewer systems). Other, more comprehensive control measures may be warranted, especially in ecologically sensitive areas of the bay system.

3. Tables 5 and 6 reflect a relation between per capita municipal-wastewater generation and the degree of urban development. Note that the areas tributary to San Pablo and Suisun Bays have the two lowest per capita wastewater-flow coefficients for 1960-64 (78 and 90 gal/cap/day) and 1970-71 (108 and 82 gal/cap/day). These two areas have low density urban development as opposed to the central bay area which exhibits the highest per capita flow coefficients of 120 gal/cap/day in 1960-64 and 131 gal/cap/day in 1970-71.

Future Municipal Wastewater Loading

Estimation of future municipal wastewater loads in the bay region is complicated by uncertainties regarding population growth and urban development. Several general predictions can be made, however.

1. Municipal wastewater flow should continue to increase at a rate roughly equivalent to population growth. The Association of Bay Area Governments (1970, p. 8) predicted that nearly two-thirds of the population increase in the bay region during the period 1970-90 would occur in Santa Clara, Alameda, and Contra Costa Counties (fig. 1). However, four northern counties--Marin, Napa, Solano, and Sonoma--are expected to show the largest rates of population growth through 1990. Presently (1972), the specific areas of high population growth are San Rafael-Novato, Santa Rosa-Petaluma, Napa, Vallejo, Fairfield, Concord-Walnut Creek, Pittsburg-Antioch, Livermore-Pleasanton, Hayward-Fremont, San Jose-Sunnyvale, and San Francisco-Mountain View metropolitan areas. Recent trends also indicate rapid population increases in several locales on the Pacific Coast, particularly in the Pacifica-Half Moon Bay area.

2. The concentration of BOD_{ult}, total nitrogen, and toxicity in untreated municipal wastewater should increase in the future, due primarily to expanded use of home garbage grinders, and larger flows of industrial wastewater to municipal sewerage systems. Source control is likely to be the principal method employed to regulate the flow of toxicants to municipal systems.

3. The concentration of phosphorus in municipal wastewater within the bay region was at one time expected to decline (Kaiser Engineers, 1969) because of increasing use of nonphosphate laundry detergents in the future. However, recent recommendations by the U.S. Environmental Protection Agency (1971) indicate that the use of phosphate-bearing detergents will not be drastically reduced. Therefore, phosphate concentrations in municipal wastewater probably will show a moderate increase in the future.

4. The regional trend toward consolidation of municipal wastewater-treatment and disposal facilities (discussed in subsequent sections of this report) will cause a change in the location and number of outfalls. The present system of numerous outfalls probably will be superseded by a system based upon several large outfalls that discharge to the deeper water of the bay.

Geographical Distribution of Industrial Wastewater Discharges

As shown in appendix A, major industrial wastewater outfalls are most heavily concentrated along the southern periphery of Suisun Bay, southern periphery of San Pablo Bay near Richmond, and in the Newark-Fremont area in the south bay. Industries utilizing these outfalls for final disposition of wastewater have been termed "discrete industrial dischargers" (Kaiser Engineers, 1969) to differentiate them from the numerous industrial establishments that discharge wastewater to municipal sewerage systems. Appendix C contains information on these industrial discharges.

The major industries discharging wastewater within the bay region have been categorized by Kaiser Engineers (1969) as follows:

1. Petroleum refining
2. Chemicals
3. Paper and allied products
4. Food and kindred products
5. Fabricated metals

In addition to these five categories, the electrical-power-generation industry also should be considered as a major wastewater-discharging industry because of the potential importance of thermal discharges in biologically-sensitive receiving water.

Industrial Wastewater Loading

No comprehensive monitoring of industrial wastewater discharges to the bay system has been done since the period 1960-64, although most industries have limited self-monitoring programs as prescribed in guidelines established by the California Regional Water Quality Control Board, San Francisco Bay Region. Results of the 1960-64 monitoring program were summarized by Pearson, Storrs, and Selleck (1969) and are presented in table 7.

TABLE 7.--*Summary of industrial wastewater loads*[1] *discharged to the San Francisco Bay system 1960-64*

[From Pearson, Storrs, and Selleck (1969, p. 95)]

Region	Flow[2] (mgd)	BOD_{ult}[3] (lbs/day)	Total nitrogen as N (lbs/day)	Total phosphate as P (lbs/day)	Relative toxicity (mgd)
South bay	12.5	11,800	1,100	3,300	15
Lower bay	5.6	4,500	250	50	3
Central bay[4]	-	-	-	-	-
North bay	8.3	390	16	6	3
San Pablo Bay	189	125,000	16,000	430	190
Suisun Bay	157	208,000	16,700	180	250
Approximate totals	367	350,000	34,100	4,000	460

[1]Summary does not include industries discharging all wastes to municipal sewerage systems.

[2]Flow includes process wastewater and process-cooling-water mixture. Recirculated bay water is not included in this tabulation.

[3]Original BOD_5 converted to BOD_{ult} as shown in table 4.

[4]Central bay received no identifiable industrial process wastewater during 1960-64.

The heavy industrial development prevalent in the San Pablo Bay and Suisun Bay areas is reflected in table 7. Industries in these areas discharge virtually all of the industrial wastewater loads in the bay region not routed to municipal sewers with the exception of phosphate, which is generated principally in the south bay area. Approximately 96 percent of the industrial process wastewater containing 95 percent of the BOD_{ult}, 99 percent of the total nitrogen, and 94 percent of the relative toxicity was produced in the San Pablo Bay and Suisun Bay areas in 1960-64. During the same period, approximately 82 percent of the industrial phosphate was discharged in the south bay area. Generally, these wastewater-loading patterns should be similar to 1971 conditions.

Figure 6 shows the magnitude of industrial wastewater loading relative to municipal wastewater loading and emphasizes the intense industrial development in the San Pablo Bay and Suisun Bay areas.

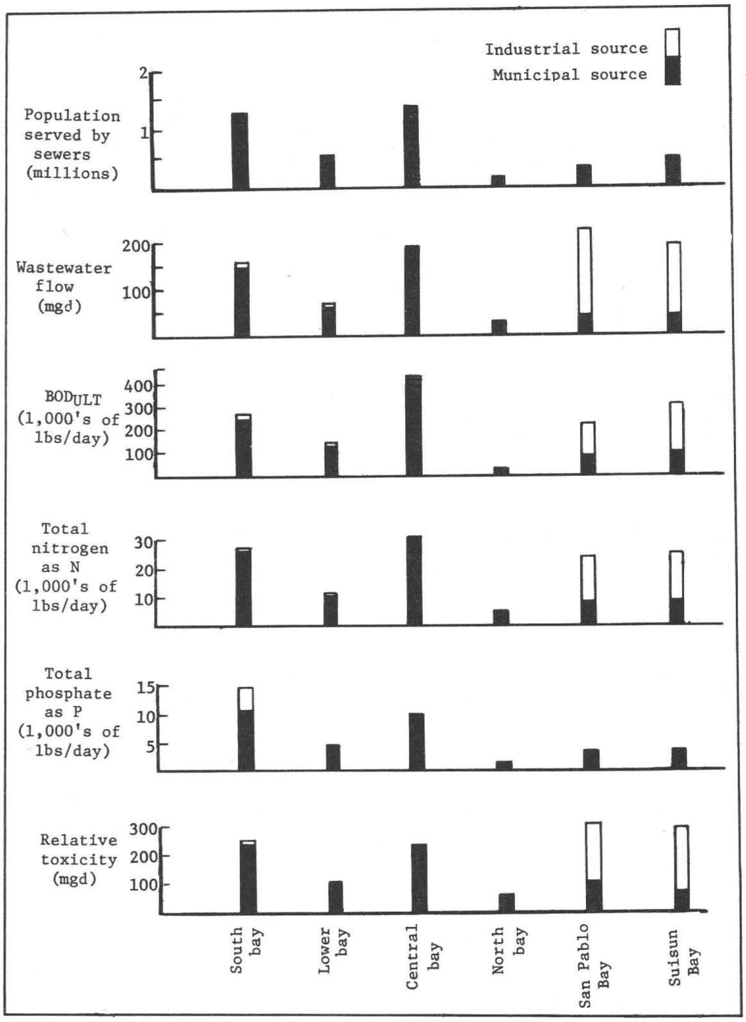


FIGURE 6.--Comparison of municipal and industrial wastewater loading in the San Francisco Bay region.

Future Industrial Wastewater Loading

Kaiser Engineers (1969, p. VII-11) indicated that the discharge of industrial process wastewater in the bay region would increase by a factor of eight between 1965 and 2020 (the Kaiser study included the Sacramento-San Joaquin Delta area shown in figure 7) and that loads of BOD_5 and total nitrogen from industrial sources would show an 8-fold increase during the same period. The California Water Resources Control Board (1971a, p. 17) predicted a 130-percent increase in industrial wastewater discharges within the same geographical area shown in figure 5 for the period 1971-90.

Thermal discharges, particularly those from electric-power-generating plants, are expected to increase markedly in the near future. The California Resources Agency (1970, p. VI-3) predicted that there would be an increase in power demand in the bay region from a 1970 level of 4,860 mw (megawatts) to a 1990 level of 22,400 mw. Without cooling towers or other thermal wastewater-treatment facilities, the increased power requirements by 1990 would cause at least a 5-fold increase in thermal discharges from electric-power-generating plants in the bay region. For this reason, future power-generating plants likely will be located along the Pacific Coast where, theoretically, the adverse effects of thermal discharges should be less than in the bay.

Industrial growth, new industrial wastewater-management concepts, new process innovations, and Federal and State regulations will undoubtedly cause deviations from past projections. Indeed, recent water-pollution-enforcement action at the State and Federal levels and increasing emphasis on industrial water conservation and wastewater reclamation should cause lower future levels of industrial wastewater discharge than previous predictions have indicated.

Agricultural Wastewater

According to the California Department of Water Resources (1970), there are approximately 290,000 acres of irrigated agricultural land in the bay region. Much of the irrigation water for this land is applied by sprinkler systems. These systems generally produce a very limited quantity of agricultural wastewater (or return flow) to streams and to ground-water reservoirs in comparison to irrigation systems utilizing flooding techniques. Of greater pollutional significance to the bay region is the agricultural wastewater produced in the Sacramento-San Joaquin Delta area (fig. 7). Water Resources Engineers, Inc. (1968, p. V-4) indicated that agricultural land use in the delta was approximately 600,000 acres in 1965. Within this area, three or more crops may be grown each year, and the land is heavily irrigated. Thus, large quantities of agricultural wastewater are produced and subsequently enter the bay system by way of Suisun Bay.

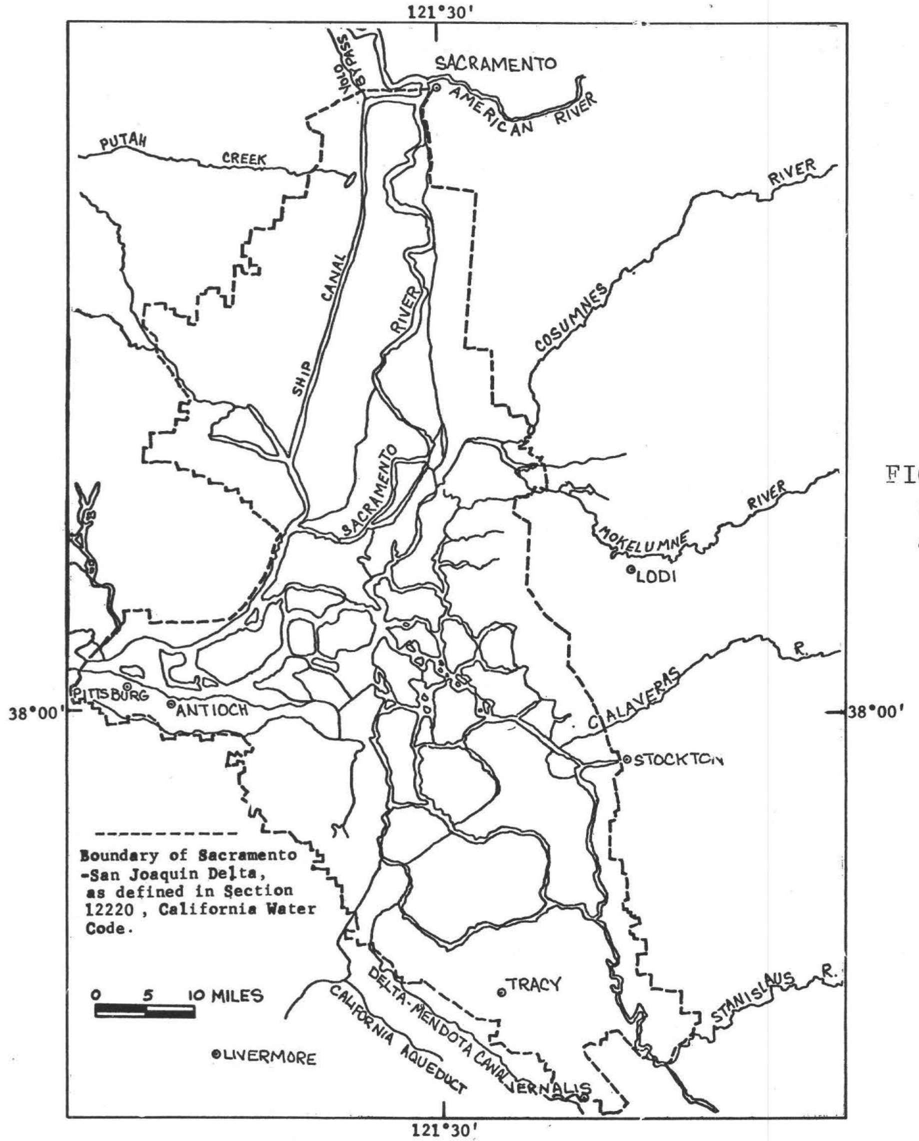


FIGURE 7.--Sacramento-San Joaquin Delta area.

The quality of agricultural wastewater is governed primarily by factors such as type of crop, irrigation technique, amount and type of fertilizer and pesticide used, and method of irrigation drainage. The most troublesome agricultural-wastewater constituents are pesticides, biostimulants, and dissolved solids.

Wastewater and runoff from livestock feedlots is a growing regional water-pollution problem. Feedlots located near streams and in areas where ground water is near the land surface can cause water-pollution problems because of high concentrations of potentially pathogenic micro-organisms, biostimulants, and oxygen-consuming materials in wastewater and runoff. Livestock feedlots are particularly numerous in the Petaluma River basin and in parts of Marin and Napa Counties.

Agricultural Wastewater Loading

Table 8 shows the estimated annual volume of agricultural return flow produced in the delta and in the bay region as of 1965. Associated with these return flows are significant loads of pesticides and biostimulants. For example, the chlorinated-hydrocarbon[1] pesticide load entering the bay system in 1965 was estimated at 8,200 pounds by Engineering Science, Inc. (1968, p. IV-14). It is probable that present loads (1972) are of about the same magnitude as those noted in 1965 since pesticide application rates have remained fairly stable.

Table 8.--*Volume of agricultural return flows with potential influence on receiving water in the bay region*[1]

County	Agricultural return flow (acre-feet/year)
Sacramento[2]	137,000
San Joaquin[2]	592,500
Yolo[2]	100,900
Contra Costa	70,500
Solano	56,000
Total (rounded)	957,000

[1]Kaiser Engineers (1969, p. IV-14).
[2]Flow generated outside the bay region but entering Suisun Bay through the delta of the Sacramento-San Joaquin Rivers.

Biostimulant concentrations in agricultural wastewater entering the bay system have not been accurately quantified. The California Department of Water Resources (1971), however, analyzed nitrogen and phosphorus in water from four large irrigation-drainage facilities in the Central Valley. The following ranges were noted: total Kjeldahl nitrogen, 0.28 to 0.40 mg/l (milligrams per liter); nitrate as nitrogen, 13 to 55 mg/l; nitrite as nitrogen, 0.003 to 0.006 mg/l; and orthophosphate as phosphorus, 0.0 to 0.06 mg/l. Although these values may be useful as estimates, the use of any average nitrogen or phosphorus coefficient for agricultural drainage is questionable because of the large range in annual and geographic fertilizer-application rates (Federal Water Pollution Control Administration, 1967, p. 43; Water Resources Engineers, 1968, p. III-3) and the difference in irrigation-drainage facilities.

---

[1]See footnote in table 2 for explanation of method for reporting chlorinated hydrocarbon pesticide concentration.

Future Agricultural Wastewater Loading

The future volume of agricultural wastewater (or return flow) discharged to the bay system is largely dependent upon (1) the increased agricultural water supply made available by the State Water Plan (California Department of Water Resources, 1970) and (2) the nature of agricultural wastewater-collection, treatment, and disposal facilities now being planned by the California Department of Water Resources and the U.S. Bureau of Reclamation.

Full development of agricultural lands tributary to the bay system, (including the Sacramento-San Joaquin Delta and Central Valley), based upon the availability of an augmented water supply, has been estimated at 8 million acres (Engineering Science, Inc., 1968, p. IV-7). Using a drainage factor of 0.34 acre-foot per acre, Engineering Science, Inc., (1968) calculated a possible irrigation return flow of 2.7 million acre-feet per year, more than 3 times the present return flow. One plan presently being evaluated by the U.S. Bureau of Reclamation and the California Department of Water Resources (1970), involves the collection of Delta-Central Valley agricultural return flow in drainage facilities and disposal at a point near Antioch (fig. 7).

Factors affecting the future load of chemical constituents in agricultural wastewater have been evaluated by several agencies. For example, the Federal Water Pollution Control Administration (1967) predicted a gradual increase in total pesticide application in the delta area and in the Central Valley in the future. Likewise, pesticide application within the bay region was projected to increase moderately until 1990 and then return to 1960 levels by the year 2020. Overall, it seems there will be a slight increase in pesticide loads from agricultural wastewater entering the bay system in the next 50 years, due primarily to increased agricultural development and a greater volume of wastewater, not necessarily to a significant increase in pesticide usage. Improved efficiency in pesticide application and irrigation methods and use of shorter-lived, biodegradable pesticides may serve to partially alleviate harmful affects of future return flows.

Predictions of future agricultural wastewater loads for nitrogen, phosphorus, BOD, and other constituents are not available. The Federal Water Pollution Control Administration (1967, p. 47) presented the future "design quality" of major streams tributary to the bay system that will be affected by agricultural wastewater and calculated pollutant loads to be carried by the proposed San Joaquin Master Drain.[1] Table 1 shows a summary of this loading data and indicates a probable gradual increase in biostimulant and BOD loads through the year 2020. Although the exact nature and design of agricultural drainage and wastewater-management facilities is still uncertain at the time of this report (1972), the loading data in table 9 should be indicative of expected future agricultural wastewater loads discharged to the bay.

TABLE 9.--*Predicted agricultural wastewater loads discharged to the planned San Joaquin Master Drain, Central Valley, California*
[From Federal Water Pollution Control Administration (1967, p. 47)]

Year	Discharge (cfs)	BOD_{ult}[1]	Total nitrogen as N	Total phosphorus as P	Chlorides	Dissolved solids
		Thousands of pounds per day				
1990	18,274	133	54.1	15.4	3,120	17,960
2020	21,472	218	103	34.2	3,450	21,280

[1]Calculated from BOD_5 data assuming that no unoxidized nitrogen was present in the wastewater. $BOD_{ult} = 1.5 (BOD_5)$.

The success of implemented management systems for agricultural wastewater generated outside the bay region will largely determine the future pollutional significance of agricultural wastewater in relation to the bay system. Pesticide, nitrogen, and dissolved solids loads will be the primary water-quality considerations in future agricultural wastewater-management planning.

[1]The San Joaquin Master Drain is a facility proposed to collect salt-laden agricultural return flows for transport away from the Central Valley (see Kaiser Engineers, 1969, p. VII-2).

Areal Distribution of Storm-Water Runoff

The distribution and, to a great extent, the magnitude of storm-water runoff in the bay region is related to the intensity, extent, and timing of seasonal runoff events. Rantz (1971, p. 4), in a discussion of regional characteristics of precipitation, stated:

> "Precipitation in the San Francisco Bay region is highly seasonal; almost 90 precent of the annual precipitation occurs during the 6-month period November through April. The great bulk of that precipitation occurs in a series of general storms that reach all parts of the region, but the storm centers usually pass to the north of the region, and the result is a general tendency for precipitation to decrease from north to south. Altitude has a strong local influence on the depth of precipitation, and because altitudes range from sea level to 4,400 feet, there is a wide range in mean annual precipitation--from 10 inches in low-lying valley areas in the east to 80 inches in some mountain areas in the north. Winter precipitation often occurs as snow at altitudes above 2,000 feet, but snowfalls are generally light, and snow does not remain on the ground for more than a few days. Snow, therefore, has an insignificant role in the hydrology of the region. Intense local convective storms are almost unknown in the region.......
>
> "Annual precipitation at any particular site varies widely from year to year. For example, at Kentfield near San Rafael, the mean annual precipitation for the period 1888-1965 is 46.4 inches, but the annual precipitation during that 77-year period ranged from 88.2 inches in 1890 to 22.3 inches in 1924. At San Jose, the mean annual precipitation for the period 1874-1965 is 14.0 inches, but the annual precipitation during that 91-year period ranged from 30.3 inches in 1890 to 4.83 inches in 1877."

The characteristics of storm runoff from any given drainage basin are governed by both natural factors and factors related to man's use of the basin. The natural factors include rainfall, amount and types of vegetation, topography, rocks, and soils. Man introduces all types of variables. The degree to which the drainage basin is covered by pavement and buildings greatly influences rates and quantities of runoff. Removal of native vegetation and disturbance of the soil during construction greatly increases the amount of sediment and organic debris carried off by storm water. However, after development is complete and the land is covered by houses and lawns, for instance, sediment production may be reduced even below preconstruction levels. Man may drastically change the pattern and place of stream discharge from the basin by building artificial channels. And he invariably introduces additional chemical loads by use and disposal of pesticides, grease, oil, and the many other products in daily demand. Some of these products enter the runoff system virtually at once. Others linger on paved and roofed surfaces until they are washed into the runoff system during storms.

Generally, paved urbanized areas such as the San Francisco-Mountain View area, Oakland, Berkeley, Santa Rosa, San Jose, and the Fremont-Newark area produce high rates of runoff during storm events. Other areas that have high seasonal runoff rates include hilly terrain such as the Coast Ranges, the hills on the eastern side of the bay, and most areas having steep slopes and moderate to high seasonal rainfall. Conversely, the relatively flat, rural areas of the bay region, which include the Santa Clara Valley, the Napa Valley, and valley lands in Sonoma, Solano, Contra Costa, and Alameda Counties, produce lesser amounts of storm-water runoff.

Storm-Water-Runoff Loading

Pollutant concentrations in storm-water runoff in the bay region have been estimated primarily on the basis of land use (see tables 2, 3, and 4). These data are, again, indicative of the effects that various land-use practices have on the quality of storm-water runoff. Generally, urban storm-water-runoff loads of oxygen-consuming materials are high relative to nonurban loads because of organic debris common to streets, gutters, developed lots, and municipal storm-drainage pipes. Conversely, biostimulant loads from rural runoff tend to be higher than for urban runoff, particularly in the vicinity of animal feedlots and in areas where agricultural fertilizers are used extensively.

The concentration of pesticides and other toxicants in storm-water runoff is poorly documented. A study in an urban drainage basin near Hayward (Castro Valley Creek basin) was begun in 1971 by the Geological Survey in cooperation with the U.S. Army Corps of Engineers. Preliminary results from this study show surprisingly high concentrations of pesticides and heavy metals, particularly lead, in runoff water and associated sediments. For example, chlordane, a chlorinated-hydrocarbon insecticide, has been detected in concentrations of more than 1.1 μg/l (micrograms per liter, or parts per billion) in runoff water and 187 μg/kg (micrograms per kilogram, or parts per billion) in sedimentary materials. Lead has been detected in concentrations up to 760 μg/l in water samples (the major part of lead detected in these samples was found to be attached to the suspended-sediment particles carried by the runoff water).

The bacteriological quality of storm-water runoff also is worthy of mention. High fecal-coliform bacteria concentrations have been detected in many storm-water runoff studies made to date. For example, in a Tulsa, Okla., study (Federal Water Quality Administration, 1970) fecal coliform concentrations in storm-water runoff from 15 drainage basins averaged about 400 colonies/100 ml and ranged from 10 to 18,000 colonies/100 ml. Fecal coliform concentrations measured in 1971-72 runoff in the Castro Valley Creek basin by the Geological Survey ranged from 400 to 9,000 colonies/100 ml. The Tulsa study also resulted in quantification of certain pollutant loadings as related to land use (table 10). Table 11 summarizes potential sources for most of the important pollutants commonly found in storm-water runoff. Although the data in table 10 and 11 are not specific to the bay region, they should, in general, be good indices of pollutional-loading trends related to land use.

TABLE 10.-- *Calculated average yearly loads for various pollutants in storm-water runoff in 15 drainage basins in the Tulsa, Oklahoma, area*[1]
[Data collected by Federal Water Quality Administration (1970)]

Area	Size (acres)	Predominant land-use type	Pollutional load (lbs/acre/year): BOD_{ult}[2]	Organic nitrogen as N	Soluble orthophosphate as P	Total solids
1	686	Light industrial	57	2.5	2.7	5,100
2	272	Shopping center	56	3.3	1.0	920
3	550	Middle class residential	34	2.6	1.1	1,200
4	938	Mixed industrial, commercial, residential	81	3.0	1.1	1,900
5	507	Old residential, large homes	56	1.3	.5	490
6	368	Industrial-residential	38	1.1	.5	600
7	197	Single family residential	30	1.5	.4	790
8	211	Nonguttered residential	58	1.5	.8	840
9	64	Lower class residential	36	1.3	.7	830
10	206	Residential-commercial, construction activity	80	3.6	1.0	1,900
11	815	Residential-commercial, construction activity	60	1.7	.7	1,400
12	223	Open space, airport runways	44	1.2	1.6	630
13	212	Upperclass residential	50	2.4	.7	780
14	263	Upperclass residential, golf course	24	1.1	.4	660
15	74	Old, middle class residential	42	.8	.6	570

[1]Average annual precipitation for the Tulsa area is approximately 37.2 inches per year.
[2]BOD_{ult} calculated from data given by FWPCA. $BOD_{ult} = 1.5\ BOD_5 + 5$(organic nitrogen as N).

TABLE 11.--*Principal sources for important pollutants normally detected in storm-water runoff*

Pollutant category	Measurement parameter	Sources
Toxicants	Heavy metals and organic chemicals, toxicity bioassay	Automobile residues, home and industrial chemicals, workshops
Pesticides, insecticides, herbicides	Chlorinated-hydrocarbon and phosphorothiorate pesticides	Insect spraying, weed spraying
Oxygen-consuming materials and organic matter	BOD, COD[1], TOC[1]	Organic matter--leaves, grass, plants, animal wastes, oil, grease
Biostimulants	Nitrogen and phosphorus, trace elements	Fertilizers, mineral leaching, organic decomposition
Pathogens	Total and fecal coliform, fecal streptococcus	Humans, land mammals, birds
Solids	Suspended, dissolved, or floatable	Erosion, street residue, mineral leaching, home and industrial chemicals

[1]COD, chemical-oxygen demand; TOC, total organic carbon.

Future Storm-Water-Runoff Loading

Estimates of future storm-water-runoff volume and pollutant loads for various water-quality zones of the San Francisco Bay system (see app. A) are shown in table 12. Note that runoff volume and total nitrogen loads are projected to increase moderately during the 1965-2020 period, runoff from 1,089 to 1,260 acre-ft/year and total nitrogen from 6.0 to 6.9×10^6 lb/year. BOD_{ult} loads are projected to increase during the same time period from 36.1 to 58.2×10^6 lb/year. These projections generally parallel expected population and urbanization trends for the 1965-2020 period

TABLE 12.--*1965 and projected future annual storm-water runoff loads tributary to the San Francisco Bay system*
[From Kaiser Engineers, 1969, p. VII-21]

Water quality zone[1]	Runoff (1,000 acre-ft/yr)		BOD_{ult}[2] (10^6 lb/yr)		Total nitrogen (10^6 lb/yr)	
	1965	2020	1965	2020	1965	2020
1	245	269	6.1	12.4	1.0	1.2
2	166	198	4.0	7.9	.7	.9
3	90	96	4.9	5.7	.4	.4
4	74	95	4.1	6.0	.4	.5
5	390	415	12.8	16.9	2.9	2.9
6	12	15	.4	.9	.1	.1
7	108	154	3.5	6.8	.5	.7
8	4	18	.3	1.6	-	.2
Totals	1,089	1,260	36.1	58.2	6.0	6.9

[1]See appendix A.

[2]BOD_{ult} calculated from BOD_5 and total nitrogen data given by Kaiser Engineers (1969, p. VII-21) using the following equation:

$$BOD_{ult} = 1.5(BOD_5) + \frac{5(\text{total nitrogen})}{2}.$$

Note that this equation differs from that used previously in this report (p. 10) in order to account for the higher percentage of oxidized nitrogen found in storm-water runoff.

Other important pollutant loads in storm-water runoff in the region also are expected to increase as urbanization, drainage-basin alterations, and other of man's activities intensify. It is highly probable that further study of storm-water runoff characteristics will lead to control measures for the more important pollutants, particularly toxicants, oxygen-consuming materials, pathogens, and solids. Control measures may include bans on the use of certain toxic chemicals and pesticides, better street-cleaning practices, stricter rubbish-disposal ordinances, and modified heavy construction practices.

Miscellaneous Wastewater Discharges

Many wastewater discharges in the bay region cannot be accurately located or quantified. Scattered, intermittent discharges from sources such as solid-waste landfills, septic tanks, and watercraft exemplify minor pollutional sources that are usually of local, but sometimes regional, significance.

Solid-Waste Landfills

Many solid-waste landfills are located on the margins of the bay, along tidal sloughs, adjacent to streams, and above shallow ground-water bodies. These landfills, in particular, have the potential for causing water pollution in surface and ground water. The overall pollutional impact of landfilling operations in the bay region is not considered large, although several landfills have been found to produce wastewater in sufficient quantity to cause local water-quality problems (California Department of Public Health, 1968).

Pollutant loads attributed to solid-waste landfills are highly variable, being governed largely by the nature of the waste in the fill, the production of leachate (contaminated runoff or seepage water), and the method of operation. Many solid-waste landfills contain such a wide variety of waste materials that sites that are improperly operated have the potential to discharge almost any of the important pollutants previously discussed in this report. Surface-water pollutant loads detected at four solid-waste landfills in the bay region are shown in table 13. Leachate production at the four sites ranged from 0.14 to 1.6 mgd.

TABLE 13.--*Range in surface-water pollutant loads generated at four solid-waste landfill sites, San Francisco Bay region*
[From California Department of Public Health, 1968, p. 1-7]

Pollutant	Loading
5-day BOD[1]	2.0-300 lbs/day
COD (chemical oxygen demand)	6.0-1,060 lbs/day
Settleable solids	1.5 lbs/day
Suspended solids	65-200 lbs/day
Total sulfide	2-72 lbs/day
Dissolved sulfide	1-38 lbs/day
Coliform bacteria	230-24x10^6/100 ml

[1]BOD_{ult} could not be calculated because data on nitrogen concentrations were not available.

The future distribution and pollutional significance of solid-waste landfills in the bay region is uncertain, although it is generally accepted that "land filling will continue to be the primary means of solid-waste disposal for the forseeable future" (California Department of Public Health, 1968, p. 7-1). Certainly, recent action by Federal and State agencies charged with controlling the use of marshlands and peripheral areas of the bay dictates that locations for future fills should be inland, away from marshlands, the bay, and population centers. Also, there will be an increased need in the future for locating special-purpose fills, such as those for exotic industrial and agricultural wastes, in well-engineered, hydrogeologically-suitable sites.

Landfill-site selection will be made more difficult by population-urbanization pressures, which make previously attractive sites unacceptable because of increasing cost and environmental and aesthetic detriments.

Solid-waste disposal problems will be further compounded by the growing annual volume of solid-waste materials generated in the region. Solid-waste production has been projected to increase from a 1970 level of over $7x10^6$ tons per year to more than $15x10^6$ tons per year by 2020 (table 14). Since suitable areas for solid-waste landfills in the bay region are a finite resource, there is a great need for investigating other feasible disposal methods and reclamation techniques.

TABLE 14.--*Projected solid-waste*[1] *production, San Francisco Bay region*
[From California Department of Public Health, 1968, p. 3-13)]

County	Annual tonnage (thousands)			
	1970	1980	1990	2000
Alameda	1,512	2,003	2,556	3,115
Contra Costa	890	1,176	1,726	2,285
Marin	299	468	603	776
Napa	166	313	416	541
San Francisco	952	1,003	1,080	1,148
San Mateo	719	961	1,294	1,491
Santa Clara	1,508	2,223	2,850	3,476
Santa Cruz	205	269	367	509
Solano	509	677	965	1,315
Sonoma	374	540	780	1,036
Totals	7,134	9,633	12,637	15,692

[1]Includes all municipal, industrial, and agricultural solid wastes except livestock manure, cannery wastes, and oil refinery.

Septic Tanks

Septic tank systems are the principal means for treatment and disposal of domestic wastewater in areas not serviced by municipal sewerage systems. Septic-tank systems are scattered throughout the rural areas of the bay region, particularly in mountainous terrain. No regional compilation of the number or distribution of septic tanks has been undertaken. It is well known, however, that the risk of pollution of surface and ground water from septic tanks can be high in local areas, although the regional pollutional impact is minor in comparison with other pollution sources.

Wastewater discharged into septic-tank drainage fields is similar in character to municipal wastewater that has received the equivalent of primary treatment without disinfection. Pollutional problems from septic-tank discharges are usually due to contamination of ground or surface water by micro-organisms or harmful chemical substances. To minimize the potential for occurrence of these problems, the U.S. Public Health Service (1963) has published a manual describing good septic tank practices that includes recommendations for the location, design, and operation of septic tank systems. In addition, many counties and municipalities have septic tank ordinances which, if enforced, can be effective in controlling pollution problems.

Watercraft Discharges

Approximately 96,000 small pleasure craft, 800 fishing vessels, and 5,000 commercial ships operate on a periodic basis on water in the San Francisco Bay system each year and discharge approximately 250 million gallons per year of wastewater (Singer, 1969, p. 151). Additionally, many military ships visit or are permanently assigned to ports in the bay region. Wastewater discharged from these watercraft is often similar in quality to untreated municipal wastewater.

Perhaps of more importance, particularly in relation to the bay, are large accidental oil spills and other batch discharges of wastes from watercraft. There is now an expanded awareness of this problem on the part of shipping firms and industries and marine regulatory agencies such as the U.S. Coast Guard. Contingency measures to manage these periodic occurrences have improved and should aid in alleviating future problems.

Recent State and Federal pollution-control legislation has set more stringent criteria for discharge of watercraft wastewater to the bay. Increased shipboard and dockside treatment capability will be the principal means employed for controlling watercraft-wastewater discharges in the future.

DISCUSSION OF WASTEWATER EFFECTS ON THE QUALITY OF REGIONAL SURFACE-WATER RESOURCES

The California Water Resources Control Board (1971b) has identified various beneficial uses and water-quality objectives for most of the ocean, estuarine, and fresh water of the bay region. It is well known (see subsequent discussion for documentation) that many of these uses and objectives have been detrimentally affected by wastewater discharges. The limited scope of this report precludes a detailed discussion of potential future water-quality problems, particularly those related to activities such as damming of streams, water diversion from drainage basins, dredging for navigation, channelization of streams, bay-filling operations, and other activities that do not actually involve direct wastewater discharges. Indeed, most of these activities have not been studied and quantified to the degree necessary for establishing cause and effect relations as is the case with many wastewater discharges.

The following discussion deals specifically with water-quality problems in the bay region that have been directly attributed to wastewater discharges. The discussion is by necessity brief, but hopefully includes a sufficient number and variety of examples to help readers understand important wastewater-water quality relations.

Documented Water-Quality Problems Attributable to Wastewater Discharges

1. *Dissolved oxygen.* Dissolved-oxygen concentrations in several shallow areas of the bay (California Water Resources Control Board, 1971a, p. 5) and in tidally-influenced reaches of the Napa, Petaluma, and San Joaquin Rivers (San Francisco Bay Regional Water Quality Control Board, 1969, p. 5-8) have historically undergone large seasonal and diurnal fluctuations. Dissolved oxygen levels commonly fall below prescribed water-quality objectives in these areas. The BOD load from municipal wastewater discharges has been identified as the chief cause of this problems.

2. *Bacteriological contamination.* Because of the public health hazard, many shallow areas of the bay have been posted to prevent shellfishing and water-contact recreation (fig. 3). High coliform-bacteria concentrations detected in posted areas are attributed to municipal wastewater discharges and, to a lesser degree, storm-water runoff.

3. *Toxicity*. The California Water Resources Control Board (1971a, p. 8) has documented the occurrence of recent fish kills (1965-70) in the bay system. Although specific causes for fish kills are often difficult to ascertain, the San Francisco Bay Regional Water Quality Control Board (1969, p. 19) cited documented cases of fish mortality traced to an industrial discharge of cyanide (Alameda Creek, Alameda County) and to agricultural wastewater containing a herbicide (Suisun Creek, Solano County).

   Another indication of wastewater-induced-toxicity problems is the number and diversity of bottom dwelling (benthic) organisms in receiving water. Kaiser Engineers (1969) presented an hypothesis directly relating the low diversity of benthic organisms in certain areas of the bay to the local municipal and industrial wastewater relative-toxicity loads.

   Peterson, McCulloch, Conomos, and Carlson (1972) measured the concentrations of toxic metals in bottom material from San Francisco Bay. Highest concentrations (lead up to 10,000 mg/l) were noted in the Suisun Bay and San Pablo Bay areas where industrial discharges are prevalent.

   The San Francisco Bay Regional Water Quality Control Board (1969, p. 19-20) in discussing the damage to fish and wildlife from pesticides noted that "insufficient data are available in the San Francisco Bay system to pinpoint specific cases of damage to fish." In subsequent discussion, however, the Board noted "the phenomenon of biological concentration of chlorinated hydrocarbon pesticides poses a potential hazard to fish and wildlife resources."

4. *Excessive aquatic plant growth*. Excessive aquatic plant growth in tidal sloughs, slow moving rivers, and in shallow areas of the bay are known to cause large diurnal dissolved-oxygen fluctuations. Within the bay system, algal concentrations greater than $4x10^6$ cells per liter have been detected in the south bay and Suisun Bay (Kaiser Engineers, 1969). The Federal Water Pollution Control Administration (1967) noted that decomposing green seaweed (*Ulva* and *Enteromorpha*) produced strong odors in the Albany tideflat north of Berkeley. Aesthetically objectionable red discoloration of bay water by the single-celled flagellate *Mesodinium* (a microscopic form of algae) has been noted by the San Francisco Bay Regional Water Quality Control Board (1969, p. 12). The causes of these problems are only infrequently traceable to specific sources, although the high concentration of biostimulants (mainly nitrogen and phosphorus) in municipal, industrial, and agricultural wastewater acting in conjunction with sunlight, high water temperature, and other factors is usually considered the primary agent.

5. *Nuisance conditions.* Odor and floating material are nuisance conditions often attributable to wastewater drainage. Odor problems caused by decomposing algae, storm-water runoff, landfill leachate, and industrial and municipal discharges have been noted periodically by the San Francisco Bay Regional Water Quality Control Board (1969, p. 14). Numerous oil-spill incidents also have been documented by the Board (1969, p. 16). Friedland, Shea, and Ludwig (1970) noted that aesthetically objectionable floating debris was a component of storm water emanating from the city of San Francisco's combined storm-water and municipal wastewater-sewer system.

Planning Implications

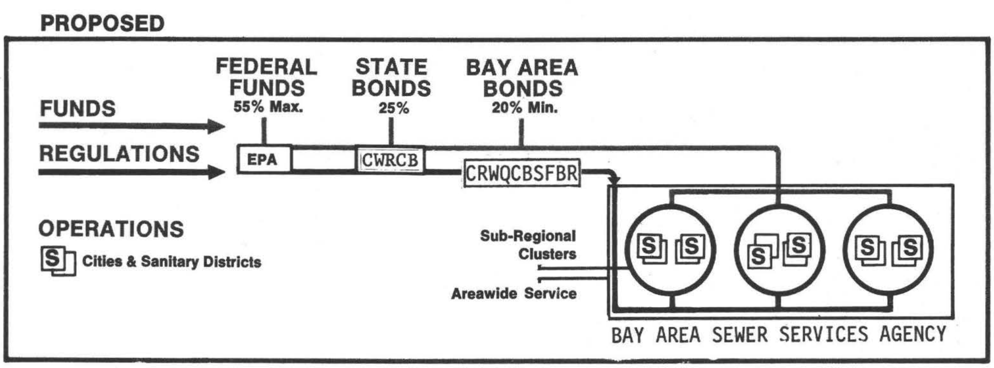
In summary, a statement made by Spieker (1970, p. 67) concerning the public viewpoint regarding water-quality problems in the Salt Creek basin, Illinois, seems appropriate to the San Francisco Bay region.

> "The public is becoming increasingly aware and increasingly intolerant of polluted conditions in general. Likewise, the public is demanding more facilities for outdoor recreation and an aesthetically pleasing living environment. For these reasons, the residents of Salt Creek basin, or any other urban area for that matter, are not likely to tolerate existing conditions for long. Public officials will thus be forced to take action to improve these conditions."

Within the context of this statement is the most visible rationale for alleviating water-pollution problems existing in the San Francisco Bay region today. An equally important, though more subtle rationale, is the growing understanding that all physical, chemical, and biological aspects of the San Francisco Bay region are interrelated and extremely important, not only individually, but one to another. Together, the natural and manmade features of the bay region define a unique, complex ecosystem. The bay, as the predominant physical feature, biological habitat, weather moderator, recreational center, and aesthetic attraction, should not be drastically altered in any manner unless potential social, economic, and environmental consequences are considered and understood not only by the specialized scientific and engineering communities, but by planners, decision makers, and general citizenry as well.

FUTURE OUTLOOK FOR MANAGEMENT OF WASTEWATER IN THE SAN FRANCISCO BAY REGION

Presently (1972), a massive interdisciplinary program is underway to determine optimal methods for managing wastewater in the bay region. Many Federal, State, regional, and local agencies and groups are actively involved with various aspects of this effort. Two agencies are, however, primarily responsible for planning, preliminary design, and funding of wastewater-management facilities (see fig. 8 for a model of funding aspects); these agencies are the California Water Resources Control Board, acting through the California Regional Water Quality Control Board, San Francisco Bay Region in Oakland, and the Environmental Protection Agency, acting through its Water Quality Office of the Pacific Southwest Region in San Francisco. The primary planning thrust is directed toward the management of municipal and industrial wastewater,[1] particularly that which is being discharged into the San Francisco Bay. Planning for the regional wastewater-management system has been designed in two phases: (1) an interim management-planning phase terminating in mid-1974 and (2) a long-range planning phase which will begin after the interim phase and continue until a fully developed management plan is implemented.



EPA Environmental Protection Agency
CWRCB California Water Resources Control Board
CRWQCBSFBR California Regional Water Quality Control Board, San Francisco Bay Region

FIGURE 8.--Proposed model for funding of regional wastewater and water-quality-management systems [adapted from California Water Resources Control Board, 1971a, p. 14].

---

[1]As mentioned previously, the California Department of Water Resources and the U.S. Bureau of Reclamation are presently investigating alternative agricultural wastewater-management systems while the U.S. Army Corps of Engineers, in 1971, began a study of storm-water runoff quality in the region. No further discussion of these programs will be presented in this report.

Interim Management Planning

As of July 1972 there were 15 subregional wastewater-management studies,[1] encompassing virtually all parts of the bay region, either underway or completed. These studies, which are being conducted by private engineering consultants under the general guidance of the California Regional Water Quality Control Board, San Francisco Bay Region, are designed to meet a preliminary planning deadline of July 1973. The primary purpose of each of the subregional studies is to assess present and future water-quality and wastewater conditions and to present recommendations for an optimal wastewater-management system within each subregion.

In conjunction with the subregional studies, the California Water Resources Control Board has commissioned a private consultant to conduct a broad-based social, economic, and environmental evaluation of the bay region. This evaluation is designed to integrate the technical aspects and recommendations of the various subregional studies into a regional wastewater-management plan that is consistent with projected population, land usage, land- and water-resource development, environmental-protection needs, and other related planning considerations. The proposed deadline for the wastewater-management planning report is July 1973. The period July 1973-January 1974 would be utilized for public hearings, discussion, and technical commentary on the plan. The January to July 1974 period would be utilized to make the necessary changes and revisions in the plan prior to its official presentation.

As previously mentioned, the subregional wastewater-management study results will form the principal technical basis for the regional wastewater-management plan. Although a detailed discussion of results of the subregional studies cannot be presented in this document, there are several important concepts that will be common to most of these studies. These concepts will undoubtedly have a strong influence on the regional wastewater-management plan.

1. Priority will be placed on the construction of wastewater-conveyance facilities. The basic goal will be to transport wastewater out of areas where pollution problems are most acute. The extreme south bay and stream and river basins are examples of areas in which wastewater discharges will be banned or very strictly controlled. Consolidated outfalls, in deeper parts of the bay closer to the Golden Gate, are planned for final disposition of most municipal and industrial effluents.

---

[1]Readers desiring detailed information on subregional wastewater-management studies should contact the California Regional Water Quality Control Board, San Francisco Bay Region, Oakland.

2. Initial planning and construction phases of the regional system will be completed during the 1971-80 period. Facilities will generally be designed to meet 1985-90 water-quality objectives, as derived from knowledge of water-quality conditions and projected wastewater quality and quantity. In effect 1985 will be the pivotal year for designing regional systems. Hopefully, wastewater-treatment technology, increased understanding of wastewater effects on fresh-water and marine ecosystems, wastewater reclamation and reuse potential, and a workable regional resources management agency will be largely developed by 1985.

3. All plans will be subject to annual review, changes, and updating as new information becomes available. This should allow the regional wastewater-management plan to be flexible enough to alleviate immediate water-quality problems through 1990 and still allow compatibility with any of several feasible long-term management alternatives available after 1990.

4. Agricultural wastewater and storm-water runoff generally will not be considered in the design of a regional wastewater-management systems, at least not until after the 1985-90 period. A notable exception to this concept will be the consideration of storm-water infiltration into municipal sewerage systems in designing the hydraulic capacity of sewer lines and treatment plants.

5. The toxicity of municipal and industrial wastewater, while generally recognized as the most acute of water-pollution problems in the bay region, will not have a marked effect on the design of wastewater-management facilities in the near future. Reduction or treatment of toxic materials at their source of generation (source control) will be the primary method recommended for alleviating the toxicity of industrial and municipal wastewater.

6. The disposal of municipal and industrial sludges (solid materials resulting from the treatment of wastewater) will be recognized as an increasingly important consideration in wastewater-management systems. All management studies are indicating the need for more efficient sludge-handling and sludge-treatment facilities in the future.

Long-Range Management Planning

There are many alternatives available for a long-range regional wastewater-management system. In light of ongoing subregional studies and interim planning, it would be premature to make a prediction as to specific types of long-range wastewater-management facilities likely to be constructed. However, there has already been intensive investigation of several conceptual plans (Kaiser Engineers, 1969; U.S. Army Corps of Engineers, 1971). These plans and their various combinations appear to offer the most promising basis upon which a viable long-range regional wastewater-management system can be designed and implemented. A summary of data relative to four conceptual wastewater-management plans is presented in tables 15 and 16.

The ocean- and estuarine-disposal alternatives are perhaps most consistent with historical concepts of wastewater management (that is, limited treatment and discharge to a receiving water having a suitable dilution and natural purification capacity). The land-disposal alternative is based upon the old, but largely unproven concept of wastewater and sludge application and irrigation. The combination alternative would be an integrated system designed with various types of ocean-, estuarine-, and land-disposal facilities. Further discussion of other possible wastewater-management alternatives for the bay region, including reclamation-reuse possibilities, is presented in the concluding section of this report.

DISCUSSION AND CONCLUSION

The magnitude of present and future water-quality and wastewater-management problems in the San Francisco Bay region is directly related to population growth and associated urban, industrial, agricultural, and resources development. This population expansion and intense development probably will continue into the early decades of the 21st century. Therefore, to maximize the usefulness of the regional resources while providing optimal environmental protection, many phases of regional planning must be initiated and carried forth into future years. The management of regional wastewater resources is an obviously important facet of total earth-science-planning requirements and is, in fact, undergoing intensive interagency study as described previously.

TABLE 15.--*Summary of conceptual long-range wastewater-management alternatives, San Francisco Bay region*
[From U.S. Army Corps of Engineers, 1971, p. 33, 52, 53]

Conceptual alternative	Disposal location	Municpal-industrial wastewater flow (mgd)		Land requirement 2020 (acres)	Treatment method	Estimated total annual cost for 100 years in millions of 1971 dollars
		1990	2020			
Ocean	Off Marin County coast	228	642	66,000 for sludge disposal	Advanced chemical and biological	472
	Off San Mateo County coast	901	1,534			
Estuarine	Selected deep water of San Francisco Bay	1,189	2,176	66,000 for sludge disposal	Advanced chemical and biological	334
Land	Agricultural areas throughout the bay region and parts of Sacramento, San Benito, San Joaquin, and Yolo Counties	1,189	2,176	335,000 for waste-water and sludge	Aeration ponds, storage ponds, spray irrigation, and soil filtration	699
Combination	Central San Francisco Bay delta area	835	1,385	42,000 for sludge disposal	Advanced chemical and biological	464
	Solano, Yolo, Marin, Sonoma, Sacramento, and San Joaquin Counties	354	791	130,000 for waste-water and sludge	Aeration ponds, storage ponds, spray irrigation, and soil filtration	

TABLE 16.--*Summary of views concerning alternative long-range regional wastewater-management systems for the San Francisco Bay region*

Type of regional wastewater-management plan	Reference documents	Commonly cited advantages of particular regional wastewater-management system	Commonly cited disadvantages of particular regional wastewater-management system
Ocean disposal	U.S. Army Corps of Engineers (1971) Kaiser Engineers (1969)	1. The bay system would be afforded maximum protection from pollution attributable to municipal and industrial wastewater. 2. The number of treatment facilities required would be fewer than for any other proposed system and allow efficient plant management.	1. Not enough is known about the effect of wastewater on coastal water and on coastal ecology to scientifically locate outfalls and to design treatment facilities. 2. Conveyance facilities would traverse earthquake faults and could be prone to massive damage. 3. Reclamation potential of wastewater committed to ocean discharge would be minimal. 4. An ocean system would likely be more expensive than any of the other management alternatives except land disposal, unless primary treatment levels are proven suitable to protect the coastal environment.
Estuarine disposal	U.S. Army Corps of Engineers (1971) Kaiser Engineers (1969)	1. Cost for implementation would be less than for any other proposed post-1990 system. 2. Proposed advanced treatment levels and proximity of treatment plants to population, industrial, and agricultural centers should help to develop the potential for a regional wastewater-reclamation market.	1. Treatment and conveyance facilities would be located on the periphery of the bay on geologically unstable ground, and thus, prone to massive failure during a large earthquake. 2. Large point discharge of pollutants will occur at combined outfall locations. Accurate prediction of long term effects on water quality and aquatic life cannot be made because of future hydrologic alterations of the bay system caused by large diversions of fresh water to the State water project. 3. Continued public health risk due to occasional bacteriological contamination of recreational and shell fishing areas of the bay.
Land disposal	U.S. Army Corps of Engineers (1971)	1. Pollution of major bay system surface water would be minimal. 2. Treatment and conveyance facilities would be located away from unstable land areas peripheral to the bay and would be less susceptible to earthquake damage than other proposed systems. 3. Biostimulatory characteristics of wastewater would not be a significant problem since irrigated crops would cause natural recycling.	1. Large land areas would be required for the system. 2. Improper system operation could cause contamination of ground water. 3. Capital cost of the system would probably be higher than any of the other proposed post-1990 alternatives. 4. Value of lands surrounding the disposal sites is likely to be decreased because of aesthetic deterioration.
Combination disposal	U.S. Army Corps of Engineers (1971)	1. Combination disposal system could be made more compatible with local economic, social, and environmental needs while still comforming to desired regionalization goals. 2. Wastewater-reclamation potential should be maximized under a combination disposal system since facilities could be designed and located to comply with local markets.	1. Because a combination disposal system would contain many different types of facilities, design and management would be more complex than for systems primarily based on one type of disposal, treatment, or reuse.

Despite this complex interagency planning effort, many decisions relative to the implementation of a regional wastewater-management system remain to be made. Indeed, there is a possibility that the general public either directly or indirectly through expression by local, county, and regional planning agencies can play a large part in defining the characteristics and goals of a regional system. Public awareness and participation will be important to the overall effectiveness and success of a wastewater-management system because of the complex social, economic, and environmental questions associated with its implementation. For example, what are the real economic and environmental costs and effects attached to ocean disposal of municipal and industrial wastewater? Are the apparent economic benefits of a conveyance-oriented system worth the ecological risk of discharging wastewater to biologically productive continental-shelf areas of the Pacific Coast? On the other hand, what are the social ramifications of a large, land-based wastewater-disposal complex in the bay region? Would land disposal ruin aesthetic values of surrounding countryside and depress property values? What are the merits and demerits of continuing to discharge wastewater to San Francisco Bay? Will a growing regional community be willing in the future to allocate part of the scarce recreational and biological resources of the bay for wastewater assimilation? Should wastewater treatment and conveyance facilities, despite higher construction costs, be located away from the seismic hazards found on bay fill and marshlands? What about the question of wastewater reclamation? Should wastewater-reclamation-reuse systems be used to augment available water supplies in lieu of further surface-water importation? Or are the environmental benefits inherent with wastewater-reclamation reuse insufficient when weighed against increased costs and the necessity for more sophisticated treatment facilities?

These and innumerable other pertinent questions cannot be answered in this report. Nor can any single Federal or State agency, no matter how large and talented, provide all the answers. The considerations relative to the implementation of a long-range wastewater-management system in the bay region are exceedingly complex, vast in scope, and most importantly, interrelated to all social, economic, and environmental resources. The expression of these considerations and their insertion into regional resources-planning processes will be an increasingly important responsibility of the land-use planner.

Local or subregional conditions that might allow unique wastewater-management alternatives in certain areas need to be identified before the vast scope necessary for regional planning precludes the consideration of these conditions. For example, a county that has limited water resources concurrent with a need for expanded parks and recreational facilities could conceivably use treated wastewater for forming recreational lakes, irrigating golf courses, or for emergency water-supply augmentation. Marin County officials are currently considering some of these possibilities. In Santa Clara County where ground water is an important source of water supply, there are possibilities for injecting highly treated wastewater into the ground-water reservoir, although such practices could conceivably minimize the need for future importation of surface water and reduce the volume of wastewater discharged to the bay. Contra Costa County officials are presently examining the feasibility of recycling municipal and industrial wastewater to help meet future industrial cooling- and process-water requirements. Sonoma and Solano Counties have possibilities for implementation of subregional wastewater-spray-irrigation systems for meeting future agricultural water needs.

If these and other unique local and subregional alternatives can be identified and evaluated early enough, they may be made compatible with long-range State and Federal regional wastewater-management goals.

It is obvious that much more data, discussion, and planning are required to insure an adequate base for technical design and public support of a long-range wastewater-management system in the region. Hopefully, this report has presented some of the information and concepts necessary for planners and interested citizens to become better informed and more meaningfully involved in the planning and management of wastewater in the San Francisco Bay region.

SELECTED REFERENCES

Adams, J. R., 1969, Thermal power, aquatic life, and kilowatts on the Pacific Coast, 1969: Proceedings of the American Power Conf., 1969, v. 31, 10 p.

American Public Health Association and others, 1971, Standard methods for the examination of water and wastewater (13th ed.): New York, Am. Public Health Assoc., Inc., 874 p.

Armstrong, N. E. Storrs, P. N., and Pearson, E. A., 1970, Development of a gross toxicity criterion in San Francisco Bay: Presented at the 5th Internat. Water Pollution Research Conf., 15 p.

Association of Bay Area Governments, 1970, Regional plan, 1970-1990, San Francisco Bay region: Assoc. Bay Area Govts., 32 p.

California Department of Public Health, 1968, Solid wastes and water quality--a study of solid wastes disposal and their effect on water quality in the San Francisco Bay-Delta area: Prepared for the California Water Resources Control Board, 7 chapters and appendices.

California Department of Water Resources, 1970, Water for California--the California water plan outlook in 1970: California Dept. of Water Resources Bull. 160-70, 179 p.

______1971, Removal of nitrate by an algal system, in series on bioengineering aspects of agricultural drainage, San Joaquin Valley, California: Washington, U.S. Govt. Printing Office, 132 p. [DWR-WQO Grant 13030 ELY, DWR-USBR Contract 14-06-200-3389A].

California Regional Water Quality Control Board, North Coast Region, 1971, Preliminary interim water quality management plan: 40 p.

California Resources Agency, 1970, Siting thermal power plants in California: 8 chapters and appendices.

California Water Resources Board, 1955, Santa Clara Valley investigation: Bull. 7, 154 p.

California Water Resources Control Board, 1971a, Clean water for San Francisco Bay: 17 p.

______1971b, Interim water quality control plan for the San Francisco Bay basin: 72 p.

Engineering Science, Inc., 1968, Reduced scale pesticide study: Consultant task IV-3, study of water quality parameters, appendix C, supplemental volume of San Francisco Bay-Delta water quality control program, 7 chapters.

Federal Water Pollution Control Administration, 1967, Effects of the San Joaquin master drain on water quality of the San Francisco Bay and Delta: 101 p.

Federal Water Quality Administration, 1970, Storm water pollution from urban land activity: Water Pollution Control Research Ser., 325 p.

Friedland, A. O., Shea, T. G., and Ludwig, H. F., 1970, Quantity and quality relationships for combined sewer overflows: Proceedings of the 5th annual Water Pollution Research Conf., August 1970, 16 p.

Hines, W. G., and Palmer, R. H., 1971, Municipal and industrial wastewater loading in the San Francisco Bay: U.S. Geol. Survey Misc. Field Studies Map, MF-332.

Kaiser Engineers, 1969, San Francisco Bay-Delta water quality control program: Consultants' final report to the State of California, 23 chapters and appendixes.

Limerinos, J. T., and Van Dine, Karen, 1970 (revised and reprinted, 1971), Map showing areas serviced by municipal and private sewerage agencies, San Francisco Bay region, California, 1970: U.S. Geol. Survey Misc. Field Studies Map, MF-330, 1:500,000.

McCulloch, D. S., Peterson, D. H., Carlson, P. R., and Conomos, T. J., 1970, A preliminary study of the effects of water circulation in the San Francisco Bay estuary: Geol. Survey Circ. 637-A, 27 p.

Nichols, D. R., and Wright, N. A., 1971, Preliminary map of historic margins of marshlands, San Francisco Bay, California: U.S. Geol. Survey open-file rept. and map, 10 p. and 1 map, 1:125,000.

Pearson, E. A., 1958, A reduced areal investigation of San Francisco Bay: Consultants' report to the California Water Pollution Control Board, 328 p.

Pearson, E. A., Storrs, P. N., and Selleck, R. E., 1969, Waste discharges and loadings, volume 3 of a comprehensive study of San Francisco Bay, SERL Rept. No. 67-3: Sanitary Engineering Research Laboratory, California Univ., Berkeley, 97 p.

______1970, Summaries, conclusions, and recommendations, volume 8 of a comprehensive study of San Francisco Bay, SERL Rept. No. 67-5, Sanitary Engineering Research Laboratory, California Univ., Berkeley, 85 p.

Peterson, D. H., McCulloch, D. S., Conomos, T. J., and Carlson, P. R., 1972, Distribution of lead and copper in surface sediments in the San Francisco Bay estuary: U.S. Geol. Survey Misc. Field Studies Map, MF-323, 1:800,000.

Rantz, S. E., 1971, Precipitation depth-duration-frequency relations for the San Francisco Bay region, California, and ishoyetal map of San Francisco Bay region, California, showing mean annual precipitation: U.S. Geol. Survey open-file rept., 5 p. and 1 map, 1:500,000.

San Francisco Bay Regional Water Quality Control Board, 1969, Water quality problems in the San Francisco Bay system: 25 p. and appendices.

Singer, S. F., 1969, Statement *in* The Nation's estuaries: San Francisco Bay and delta, California: Hearing before a subcommittee of the committee on govt. operations, House of Representatives, 91st Cong., 1st sess., p. 151.

Spieker, A. M., 1970, Water in urban planning, Salt Creek basin, Illinois: U.S. Geol. Survey Water-Supply Paper 2002, 147 p.

U.S. Army Corps of Engineers, 1971, Alternatives for managing wastewater in the San Francisco Bay and Sacramento-San Joaquin Delta area; a summary report: U.S. Army Engineer District, San Francisco Corps of Engineers, 63 p.

U.S. Department of Health, Education, and Welfare, 1963, Manual of septic tank practice: Public Health Service Pub. No. 526, 93 p.

U.S. Environmental Protection Agency, 1971, Eutrophication and detergents: EPA Citizens' Bull., 4 p.

Water Resources Engineers, 1968, Agricultural practices and drainage from agricultural lands, Task VII-If, San Francisco Bay-delta water quality control program: Consultants' final report to the State of California, 5 chapters.

APPENDIX

APPENDIX B

MUNICIPAL WASTEWATER INFORMATION, SAN FRANCISCO BAY REGION, 1971
[From California Water Resources Control Board, 1971b, p. 25-28]
[mgd, million gallons per day]

			Type of Waste		Flow					Discharge Load	Type of Treatment							
Water Quality Zone[1]	Identification No.[1]	Discharger	Municipal Sewage	Industrial Waste and Municipal Sewage	Design capacity (mgd)	1970 Average Annual (mgd)	1970 average as % of design capacity	1970 Wet Weather[2] Peak (mgd)	1970 peak as % of design capacity	Average Annual BOD_5 (lbs/day)	None	Primary		Biological Secondary	Chemical	Stabilization Pond	Disinfection	Other
1	002	Alviso, City of	x		0.52	0.18	36	0.24	44	8		x		x		x	x	
1	046	Los Altos, City of	x		6.0	1.81	31	1.92	32	1,780		x					x	
1	059	Milpitas Sanitary District		x	4.5	2.76	61	2.86	64	345		x		x			x	
1	062	Mountain View, City of	x		6.0	7.4	120	7.94	132	8,730		x		x			x	
1	074	Palo Alto, City of		x	10.	13.1	130	14.85	149	8.860		x			x		x	
1	099	San Jose, City of		x	94	74.9	82	76.8	82	25,750		x		x			x	
1	113	Sunnyvale, City of		x	15	17.4	116	19.1	127	5,440		x			x	x	x	
1	119b	Union S.D. – Irvington		x	10.5	5.11	49	5.32	49	2,750		x		x			x	
1	119c	Union S.D. – Newark		x	7.0	5.31	76	5.51	79	4,770		x		x			x	
2	056	Menlo Park Sanitary District	x		8.0	5.4	65	6.17	77	1,175		x				x	x	x
2	080	Redwood City, City of		x	8.5	7.66	90.1	10.35	122	7,200		x		x			x	
2	094	San Carlos-Belmont, Cities of		x	11.0	3.72	33	4.19	38	2,560		x		x			x	
2	119a	Union Sanitary District – Alvarado	x		3.0	1.95	65	2.17	72	450		x		x			x	
3	011	Burlingame, City of	x		9.7	4.13	76	7.35	76	654		x		x	x		x	
3	025	East Bay Municipal Utility District – Special District No. 1		x	128	81.5	61	113.2	88	113,760		x					x	
3	028	Estero Municipal Improvement District	x		2.16	1.5	69					x					x	
3	035	Guadalupe Valley M.I.D.	x		2.0	0.15						x					x	
3	037	Hayward, City of		x	18	11.86	66	12.95	72	13,040		x		x		x	x	
3	058	Millbrae, City of	x		5.3	2.30	43	2.72	51	570		x		x			x	
3	070	Oro Loma Sanitary District		x	25	14.1	56					x		x			x	
3	140c	San Francisco – Southeast		x	51.0	20.0	39	24.3	48	29,880		x			x		x	
3	096a	San Francisco International Airport – Sewage		x	0.75	0.92	123					x					x	
3	100	San Leandro, City of		x	11.0	7.69	70	9.30	85	4,780		x		x			x	
3	102	San Mateo, City of	x		13.5	10.6	79	15.9	118	11,200		x					x	
3	110	South San Francisco-San Bruno		x	16.0	9.06	57	13.82	86	5,850		x		x			x	
3	125b	U.S.N. Yerba Buena Island										x					x	
4	014	California State Prison – San Quentin	x		1.5	0.78	47	1.06	70	760		x		x			x	
4	050	Marin County S. D. No. 1	x		5.0	5.46	86	9.47	189	650		x		x			x	
4	051	Marin County S. D. No. 5 – Main Plant	x		1.6	0.71	41	1.20	75	500		x					x	
4	057	Mill Valley, City of	x		1.8	2.06	114	4.44	261	440		x		x			x	
4	081	Richardson Bay S.D.	x		0.4	0.22	45	0.35	88	41		x		x			x	
4	082	Richmond, City of		x	16	9.78	61	19.27	120			x		x				
4	140a	San Francisco – North Point	x		57.6	62.2	108	79.6	138	91,400		x			x		x	
4	106	Sausalito-Marin City S.D.	x		2.0	1.93	97	3.36	168	1,290		x					x	
4	107	Seafirth Estate	x		0.01	0.01	100					x		x			x	

See footnotes at end of table.

APPENDIX B.--Continued.

			Type of Waste		Flow					Discharge Load	Type of Treatment							
Water Quality Zone [1]	Identification No. [1]	Discharger	Municipal Sewage	Industrial Waste and Municipal Sewage	Design capacity (mgd)	1970 Average Annual (mgd)	1970 average as % of design capacity	1970 Wet Weather[2] Peak (mgd)	1970 peak as % of design capacity	Average Annual BOD_5 (lbs/day)	None	Primary		Biological Secondary	Chemical	Stabilization Pond	Disinfection	Other
4	111	Stege Sanitary District (connected to East Bay M.U.D.)		x	5.0	4.5	90	6.64	133	4,170		x						
4	125a	U. S. N. Treasure Island		x								x		x			x	
5	003	American Canyon Compnay Water District	x			0.52		0.91								x		
5	015	Calistoga, City of	x		0.5	0.58	116	1.43	286	55		x				x		
5	019a	Contra Costa County S. D. No. 7A	x		0.4	0.79	198	0.945	236	1,020		x					x	
5	021	Crockett-Valona Sanitary District	x		0.55	0.21	41	0.25	46	204								
5	036	Hamilton Air Force Base		x	0.50							x		x			x	
5	038	Hercules, Town of	x		0.02	0.015											x	x
5	040	Las Gallinas Valley S. D.	x		2.25	2.89	128	4.55	202	803		x		x			x	
5	057a	Marin County Sanitary District No. 6 – Ignacio	x		0.90	0.75	70	1.26	140	804		x		x			x	
5	052b	Marin County Sanitary District No. 6 – Novato	x		2.7	2.17	51	4.3	159	770		x		x			x	
5	052c	Marin County Sanitary District No. 6 – Bahia	x		0.2							x		x		x	x	
5	054	Meadowood Development Company	x		.028									x			x	
5	064	Napa County Sanitary District		x	11	6.09	43	9.307	85	270						x	x	
5	075	Petaluma, City of		x	3.0	2.7	90	4.54	151	4,230		x		x			x	
5	076	Pinole, City of	x		1.1	0.98	77	1.49	135	1,210		x					x	
5	086	Rodeo Sanitary District	x		0.84	0.63	58	0.90	107	530		x					x	
5	091	St. Helena, City of	x		0.50	0.30	60	1.09	128	10						x		x
5	103	San Pablo Sanitary District		x	7.0	7.97	114	9.82				x					x	
5	104a	San Rafael Sanitary District – Main Plant	x		5.0	2.84	57	5.82	116	620		x		x			x	
5	104b	San Rafael Sanitary District – Marin Bay Plant	x		0.16	0.11	69	0.24	150					x			x	
5	109	Sonoma Valley County Sanitary District		x	4.0	2.59	65	6.6	165	515		x		x			x	
5	123	U. S. N. Radio Station, Skaggs Island	x									x					x	
5	124	U. S. N. Mare Island		x								x					x	
5	128	Vallejo Sanitary and Flood Control District	x			8.46		11.89		9,630		x					x	
5	131	Veterans Home of Yountville	x		1.5	0.31	21					x		x			x	
5	121	U. S. Naval Fuel Annex, Pt. Molate																x
6	009	Benicia, City of	x		3.0	0.7	23	1.19	40	570		x					x	
6	019b	Contra Costa County Sanitary District No. 5	x		0.05	0.04	80					x						
7	017	Central Contra Costa Sanitary District – Main Plant		x	31.0	24.9	72	41.75	135	24,790		x					x	
7	018	Concord, City of	x		6.2	4.93	77	5.74	93			x		x		x	x	x
7	019c	Contra Costa County Sanitary District No. 3	x		0.6	1.08	178	1.22	203	2,205		x					x	
7	029	Fairfield-Suisun Sewer District	x		5.0	4.61	94	5.7	114	5,850		x				x		x
7	053a	Martinez, City of – Main Plant		x	3.23	1.4	43	1.67	52			x						x
7	053b	Martinez, City of – Fairview Septic Tank	x		0.17												x	

See footnotes at end of table.

APPENDIX C.--Continued.

Water Quality Zone[1]	Identification No.[1]	Discharger	Type of Waste: Municipal Sewage	Type of Waste: Industrial Waste and Municipal Sewage	Flow: Design capacity (mgd)	Flow: 1970 Average Annual (mgd)	Flow: 1970 average as % of design capacity	Flow: 1970 Wet Weather Peak[2] (mgd)	Flow: 1970 peak as % of design capacity	Discharge Load: Average Annual BOD5 (lbs/day)	Type of Treatment: None	Primary		Biological Secondary	Chemical	Stabilization Pond	Disinfection	Other
7	063	Mountain View Sanitary District	x		1.6	0.93	46	1.91	119			x		x			x	
7	117	Travis Air Force Base		x	2.5	1.5	60	2.6	104			x				x		
7	122	U. S. Naval Weapons Station – Concord																x
8	004	Antioch, City of		x		3.3						x					x	
8	010	Brentwood Sanitary District	x			0.3						x				x		
8	012	Byron Sanitary District	x			0.1						x				x		
8	019d	Contra Costa County Sanitary District No. 15	x			0					x							
8	069	Oakley Sanitary District	x			0.2						x				x		
8	077a	Pittsburg, City of – Montezuma Plant		x	3.5	1.48	41	1.764	53	2,160		x					x	
8	077b	Pittsburg, City of – Camp Stoneman Plant	x		7.5	0.63	7	0.73	10			x					x	
10	164	Bolinas Community P. U. D.	x								x							
10	034	Granada Sanitary District	x		0.3	0.16	44	.27	90	195		x					x	
10	177	Half Moon Bay Sanitary District	x			0.2												
10	060	Montara Sanitary District	x		0.5	0.29	38	0.51	102			x		x			x	
10	067	North San Mateo County Sanitary District	x		12	4.11	39			7,720		x					x	
10	072a	Pacifica, City of – Sharp Park	x		4.0	1.08	25	1.48	37	990		x			x		x	
10	072b	Pacifica, City of – Linda Mar	x		4.0	1.77	39	2.42	61	1,690		x			x		x	
10	140b	San Francisco – Richmond-Sunset	x		22.5	19.4	86	24.7	127			x					x	
10	115	Tomales Sewer Maintenance District	x								x							
land	001	Almaden Air Force Base	x									x				x		
land	016	Castlewood Corporation	x									x		x		x		
land	043	Livermore, City of	x		5.0	3.6	74	3.7	74	309		x		x			x	
land	160	Mill Valley Air Force Base	x		.03							x		x			x	x
land	065	Napa Valley Mobile Home Park	x		.03											x		
land	071	Pacific Union College	x		.20							x		x		x		
land	078	Pleasanton, City of	x		1.7	0.9	52					x				x		x
land	129	Valley Community Services District	x		2.5	2.17	86	3.14	125	32		x		x			x	
land	130a	Veterans Administration Hospital – Livermore	x		.20	.16	80					x		x		x	x	

[1]Referenced to map in appendix A.
[2]Average daily flow for the peak month.

INDUSTRIAL WASTEWATER INFORMATION, SAN FRANCISCO BAY REGION, 1971
[From California Water Resources Control Board, 1971b, p. 25-28]
[mgd, million gallons per day; small industries and wineries not included in app. C]

Water Quality Zone[1]	Identification No.[1]	Discharger	Type of Waste: Sanitary Sewage	Type of Waste: Chemical or Petroleum Process Waste	Type of Waste: Food Processing Waste	Type of Waste: Other Industrial Waste[2]	Flow: Average Annual (mgd)	Type of Treatment: None	Primary	Settling Pond	Biological Secondary	Chemical	Stabilization Pond	Disinfection	Screening	Oil Removal	pH Adjustment	Source Control
1	020a	FMC Corporation, Inorganic Chemical Division				x	1.69											
1	011	Campbell Chain Company				x			x							x		
2	012	Cerro Corporation		x									x				x	
2	020b	FMC Corporation, Niagara Chemical Division		x			1.7						x					
2	030b	Kaiser Gypsum Company – Redwood City				x	0.072			x								
3	004	American Pipe and Construction Company				x				x								
3	022	Fuller-O'Brien Corporation		x			.07											x
3	034	Merck and Company, Incorporated		x			5.8	x										
3	037a	PG&E – Oakland				x		x										
3	037g	PG&E – San Francisco				x		x										
3	037h	PG&E – Hunters Point				x		x										
4	001a	Allied Chemical Corporation – Richmond		x			0.04										x	
4	014	Colgate-Palmolive Company				x	1.93	x										
4	016	Cutter Laboratories				x		x										
4	039	Pfizer Company				x	0.1	x										
4	045a	Stauffer Chemical Company – Richmond	x	x			3.56			x							x	x
5	005b	American Radiator & Standard Sanitary Corporation-San Pablo				x				x								
5	007a	Bethlehem Steel Company – Pt. Pinole				x				x								x
5	013	Chevron Chemical Company – Ortho Division		x			0.45			x							x	x
5	024	Hercules, Incorporated	x	x			2.18				x		x	x		x	x	x
5	037f	PG&E – Oleum				x		x										
5	044a	Standard Oil Company of California	x	x		x	114.4				x		x			x	x	x
5	046	Union Oil Company	x	x		x	52.6						x	x		x	x	x
5	090	Sequoia Refining Company	x	x			0.1						x					x

See footnotes at end of table

APPENDIX C.--Continued.

Water Quality Zone[1]	Identification No.[1]	Discharger	Type of Waste: Sanitary Sewage	Type of Waste: Chemical or Petroleum Process Waste	Type of Waste: Food Processing Waste	Type of Waste: Other Industrial Waste[2]	Flow: Average Annual (mgd)	Type of Treatment: None	Primary	Settling Pond	Biological Secondary	Chemical	Stabilization Pond	Disinfection	Screening	Oil Removal	pH Adjustment	Source Control
6	008	C&H Sugar Refining Corporation			x		27.75					x				x	x	x
6	058	Humble Oil and Refining Company	x	x			2.96		x		x	x	x			x	x	x
6	043	Shell Oil Company – Martinez	x	x			4.3					x				x	x	x
7	001b	Allied Chemical Company – Nichols	x	x		x	4.0			x		x		x			x	
7	037d	PG&E – Avon				x		x										
7	037e	PG&E – Martinez				x		x										
7	040a	Phillips Petroleum Company – Avon	x	x		x	12.8						x			x	x	x
7	040b	Phillips Petroleum Company – Amorco	x													x		
7	042b	Shell Chemical Company – Pittsburg		x			9.35									x		
7	045b	Stauffer Chemical Company – Martinez		x			0.05			x							x	x
7	047a	U. S. Steel Corporation – Pittsburg				x	20.4			x		x				x	x	x
8	015	Crown Zellerbach Corporation				x	15.								x			
8	018	Dow Chemical Company		x			25.8			x				x			x	x
8	019	duPont deNemours, E. I.	x	x		x	1.5						x			x	x	x
8	068a	Fibreboard Corporation – Board Mill				x	5.0										x	
8	068b	Fibreboard Corporation – Pulp-paper mill				x	16.0								x		x	
8	025	Hickmont Canning Company			x		0.2								x		x	
8	030a	Kaiser Gypsum Company, Incorporated – Antioch				x	0.4	x										
8	037b	PG&E – Pittsburg				x				x						x		x
8	037c	PG&E – Contra Costa				x	970.			x						x		
8	091	Tillie Lewis Foods			x		4.0 max.								x		x	
10	044b	Standard Oil Company – Ocean					3.71	x										
10	043b	Shell Oil – Ocean					–	x										
land	023	General Electric Company – Vallecitos					.29				x		x					

[1]Reference to appendix A.
[2]Including cooling water.