ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

A Preliminary Assessment of the Economic Impact of Water Pollution on the Shellfish Resources of San Francisco Bay, California

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INTRODUCTION

San Francisco Bay and adjoining bays form the largest estuarine system in California. The San Francisco metropolitan area and adjacent urban areas surrounding the Bay system, with a population of more than six million, form the second largest population center in California. Large industrial complexes are also located in close proximity to the Bay system. The Bay is a major international port.

Pollution from municipal and industrial waste sources, urban runoff, vessel wastes and agricultural drainage have degraded water quality throughout the estuary. Although water quality has improved in recent years as the result of improved waste disposal practices, water quality is still substantially degraded and violations of water quality regulations and impairment of water uses presently occur.

The estuary historically supported a major commercial fishery. As early as 1870, pollution caused some impairment of this water use, especially commercial shellfishing. Although a large commercial fishing industry still operates in the San Francisco area, pollution has contributed to a decline in the annual harvest of seafood directly from the estuarine system and has essentially eliminated the commercial harvest of shellfish. Oysters and clams are still present in the estuary in substantial numbers but bacterial contamination prevents their harvest for human consumption.

This paper summarizes water quality conditions existing in the San Francisco Bay system and lists principal sources of pollution. Water quality regulations applicable to abatement of present pollution are also summarized.

The history of the commercial shellfish industry is discussed and the economic impact of pollution on this industry evaluated. In short, this paper presents background information from which an assessment can be made to determine if the conditions precedent to calling an Enforcement Conference pursuant to the provisions of the Federal Water Pollution Control Act exist with respect to the San Francisco Bay system.

SUMMARY AND CONCLUSIONS

1. Water quality degradation in San Francisco Bay and adjoining estuarine waters impairs beneficial water uses including water contact recreation, fish and wildlife propagation and shellfish harvesting.

2. The San Francisco Bay system is a navigable coastal water. Pollution of the Bay system is subject to abatement under the provisions of the Federal Water Pollution Control Act, as amended.

3. Discharges of industrial wastes to the Bay system are subject to the requirements of the Rivers and Harbors Act of 1899.

4. Low dissolved oxygen levels at several locations in the Bay and tidal tributaries have caused depletion or elimination of aquatic life populations.

5. Bacterial concentrations in much of the Bay system exceed allowable limits for water contact sports and shellfishing. In spite of this health hazard, recreational and sport shellfishing continues.

6. A number of fish kills have resulted from spills or discharges of toxic materials. In addition to acute toxicity problems, chronic toxic effects are also present. Pesticide concentrations exceed recommended limits.

7. Shellfish and other aquatic life are contaminated by noxious chemicals and taste and odor producing substances in addition to bacterial contamination.

8. Nutrient concentrations are above desirable limits and nuisance aquatic growths are present in several locations.

9. About 400 million gallons per day of municipal wastes are discharged to the Bay system by 66 treatment facilities serving a population of more than four million and numerous industries. About half the flow volume is treated in 25 plants which provide only primary treatment. Much of the wastes discharged do not receive chlorination or adequate disinfection. Municipal wastes are a major source of oxygen demanding materials.

10. Only limited information is available on industrial wastes discharged directly to the Bay system. Their volume is probably about one-tenth of the municipal waste discharges but may have a proportionally greater water quality impact due to its constituents. Industrial waste discharges are known to be sources of toxic materials and taste and odor producing substances.

11. Prior to 1900 the San Francisco Bay system supported a major shellfish industry. During the 1890's, the oyster fishery was the single most valuable fishery in California. Commercial oyster culture was a million dollar business. A number of factors of which pollution was the most important caused the rapid decline of the shellfish industry after 1900. Today, the industry is essentially non-existent.

12. Water quality conditions, including bacterial contamination, are the major factor preventing the reestablishment of a shellfish industry in San Francisco Bay. South San Francisco Bay is potentially the best

oyster producing area in California.

13. It is estimated that the economic impact on the regional economy produced by the elimination of the oyster industry by pollution of San Francisco Bay is in the range of $820,000 to $4,000,000 annually. The elimination of the clam and mussel fishery produces an additional economic impact.

14. Pollution of San Francisco Bay affects the interstate shipment of oysters into California for marketing in the Bay area, blocks the interstate shipment of seed oysters for use in oyster culture in the Bay, and prevents development of potential oyster production which could create a surplus supply for interstate shipment to other areas.

DESCRIPTION OF AREA

The San Francisco Bay system includes San Francisco Bay, San Pablo Bay, and Suisun Bay, and extends from the eastern end of Chipps Island at the City of Pittsburg, where the Sacramento and San Joaquin Rivers join, westward and southward to the mouth of Coyote Creek near the City of San Jose, a distance of approximately 85 miles. The Golden Gate is about halfway between San Jose and Antioch and is the Bay's only connection with the ocean. The San Francisco Bay system is illustrated in Figure 1.

The normal annual precipitation over the San Francisco Bay system and its local drainage areas amounts to 19 inches per year. Over the entire Bay system the mean annual evaporation is almost 48 inches, more than twice the annual precipitation. The difference between precipitation and evaporation accounts for the loss of more than 650,000 acre-feet of water each year from the water surfaces alone.

While the Sacramento and San Joaquin Rivers contribute the greatest inflow to the Bay (seventeen million acre-feet annually), eight smaller streams also discharge to the Bay system. The combined mean annual discharge of these local streams is only 435,000 acre-feet per year, and for this reason most of the cities around the Bay of necessity have developed or depend upon water sources outside the Bay system.

One hundred years ago the area of San Francisco Bay was nearly 700 square miles including more than 300 square miles of marsh land. Almost 80 percent of this marsh land has been reclaimed, chiefly for agricultural use and salt ponds. Now, the area of the Bay at mean tide is approximately 435 square miles.

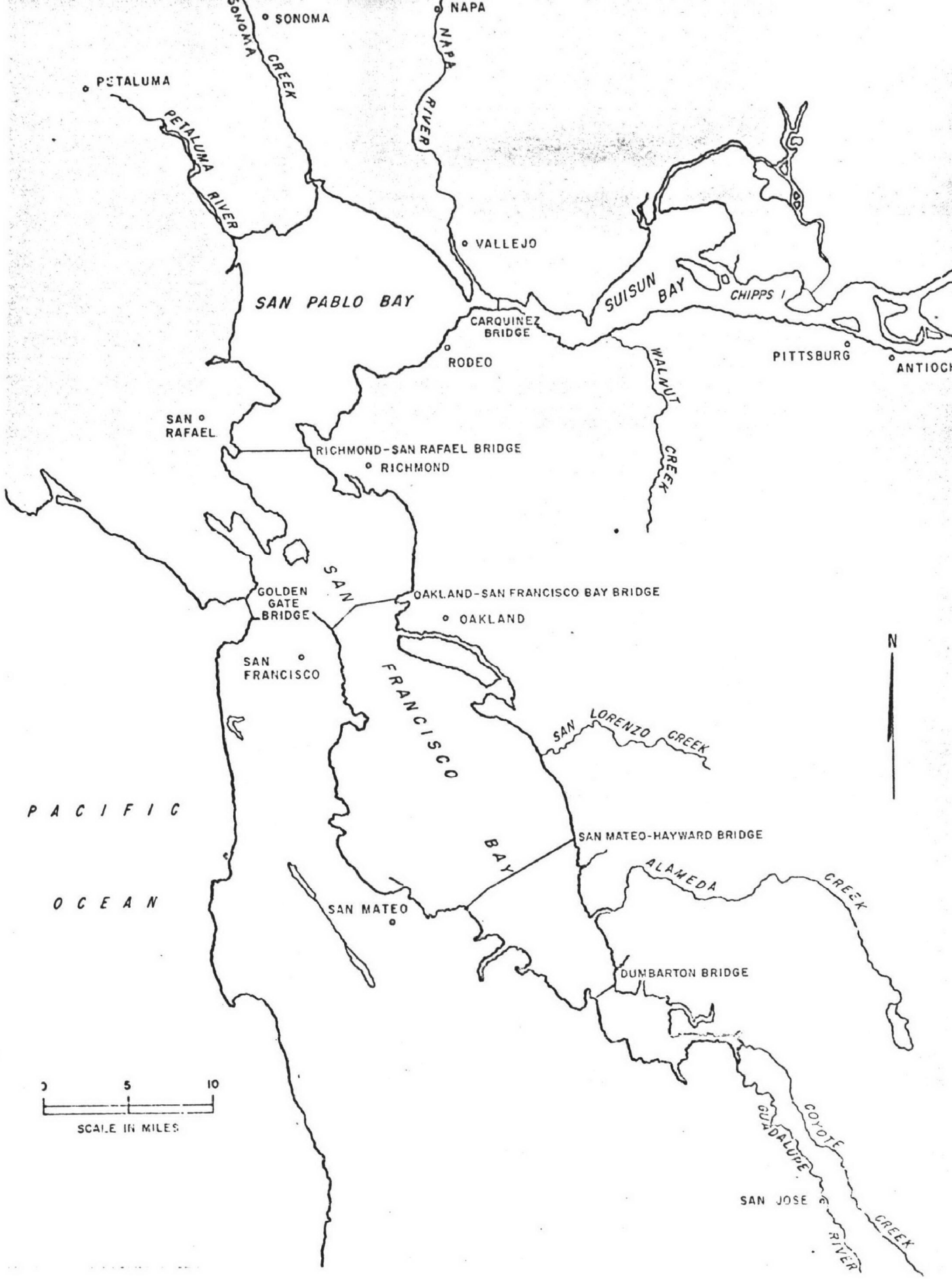

Figure 1. San Francisco Bay System

The total water volume at mean tide in the San Francisco Bay system is approximately 235 billion cubic feet, or more than one and one-half cubic miles of water. The tidal prism, or the volume between high and low tides, is about 50 billion cubic feet or 21 percent of the average total volume of water in the Bay. Fifteen to 20 percent of this tidal prism is replaced by new ocean water during each tidal cycle. This is the principal mechanism by which pollutants are ultimately removed from the Bay.

Much of the Bay is very shallow, the average depth being only 20 feet. The shallowness of the Bay has a number of important consequences. Wind-generated waves disturb the bottom and contribute substantially to the high turbidity of the water. Again, the shallowness is an important factor in determining the relative importance of surface reaeration and overall oxygen balance of the Bay.

Nine counties, with a total population of more than six million, are located adjacent to the Bay system. These counties are Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Sonoma, and Solano. Three major cities, San Francisco, Oakland and San Jose, as well as many smaller cities, are located in the Bay area. Topographical features are such that much of the urban development is located in close proximity to Bay shorelines.

The geographical features of the area have led to its development as one of the world's leading ports of commerce. The Bay area, with its excellent harbor facilities and thorough accessibility by ship, has developed large industries in food products, paper, metal, petroleum and textiles. There are extensive agricultural lands in the vicinity and in the nearby Central Valley which produce fruit, vegetables, dairy products, grains and

wine. Salt and cement products are produced in large quantities directly from the Bay. The geographical setting has also made the area a strategic location for military bases and shipyards.

Commercial fisheries which obtain seafood products directly from the Bay system and from the nearby Pacific Ocean are also a significant industrial enterprise in the Bay area. The relative importance of the seafood industry in the San Francisco area with respect to the total California seafood industry has declined in recent years. This decline is due to the combination of the increased development of fisheries in other parts of the State and a reduction in the seafood harvest in the Bay area due to pollution and other factors.

APPLICABLE WATER QUALITY REGULATIONS

San Francisco Bay is a navigable water which is also a coastal water subject to the ebb and flow of the tide. The Bay and adjacent waters are contained entirely within the State of California and are therefore intrastate waters. Several provisions of the Federal Water Pollution Control Act are applicable to pollution of intrastate coastal waters. Water quality standards applicable to the Bay system have been established by the State and approved as Federal standards pursuant to the provisions of the Water Quality Act of 1965. The Rivers and Harbors Act of 1899 is applicable to discharges of industrial wastes to navigable waters. These water quality regulations are discussed below.

Federal Water Pollution Control Act

Section 10(a) of the Federal Water Pollution Control Act, as amended, (33 U.S.C. 466 et. seq.) provides that "the pollution of interstate or navigable waters in or adjacent to any state...which endangers the health or welfare of any persons, shall be subject to abatement as provided in this Act".

Since San Francisco Bay is navigable, pollution of the Bay is subject to abatement under the provisions of the Act. One step in securing such abatement is the calling of a Federal-State Enforcement Conference. Section 10(d) provides the following basis for calling such a conference:

> "The Secretary shall also call such a conference whenever, on the basis of reports, surveys, or studies, he has reason to believe that any pollution referred to in subsection (a)...is occurring, or he finds that substantial economic injury results from the inability to market shellfish or shellfish products in interstate commerce because of pollution referred to in subsection (a) and action of Federal, state, or local authorities."

The "Secretary" referred to above was the Secretary of the Interior. Administration of the provisions of the Act, formerly assigned to the Secretary, is assigned to the Administrator of the Environmental Protection Agency.

As discussed in following sections, pollution of San Francisco Bay is preventing the marketing of shellfish in interstate commerce with attendant substantial economic injury. Shellfishing areas in the Bay have been closed to shellfish harvesting by State authorities because of such pollution. The requirements for calling a Federal-State Enforcement Conference are thus met.

Federal rules regulating the discharge of oil to navigable waters were established on September 11, 1970, pursuant to the provisions of Section 11(b)(3) of the Act, as amended by the Water Quality Improvement Act of 1970. These rules prohibit discharges of oil to navigable waters from any source which:

"(a) Violate applicable water quality standards, or

(b) Cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines".

All discharges of oil to the San Francisco Bay system are subject to the provisions of these regulations.

Water Quality Standards

Water quality standards have been established for the San Francisco Bay system by the State of California and approved as Federal standards

in accordance with provisions of the Federal Water Pollution Control Act, as amended. A complete set of current standards was not immediately available to DFI-DC. The following discussion is based on the standards originally submitted for Federal approval but subsequently revised.

The waters of the Bay system have been divided into seven water quality zones.[1/] These zones are shown in Figure 2.

The water quality standards specify various beneficial water uses which are to be protected in the San Francisco Bay system.[1/] These uses are listed in Table 1 by water quality zone.

Water quality criteria which specify numerical and/or narrative limits for various parameters were established for each beneficial water use to be protected. The most restrictive numerical limit or narrative criterion for each parameter is listed in Table 2.

The Rivers and Harbors Act of 1899

The Rivers and Harbors Act of 1899 prohibits the discharge of industrial wastes to navigable waters without a permit from the U. S. Army Corps of Engineers. Section 407 of the Act, referred to as the Refuse Act of 1899, makes it unlawful to discharge from any "...manufacturing establishment, or mill of any kind, any refuse matter of any kind or description whatever other than that flowing from streets and sewers and passing therefrom in a liquid state, into any navigable water from which the same shall float or be washed into such navigable water..." provided that a discharge may be permitted under certain conditions specified by the Corps of Engineers.

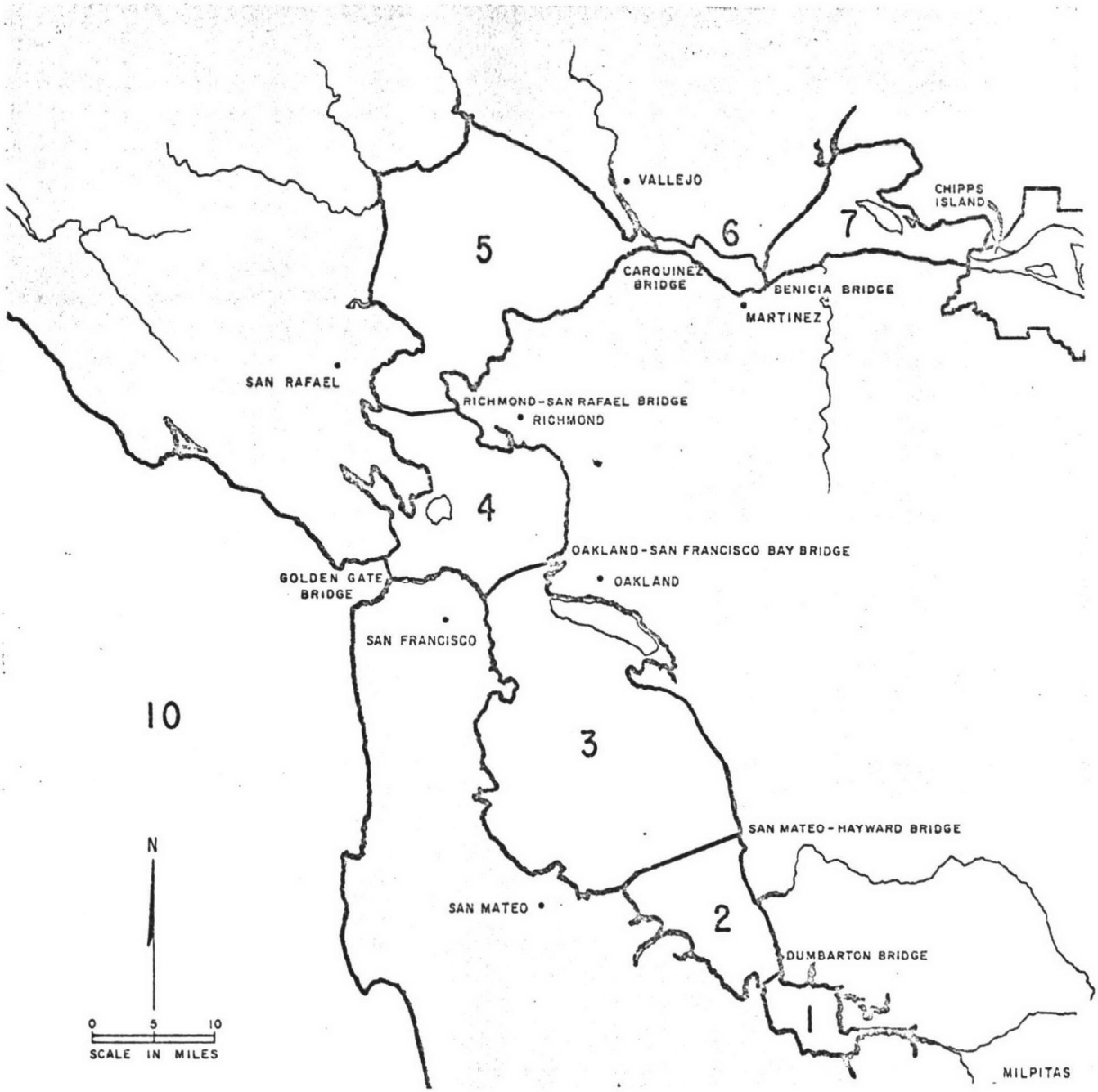

Figure 2. Water Quality Zones

Table 1. Beneficial Uses to be Protected in San Francisco Bay

Uses	Water Quality Zone						
	1	2	3	4	5	6	7
Industrial Supply:							
boiler							X
cooling	X	X	X	X	X	X	X
rinsing	X	X	X	X	X	X	X
processing	X	X	X	X	X	X	X
Agricultural Supply: [1]							
irrigation							X
Fish and Wildlife Propagation and Aquatic Growth:							
fish habitat, migration, spawning	X	X	X	X	X	X	X
shrimp and crab habitat	X	X	X	X	X	X	X
shellfish habitat	X	X	X	X	X	X	X
waterfowl habitat	X	X	X	X	X	X	X
mammal rookery	X	X	X	X	X		
Commercial Fishing and Shellfishing	X	X	X	X	X	X	X
Recreation:							
swimming, waterskiing, skindiving, picnicking	X	X	X	X	X	X	X
pleasure boating	X	X	X	X	X	X	X
fishing	X	X	X	X	X	X	X
shellfishing	X	X	X	X	X	X	X
hunting	X	X	X	X	X		X
Enjoyment of Esthetic Values	X	X	X	X	X	X	X
Navigation	X	X	X	X	X	X	X

[1] Some seasonally.

Table 2.

WATER QUALITY STANDARDS

Applicable to the San Francisco Bay System

Parameter	Standard
pH	7.0 - 8.6
Temperature	Shall not be significantly increased above natural nor altered to adversely affect aquatic life. (This standard not Federally approved.)
Dissolved Oxygen (minimum allowable concentration)	5.0 mg/l (except when natural conditions cause lower concentrations)
Coliform Organisms	Median shall not exceed 70 coliform organisms per 100 milliliter in any sample, nor shall more than 10 percent of the samples collected in any month exceed 230 per 100 milliliters.
Radioactivity (maximum allowable)	Shall not exceed 1/10 of the MPC_w values given for continuous occupational exposure in "National Bureau of Standards Handbook 69".
Turbidity (maximum allowable) (JCU)	Shall not be significantly increased above natural background levels, nor to a degree which adversely affects aquatic life.
Color	Free from substances attributable to wastes that produce detrimental color.
Taste and Odor	No organic or inorganic substances which impart undesirable tastes or odors to species of commercial or sport importance.
Solids	Floating and settleable solids shall not be discharged or left along the shoreline; (shall be) less than the concentration of settleable solids that would change the physical nature of the stream bottom or adversely affect the aquatic environment.

Table 2 (cont'd)

WATER QUALITY STANDARDS

Applicable to the San Francisco Bay System

Parameter	Standard
Toxic Substances (maximum allowable)	No organic or inorganic substances in concentrations which are toxic or detrimental to human, animal, plant, or aquatic life.

Executive Order No. 11574, signed by President Nixon on December 23, 1970, tightens enforcement of the Refuse Act of 1899 by requiring that all sources of industrial wastes discharging to navigable waters or their tributaries must apply to the Corps of Engineers for permits to continue such discharges by July 1, 1971. This deadline was later extended to October 1, 1971, for certain application data. Permit applications are currently being processed cooperatively by the Corps of Engineers and EPA. All sources of industrial wastes discharging directly to the Bay system will be required to apply for such permits. Application data will provide a detailed inventory of industrial waste discharges.

WATER QUALITY PROBLEMS

The San Francisco Bay system has been polluted to some degree since 1848, when the California gold rush caused a sharp increase in population in the Bay area. By 1900, pollution had become severe enough to cause a decline in the productivity of the Bay fishery. Improved treatment for various municipal and industrial waste sources has resulted in improved water quality conditions in some areas of the Bay system in recent years, but this improvement has been largely offset by population increases and industrial development.

Water quality data on the Bay system immediately available to DFI-DC are extremely limited. Much of the past Federal-State water quality study and surveillance activities in this area were directed toward evaluating the impact of agricultural drainage and water resource development in the Central Valley on water quality in the Sacramento-San Joaquin Delta in the upper portion of the Bay system, and did not provide information on water quality conditions in the greater Bay system. As late as 1962, the State maintained only five water quality sampling points in the Bay area, all on tributary streams above the Bay system except a station on Carquinez Straits, which recorded only water temperature and conductivity. Retrieval of all data in the STORET system produced only a few pieces of data, of limited value. Due to this lack of data, it is not possible to define present water quality conditions with respect to specific parameters or to evaluate compliance with water quality standards.

Various reports are available, however, which describe water quality conditions in general terms and outline the most serious pollution

problems [1], [2], [3], [4]. These reports form the basis for the following discussion.

Dissolved Oxygen

Throughout most of the San Francisco Bay system, dissolved oxygen concentrations are consistently above 80 percent of saturation; however, significant dissolved oxygen depletions occur in several critical areas of the Bay. The most serious dissolved oxygen deficits occur in the southernmost part of San Francisco Bay below Dumbarton Bridge and in Coyote Creek downstream from the discharge of the San Jose waste treatment plant, where dissolved oxygen concentrations often fall to zero in the late summer at the height of the canning season.[1] Similar water quality problems are observed in the sloughs receiving waste effluents along the west side of San Francisco Bay between San Jose and San Francisco, and the Napa and Petaluma estuaries.

The low dissolved oxygen levels have resulted in the elimination or reduction of fish and other aquatic life populations in several areas of the Bay, especially the south Bay. In some of the most degraded areas, fish are not present.[2] Some of this depletion of aquatic life may be due to toxic materials, as discussed below, as well as dissolved oxygen depletions.

The primary factor contributing to dissolved oxygen depletions is the discharge of organic materials from municipal waste sources. These discharges are the most damaging during the canning season, when a number of plants receive large loads of organic waste materials from food processing plants.

Bacterial Contamination

Studies conducted in San Francisco Bay between 1959 and 1964, and in 1968, show that coliform bacteria levels exceeded water quality standards for water contact sports in most parts of the Bay system.[1/] Such high bacteria levels would pose a health hazard to sport shellfishing and would exceed allowable limits for commercial harvesting of shellfish. About 90 percent of the areas supporting harvestable populations of shellfish have been declared unsafe for harvesting of shellfish for human consumption.[2/]

In spite of the known bacterial contamination of the Bay system, extensive recreation use such as boating, water skiing and swimming is made of various areas of the Bay. Some sport fishing for clams also takes place.

The principal sources of bacterial contamination are domestic wastewater discharges. Watercraft wastes, urban runoff, and combined sewer overflows also contribute to this pollution.

Toxic Materials

A serious problem exists in the Bay system as the result of the presence of various toxic materials. Periodic and widespread fish kills have occurred in various portions of the Bay. In the five years between 1963 and 1968, the California Department of Fish and Game investigated 31 reported fish kills in the Bay system and adjacent delta.[1/] Eleven of the 31 fish kills were identified with wastewater discharges or spills. Causes of the remaining incidents have not been explained. Evaluation of the toxicity of municipal and industrial waste waters has shown that almost all of these wastes are toxic in varying degrees to fish. Oil refineries, shipping, and certain communities in South San Francisco Bay have been the most common offenders with

respect to discharges of acute toxic pollution.

Mysterious annual die-offs of thousands of striped bass, an important commercial and sport fishing species, have occurred in the Bay. These fish kills have not been traced to specific pollution sources; however, a life history of this species does not indicate that this is a normal occurrence.

Pesticide concentrations in the Bay system are also of concern. Chlorinated hydrocarbon concentrations in most areas of the Bay exceed the maximum concentration recommended by the National Technical Advisory Committee on Water Quality Criteria.[1/] Although present concentrations of chlorinated hydrocarbons in aquatic organisms are less than those found to be lethal to the organisms in most cases, the concentrations are high enough to warrant concern about sublethal damage to the organisms.

Contamination of Aquatic Life

In addition to the contamination of shellfish by bacterial pollution, as discussed above, both shellfish and other aquatic life have been contaminated by noxious chemicals which render them unsafe for human consumption. In many cases, this contamination does not kill or damage the aquatic organism, but rather, poses a health hazard if consumed by humans. Domestic sewage and phenolic wastes from oil refineries are the usual sources of contamination.[2/] Shellfish are more commonly affected, although there is some evidence that fishes are also affected.

No information was available on hydrocarbon residues in shellfish. The presence of industrial waste discharges from oil refineries and the usual oil spills from commercial shipping would indicate the probability that such hydrocarbon residues are present in shellfish.

Biostimulants and Algal Populations

The San Francisco Bay system exhibits evidence of enrichment at various locations, mainly along the shores and in tidal reaches of some tributaries. Nitrogen and phosphorus concentrations in the waters of the Bay system are substantially higher than levels where either nitrogen or phosphorus might be growth-limiting.[1/] Decaying of aquatic vegetation has produced hydrogen sulfide odors and caused blackening of lead-based paints. Mats of these plants have reached nuisance proportions in the Albany Tide Flats. Discoloration of Bay waters due to green algae and the red-pigmented marine ciliate, mesodinium has raised concern among fishermen and shore-side property owners.

Agricultural drainage from the Central Valley, entering the Bay system through the Delta, is one main source of nitrogen and phosphorus. Municipal and industrial waste discharges also contribute substantial nutrient loads to the Bay.

Sediments

Much of the Bay's bottom is covered with fine sediments and mud. Large sediment loads are carried into the Bay system in tributary inflow. Spoil disposal from various dredging activities results in the movement of sediment loads into various parts of the Bay system. In the shallower portions of the Bay, wind and wave action can stir up bottom sediments. As a result, much of the Bay system exhibits high turbidity levels at various times. This high turbidity has a detrimental effect on aquatic life production. As sediments settle out, they may blanket the bottom and smother aquatic life. High turbidity and sediment concentrations were believed to be one factor contributory to the decline of the Bay system's shellfish populations.

SOURCES OF POLLUTION

The principal source of pollution in the San Francisco Bay system is the large population located adjacent to Bay waters. Most of the pollution from this source enters waters as municipal waste discharges. Combined sewer overflows and urban runoff also contribute some pollution.

Industrial developments also account for significant pollution loads, especially toxic materials. An unknown but major industrial waste load is discharged to municipal treatment systems.

All of the residual pollution from the Central Valley, including agricultural drainage containing pesticides and nutrients, enters the San Francisco Bay system by way of the San Joaquin - Sacramento River Delta. Commercial shipping and pleasure boating contribute vessel pollution. Dredging to maintain navigation channels and for construction of shoreside facilities redistributes pollutants in the vicinity of dredging and spoil disposal areas. The relative magnitude of these various pollution sources is discussed below.

Municipal Waste Sources

A total of more than 400 million gallons of treated wastes are discharged to the Bay system daily by 66 major publicly-operated treatment facilities. These facilities primarily treat municipal wastes, but the volume of industrial waste treated by a number of plants is also believed to be significant. Basic information on these municipal facilities is contained in Table 3. Plant locations are shown in Figure 3.

Basic data on the municipal sources listed in Table 3 were obtained from the STORET municipal inventory. The current validity of the data is unknown, as the date when each source was last reviewed was unavailable. The

Table 3. Municipal Waste Sources

Map Key	Source	Population Served	Flow MGD	Type Treatment	Receiving Water
		ALAMEDA COUNTY			
1	East Bay Municipal Utilities District	608,000	74.0	Primary	Central San Francisco Bay
2	City of San Leandro	50,000	7.6	Secondary	South San Francisco Bay
3	Oro Loma Sanitary District	185,000	11.9	Secondary	South San Francisco Bay
4	City of Hayward	97,500	9.4	Secondary	South San Francisco Bay
5	Union Sanitary District Alvarado Plant	21,000	1.2	Secondary	Alameda Creek to South San Francisco Bay
6	Union Sanitary District Newark Plant	62,000	2.8	Secondary	Newark Slough to South San Francisco Bay
7	Union Sanitary District Irvington Plant	64,000	5.1	Secondary	Mud Slough to South San Francisco Bay
		SANTA CLARA COUNTY			
8	Milpitas Sanitary District (2 plants)	34,000	2.8	Secondary	Coyote Creek to South San Francisco Bay
9	City of San Jose	700,000	67.4	Secondary	Coyote Slough to South San Francisco Bay

Table 3. Municipal Waste Sources (cont'd)

Map Key	Source	Population Served	Flow MGD	Type Treatment	Receiving Water
10	City of Alviso	1,200	0.3	Secondary	Artesian Slough to Coyote Creek to South San Francisco Bay
11	City of Sunnyvale	100,000	12.5	Secondary	Guadalupe Slough to South San Francisco Bay
12	Moffet Naval Air Station	---	---	Primary	South San Francisco Bay
13	City of Mountain View	55,000	5.5	Primary	South San Francisco Bay
14	City of Los Altos	27,500	1.7	Primary	South San Francisco Bay
15	City of Palo Alto	89,600	10.8	Secondary	South San Francisco Bay
	SAN MATEO COUNTY				
16	Menlo Park Sanitary District	55,000	5.0	Secondary	West Point Slough to South San Francisco Bay
17	City of Redwood City	74,000	8.5	Secondary	Redwood Creek to South San Francisco Bay
18	San Carlos - Belmont	50,000	5.0	Secondary	Steinburger Slough to South San Francisco Bay
19	Estero Municipal Improvement District	10,000	0.6	Primary	South San Francisco Bay
20	City of San Mateo	90,000	8.8	Primary	South San Francisco Bay

Table 3. Municipal Waste Sources (cont'd)

Map Key	Source	Population Served	Flow MGD	Treatment	Receiving Water
21	City of Burlingame	34,000	---	Tertiary	South San Francisco Bay
22	City of Millbrae	22,000	1.8	Secondary	South San Francisco Bay
23	San Francisco International Airport	---	---	Primary	South San Francisco Bay
24	South San Francisco San Bruno Plant	83,000	9.5	Secondary	
25	Guadalupe Valley Municipal Improvement District	5,000	0.1	Primary	South San Francisco Bay
	SAN FRANCISCO COUNTY				
26	San Francisco Municipal Sewage System - Southeast Plant	160,000	18.5	Primary	South San Francisco Bay
27	San Francisco Municipal Sewage System - North Point Plant	370,000	56.0	Primary	San Francisco Bay
28	Treasure Island U. S. Navy	---	---	Secondary	San Francisco Bay

Table 3. Municipal Waste Sources (cont'd)

Map Key	Source	Population Served	Flow MGD	Treatment	Receiving Water
			MARIN COUNTY		
29	Sausalito - Marin City Sanitary District	13,000	1.8	Primary	San Francisco Bay
30	City of Mill Valley	16,000	1.5	Secondary	Richardson Bay to San Francisco Bay
31	Richardson Bay Sanitary District	3,300	0.2	Secondary	Richardson Bay to San Francisco Bay
32	Sanitary District No. 5 of Marin County - Paradise Cove Plant	4,000	---	Primary	Raccoon Strait to San Francisco Bay
33	USDI, Bureau of Mines	---	---	Primary	San Francisco Bay
34	Sanitary District No. 1 of Marin County - Tiburon Plant	1,500	---	Primary	Richardson Bay to San Francisco Bay
35	San Quentin Prison	6,000	---	Secondary	Corte Madera Creek to San Francisco Bay
36	Sanitary District No. 1 of Marin County	50,000	---	Secondary	San Francisco Bay
37	San Rafael Sanitation District - Main Plant	25,000	2.6	Secondary	San Pablo Bay

Table 3. Municipal Waste Sources (cont'd)

Map Key	Source	Population Served	Flow MGD	Treatment	Receiving Water
38	San Rafael Sanitation District - Marin Bay Plant	1,500	0.1	Secondary	San Pablo Bay
39	Los Gallinos Valley Sanitary District	27,000	1.6	Secondary	San Pablo Bay
40	Hamilton Air Force Base	---	---	Primary	San Pablo Bay
41	Sanitary District No. 6 of Marin County - Ignacio Plant	11,000	0.7	Secondary	Novato Creek to San Pablo Bay
42	Sanitary District No. 6 of Marin County - Novato Plant	24,000	2.3	Secondary	Novato Creek to San Pablo Bay
43	Sanitary District No. 6 of Marin County - Bahia Plant	---	---	Secondary	Petaluma River to San Pablo Bay
	SONOMA COUNTY				
44	City of Petaluma	24,000	1.8	Secondary	Petaluma River to San Pablo Bay
45	Sonoma Valley County Sanitation District	26,000	1.5	Secondary	San Pablo Bay

Table 3. Municipal Waste Sources (cont'd)

Map Key	Source	Population Served	Flow MGD	Treatment	Receiving Water
46	Skaggs Island Naval Reservation	---	---	Primary	San Pablo Bay
	NAPA COUNTY				
47	Napa County Sanitation District	50,000	5.2	Secondary	Napa River to San Pablo Bay
	SOLANO COUNTY				
48	Mare Island Naval Shipyard	---	---	Secondary	San Pablo Bay
49	Vallejo Sanitation & Flood Control District	82,000	7.0	Primary	Carquinez Straits
50	City of Benicia	7,000	0.6	Primary	Carquinez Straits
51	Fairfield - Suisun Sewer District	35,000	3.2	Secondary	Suisun Slough to Suisun Bay
52	Travis Air Force Base	---	---	Secondary	Suisun Bay

Table 3. Municipal Waste Sources (cont'd)

Map Key	Source	Population Served	Flow MGD	Treatment	Receiving Water
			CONTRA COSTA COUNTY		
53	City of Pittsburg - Montezuma St. Plant	16,000	1.2	Primary	New York Slough to Suisun Bay
54	City of Pittsburg - Camp Stoneman Plant	8,000	0.5	Primary	New York Slough to Suisun Bay
55	Contra Costa County Special District No. 7A	12,000	0.6	Secondary	Suisun Bay
56	City of Concord	73,000	3.8	Secondary	Walnut Creek to Suisun Bay
57	Central Contra Costa County Sanitary District	275,000	16.3	Primary	Suisun Bay
58	Mountain View Sanitary District	12,000	0.6	Secondary	Suisun Bay
59	City of Martinez	10,000	1.4	Intermediate	Carquinez Straits
60	Crockett-Velona Sanitary District	5,000	0.3	Primary	Carquinez Straits
61	Rodeo Sanitary District	8,000	0.6	Secondary	San Pablo Bay
62	City of Pinole	13,000	0.8	Primary	San Pablo Bay

Table 3. Municipal Waste Sources (cont'd)

Map Key	Source	Population Served	Flow MGD	Treatment	Receiving Water
63	Contra Costa County Special District No. 3	12,000	0.7	Secondary	San Pablo Bay
64	San Pablo Sanitary District	69,000	6.2	Primary	San Pablo Bay
65	City of Richmond	72,000	8.0	Secondary	Central San Francisco Bay
66	Stege Sanitary District	45,000	3.9	Primary	Central San Francisco Bay

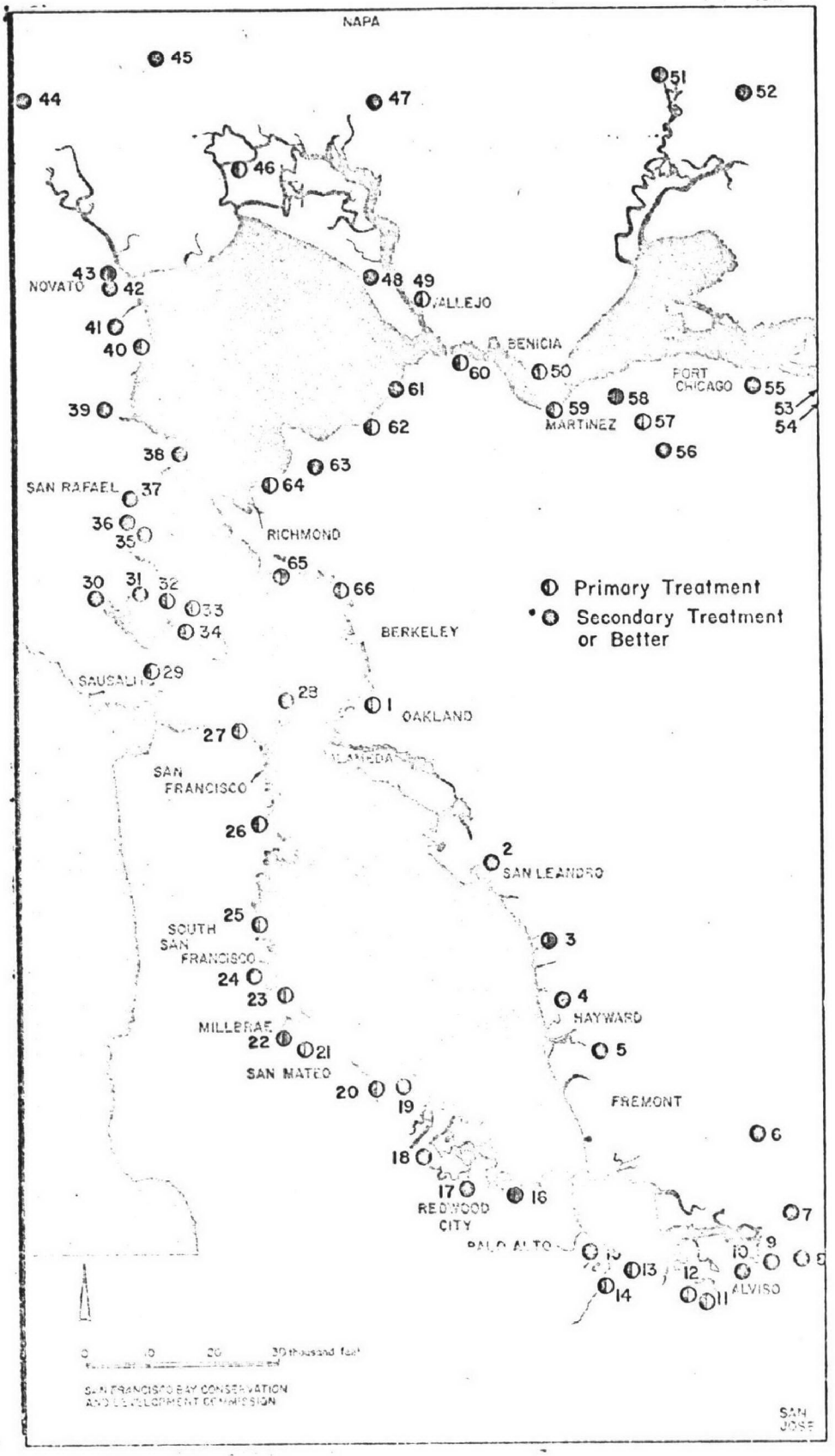

Figure 3. Locations of Municipal Waste Sources

STORET data are comparable to the 1965 flow data presented in the San Francisco Bay-Delta Water Quality Control Program.[3/] A summary of the municipal and industrial waste discharges in 1965 by water quality zones is shown in Table 4. A more detailed summary of the STORET municipal and industrial inventory data is shown in Table 5.

Of the 4,096,000 population served by the municipal treatment facilities discharging to the Bay system, 1,865,000, or 45 percent, are served by plants providing primary treatment only. Primary treatment only is provided at 25 of the 66 sources. These primary plants treat about one-half of the total waste volume.

The STORET inventory data were incomplete with respect to type of treatment units utilized at each source. Treatment data were available on enough sources, however, to indicate that substantial quantities of domestic wastes may be discharged to the Bay system without chlorination or adequate disinfection.

Overloading of municipal waste facilities by heavy industrial organic waste loads during the food processing season has occurred in the past at such locations as San Jose and Sunnyvale, and may be continuing as a problem in several areas.

Industrial Waste Sources

Available information on industrial waste discharges in the Bay area is very meager. The STORET industrial inventory listed only 11 sources of industrial waste discharges to the Bay system. These sources are listed in Table 6. These waste discharges total about 37 million gallons per day. The current validity of these data is unknown.

The San Francisco Bay-Delta Water Quality Control Program evaluated

Table 4. Summary of Municipal and Industrial Waste Sources - 1965

Water Quality Zone	Waste Source	Flow (MGD)	BOD Load (10^6 lb/yr)
1, 2 & 3	Municipal	273	384
	Discrete Industrial	4	-
4	Municipal	78	90
	Discrete Industrial	1	-
5, 6 & 7	Municipal	55	52
	Discrete Industrial	18	65
Total Municipal and Industrial		429	591

Source: San Francisco Bay - Delta Water Quality Control Program

Table 5. Summary of STORET Inventory of Municipal and Industrial Waste Sources

Water Quality Zone	Municipal Waste Sources		Industrial Wastes (MGD)		Total Flow (MGD)
	Population Served	Flow (MGD)			
1	1,134,000	108	0	)	
2	308,000	30	13	)	298
3	1,238,000	135	12	)	
4	541,000	72	0		72
5	422,000	36	0	)	
6	22,000	2	6	)	70
7	431,000	26	0	)	
Total	4,096,000	409	31		440

Table 6. Industrial Waste Sources

Source	Flow MGD	Receiving Water
ALAMEDA COUNTY		
Colgate Palmolive	2.2	South San Francisco Bay
FMC Corporation	1.8	Newark Slough to South San Francisco Bay
Charles Pfizer Co.	0.2	Temescal Creek to South San Francisco Bay
SANTA CLARA COUNTY		
None		
SAN MATEO COUNTY		
Ideal Cement Co.	11.0	Redwood Creek to South San Francisco Bay
Merck Co.	10.0	South San Francisco Bay
SAN FRANCISCO COUNTY		
None		
MARIN COUNTY		
None		

Table 6. Industrial Waste Sources (cont'd)

Source	Flow MGD	Receiving Water
SONOMA COUNTY		
None		
NAPA COUNTY		
None		
SOLANO COUNTY		
None		
CONTRA COSTA COUNTY		
Johns-Manville Products	1.0	---
Monsanto Chemical Co.	0.1	Suisun Bay
Shell Oil Co.	4.0	Carquinez Straits
American Smelting & Refining Co.	1.0	Carquinez Straits

industrial waste discharges existing in 1965.[3/] These waste discharges are summarized by water quality zone in Table 5. Food cannery discharges to municipal waste systems and industrial waste discharges directly to the Bay system from petroleum refining, paper processing plants, chemical processing plants, steel manufacturing plants and electrical generation plants were evaluated and summarized. No individual breakdown by waste source is available.

No information is currently available as to the characteristics of wastes discharged or to the treatment processes employed. As discussed in the previous section on water quality problems, it is known that toxic materials and taste- and odor-producing substances from industrial discharges are present in the Bay system.

Combined Sewer Overflows

The major cities of San Francisco and Oakland, and several smaller cities, are partially served by combined sewer systems. Overflows from these combined sewers can occur during heavy runoff following periods of precipitation. Such overflows can contribute substantial bacterial contamination and minor organic pollution. Sewer overflows are most likely to occur during the winter rainy season, which coincides with the shellfish harvesting season.

Vessel Pollution

A large volume of commercial shipping passes through the ports of the Bay area. Numerous vessels ranging from small pleasure craft to large ocean-going ships ply the waters of the Bay system. Untreated waste discharges from these vessels, although contributing a small volume relative to overall waste

discharges in the Bay system, may be significant sources of bacterial contamination, especially in the area of shellfish beds. Spills of oil and hazardous materials, such as the major oil spill that occurred when two oil tankers collided in the Golden Gate in early 1971, have created serious pollution problems and have been the cause of several fish kills.[2/]

Dredging

A total of about 8 million cubic yards of material is dredged each year from the various navigation channels in the Bay system for maintenance purposes. Much of this dredged material is dumped in spoil areas in other Bay locations. Additional dredging is done to provide for construction of shore facilities and other water-related activities. Large volumes of shell materials are dredged from the South Bay for use in producing cement. These dredging activities stir up pollutants from the bottom, which are redistributed by wind and tide currents. Disposal of spoil materials also creates a pollution potential in the vicinity of the spoil areas. The extent of water quality degradation resulting from dredging activities has not been evaluated.

Urban Runoff

Much of the area immediately adjacent to the Bay waters is heavily built up, with much paving and roof surfaces. As a result, even small amounts of rainfall may produce surface runoff which may carry pollutants into the Bay system. The magnitude of pollution from this source is unknown. As in the case of combined sewer overflows, this runoff is most likely to occur during the period when it is most damaging to the shellfish industry.

Agricultural Drainage

Irrigation return flows and other agricultural runoff from millions of acres of irrigated land in the Central Valley are carried by the San Juaquin and Sacramento Rivers through the Delta into the Bay system. This agricultural pollution includes pesticides, nutrients, sediments and other deleterious materials. Much of this material is distributed throughout the Bay system by wind and tidal currents. An extensive Federal-State study of the water quality impact of future agricultural waste waters from the Central Valley has been made. This study concluded that treatment of agricultural waste waters for removal of nutrients would be necessary to prevent severe degradation of waters in the San Francisco Bay system. Pilot studies to develop such treatment methods are currently underway.

Natural Runoff

Placer mining during the early gold-mining period in California released very large volumes of fine sediments into the streams of the Sierra Mountains. Over the past century, these sediment loads have been moved downstream by the major rivers, with much of the sediment volume ending up in the San Francisco estuarine system. Although the volume of sediments discharged to the estuary has decreased in recent years, such sediments,contained in natural runoff, are still a significant source of pollution of Bay waters. Some sediments are also discharged to the Bay system by natural runoff from non-urban areas.

IMPACT OF POLLUTION ON THE SHELLFISHING INDUSTRY

A century ago, a major commercial shellfishing industry was centered on San Francisco Bay. Harvests of oysters and clams reached a peak in the 1890's and then declined sharply after 1900. Presently, this industry is essentially non-existent. A number of factors contributed to this decline, of which water pollution was the most important.

At its peak, the shellfish industry contributed several million dollars annually to the regional economy. The economic impact of the elimination of the shellfish fishery has thus been great.

San Francisco Bay is proven ground for commercial culture of oysters. The only factors preventing reestablishment of commercial oyster-growing areas are unsuitable water quality and sanitary conditions. In areas where water quality has improved over past conditions, shellfish have reestablished themselves. With improved water quality, South San Francisco Bay would potentially be the best oyster-growing area in California.

There is presently no interstate shipment of oysters or clams out of California. The State consumes more shellfish than the available supply and shellfish are shipped in from other areas. In the past when oyster culture was practiced in San Francisco Bay, a major interstate industry existed to supply seed oysters to the oyster farms. San Francisco Bay, with improved water quality, has the potential to produce a major oyster harvest which could supply California demands and create a surplus for interstate shipment to other areas. Such a major oyster industry would create related interstate shipments of seed oysters as in the past. Pollution of San Francisco Bay has thus effectively resulted in constraints on interstate shipments of shellfish and shellfish products.

Oyster Fishery

History -- Historically, the native western oyster (Ostrea lurida) was present in San Francisco Bay in prodigious quantities and clams and mussels were plentiful. Extensive beds of the oysters were located in shallow areas along the west side of the Bay. The extent of the shell deposits built up by the native oysters is reflected by the fact that more than 50 million cubic yards of shell have been dredged from the Bay over the past 30 years and an estimated 75 million cubic yards still remain in the Bay.

The native oyster was exploited commercially by simply harvesting oysters from the natural beds. No attempt at oyster culture was made. The introduction of other commercially important oyster species combined with destruction of oyster beds by siltation and pollution rapidly decreased the importance of the native oyster. Since 1945, there has been little or no commercial harvest of the native oyster in California.

In 1869, the large eastern oyster (Crassostrea virginica) was introduced to San Francisco Bay. The oyster thrived under culture and provided a major source of oysters during the next 30 years. The method of culture was simple. Seed oysters (spat) were imported from East coast locations. The spat attached to shell pieces were set out in suitable beds and allowed to reach market size. The adult oysters were then harvested by hand means.

The first commercial beds were located at Sausalito, Point San Quentin, Sheep Island, Oakland Creek and Alameda Creek.[4/] These beds were soon abandoned, and by 1875 all beds were located in South San Francisco Bay. The locations of commercial oyster beds in 1890 are shown in Figure 4. The Oakland and Alameda Creek beds were abandoned because of sewage and traffic on the Bay.[4/] The Alvarado beds were abandoned because of adverse hydrographic conditions.

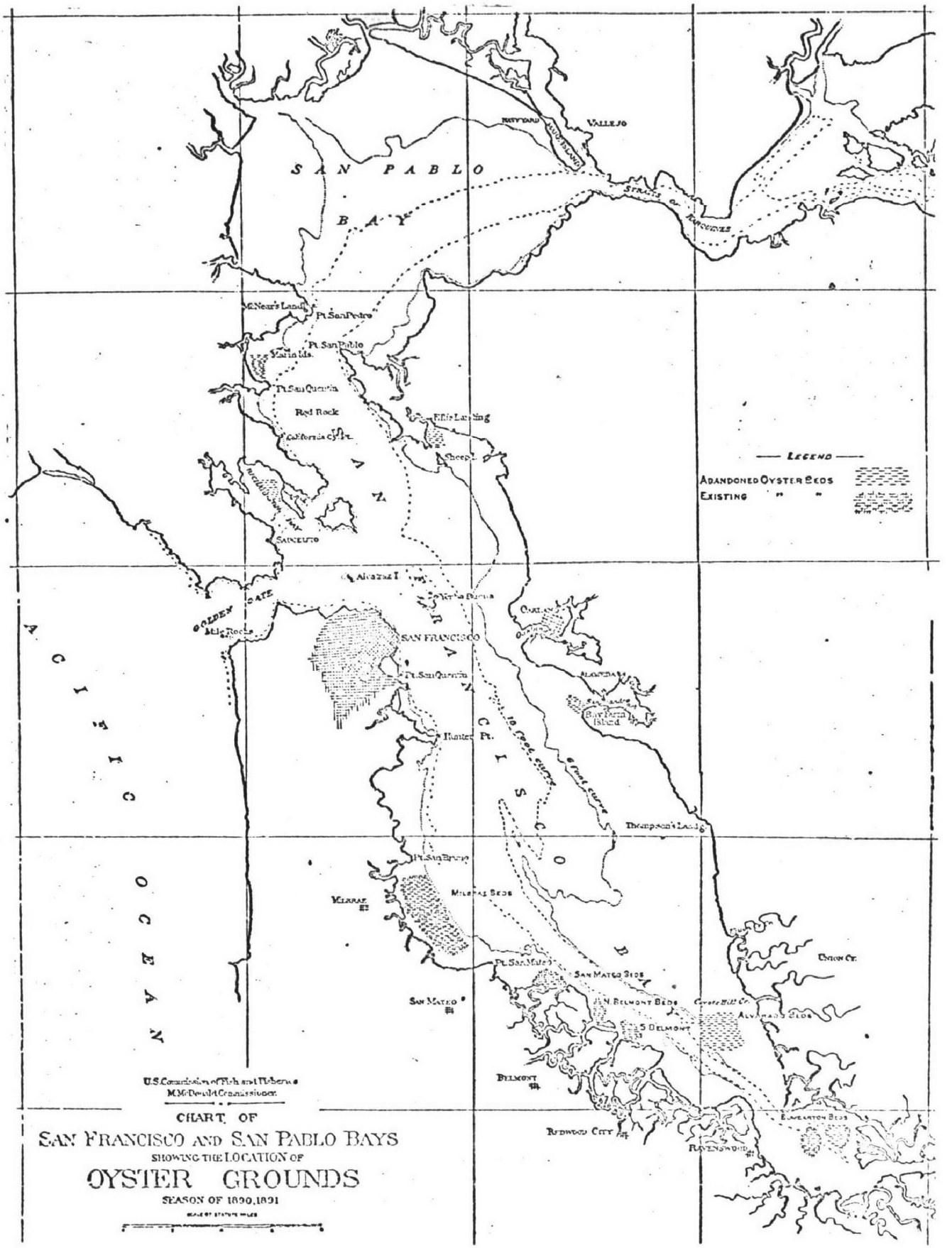

Figure 4. Location of Oyster Beds in 1890

Between 1880 and 1900, the culture of eastern oysters in San Francisco Bay and the importing of seed oysters from the east coast was a million dollar business. During the 1890's, the oyster industry was the single most valuable fishery in California. Records of oyster harvests during this peak period are incomplete and conflicting, but they do provide an idea of the major oyster production then existing. Between 1888 and 1895, oyster production (whole oysters including shells) was estimated to range from 9 to 15 million pounds annually with a value of 500 to 700 thousand dollars annually.[4/] Other records of oyster harvests (meats only) indicated that the peak production of 3,060,000 pounds of oyster meat valued at $867,000 was reached in 1899. During the 1887 to 1895 period, imports of seed oysters ranged from 1.0 to 3.3 million pounds annually. Most of the oyster harvest was obtained from commercial beds totalling 3,000 to 4,000 acres in area.[4/]

About 1900, some unknown factors caused a radical change in the southern end of San Francisco Bay which adversely affected the growth rate and market condition of oysters grown there. Pollution also affected conditions in much of the Bay. The choicest oyster growing locations were heavily contaminated, resulting in oysters of poor quality. As a result, the oyster industry was short-lived. By 1908, oyster production had decreased 95 percent from reported landings in 1892.[4/]

Attempts were made to grow eastern oysters in other California waters but met with little success. Shellfish harvests in California continued a long decline until 1931, when the Pacific oyster (Crassostrea gigas) was imported from Japan. Commercial beds were successfully established in Bodega Lagoon, Tomales Bay and Drakes Estero, small bays on the coast a short distance north of San Francisco Bay. Culture of the Pacific oyster

was also successful in Humboldt and Morro Bays farther north. Pacific oysters were not cultured in San Francisco Bay, due to the adverse water quality conditions still present.

The culture of Pacific oysters revived the California oyster industry and statewide landings steadily increased except during and immediately after World War II, when imports of seed oysters from Japan were stopped. At the same time, the San Francisco Bay oyster fishery steadily declined and presently is non-existent.

Present Status -- Native oysters are present in significant numbers in much of the deeper waters of the Central and South San Francisco Bay.[1/] There multiplication is limited by the lack of dead shells to which the spat may attach. The commercial value of these native oysters is unknown. Eastern and Pacific oysters have not established themselves in the Bay except where cultured.

There are presently no commercial oyster beds in the Bay system. A State allotment of 3,000 acres for oyster cultural purposes in San Pablo Bay existed in 1962 but was not being utilized.[4/] Another oyster company had also expressed interest in the same area. San Pablo Bay appeared to be the least affected by pollution in 1962 of the several bays in the Bay system. Most of the bay is physically suitable for oyster culture. Portions of the bay are closed to shellfishing because of bacterial contamination and industrial pollution is serious in some areas.

North San Francisco Bay appears to have only a few areas suitable for oyster culture. No oysters are currently grown there.

South San Francisco Bay is proven ground for oyster culture. No oysters are presently grown there commercially due to bacterial contamination and

associated public health hazards. The entire South Bay is potentially valuable oyster ground, perhaps the finest in the State.[4/] The only serious factors limiting its use are pollution and public health restrictions.

In 1966, there were nine shellfish growing areas with a total area of 8,500 acres registered in California.[8/] Three of these areas totalling 4,400 acres were currently growing shellfish and were approved or conditionally approved for shellfish harvesting. One area of 2500 acres was closed to harvesting. Five areas totalling 1600 acres were listed as biologically capable of producing shellfish but not currently growing shellfish. The location of each of these areas was not specified. It is not known if any areas are registered in San Francisco Bay. All areas were designated as intrastate areas, indicating harvested shellfish are not shipped interstate.

Potential Development -- In view of the physical conditions of the Bay and the fact that high oyster production capability has been demonstrated in the past, it is possible that an oyster fishery of exceptional proportions could be developed.[4/] The major constraint on such development appears to be water quality. The market for oysters is unfailing and prices excellent. In past years, the California oyster supply fell far short of the demand and oysters were shipped in from the North. Interest in reestablishing commercial beds has been shown by oyster growers. The economic basis for an expanded oyster industry would appear to exist.

Based on physical conditions, about 175,000 acres of the Bay system are potential oyster grounds.[4/] In the past, about 3,000 to 4,000 acres of oyster beds were commercially maintained. In view of the large potential area, it would appear that as much as 10,000 acres could easily be commercially operated.

During the 1890's, oyster production was in the range of 2,500 to 5,000 pounds of oysters per acre per year.[4/] This corresponds to an oyster meat production of 400 to 750 pounds per acre. From 1958 to 1967, oyster meat production in California averaged about one million pounds annually. If it is assumed this harvest was taken from the 4400 acres of registered shellfish areas, the average oyster meat production was about 230 pounds per acre. This compares favorably with a California Department of Fish and Game estimate of yields of 150 to 300 pounds per acre for culture of Pacific oysters.[4/] The oysters harvested in the 1890's were eastern oysters, while recent harvests in California were primarily Pacific oysters.

A yield of 250 pounds per acre of oyster meat from 10,000 acres would produce an annual harvest of 2.5 million pounds. It can thus be seen that the oyster fishery potential of San Francisco Bay far exceeds the existing California oyster fishery.

Clam Fishery

History -- The original shellfish fauna of the Bay system was extensive, but few species were of commercial importance. The most common edible species was the bent-nose clam (Macoma nasuta). Large quantities of these clams were probably dug from the South Bay for the market prior to 1876.[4/]

The soft-shelled clam was accidentally introduced in oyster shipments about 1870. It soon displaced the native species and became widely distributed. It is an excellent food clam and formed the bulk of the San Francisco clam trade. The mud flats of San Pablo Bay and the South Bay were particularly favorable locations.

Harvests of clams from the Bay system exhibited the same rise and fall as the oyster fishery. Between 1880 and 1900, the clam production ranged

between one and three million pounds annually, the highest production recorded.[4] After 1900, clam production decreased sharply. Pollution and excessive digging contributed to this decline. Between 1916 and 1935, the annual harvest ranged from 100 to 300 thousand pounds. The production continued to decline after 1935 and was essentially zero after 1949.[8]

Present Status -- No commercial harvesting of clams from the Bay system is currently done, although some sport clamming takes place. Clams are abundant in several areas, but bacterial contamination makes sport or commercial harvesting unsafe.

San Pablo Bay formerly produced the greatest share of clams in the Bay system. This source has not been exploited recently, largely because of the public health problem. Soft-shell clams were still present in good numbers in 1960.[4]

Clams are also currently present in areas of the South San Francisco Bay.[1] However, domestic and industrial pollution have resulted in the complete loss of the South Bay clam fishery.[4] In areas where water quality improvement has allowed clams to reestablish themselves, contamination of these clams poses a health hazard preventing their safe harvest.

In North San Francisco Bay, clam habitat is limited. Only a few clams are currently present.

Potential Development -- The potential for development of the clam fishery differs significantly from that of the oyster fishery. Labor costs are high for the digging of clams. To maintain a commercially harvestable clam population, substantial habitat improvement including fencing against aquatic predators must be done. Thus, if water quality constraints were lifted, economic

constraints might limit any substantial development of the clam fishery. No estimates of potential clam production or of the size or value of the standing clam crop are available.

Economic Impacts

Both the oyster and clam fishery in the San Francisco Bay system have been either greatly reduced or completely eliminated by the effects of pollution for many years. The major fishery existing prior to 1900 was essentially eliminated as a factor in the regional economy. Since 1930, a major increase in the oyster fishery at other California locations indicates that the San Francisco fishery could have thrived economically if water quality constraints were removed.

It is impossible to estimate the economic impact that has accrued during the past 70 years as a result of this lost fishery. It is obvious, however, that the elimination of an industry generating a million dollars annually in 1900 was a major economic impact.

There are two possible approaches to evaluating the approximate magnitude of the economic impact of the pollution-eliminated shellfish fishery. Since the growth of the shellfish industry in other areas of California was primarily the result of a shift in commercial beds from San Francisco Bay to these areas as Bay beds became polluted, the value of the out-state fishery could be considered one measure of the value of the lost fishery. A second estimate can be obtained from the value of the potential production discussed previously.

Fishery statistics are available by fishing region for the period from 1939 to 1967.[7/] The San Francisco fishing region includes the Bay system and coastal waters from Point Arena to Pigeon Point including Tomales Bay, Bodega

Bay, Bolinas Lagoon and Drakes Estero. The weight and value of the oyster harvest in the San Francisco region is shown in Table 7. Concurrent figures for California are shown in Table 8. By subtracting the regional figures from the State figures, the value of the out-state oyster harvest can be evaluated. For the period 1958-1967, this harvest was valued at $2,050,000, an annual value of $205,000.

As shown in Table 7, the dockside value of oysters in the San Francisco region has fluctuated substantially, largely as a function of supply. Over the last five years for which published statistics are available, the price steadily increased, however, while the supply remained relatively constant. The most recent price available (1967) was $0.40 per pound of oyster meat.

As discussed above, it is believed that San Francisco Bay could potentially maintain an annual production of oyster meats of 2.5 million pounds if water quality constraints were removed. At 1967 prices, this production would have a dockside value of $1 million per year.

There has been no recent sale of significant amounts of clams in the San Francisco area. No estimates of potential production are available. Therefore, no estimate can be made of the economic impact of the loss of the clam fishery.

Various studies have shown that the economic impact of the shellfish industry on the regional economy is about four times the dockside value of shellfish products.[10/] Using this multiplier, the total economic impact of pollution on the economy of the San Francisco area as the result of the loss of the oyster fishery is in the range of $820,000 to $4,000,000. This estimate considers only the multiplied economic effect of the harvested oysters. An additional economic impact would be produced by the importation of seed

Table 7. Summary of Oyster Harvest
San Francisco Fishing Region

Year	Total Oyster Harvest (1,000 pounds of meat)	Value ($1,000)	Price ($/#)
1939	242	50	0.21
1940	180	25	0.14
1941	240	42	0.18
1942	50	17	0.34
1943	57	19	0.33
1944	35	24	0.69
1945	19	17	0.90
1946	12	14	1.17
1947	19	22	1.16
1948	48	53	1.10
1949	20	18	0.90
1950	32	35	1.09
1951	41	53	1.29
1952	39	46	1.18
1953	34	43	1.26
1954	36	47	1.30
1955	42	56	1.33
1956	59	75	1.27
1957	64	41	0.64
1958	75	54	0.72
1959	54	42	0.78
1960	32	34	1.06
1961	79	63	0.80
1962	61	46	0.75
1963	186	36	0.19
1964	213	47	0.22
1965	195	64	0.33
1966	234	92	0.39
1967	199	81	0.40

Table 8. Summary of California Oyster Harvest

Year	Total Oyster Harvest (1,000 pounds of meat)	Value ($1,000)	Unit Price ($/#)
1892	1,316	-	-
1895	1,145	-	-
1899	3,060	867	.28
1904	1,406	536	.38
1908	729	337	.46
1915	387	166	.43
1922	74	-	-
1923	69	24	.35
1924	53	23	.43
1925	57	24	.43
1926	61	26	.43
1927	55	24	.43
1928	77	32	.43
1929	53	27	.50
1930	78	32	.42
1931	245	76	.32
1932	59	19	.33
1933	86	29	.33
1934	101	43	.43
1935	107	40	.37
1936	105	27	.26
1937	163	38	.24
1938	213	50	.23
1939	246	51	.21
1940	193	27	.14
1941	256	48	.19
1942	85	29	.34
1943	117	38	.33
1944	90	48	.53
1945	48	28	.59
1946	22	19	.86
1947	24	26	1.05
1948	66	63	.95
1949	35	26	.76
1950	39	36	.94
1951	43	46	1.06
1952	45	47	1.04
1953	38	44	1.18
1954	74	54	.73
1955	218	89	.40
1956	756	178	.23
1957	1,359	287	.21
1958	1,159	242	.21
1959	1,653	309	.19

Table 8. Summary of California Oyster Harvest (cont'd)

Year	Total Oyster Harvest (1,000 pounds of meat)	Value ($1,000)	Unit Price ($/#)
1960	1,283	289	.23
1961	1,221	296	.25
1962	1,339	306	.23
1963	1,300	226	.17
1964	1,360	254	.19
1965	1,063	263	.25
1966	790	222	.28
1967	742	207	.28

oysters to supply cultural requirements. This economic effect is unknown. An additional but unknown economic impact also is produced by the loss of the clam and mussel fishery.

Interstate Aspects

There are currently no interstate shipments of oysters out of California. No interstate shippers are registered.[9/] The state consumes a greater amount of shellfish than can be supplied locally and oysters are shipped in from the North. In the sense that the loss of the San Francisco Bay oyster fishery to pollution creates a greater need for interstate imports of shellfish, pollution of San Francisco Bay directly affects interstate shipments of shellfish.

San Francisco Bay has the potential to produce a shellfish supply adequate to meet local needs and create a surplus which could be marketed in interstate commerce. Pollution of the Bay prevents the realization of this potential.

Large-scale commercial production of oysters in San Francisco Bay would require culture of either Eastern oysters or Pacific oysters. The Eastern variety was successfully cultured in the past and Pacific oysters are cultured in other California bays. Such cultural practices would require the interstate importation of large numbers of seed oysters. Pollution of San Francisco Bay prevents the practice of oyster culture and thus prevents the market of seed oysters in interstate commerce to provide the basis for oyster production.

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