2.222 (2) Historic Reclamation of Marshlands. The preservation of marshlands is a particularly important issue in California, for the State has the dubious distinction of being the Nation's leader in the destruction of marshes and wetlands. Since California was admitted into the Union (1850) as the 31st State with a population of less than 100,000, more than 250,000 acres of wetlands have been diked and filled. The National Estuarine Study completed in 1967 by the U.S. Bureau of Sport Fisheries and Wildlife indicated that California had lost 67 percent of wetland habitats in existence within State boundaries at the close of World War II (239). The next most severe loss nationally was in New York State which lost 15 percent over the same period.

2.223 When the rush for gold began in California during the mid-1800's marshlands covered more than 200,000 acres of the San Francisco Bay Shoreline (123). Today fewer than 80,000 acres of marsh remain. Levee systems and dikes greatly limit tidal exchange in the marsh areas which remain causing seasonal drought, stagnation, and high soil salinity particularly during the arid summer. The Table II-15 gives a general breakdown of land uses in the diked or filled areas surrounding the Bay.

TABLE II-15

PRESENT LAND USES OF DIKED AND FILLED AREAS SURROUNDING SAN FRANCISCO BAY

LAND USE	PERCENT RECLAIMED LANDS
Recreation	25
Salt Production	25
Agriculture	25
Others (urban, industrial, commerical)	25

2.224 Historically, much of the Bay's natural productivity has been preserved in spite of human efforts to utilize the tidelands for something other than preserving the Bay's ecosystem. Intertidal marshes were once dominant features of the landscape in the shallow regions of the Bay principally Suisun Bay, San Pablo Bay, and South Bay (Plate II-34).

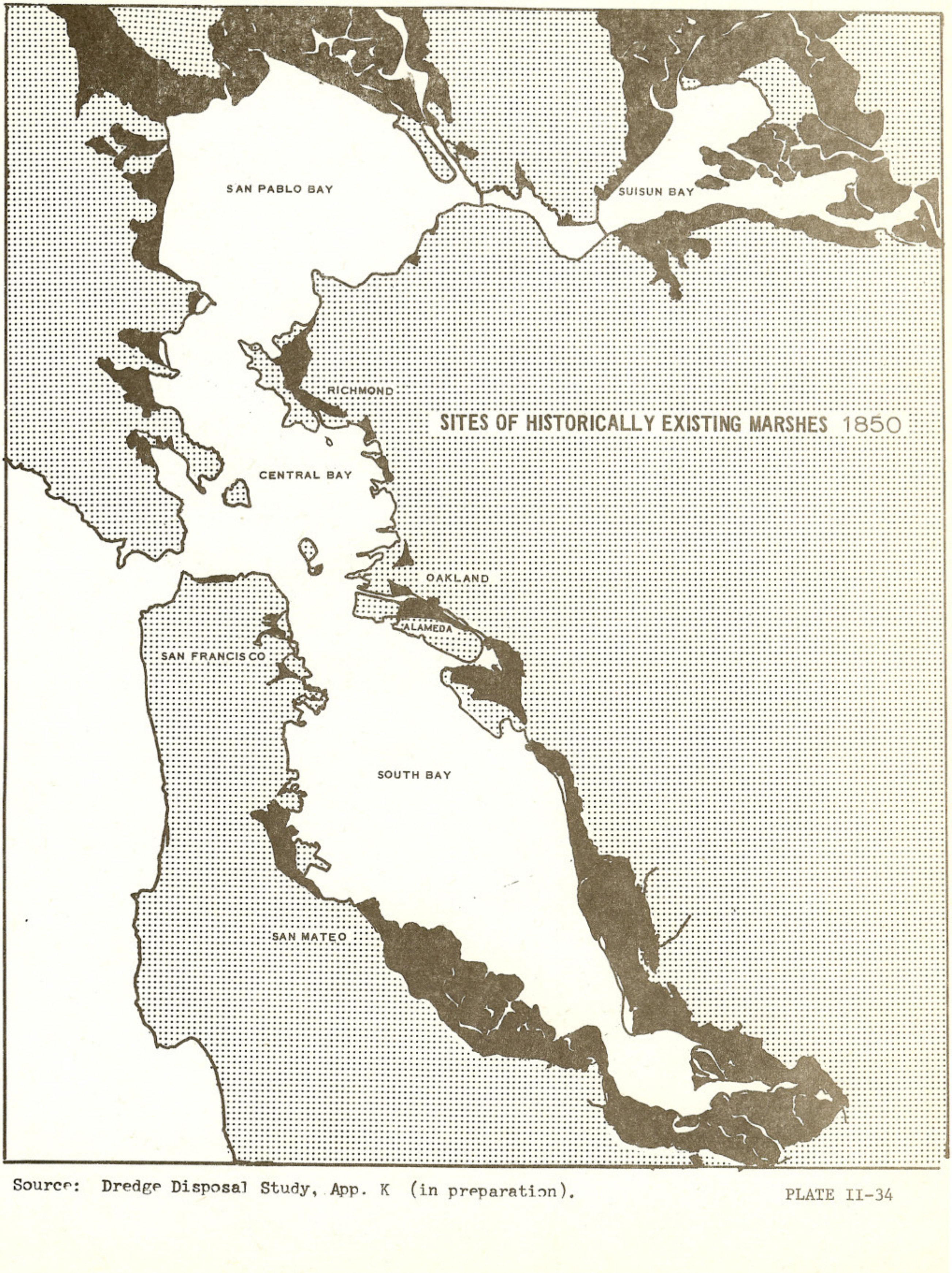
TABLE II-16

HISTORIC ABUNDANCE
OF
MARSHLANDS SAN FRANCISCO BAY

AREAS	MARSHLANDS (ACRES)
Suisun Bay	65,000 to 70,000
San Pablo Bay	75,000 to 80,000
South Bay	65,000 to 70,000

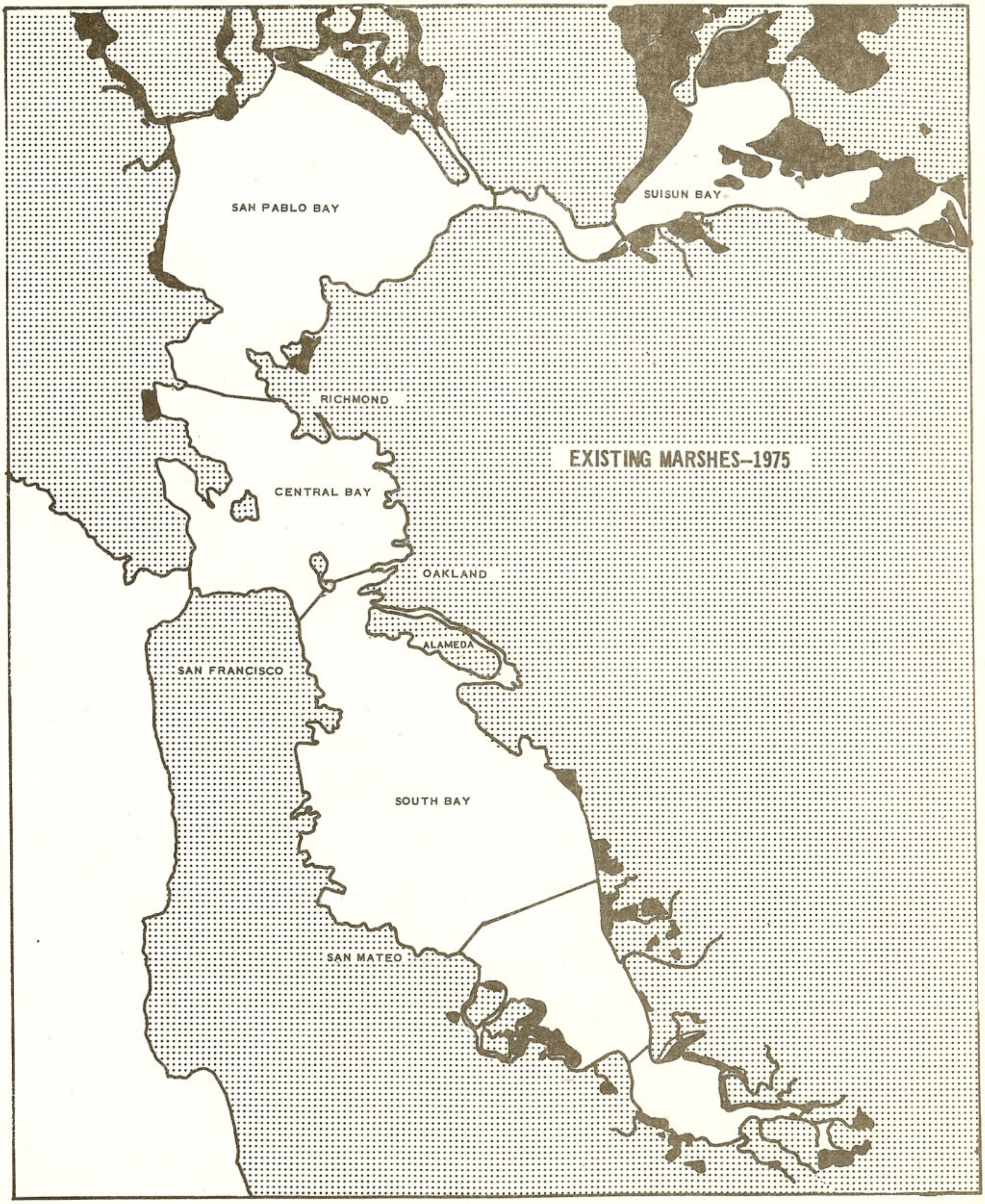
2.225 (a) Suisun Bay. More than 85 percent of the marshlands in Suisun Bay were reclaimed during the late 1800's for use as pasturelands. Major sloughs were blocked with wooden gates connecting with an intricate system of "hand made" levees constructed by Chinese laborers. Due to subsidence and levee failures only approximately 5,000 acres out of 60,000 acres of reclaimed marshes proved to be a successful agricultural venture. With the decline of agriculture in the 30's nearly all reclaimed marshlands were purchased by the State of California Department of Fish and Game and some 200 private duck hunting clubs to be managed as waterfowl areas. These 55,000 acres of managed wetlands represent 10 percent of California's remaining wetlands and support peak waterfowl populations of from 500,000 to 750,000. Only about 7,000 acres of undisturbed intertidal marshlands remain in Suisun Bay.

2.226 In addition to waterfowl and other birds, Suisun Bay marsh supports an important fisheries resource. Two relatively large sloughs cut into Suisun Marsh: Montezuma Slough, the largest slough, and Suisun Slough which is navigable and periodically dredged by the Corps. Montezuma Slough is not dredged. These sloughs are important nursery areas for Striped-bass juveniles which feed mainly on Opossum shrimps. The White catfish, a popular sport fish, also utilizes these sloughs as feeding and nursing areas. Both the King salmon and Steelhead rainbow trout use Montezuma Slough as a migratory route to and from their spawning areas in the Sacramento River. Many non-game fish species also depend on these sloughs for shelter and food, which include, among others, carps, suckers, shads, crappies, smelts, perches and sculpins.



Source: Dredge Disposal Study, App. K (in preparation).

PLATE II-34



Source: Dredge Disposal Study, App. K (in preparation).

2.227 (b) San Pablo Bay. The deltas formed by Sonoma Creek, the Napa, and Petaluma Rivers (Plate II-34) once flowed together forming a continuous expanse of tidal marshlands. About 75 percent of these marshes were reclaimed primarily for agricultural and urban uses. Today approximately 1,700 acres of remaining marshlands, 5,000 acres of tidal mudflats, and 4,700 acres of open water have been incorporated into the San Francisco Bay National Wildlife Refuge to be preserved or enhanced for the uses of wildlife and the public.

2.228 (c) South San Francisco Bay. More than 65,000 acres of marshlands once surrounded the South Bay (Plate II-34). Approximately 40,000 acres of marsh were diked for use as solar evaporation ponds in the production of salt. Though less productive than their tidal ancestors these ponds have preserved 40,000 acres of tidelands from permanent filling and have provided a valuable service in the preservation of wildlife resources. Usage of saltponds at peak periods is in excess of 50 shorebirds and ducks/acre. Three million birds may be found on the ponds during December. The ponds provide isolation from human activities which encourages feeding and nesting by numerous wildlife species.

2.229 More than one half of the 25,000 acres of marsh not diked for salt production have been permanently filled primarily for urban, commercial, and industrial uses. About 10,000 acres or approximately 15 percent of the South Bay remains as original marshland heritage.

2.230 Plate II-35 delineates the approximate location of the 80,000 acres of marshlands which remain in the San Francisco Bay.

2.231 (3) Marshland Flora. Because of the constricted configuration of the San Francisco Bay system, tidal range within the Bay generally increases in the bays inland from the Golden Gate. For instance, the mean tidal range at the Golden Gate is approximately 5.8 feet, where as, the southern tip of the South Bay has a tidal range of 9.0 feet. This broad tidal range combined with the shallow nature of a large portion of the bay results in the exposure of large intertidal lands. In general, only areas above the mean tide (approximately the mean of all high and low tides at a particular locale) are colonized by vascular plant life. Within this area between mean tide and the highest estimated high water are two dominant vegetative zones: the Spartinetium (consisting of genetic varients of California cordgrass) and the Salicornietum (primarily consisting of genetic varients of pickleweed). In general, the Spartinetum lies between the mean tide level and mean high water. The Salicornietum lies above mean high water and continues in saline soils above the estimated highest tide.

2.232 (a) The Spartinetum. The Spartinetum intertidal plant community is named for its dominant plant variety, California cordgrass (*Spartina foliosa*). This cordgrass zone represents the frontier of intertidal colonization by phanerogams (seed producing plants). Cordgrass is uniquely qualified to withstand the stresses of regular inundation, erosion, and fluctuating salinities. Cordgrass possesses an abundance of air storage and conduction tissue (aerenchyma). This tissue allows the plant to store its own oxygen supply during long periods of submergence. To withstand the constant buffeting by wind and waves more than 70 percent of the plants growth is concentrated in its root system below the surface of the mud. Cordgrass also utilizes a glandular apparatus (hydathodes) which actively secretes salt allowing the plant to tolerate high salinities greater than sea water concentrations. No other local plants display the unique abilities of cordgrass and consequently the Spartinetum is typically represented in San Francisco Bay by pure homogeneous stands of this single species.

2.233 (b) The Salicornietum. Similarly the Salicornietum is named after the dominant plant variety, pickleweed (*Salicornia pacifica*). Unlike cordgrass, pickleweed does not have the abundance of aerenchyma tissue for the storage of oxygen for respiration during long periods of submergence. In general, pickleweed will be found dominant only above the mean of the high waters where submergence occurs on the average of only once per day. In these higher areas of the intertidal zone evaporation causes higher soil salinities than found in the lower intertidal substrates. Pickleweed's ability to withstand high salinities is.its greatest asset. The plant generally occurs in soils with salinities between 18 ppt and 81 ppt (the salinity of sea water is approximately 33 ppt). It is generally dominant even in upland areas where soil salinities are greater than sea water strengths. It is virtually without a floral competitor along the shores of San Francisco Bay in soils with salinities between 35 ppt and 80 ppt. In the parts of the Salicornietum where salinity is not so extreme several other varities intertidal and near intertidal plants may be found. The following is a list of some of the more common high marsh plants:

Salt bushes (*Atriplex patula* and *Atriplex semibaccata*)
Salt grass (*Distichlis spicata*)
Gum plant (*Grindelia humilis*)
Alkali heath (*Frankenia grandifolia*)
Sea lavender (*Limonium californica*)
Jaumea (*Jaumea carnosa*)

2.234 (4) Marshland Fauna. Marshlands are utilized as feeding and nursery areas by many of the fish varieties found in the Bay. In addition, many species of birds and several mammalian species utilize marshlands for nesting, feeding, and resting. Table II-17 lists some of the variety of water-associated birds which inhabit the Bay Area and depend upon marshlands for some part of their life cycles.

2.235 Many non-water birds, such as song birds, hawks, and owls inhabit the tidal marshes of the bay, either as residents or winter visitors. The marshes are particularly important to Marsh hawks (*Circus cyaneus*) and White-tailed kites (*Elanus leucurus*) both as feed and nesting areas. The area is also inhabited by three sub-species of Song sparrow (*Melospiza melodia*); namely, the Suisun, San Francisco, and the Samuel's Song sparrow. These sparrows are dependent on the salt marsh and are being studied for possible inclusion on the rare or endangered lists. For additional information on non-aquatic birdlife, see the discussion under Terrestrial Environment.

2.236 Mammals of the salt marshes and tidal meanders of the San Francisco Bay System consist mainly of small animals whose life styles are closely related to tidal fluctuations. They usually occupy a narrow zone of marsh plants in the upper limits of tidal action but must be able to use additional protective shelter. They include the Salt marsh harvest mouse (*Reithrodontomys raviventris*) (endangered), Vagrant shrew (*Sorex vagrans*), Suisun shrew (*Sorex sinuosus*), Black rat (*Rattus rattus*), Norway rat (*Rattus norvegicus*), Brush rabbit (*Sylvilagus bachmani*), the Black-tailed jack rabbit (*Lepus californicus*), Opossum (*Didelphis marsupialis*), Raccoon (*Procyon lotor*), Long tailed weasel (*Mustela frenata*) and Striped skunk (*Mephitis mephitis*) (16).

2.237 Predation by the two introduced Old World rats (the Black and Norway rats) interrupts nesting of various marshbirds and has contributed to endangering the existence of the California clapper rail (24).

TABLE II-17

BIRDLIFE UTILIZING
SAN FRANCISCO BAY
MARSHLANDS 1/

	Area Use 2/	Nesting Habitat in the Bay
GREBES		
Horned	W	
Eared	W	
Western	W	
Pied billed	R	Fresh marsh (reeds)
HERONS		
Great egret	R,W	Marsh grassland
Great blue heron	R,W	
Snowy egret	R,W	Bushes, trees
Black-crowned nigh heron	R,W	Bushes, trees
DUCKS		
Mallard	R,W	Marsh
Gadwall	M,W	
Pintail	W	
Green-winged teal	M,W,	
Cinnamon teal	R	Marsh
American widgeon	M,W	
Shoveler	M,W	
Canvasback	W	
Greater Scaup	W	
Lesser Scaup	W	
Goldeneye	W	
Bufflehead	W	
Ruddy duck	R	Marsh
Red-breasted merganser	R,W	Grassland, shore

1/ (Carpelan, 1957), (Conradson, 1969), (Bollman et al, 1970), (George, et al, 1963).

2/ Resident - (R) Winter - (W)
Migratory - (M) Summer - (S)

TABLE II-17 (Cont'd)

	Area Use 2/	Nesting Habitat in the Bay
RAILS & GALLINULES		
American Coot	R	Marsh
Black rail		
Clapper rail		
SHOREBIRDS		
Plover species		
Killdeer	R	Rocks
Black turnstone		
Long-billed curlew	M,W	
Whimbrel		
Willet	R,W	Marsh
Yellowlegs		
Knot		
Sandpiper species	M,W	
Dunlin	M,W	
Marbled Godwit	M,W	
Avocet	R	Marsh
Black-necked stilt	R	Marsh
Phalerope species		

2/ Resident - (R) Winter - (W)
Migratory - (M) Summer - (S)

2.238 (5) Ecological Importance. All ecosystems are vitally dependent upon plant life. Plants utilize the sun's energy to convert simple substances into sugars, starches, and proteins which are the fuels which power the system. This critical role played by plants in the ecosystem is referred to by ecologists as "primary production". In an estuary, this role of "primary production" is performed principally by single-celled plants (diatoms) found on tidal flats and in the water column, and by intertidal plants which stand emergent at the shoreline. Teal, from his observations of a cordgrass marsh in Georgia, has estimated that 45 percent of an intertidal marsh's net production may be washed into adjacent estuarine waters (195). He found that in one Georgia estuary cordgrass accounted for 2/3 to 3/4 of the primary production while diatoms accounted for the rest. It has been estimated that cordgrass may produce as much as 10 tons of organic material per acre to feed an estuary each season.

2.239 It has also been well documented that estuarine marshes are utilized by many commercially important fish and shellfish as rearing and nursery areas. Some of the locally, more important species include Striped bass, Jacksmelt, Northern anchovy, and King salmon. In addition to the above, a number of sport fishes (Threadfin shad, American shad, White catfish, Starry flounder, and steelhead trout) depend on the marsh environment for food and protection particularly during juvenile stages.

2.240 Marshes also have an important role in trapping, removing, and recycling organic and inorganic nutrients. Organic nutrients are trapped in intertidal marshes where they may be assimilated into productive biological systems. Marsh soils are a sink for heavy metal contaminants and are ideally suited for converting organic nitrogen to nitrogen gas.

2.241 d. Diked Salt Ponds. Salt ponds are another important habitat of the Bay area but are not discussed in any detail here because they are not affected by the maintenance dredging program. Presently, the Leslie Salt Company has holdings in four Bay counties, totalling about 47,000 acres of which approximately 40,000 acres are salt evaporation ponds. Most of these ponds are situated in the southern reach of South Bay and around San Pablo Bay.

2.242 The salt ponds provide a unique environment for those plants and animals that can adapt to the relatively high salinity and temperature ranges and variable oxygen levels of these ponds. Carpelan (31), Anderson (2) and others have found these ponds to support abundant life, and many water-associated birds feed in these ponds. In terms of primary productivity, Carpelan calculated the annual production of Stichococus bacillaris, a common green alga, in the Alviso salt ponds. The annual production of Stichococcus was 6.5 tons of organic matter per acre, which is quite remarkable when this rate is compared to the production rate of an estuary (with no salt ponds) or a coastal zone. According to Teal and Teal, the annual production rate of an estuary ranges from 5 to 10 tons per acre and a coastal zone from 1 to 1-1/2 tons per acre (195). On a volume basis (salt ponds are only a few feet deep at most), and when all salt pond plant life is considered (not just Stichococcus), the salt ponds of San Francisco Bay must be one of the most biologically productive areas in the world. However, little of this productivity enters the food-web of the Bay ecosystem as compared to the percent of productivity contributed by salt marshes and tidal flats.

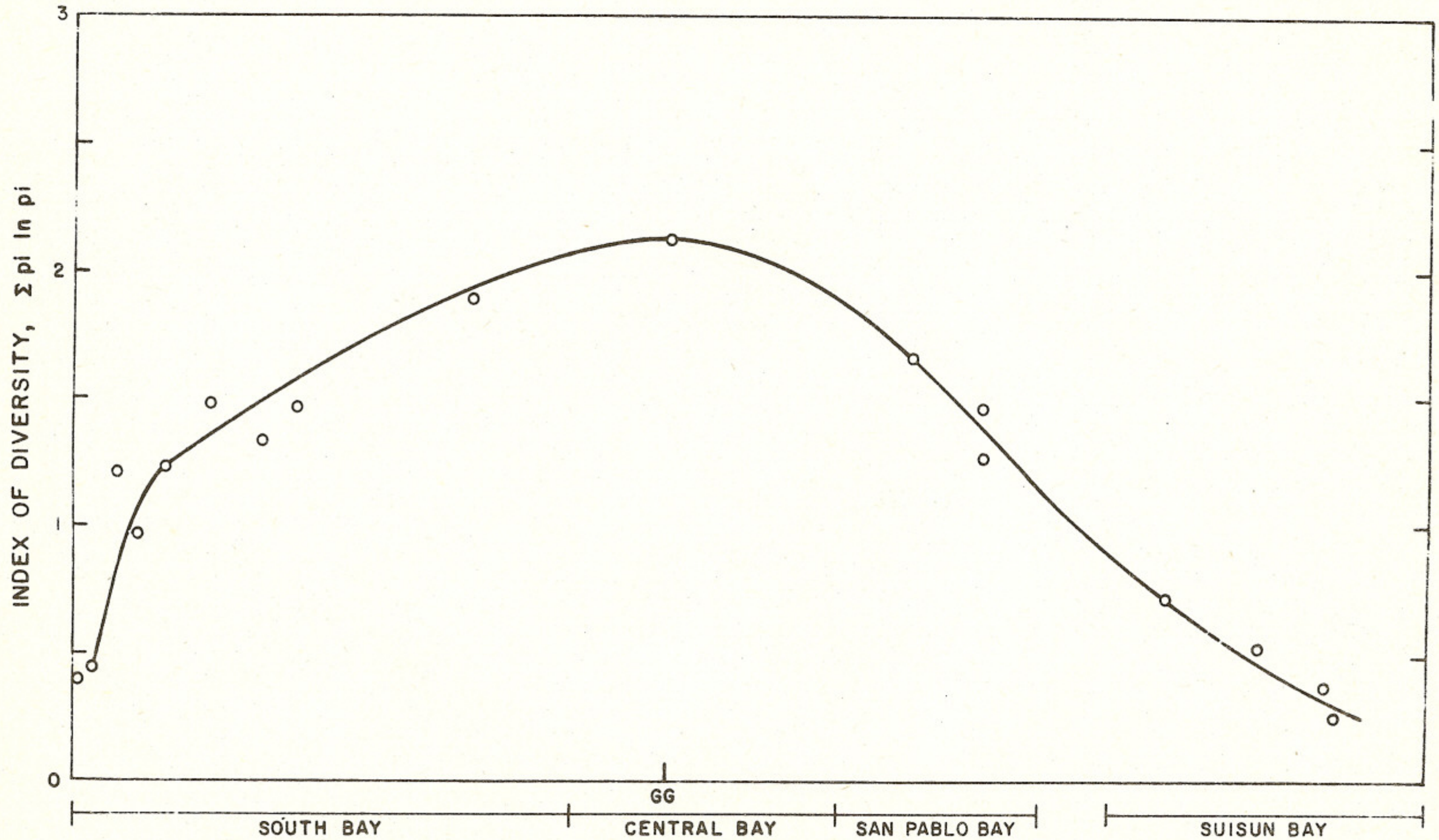
2.243 Besides algae, these salt ponds support many other forms of life as well. This is particularly exemplified by the number and variety of birds that forage in the salt ponds. Bollman et al made comparisons of bird densities between salt ponds and tidal flats in 1964 and 1965 and interestingly, observed that the Alviso ponds averaged 65 birds per acre as compared to 30 birds per acre for tidal flats (17). Anderson, in his survey of the Alviso salt ponds between 1967 and 1969, enumerated 55 bird species associated with the ponds (2). Among the general types of birds making heavy use of the ponds were shorebirds, ducks, grebes and gulls. The salt evaporation ponds, although man-made and have displaced many acres of tidal flats and saltmarshes, have become an important habitat and an integral part of the ecology of San Francisco Bay.

2.244 e. Subtidal Benthic Habitat. In terms of surface area, the bottom of the Bay below mean lower low water (MLLW), or the subtidal benthic habitat, is the largest of the five generalized estuarine habitats (the open bay habitat to be discussed later is the largest habitat in volume). The superficiality of separating the estuarine ecosystem into habitats, and the intimate relationship between the subtidal benthic habitat with the shallow tidal flat (which generally grades into the subtidal) and the open bay habitat which overlies the bottom, becomes apparent in the discussion of the subtidal benthic habitat.

2.245 An overall biological study of the Bay system (Suisun Bay, San Pablo Bay and San Francisco Bay) was conducted by the Sanitary Engineering Research Laboratory (SERL) of the University of California, Berkeley, between 1958 and 1964 for the purpose of collecting base-line data from which the effects of wastewater discharge into the Bay could be assessed. Results of the study were published in four annual reports and subsequent final reports (consisting of eight volumes) between 1962 and 1970. The eighth volume of the final report tersely summarized the previous seven volumes of the final report (130).

2.246 The study identified over 150 macrobenthic invertebrate species in the Bay, but the majority of species, however, was comprised of perhaps 30 species. A recent benthic study by the Stanford Research Institute (SRI) for the Corps of Engineers enumerated over 340 bottom species in the Bay (west of Carquinez Strait) with 41 species constituting the greatest number of individuals (224). This large discrepancy in identified species numbers between the two studies is indicative of the taxonomic problems of classification of bottom organisms (especially marine worms) in the Bay, which has lead to inadequate descriptions of the benthos in the past. Taxonomy of many of these marine organisms still has not been clearly elucidated and therefore the actual numbers of marcrobenthic species in the Bay are probably much higher than 340. Despite the taxonomic difficulties, the general, qualitative conclusions of these two studies (as well as others) such as to the more common subtidal bottom species, general locations, differences between the four sub-bays, and generalized concepts of benthic animal interrelationships are probably valid.

2.247 In general, SERL has found, and is supported or inferred by other studies, that the greatest number of species of bottom animals inhabit Central San Francisco Bay which primarily includes a diverse, exclusively marine fauna very similar to that found on the continental shelf of central California. Extending beyond Central Bay, north into San Pablo and Suisun Bays and south into South Bay, the numbers of species dwindle. Wide fluctuating temperatures and salinities at the lower end of South Bay and the predominance of freshwater in Suisun Bay are the probable major reasons limiting the diversity of animals in these regions. In Suisun Bay, the bottom fauna is primarily of freshwater origin although some marine species inhabit the lower reach of Suisun Bay. Most of the species found in the San Francisco Bay system belong to genera that are found in most temperate estuaries of the world. Plate II-36 gives a conceptual idea of the relative diversity of bottom invertebrates between the sub-bays of San Francisco Bay.



MEAN BENTHIC ANIMAL DIVERSITY IN SAN FRANCISCO BAY

SOURCE: Modified from Storrs et al. 1966. A Comprehensive Study of San Francisco Bay, Vol. V, SERL Rept. No. 67-2.

2.248 (1) Benthic Biovolume. In terms of biovolume, SERL determined that molluscs (snails, clams, etc.) far exceeded all other subtidal bottom invertebrates in the Bay, totalling 70 percent of the entire collection volume. The biovolume of molluscs was three times that of the second largest volume of animals, the annelids (segmented worms), and 14 times that of the third largest volume, the arthropods (crustaceans, etc.). Annelids totalled 25 percent and arthropods only 5 percent of the total volume collected. All other animals combined did not total to even one percent of the entire collected volume.

2.249 The dominant molluscs, on biovolume basis, were: the Japanese littleneck clams particularly south of Hunter's Point (contributing more than 66 percent of the mollusc volume in this area) and in San Pablo Bay; the Bent-nose clam, especially in Central Bay; the "mud" mussel (Musculus senhousia) in San Pablo Bay; the Soft-shell clam in all parts of the Bay system (including Suisun Bay); and Corbicula fluminea (a freshwater clam) in Suisun Bay. Note that most of the mentioned bivalves also occur in the tidal flat habitat discussed earlier, indicating that they range from the intertidal to the deep channels of the Bay. The dominant arthropods were amphipods, Corophium insidiosum (which build tubes in soft mud) and Photis californica in South Bay, accounting for 96 percent of the arthropod volume in this sub-bay; Corophium spinocorne (also a tube builder in soft mud) in Suisun Bay; barnacles throughout the Bay system; and Photis in Central Bay. Finally, the dominant marine segmented worms were the polychaetes, Neanthes succinea and Ploydora uncata in Suisun Bay, which made up more than 80 percent of the annelid volume in this area; Glycinde armigera in San Pablo Bay; and Glycinde and Asychis amphiglypta in South Bay which attributed over 66 percent of the annelid biovolume. In other parts of the Bay system, no one worm species dominated the biovolume.

2.250 There are no biovolume data for fish species inhabiting the bottom of the Bay, such as for sharks, sculpins, gobies and flounders (flatfishes).

2.251 (2) Numerical Abundance and Distribution of Bottom Invertebrates. Of the more than 150 species or types of bottom animals identified by SERL, the most common was the amphipod Photis californica occuring in all sub-bays but most numerous west of Suisun Bay. A given sample could contain thousands of individuals especially in Central Bay. Whether they are as numerous as that indicated by SERL is open to question by Bay Area amphipod experts. These experts feel that Photis was possibly misidentified and could have been any number or combination of amphipod species found in the Bay. The SRI study did not find Photis to be in great abundance although the Photis population could be seasonal, being abundant and scarce on a cyclic pattern.

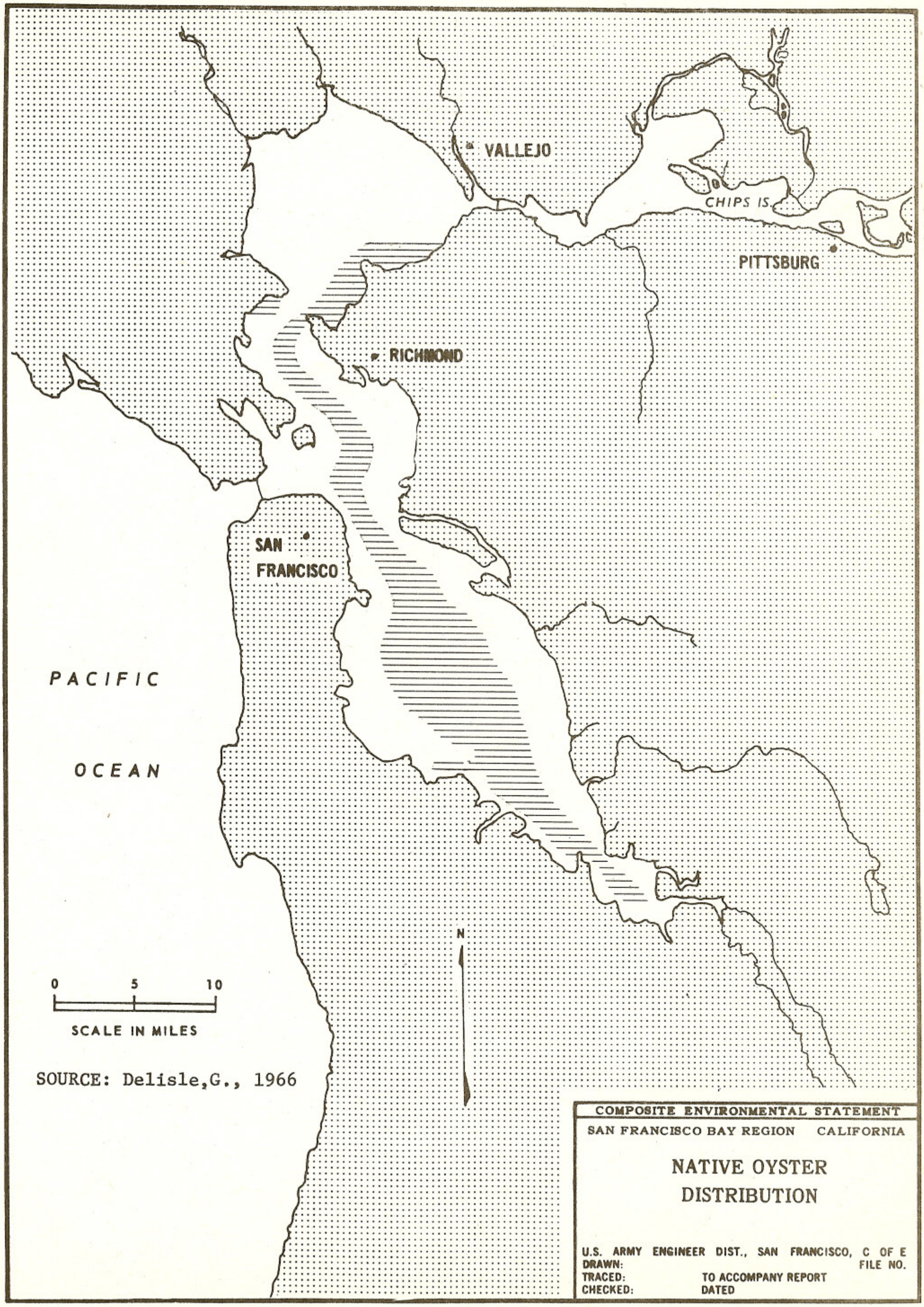
2.252 The second most numerous animal sampled by SERL was the Gem clam, Gemma gemma found in San Pablo Bay southward with greatest numbers sampled in Central Bay. Other numerically abundant benthic animals are the same ones that make up the greatest biovolume in each sub-bay; such as, the Bent-nose clam in Central Bay, the Soft-shell clam in all four sub-bays, the mud mussel in San Pablo Bay southward, Corophium species (amphipods) in all sub-bays (depending on the species) as well as others.

2.253 Although not abundantly collected compared to other species of bivalves and crustaceans, the Native oyster (Ostrea lurida), the Dungeness or Market Crab (Cancer magister), and bay shrimps (Crangon spp.), nevertheless, constitute an important resource in the Bay. Dungeness crabs and bay shrimps are commercially important and while oysters are not presently, they were very important in the past and could again become commercially important (based on past production records) in the future.

2.254 Native oysters essentially live throughout the intertidal zone and although they range into San Pablo Bay, they are particularly abundant in the deeper portions of South Bay (Plate II-37). Their abundance is presently limited by lack of dead shells and other suitable substrate for the young larvae or spats to attach and successfully grow.

2.255 The Dungeness crab is an important commercial shellfish landing in San Francisco eventhough the catch has been declining in recent years. On-going research being conducted by California Fish and Game indicates that San Francisco Bay (especially San Pablo Bay) is an important nursery area for the young Dungeness crabs. What is known of its life history is dealt with in the open bay habitat discussion. According to Delisle, immature crabs are abundant year-round in Central and San Pablo Bays (45). These young crabs are normally found on sandy bottoms in which they burrow. Like all crabs, Dungeness crabs are very mobile and are active scavangers, eating anything organic that falls to the bottom. Plate II-38 shows their distribution in the the Bay.

2.256 There are three species of bay shrimps found throughout the Bay system as shown in Plate II-39. They move into the tidal flats during flood tide and return to deeper water with ebb tide. Being filter feeders, they feed on detrital matter such as decaying marsh plants and phytoplankton, and in turn, are heavily preyed upon by anything large enough to eat them, such as fish. Bay shrimps are particularly abundant in San Pablo Bay during the summer which is where they are commercially harvested for fish bait and human consumption. The principal areas of netting bay shrimp are off Rodeo, Mare Island, Richmond and China Camp (Marin County), and in recent years, fishing has occurred in South Bay near Alviso. Approximately 10,000 pounds are landed annually (28).

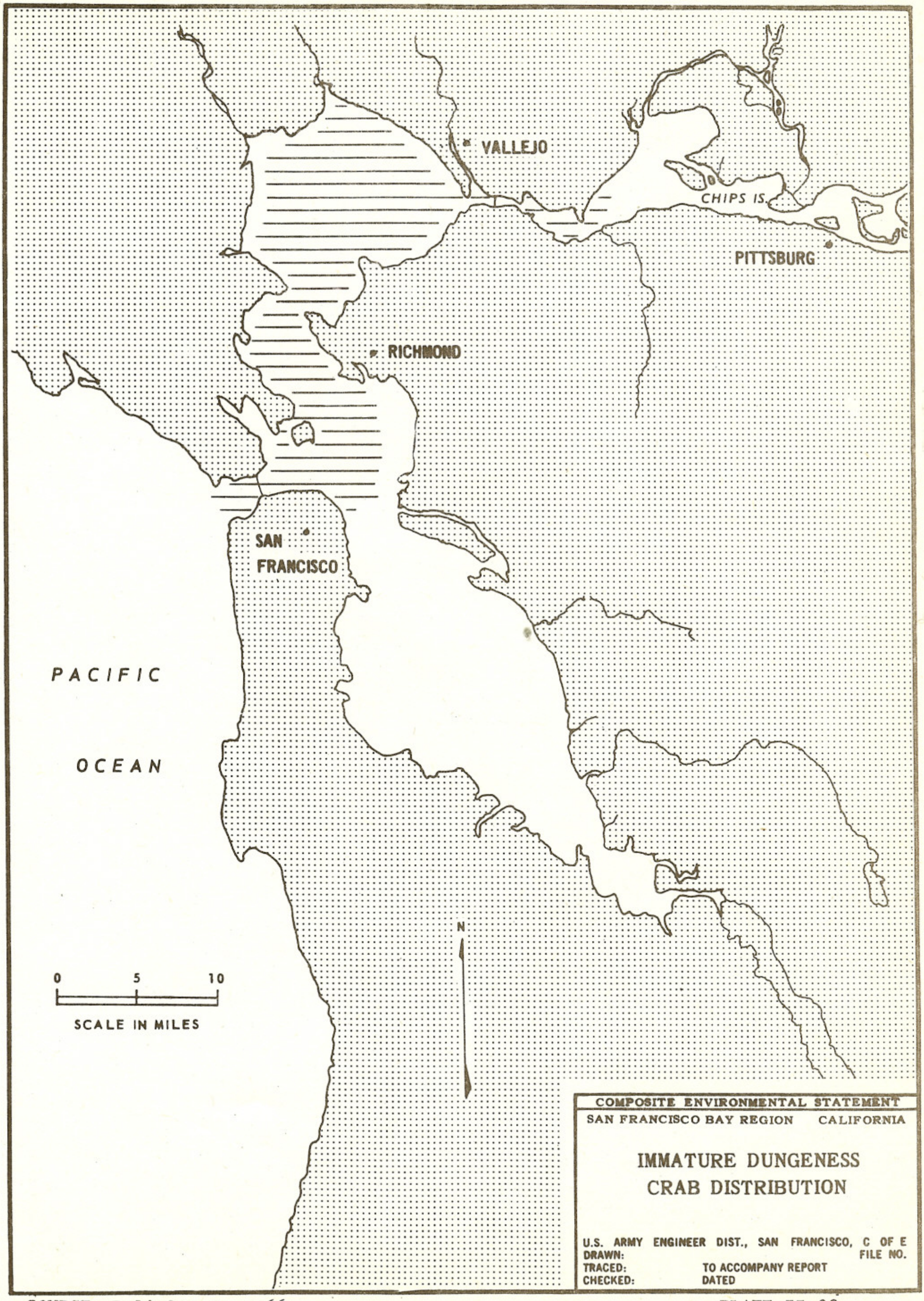


COMPOSITE ENVIRONMENTAL STATEMENT

SAN FRANCISCO BAY REGION CALIFORNIA

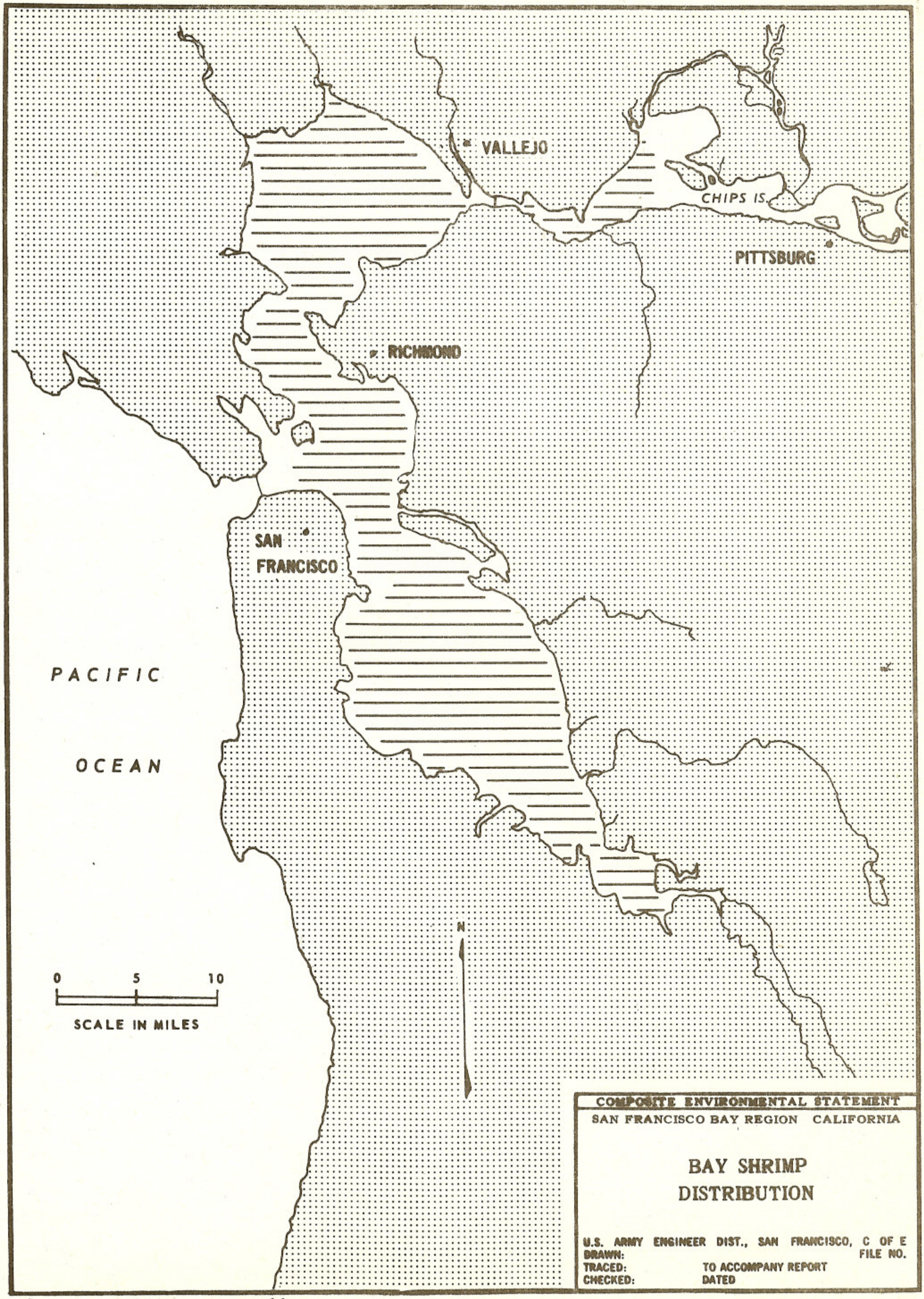
NATIVE OYSTER DISTRIBUTION

U.S. ARMY ENGINEER DIST., SAN FRANCISCO, C OF E
DRAWN: FILE NO.
TRACED: TO ACCOMPANY REPORT
CHECKED: DATED



SOURCE: Delisle, G. 1966.

PLATE II-38



Source: Delisle, G. 1966.

PLATE II-39