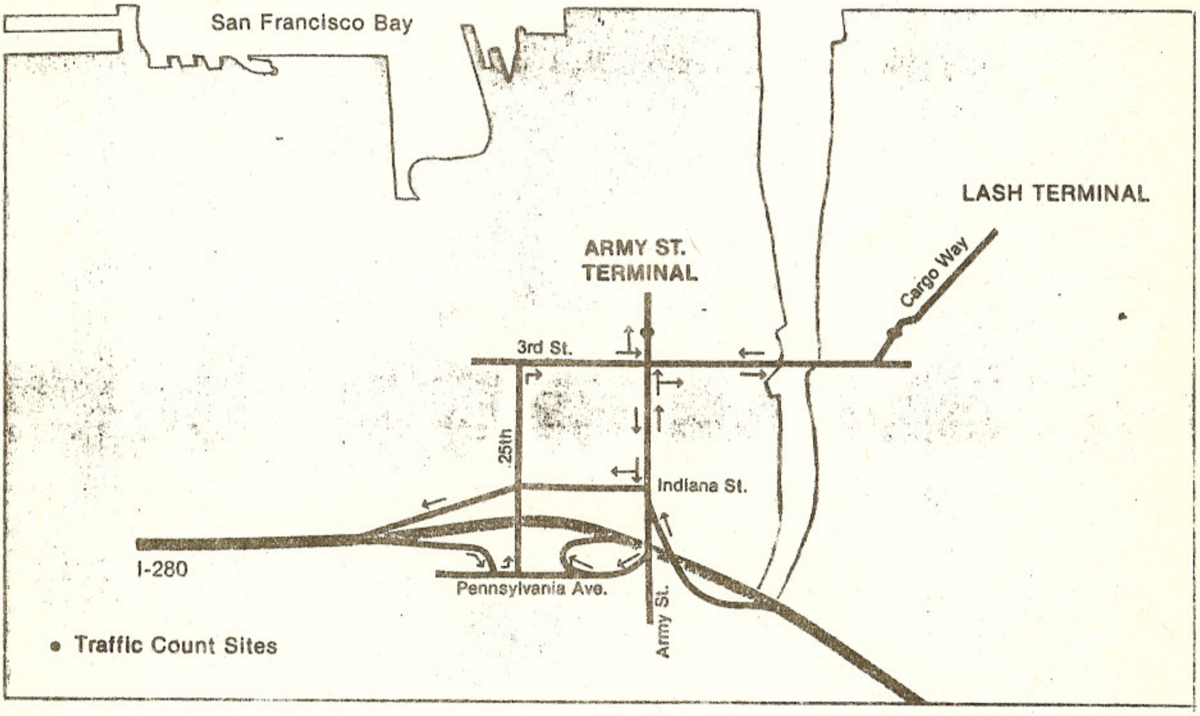
# Ingress/Egress, Port of San Francisco,
# Army Street Terminal — Pier 80, Lash Terminal — Pier 96




**Army Street Terminal — Pier 80**

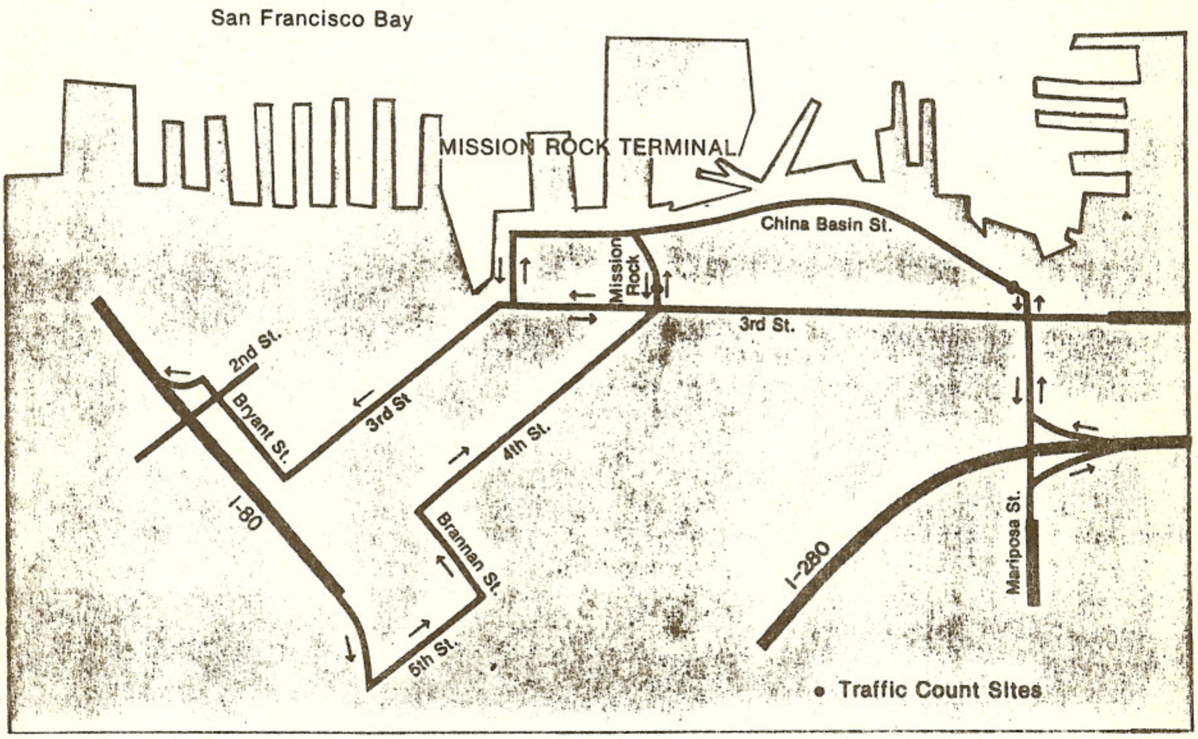
| REGIONAL HIGHWAY | ROUTE |
|---|---|
| Ingress from Southbound I-280 | Army Street ramp (2 lanes, stop); Pennsylvania (2 lanes); 25th (2 lanes, stop, signal at 3rd); 3rd (6 lanes, divided, left-thru lane and phase at Army; Army (2 lanes); |
| Ingress from Northbound I-280 | Army Street ramp (free right turn); Army (4 lanes, signal at 3rd, 2 lanes); |
| Egress to Northbound I-280 | Army (2 lanes, signal at 3rd, 4 lanes); Indiana (2 lane on-ramp); |
| Egress to Southbound I-280 | Army (2 lanes, signal at 3rd, 4 lanes, free right turn onto Pennsylvania); Pennsylvania (4 lanes); ramp (1 lane). |

**Lash Terminal — Pier 96**

| REGIONAL HIGHWAY | ROUTE |
|---|---|
| Ingress from Southbound I-280 | Army Street ramp (2 lanes, stop); Pennsylvania (2 lanes); 25th (2 lanes, railroad tracks, stop, signal at 3rd); 3rd (6 lanes, divided, left-turn lane but no phase at Cargo Way); Cargo Way (2 lanes); |
| Ingress from Northbound I-280 | Army Street ramp (free right turn); Army (4 lanes, signal at 3rd); 3rd (6 lanes, divided, left-turn lane, but no phase at Cargo Way); Cargo Way (2 lanes). |
| Egress to Northbound I-280 | Cargo Way (2 lanes); 3rd (6 lanes divided, left-turn lane and phase at Army Street); Army Street (2 lanes, signal at 3rd, 4 lanes); Indiana (2 lane on-ramp). |
| Egress to Southbound I-280 | Cargo Way (2 lanes); 3rd (6 lanes divided, left-turn lane and phase at Army); Army (4 lanes, free right turn onto Pennsylvania); Pennsylvania (4 lanes); ramp (1 lane). |

(Ref. 282)

# Ingress/Egress, Port of San Francisco, Mission Rock Terminal Area

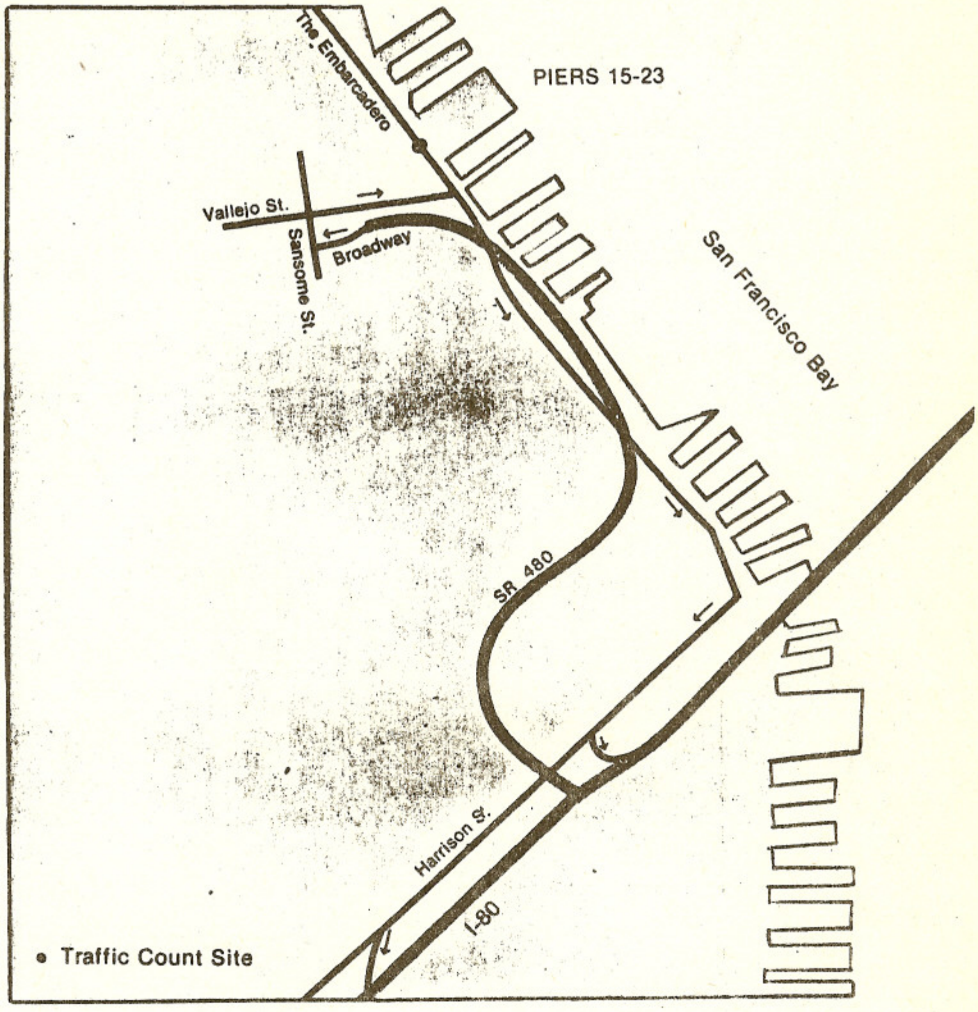



| REGIONAL HIGHWAY | ROUTE |
|---|---|
| Ingress from Westbound I-80 | 5th Street ramp (4 lanes at signal at 5th, one left-turn lane with no conflicting movement); 5th (4 lane, signals, left turn at signal at Brannan with no separate lane or phase); Brannan (4 lanes, right turn at signal at 4th); 4th (4 lanes, railroad tracks, stop, 2 lanes, draw bridge, 4 lanes at signal at Mission Rock); Mission Rock (4 lanes). |
| Ingress from Northbound I-280 | Mariposa ramp (1½ right turn lanes at signal at Mariposa); Mariposa (2 lanes plus one lane in peak direction in peak hours, signal at 3rd, 2 lanes); China Basin (2 lanes, railroad tracks, 4 lanes). |
| Egress to Eastbound I-80 | Mission Rock (4 lanes, signal at 3rd); 3rd (6 lanes); China Basin (4 lanes, signal at 3rd); 3rd (4 lanes, draw bridge, railroad tracks, 5 lanes, signals, 4 lanes one-way west on Brannan); Bryant (5 lanes one-way, hill signals, 1½ lanes on-ramp north on 2nd). |
| Egress to Southbound I-280 | China Basin (4 lanes, railroad tracks, 2 lanes, signal at 3rd); Mariposa (2 lahes plus 1 lane in peak direction in peak hours, signal, left-turn lane at on-ramp); ramp (1 lane). |

(Ref. 282)

PLATE II-5

## Ingress/Egress, Port of San Francisco, Piers 15-23

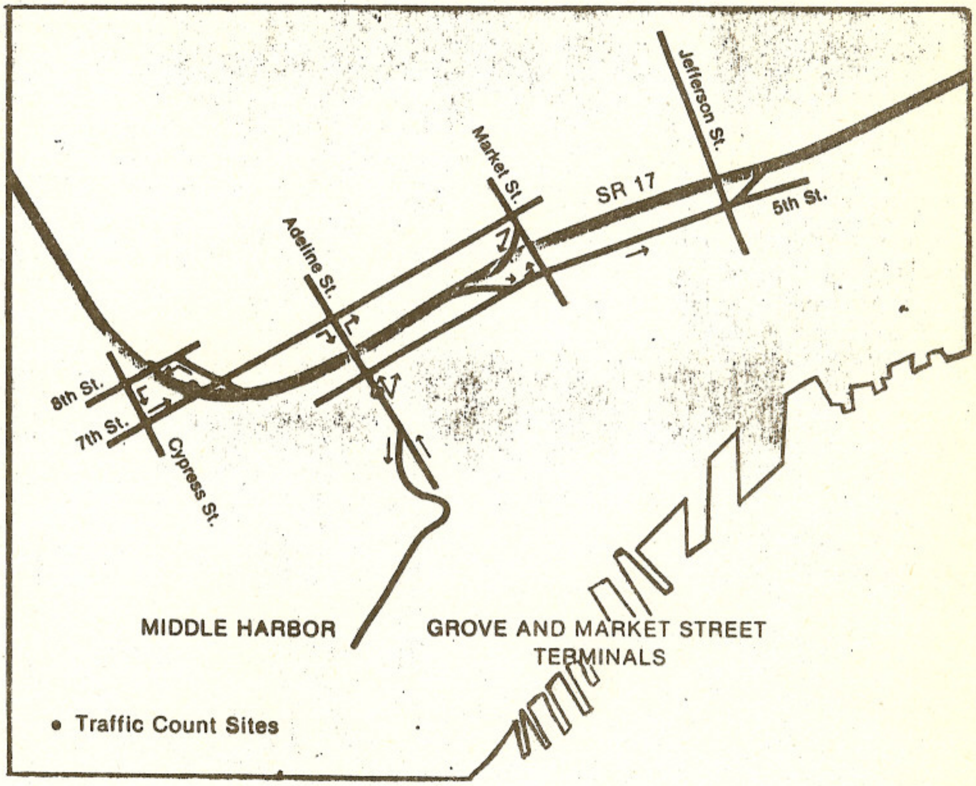



| REGIONAL HIGHWAY | ROUTE |
| --- | --- |
| Ingress from Westbound SR 480 | Broadway ramp (2 lanes, signal at Broadway); Broadway (4 lanes, 1½ right-turn lanes at signal at Sansome); Sansome (2 lanes one-way); Vallejo (2 lanes, stops); the Embarcadero (4 lanes, railroad tracks, signals). |
| Egress to Eastbound I-80 | The Embarcadero (4 lanes, railroad tracks, signals, some 6 lane sections); Harrison (4 lanes, stop, hill, signals, on-ramp at First); ramp. |
| Egress to Westbound I-80 | The Embarcadero (4 lanes, railroad tracks, signals, some 6 lane sections); Harrison (4 lanes, stop, hill, signals, 4 lanes one-way west on 3rd, ramp at 4th); ramp. |

(Ref. 282)

PLATE II-6

## Ingress/Egress, Port of Oakland, Middle Harbor Terminal Area, Grove and Market Street Terminals

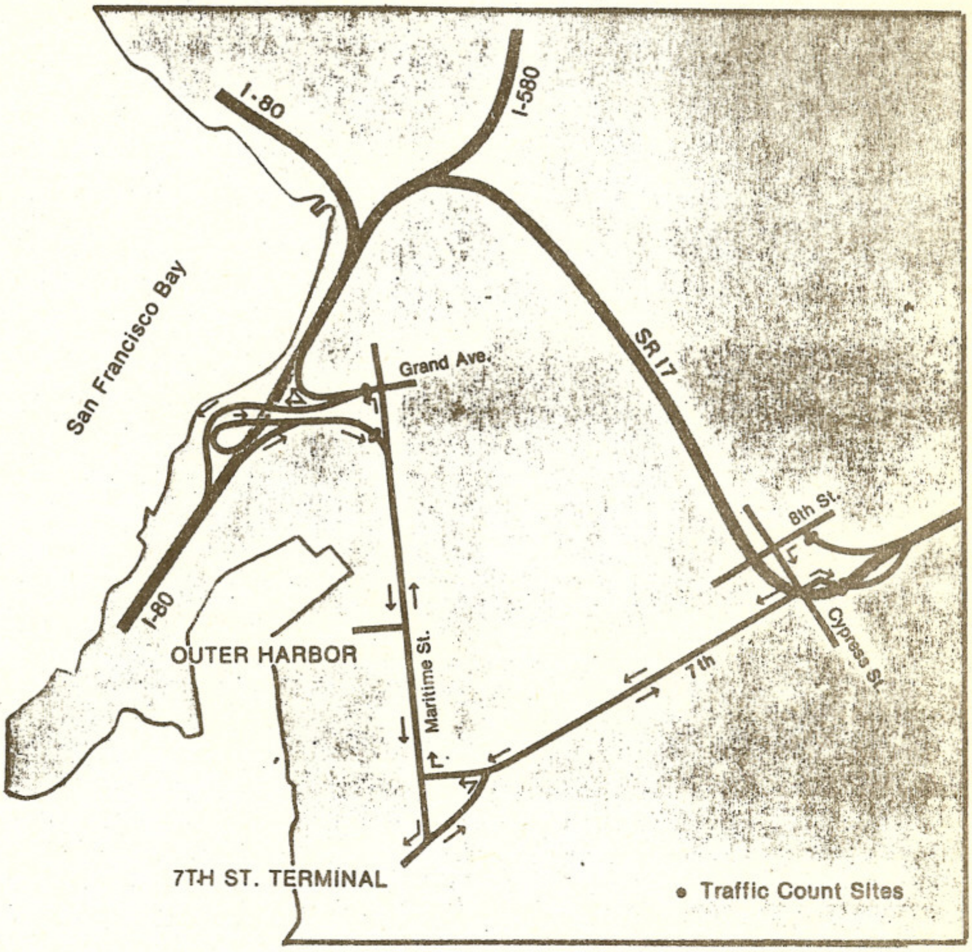



| REGIONAL HIGHWAY | ROUTE |
|---|---|
| Ingress from Northbound SR 17 | Cypress ramp (1 lane merges into 8th); 8th (one-way, 1½ left-turn lanes at Cypress signal); Cypress (3 westbound lanes, 1½ left-turn lanes at 7th St. signal, left-turn phase); 7th (4 lanes plus left-turn lanes, signals); Adeline (4 lanes, signal at 5th, 2 lanes, railroad tracks, 1 lane one-way, poor alignment); Middle Harbor (2 lanes). |
| Ingress from Southbound SR 17 | Market ramp (2 lanes); 5th (3 lanes at Market signal); Market (6 lanes divided plus left-turn lanes, left turn at signal at 7th, no left turn phase); 7th (6 lanes divided plus left-turn lanes, left turn at signal at Adeline, no left-turn phase); Adeline (4 lanes, signal at 5th, 2 lanes, railroad tracks, one lane one-way, poor alignment); Middle Harbor (2 lanes). |
| Egress to Northbound Sr 17 | Middle Harbor (2 lanes); Adeline (2 lanes, railroad tracks, poor alignment, signal at 5th, 4 lanes, right turn at signal at 7th); 7th (6 lanes divided plus left-turn lanes, right turn at signal at Market); Market (free right turn at ramp); ramp. |
| Egress to Southbound SR 17 | Middle Harbor (2 lanes); Adeline (2 lanes, railroad tracks, poor alignment, right turn at signal at 5th); 5th (3 lanes one-way, signals, 2 lanes approaching signal at Jefferson ramp); ramp. |



(Ref. 282)

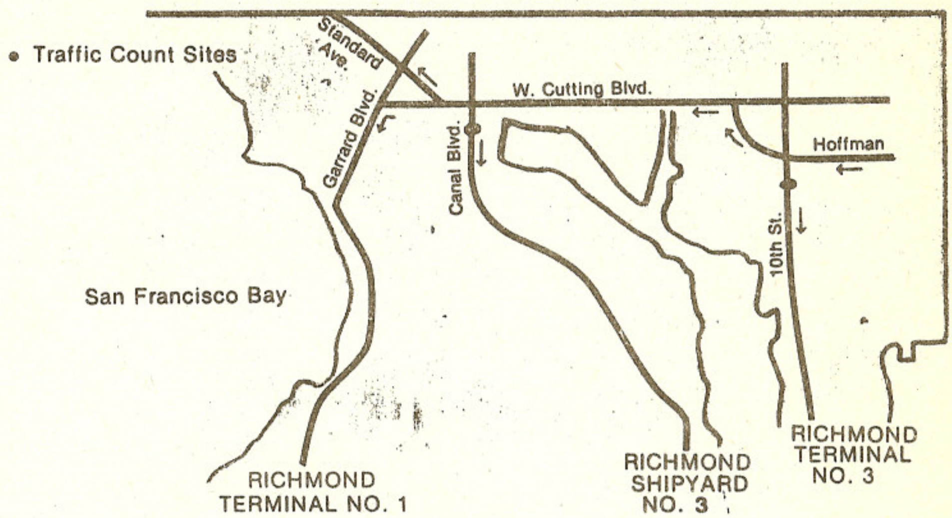
## Ingress/Egress, Port of Oakland, Outer Harbor Terminal Area, Seventh Street Terminal




| REGIONAL HIGHWAY | ROUTE |
|---|---|
| Ingress from Northbound SR 17, Westbound I-80, Westbound I-580, Eastbound I-80 | Grand Ave. ramp (2 lanes from westbound I-80 and one lane from eastbound I-80 weave into one lane, free right turn onto Maritime); Maritime (4 lanes, signalized intersections, railroad tracks); Maritime (1 lane, one-way, stop at 7th); 7th (4 lane divided, railroad tracks). |
| Ingress from Northbound SR 17 | Cypress ramp (1 lane merges into 8th); 8th (one-way, 1½ left-turn lanes at Cypress signal); Cypress (3 westbound lanes, right turn at signal at 7th); 7th (4 lanes undivided, 4 lanes divided north of Peralta, signals, railroad tracks). |
| Egress to Westbound I-80 Eastbound I-80 Eastbound I-580, Northbound SR 17 | 7th (4 lanes divided, railroad tracks, left turn lane and phasing at signalized intersection, right turn onto Maritime); Maritime (4 lanes, signals, railroad tracks, 1½ left turn lanes at Grand Ave. signal); Grand Ave. ramp (2 lanes). |
| Egress to Southbound SR 17 | 7th (4 lanes divided, railroad tracks, signals, 4 lane undivided south of Peralta); ramp south of Cypress (1 lane). |

(Ref. 282)

## Ingress/Egress, Port of Richmond, Richmond Terminal No. 1, Richmond Terminal No. 3, Richmond Shipyard No. 3




**Richmond Terminal No. 1**

| REGIONAL HIGHWAY | ROUTE |
|---|---|
| Ingress from Eastbound SR 17 | Right turn at signal at Standard; Garrard (2 lanes, stop, 4 lanes, tunnel). |
| Ingress from Westbound SR 17 | Left turn at Cutting/Standard (separate lane, no signal); Cutting (2 lanes, left turn at stop at Garrard); Garrard (see above). |
| Egress to Eastbound SR 17 | Garrard (see above); Cutting (2 lanes); SR 17 |
| Egress to Westbound SR 17 | Garrard (see above); left turn at signal at Standard (no separate lane or phase). |

**Richmond Terminal No. 3**

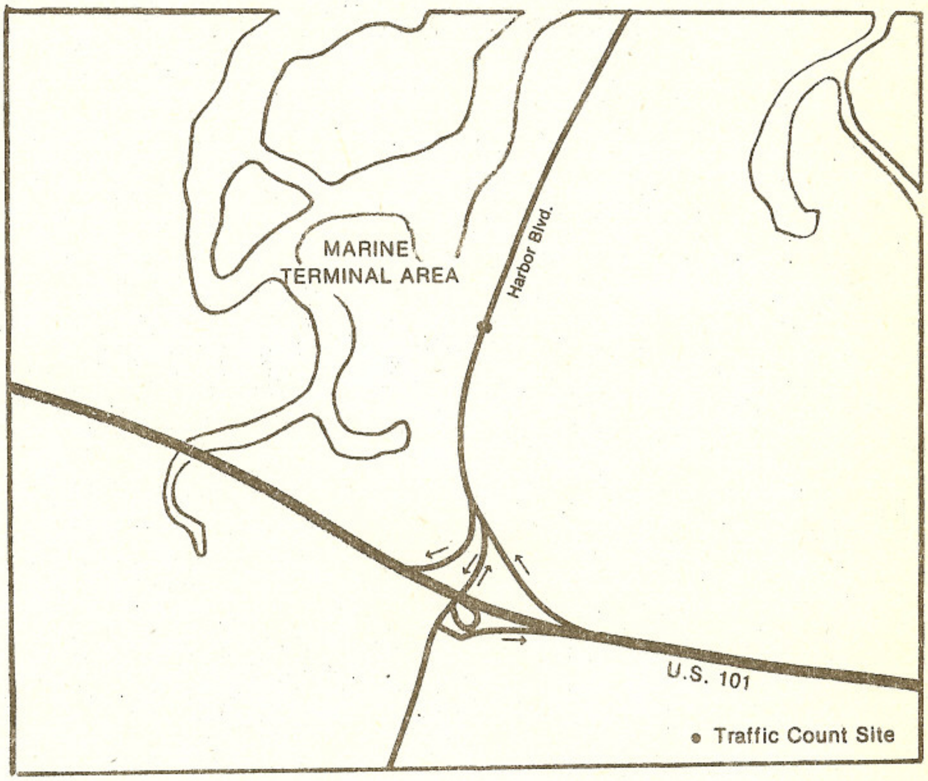
| REGIONAL HIGHWAY | ROUTE |
|---|---|
| Ingress from Eastbound SR 17 | Right turn at signal at Hoffman and 10th; 10th (2 lanes, railroad tracks, rough surface). |
| Ingress from Westbound SR 17 | Left turn (no separate lane or phase) at signal at Hoffman and 10th; 10th (see above). |
| Egress to Eastbound SR 17 | 10th (see above); right turn at signal at Hoffman. |
| Egress to Westbound SR 17 | 10th (see above); left turn (no separate phase or lane) at signal at Hoffman. |

**Richmond Shipyard No. 3**

| REGIONAL HIGHWAY | ROUTE |
|---|---|
| Ingress from Eastbound SR 17 | Richt turn at signal at Cutting and Canal; Canal (2 lanes, railroad tracks). |
| Ingress from Westbound SR 17 | Left turn at signal at Cutting and Canal (separate lane and phase); Canal (see above). |
| Egress to Eastbound SR 17 | Canal (see above); right turn at signal at Cutting (one right-turn-only plus optional). |
| Egress to westbound SR 17 | Canal (see above); left turn at signal at Cutting (no separate lane or phase). |

(Ref. 282)

## Ingress/Egress, Port of Redwood City




| REGIONAL HIGHWAY | ROUTE |
|---|---|
| Ingress from Southbound US 101 | Harbor ramp; Harbor Blvd. (2 lanes). |
| Ingress from Northbound US 101 | Harbor ramp; Harbor Blvd. (2 lanes). |
| Egress to Northbound US 101 | Harbor Blvd. (2 lanes, free right turn at ramp); ramp. |
| Egress to Southbound US 101 | Harbor Blvd. (2 lanes, left turn must yield at ramp); ramp. |

(Ref. 282)

2.041 Present surface area of the Bay system at high tide is approximately 440 square miles including about 127 square miles of marshland. This is a far cry from what the Bay used to be over a century ago when it was about 700 square miles including 330 square miles of marshland.

2.042 The Bay system can be generally divided into four sub-bay systems (Plate II-11). These are: Suisun Bay, San Pablo Bay, Central San Francisco Bay (or Central Bay) and South San Francisco Bay (or South Bay). Suisun Bay forms the eastern reach of the bay system and is bounded by Chipps Island to its east and the Benicia-Martinez Bridge to the west. Surface area of Suisun Bay at high tide is over 39 square miles. San Pablo Bay, which includes Carquinez Strait, constitutes the northern end of the Bay and encompasses the area from the Benicia-Martinez Bridge to San Pablo Strait; a total surface area at high tide of about 115 square miles. South of San Pablo Bay is the smaller Central Bay from San Pablo Strait to the San Francisco-Oakland Bay Bridge as its southern limit, and to the Golden Gate as its western boundary. Its surface area is about 87 square miles. South Bay, the fourth sub-bay, covers the remainder of San Francisco Bay which is the area south of the Bay Bridge and is by far the largest of the sub-bay systems. Its surface area at high tide is 203 square miles. There are also several smaller "bays" or coves within the sub-bays but these will only be referred to where applicable.

2.043 Except for the Sacramento and San Joaquin Rivers which drain into the Bay through the Delta, only eight other major tributaries contribute to the Bay system. These are: Walnut Creek, which flows into Suisun Bay; Napa River, Sonoma Creek and Petaluma River which drain into north San Pablo Bay; San Lorenzo Creek which flows into the east side of Central San Francisco Bay; and Alameda Creek, Coyote Creek, and the Guadalupe River (via Alviso Slouth), which drain into South San Francisco Bay (see Plate II-12). There are smaller tributaries that flow into the Bay system but are minor compared to the mean annual flow of the eight mentioned above. Even the outflows from the above eight are surprisingly small when one considers that they make up about 60 percent of the 3,500 square mile watershed of San Francisco Bay. The combined mean annual flow of these streams is less than 500 cubic feet per second (360,000 acre-feet per year) and because of this low flow, Bay Area communities depend on other systems for their water supply (87).

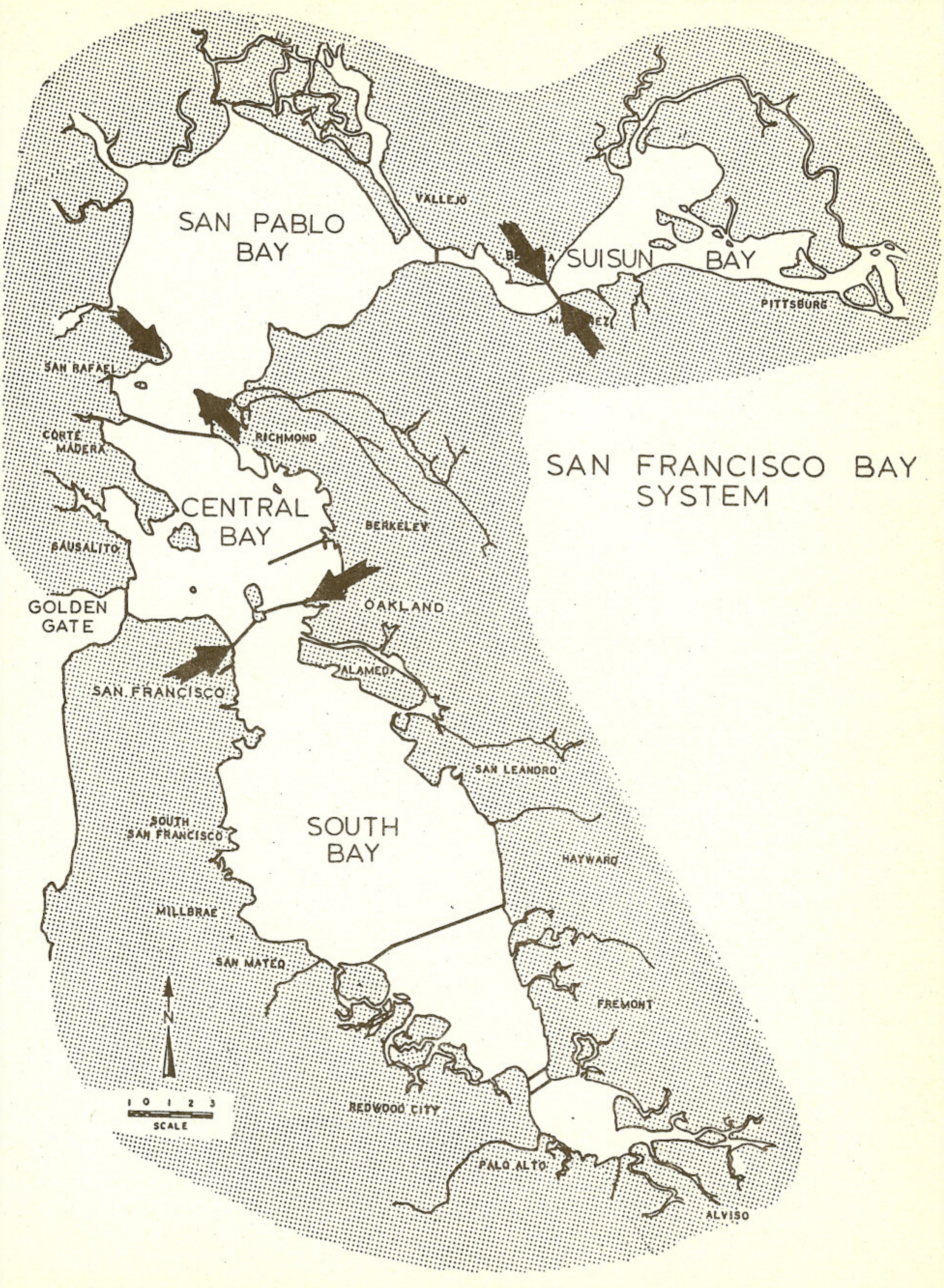
2.044 Delta inflow into the Bay by way of Suisun Bay primarily stems from the two major river systems of the Central Valley Basin; namely, the Sacramento and San Joaquin Rivers. The net delta inflow is complicated by tidal action but it is estimated to be about 16,800,000 acre-feet per year under present upstream development conditions. Historically, without any flow regulation or diversion, Delta input was estimated to be 30,300,000 acre-feet per year (87).

2.045 Determination of net delta inflow into the Bay is complex because tidal volume is much greater than tributary input on a day-to-day basis. At Rodeo in San Pablo Bay, the tidal volume in one tidal cycle is almost ten times the average volume of Delta input.

2.046 b. The Bay as an Estuarine System. Before discussing the detailed, physical aspects of the Bay, such as tides, currents, bottom topography, etc., a brief explanation of the Bay as an estuary and its uniqueness is in order, since it will facilitate our understanding of the Bay processes much better, of how the physical and biotic conditions interrelate and how these conditions dictate the effects of dredging and disposal.

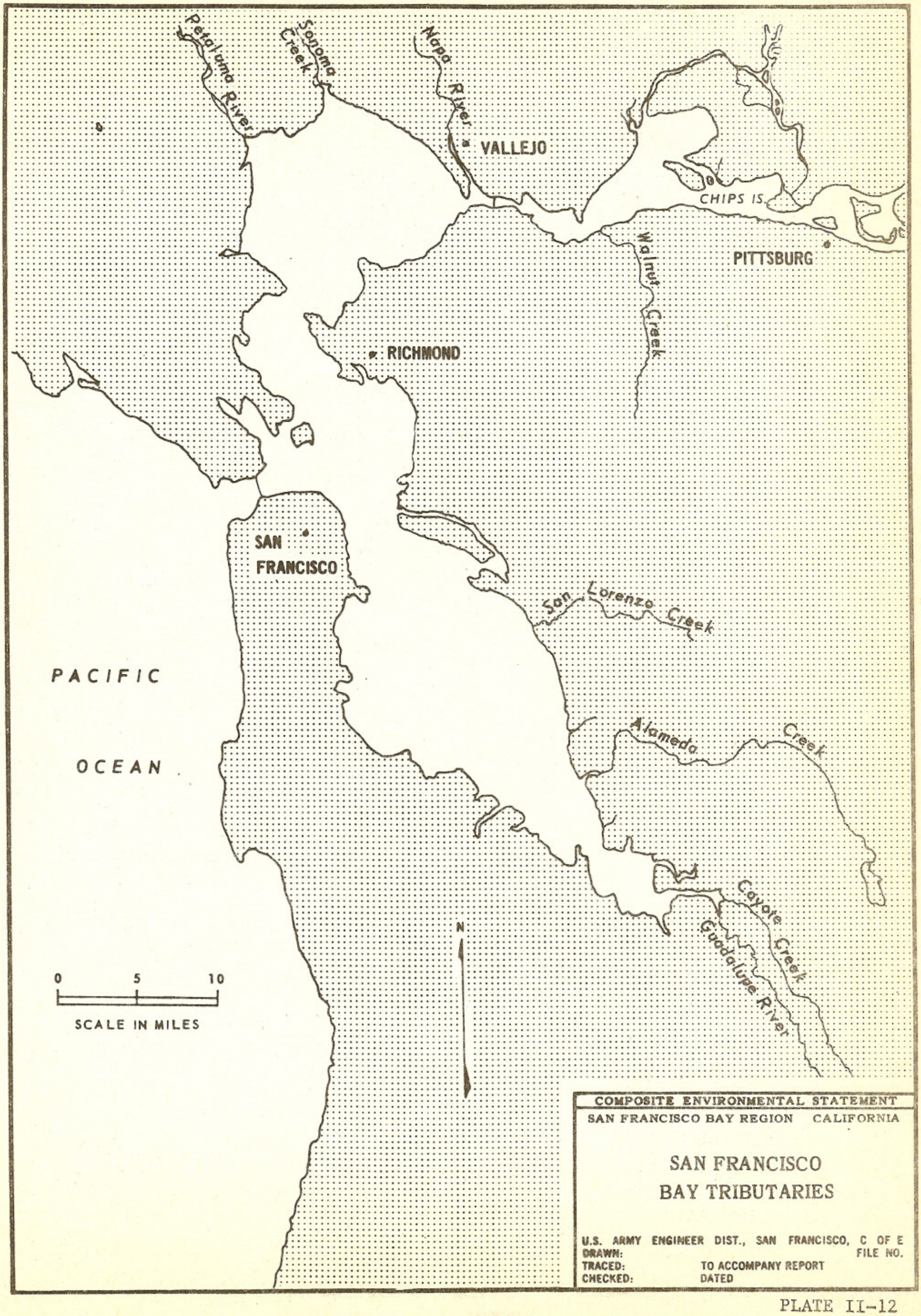
2.047 San Francisco Bay estuary is a very complex environment not easily classified by typical, estuary types. It is atypical in that its opening to the Pacific Ocean is not at the end but near the middle and thus divides the Bay into a "north" bay and "south" bay. Conditions are further complicated by the asymmetrical freshwater input into the Bay. Greatest influx is from the north end through the Delta whereas in South Bay there is very little freshwater inflow; consequently, the oceanographic conditions between opposite ends of the Bay are quite different.

2.048 An estuary is a mixing area between the sea and river, and it is this interaction between these two dissimilar bodies of water that essentially influences all other environmental conditions in an estuary. Ocean water is brought in by the tides and because of its salinity, is denser than freshwater. Typically, this dense, saline water flows beneath lighter, river water and a two-layer circulation system is established: saline, oceanic water flowing into an estuary along the bottom during flood tide, and fresh, river water moving to sea along the surface (Plate II-13). Degree of stratification between these two water bodies depends on the volume of water contributed by each. In San Francisco Bay, where tidal volume is much greater than river volume, there is little stratifcation except at the north end of San Pablo Bay and Suisun Bay during high, winter




SUBSYSTEM BOUNDARIES

Source: Dredge Disposal Study, App. B (in preparation). PLATE II-11


Petaluma River
Sonoma Creek
Napa River
VALLEJO
CHIPS IS.
PITTSBURG
Walnut Creek
RICHMOND
SAN FRANCISCO
San Lorenzo Creek
PACIFIC
OCEAN
Alameda Creek
Coyote Creek
Guadalupe River
N
0 5 10
SCALE IN MILES
COMPOSITE ENVIRONMENTAL STATEMENT
SAN FRANCISCO BAY REGION CALIFORNIA
SAN FRANCISCO BAY TRIBUTARIES
U.S. ARMY ENGINEER DIST., SAN FRANCISCO, C OF E
DRAWN:
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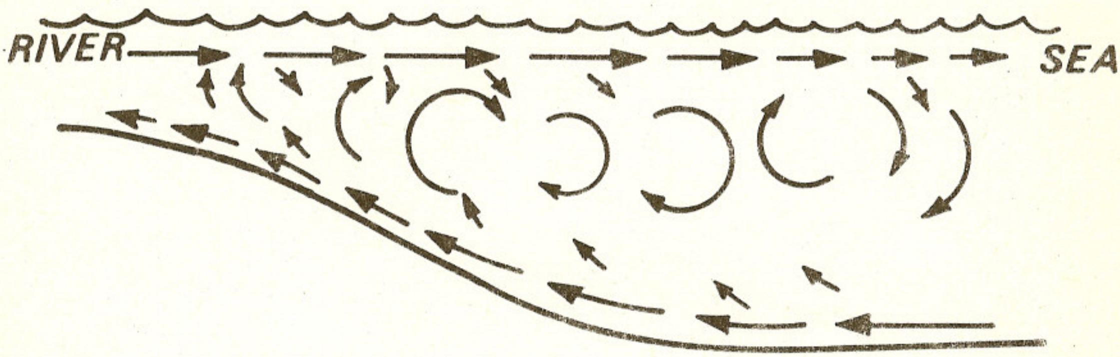
TRACED:
TO ACCOMPANY REPORT
CHECKED:
DATED

PLATE II-12

# TWO-LAYER CIRCULATION IN AN ESTUARY




Schematic diagram of circulation in a partially mixed estuary, showing the mixing pattern between lighter freshwater with heavier seawater. (After Odum. E. P. 1971. Fundamentals of Ecology.)

runoff. In other words, the Bay system, for the most part, is a well mixed estuary with its physical properties fairly uniform throughout the water column.

2.049 Mixing of bay water affects the transport of sediments, nutrients and other organic and inorganic substances brought into the estuary by both tides and freshwater runoff. In a well mixed estuary, sediments and other suspended material brought in from the river flocculate and settle to the bottom in a uniform manner throughout the estuary; unlike a stratified estuary where intensive flocculation and shoaling occur sporadically throughout. Tidal and wind-induced currents together with the mixing action are one of the primary reasons why San Francisco Bay is naturally turbid year-round with visibility confined only to a few feet (probably less than three feet for the most part).

2.050 The currents and wind-wave action tend to keep the material suspended throughout the water column but it eventually settles out either in the ocean or in the shallows of the estuary. Sedimentation normally occurs where low salinity water meets high salinity water, and the material differentially settles onto the intertidal flats and channels. The fine material that settles on the tide flats is often resuspended and redistributed by wind-generated currents and waves whereas sedimentation of coarser material in the deep channel is more or less permanent and often compacted to tens of feet deep. Many of these deep channels are periodically dredged for use as shipping lanes, and as a result are out of equilibrum with their environment.

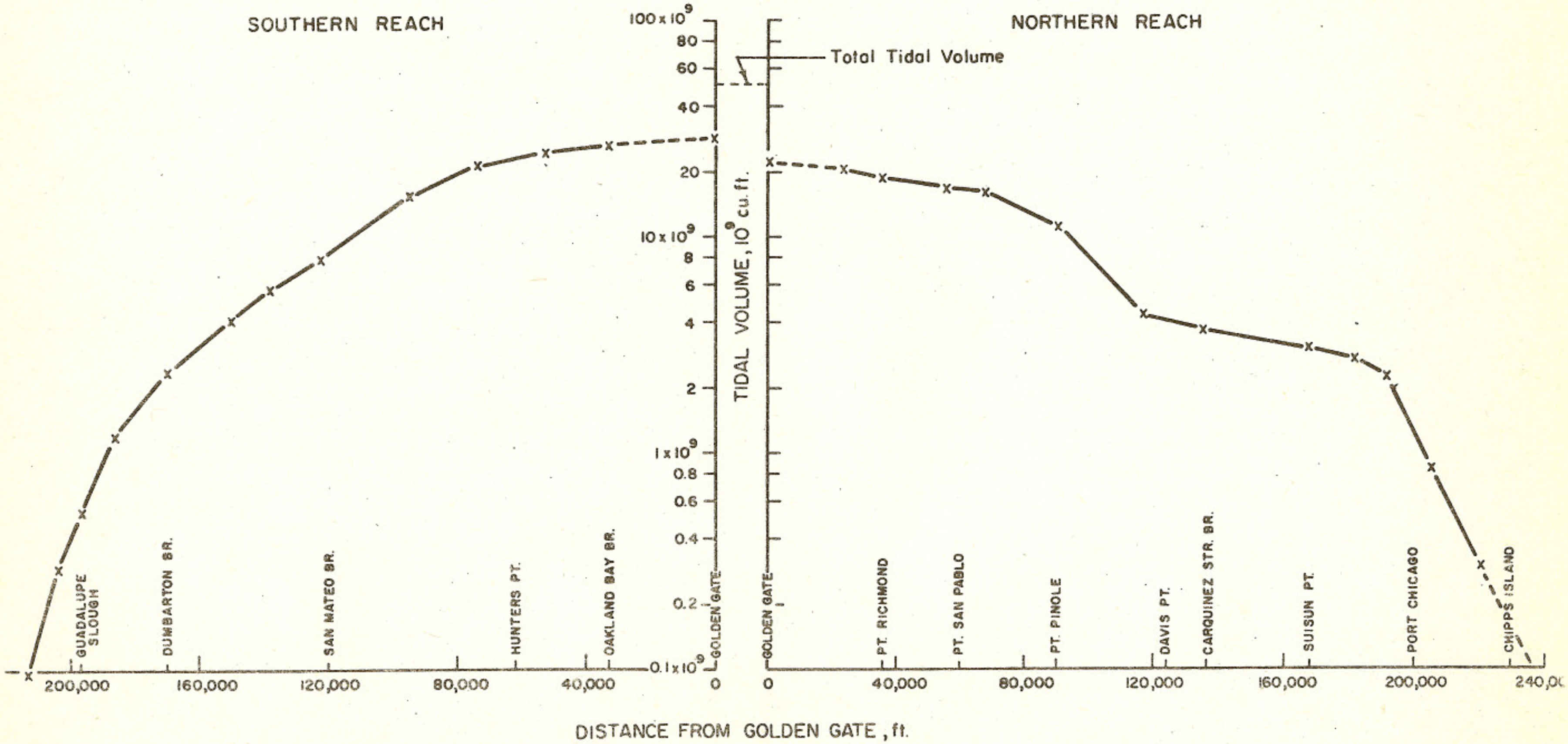
2.051 Another important process of mixing in an estuary is that it creates a unique physico-chemical environment so different from fresh or saline water alone. Sediments in an estuary adsorb or chelate many chemicals and thereby play an important role in trapping and releasing nutrients and trace metals. These chemicals can range from a simple metal ion to a complex hydrocarbon molecule (such as pesticides, plastics, oil, etc.). Trapping and releasing of these chemicals could thus have a profound effect on the estuarine biota.

2.052 All of these estuarine processes-tides, salinity, temperature, turbidity, transparency and their interaction--which result from mixing of the sea and river are the reasons why a very rich and diverse ecosystem is so characteristic of an estuary--different from that of the original waters. The San Francisco Bay estuary is no exception.

2.053 c. Physical Features of San Francisco Bay. With the general estuarine processes in mind, the more salient physical feature of the Bay will now be discussed.

2.054 (1) Tidal Characteristics. It was mentioned earlier that the tidal volume in the Bay is almost ten times the average volume of freshwater input. At mean tide, the San Francisco Bay system contains 235 billion cubic feet of brackish water (168). South San Francisco Bay is the largest of the four sub-bay systems and contains about 90 billion cubic feet of water or 38 percent of the total mean tidal volume of the Bay. Central Bay, although it has a smaller surface area than South Bay and San Pablo Bay, has about the same mean-tide volume as South Bay and 2 1/4 times the volume of San Pablo Bay. This is due to the deeper depths in Central Bay than in all other sub-bays. San Pablo Bay contains approximately 40 billion cubic feet of water at mean tide or 17 percent of the total volume. Suisun Bay, the smallest of the sub-bays in terms of surface area, also has the smallest volume: 15 billion cubic feet or slightly over six percent of the mean tidal volume of the Bay system.

2.055 The volume is referenced to mean tide because it depends on the phase of the tide. Variation in the volume of the Bay system can be as much as 50 billion cubic feet between mean higher-high tide and mean lower-low. In other words, as much as 21 percent of the mean tide volume (commonly called the tidal prism volume) could change within one tidal cycle. Of this tidal prism, it is estimated that new ocean water replaces 15-20 percent of it during each tidal cycle, which is the principal mechanism by which dissolved and suspended pollutants are flushed from the Bay (87). The mean tidal prism of the Bay from Guadalupe (Alviso) Slough in South Bay to Chipps Island in Suisun Bay is shown in Plate II-14.




MEAN TIDAL PRISM

SOURCE:

U.S. Army Engineer District, San Francisco. 1963. Comprehensive Survey of San Francisco Bay and Tributaries, California. Appendix "H" Hydraulic Model Studies, Volume I - Text and Figures to the Technical Report on San Francisco Bay Barriers, Corps of Engineers.

PLATE II-14

2.056 The back-and-fourth movement of the tidal prism occurs twice daily with one cycle completing every 12.42 hours. This semidiurnal tide consists of two highs and two lows and the difference between the two cycles is large, resulting in one low-low tide, and one high-high tide, and one high-low and one low-high tide (Plate II-15). Such a diurnal inequality of tidal heights is characteristic of the West Coast, and for San Francisco Bay, this phenomenon coupled with the effect of long ebb, exposes a wide expanse of intertidal sediments to wave generated erosion, resuspension and transportation for an extended period of time. The mean tidal range at the Golden Gate is 5.8 feet. In South San Francisco Bay, the tide range average is 8.7 feet at the mouth of Coyote Creek but is closer to 7 feet for the entire South Bay. In San Pablo Bay at Selby, the range is 3 feet. Table II-4 below gives the height and ranges of tides from selected locations in the Bay, and Plate II-16 graphically depicts the mean tidal ranges within the Bay system.

TABLE II-4

HEIGHTS AND RANGES OF TIDE AT SEVERAL LOCALITIES IN SAN FRANCISCO BAY

| Location | MHHW | MLLW | Range |
|---|---|---|---|
| Golden Gate | 2.7 | -3.1 | 5.8 |
| Central San Francisco Bay | 2.8 | -3.0 | 5.8 |
| Coyote Creek | 4.2 | -4.5 | 8.7 |
| San Pablo Bay | 3.1 | -3.0 | 6.1 |
| Suisun Bay | 3.3 | -2.3 | 5.6 |

Source: U.S. Army Engineer District, San Francisco, 1966.

2.057 Topography and varying depths not only cause these differences in tidal range but also affect the lag time or time differential of the tidal phase in different areas of the Bay. For example, high tide at Yerba Buena Island (Treasure Island) occurs 1.4 hours earlier than high tide at the mouth of Alviso Slough in South Bay, a distance of 36.5 statute miles. High tide occurs at the Presidio 1.7 hours earlier than it does at

Selby, at the upstream limit of San Pablo Bay; a 25.8 mile distance. The tidal cycle in South Bay is shorter than in the northern reach so than when San Pablo Bay reaches flood or high tide, ebbing will have already begun in South Bay. Similarly, when San Pablo Bay reaches low tide, the tide will be flooding in South Bay. This lag time in the tidal phase is important to circulation in the southern reach of South Bay (south of the San Mateo-Hayward Bridge) since flows from causes other than tides are negligible in this area.

2.058 Tide lags, tide ranges, advective flow, and mixing determine the residence time of dissolved pollutants in the Bay. In the area south of San Mateo-Hayward Bridge where there is little flow other than tidal flow, residence time of pollutants is very long compared to other regions of the Bay; perhaps up to one year (87). In San Pablo Bay, residence time largely depends on Delta flow. At minimum Delta flow, residence time between Antioch and the Golden Gate can be up to 300-400 days whereas at high flow, the time is shortened to 20-30 days (87).

2.059 (2) Currents. Currents in the Bay system are primarily induced by tides, river inflow and wind but the current pattern is influenced by bottom topography and depth. As mentioned earlier, during certain stages of the tidal cycle, ebb flow from San Pablo Bay and the northern part of Central Bay move into South Bay as flood current and vice versa. This also occurs at junctures of San Pablo Bay, Mare Island Strait and Carquinez Strait. For example, at times, ebb from Mare Island Strait is directed into Carquinez Strait as flood tide and conversely, ebb current from Carquinez Strait moves into Mare Island as flood current.

2.060 Plates II-17 and II-18 show current velocities and directions in the Bay three hours after maximum flood and three hours after maximum ebb at the Golden Gate. 1/ When San Pablo Bay is flooding, currents in South Central Bay are slightly ebbing. Conversely, three hours after maximum ebb at the Golden Gate, San Pablo Bay is still ebbing while South Central Bay is beginning to flood.

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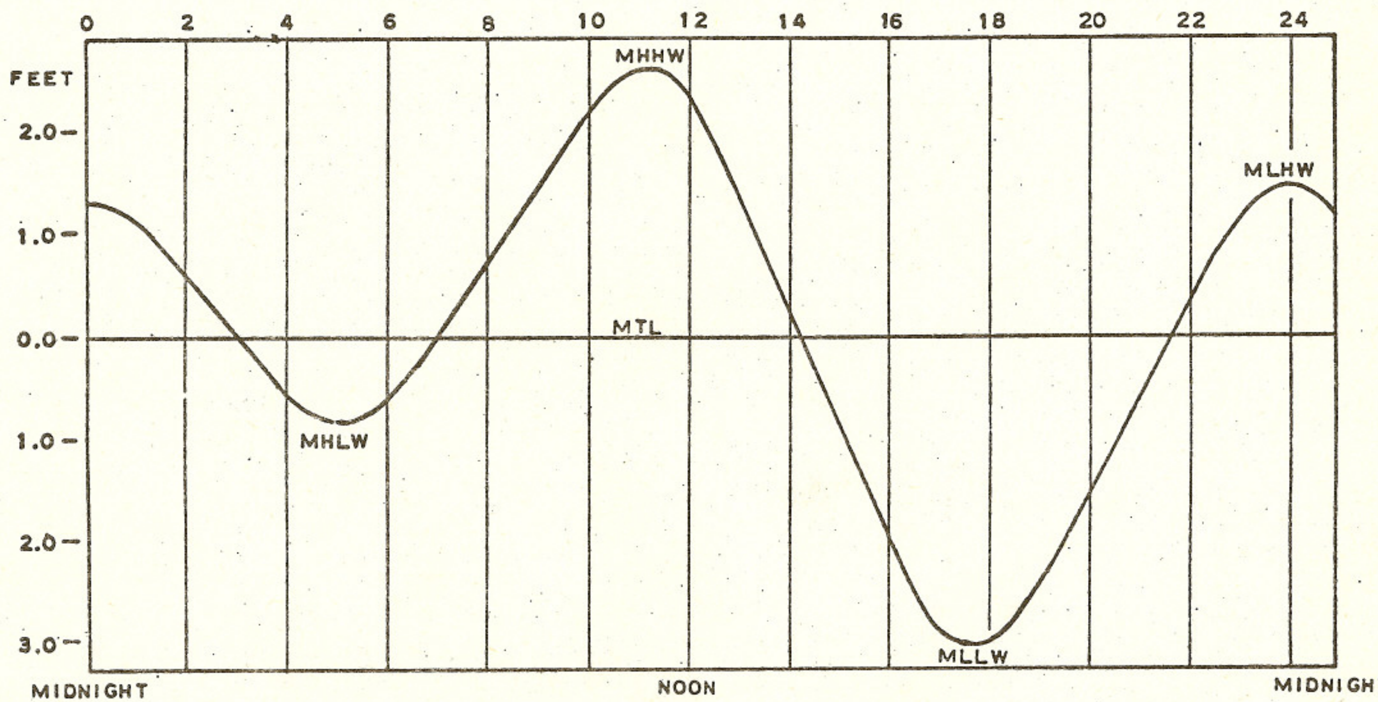
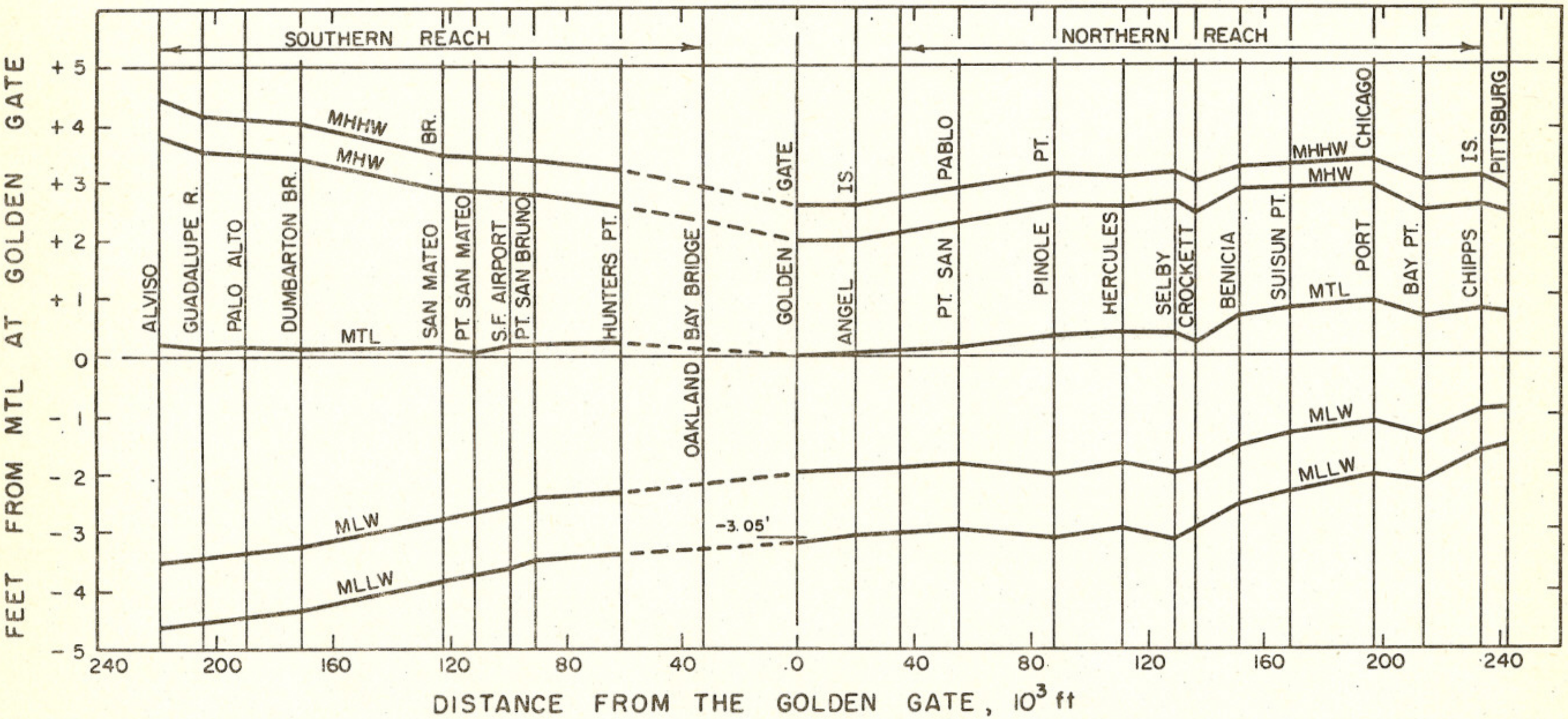
1/ Maximum flood is defined as the maximum current velocity as the tide is rising. Maximum ebb is the maximum current velocity in the opposite direction as the tide is falling.




MEAN TIDE CURVE AT GOLDEN GATE
SAN FRANCISCO BAY




ELEVATION OF MEAN ANNUAL TIDAL STAGES

**SOURCE:**

U.S. Army Engineer District, San Francisco. 1963. Comprehensive Survey of San Francisco Bay and Tributaries, California. Appendix "H" Hydraulic Model Studies, Volume I - Text and Figures to the Technical Report on San Francisco Bay Barriers, Corps of Engineers.

PLATE II-16

2.061 Since currents and circulation have a pronounced effect on sedimentation in San Francisco Bay, it follows then, that overflow from hopper dredging and disposal could also be affected by currents and circulation. Because of this, a more detailed discussion is provided below on the general current characteristics of the Bay.

2.062 The Golden Gate area, from about one mile inside the Bridge to four miles outside, is subject to violent swirls, eddies, whirlpools and boils. The eastern limit of the area is known locally as the "waterfall," and during ebb, steep rip tides and waves of three to 3.5 feet are not uncommon. The constricted passage of the Golden Gate which opens into the wide expanse of the Pacific Ocean and San Francisco Bay intensifies these violent conditions.

2.063 During flooding, the tide current at the Golden Gate parallels the channel with greater velocities along the north shore (Lime Point) than the south shore. Maximum flood velocity under the bridge is above four knots. The current sets easterly and follows the deep channels leading into north and south bays. Currents around Angel Island consist of swirls and are between one to two knots at maximum flood. They progress northward into San Pablo Bay at about the same rate. Flood currents through San Pablo Bay can be above two knots because of the narrow passage through the strait but highest velocities in San Pablo Bay are not attained until one to two hours after maximum flood at the Golden Gate. Greatest velocities in San Pablo Bay, as can be expected, are in the deep channels. Flood currents across the mud flats moving into Petaluma Creek and Napa Slough are normally less than one knot.

2.064 All phases of the current in Mare Island Strait occur earlier than in Carquinez Strait. Flooding begins in Mare Island Strait about two hours before flooding in Carquinez Strait because during the last two hours of ebb in Carquinez Strait, part of the ebb enters Mare Island Strait as flood. Flood velocity is above one knot. Ebbing in Mare Island Strait starts about 1.5 hours before ebb in Carquinez Strait and flows into Carquinez Strait as flood current. Ebbing is augmented by Napa River flow and current velocities can reach over two knots.

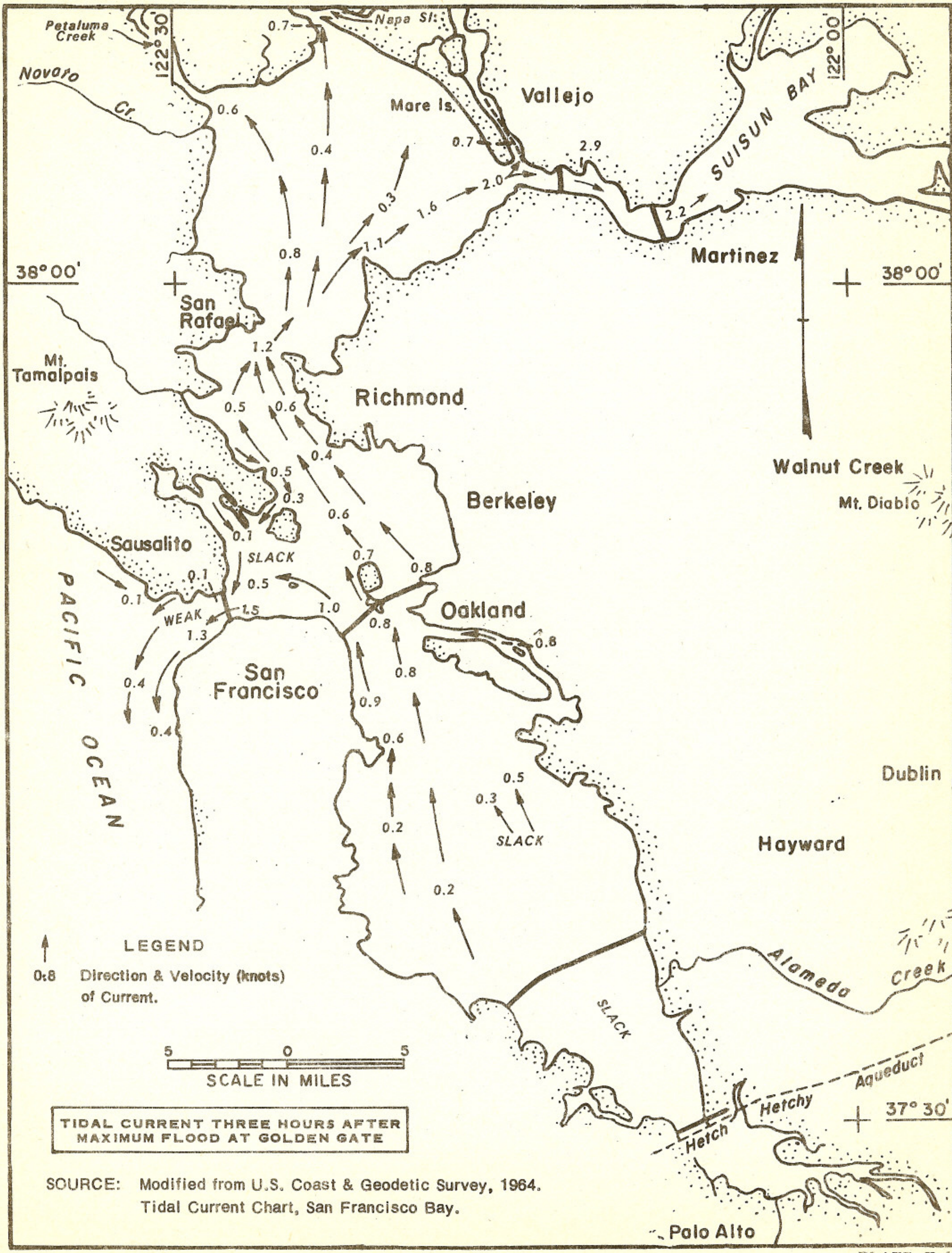
2.065 Southeast of Angel Island flood currents rotate counterclockwise and move past Treasure Island between one to two knots down the main channel. Maximum velocity under the Dumbarton Bridge is over two knots.

2.066 Slack tide in South Bay occurs three hours after maximum flood at the Golden Gate while in south Central Bay, ebbing has begun. Note from Plate II-17 that north Central Bay and San Pablo Bay are still flooding at this time. Maximum ebb under the Dumbarton Bridge is about two knots and generally increases above three knots at Treasure Island. Maximum ebb at the Golden Gate is close to six knots.

2.067 Maximum ebb velocity in San Pablo Bay is above 1-1/5 knots and increases to over three knots in San Pablo Strait. Maximum ebb velocities in these two waterways are attained two to three hours after maximum ebb at the Golden Gate. During this time, when ebb currents are greatest in San Pablo Bay, flooding has begun in south Central Bay, which is being partly contributed by the ebb waters from north Central and San Pablo Bays (See Plate II-18).

2.068 At Oakland Inner Harbor, which is southeast of Treasure Island in Central Bay, maximum flood velocity is one knot is attained one hour before maximum flood at the Golden Gate, and decreases until it is slack two hours after maximum flood. Ebb velocity is close to 1-1/2 knots in Oakland Harbor two hours before maximum ebb at the Golden Gate and is slack again two hours after maximum ebb.

2.069 The above discussion has centered on tidal currents because tides are the dominating force dictating the overall current pattern in San Francisco Bay. However, non-tidal currents also occur in the Bay, which are principally produced by wind, salinity-density differences, and river inflow. These non-tidal currents can have a localized effect on sedimentation and dredge/disposal operations. For example, wind-generated currents erode and resuspend tide flat sediment and transport them to low energy areas where shoals build up. A more detailed discussion of how currents affect sedimentation can be found under Submarine Geology of the Bay.




TIDAL CURRENT THREE HOURS AFTER MAXIMUM FLOOD AT GOLDEN GATE

SOURCE: Modified from U.S. Coast & Geodetic Survey, 1964. Tidal Current Chart, San Francisco Bay.

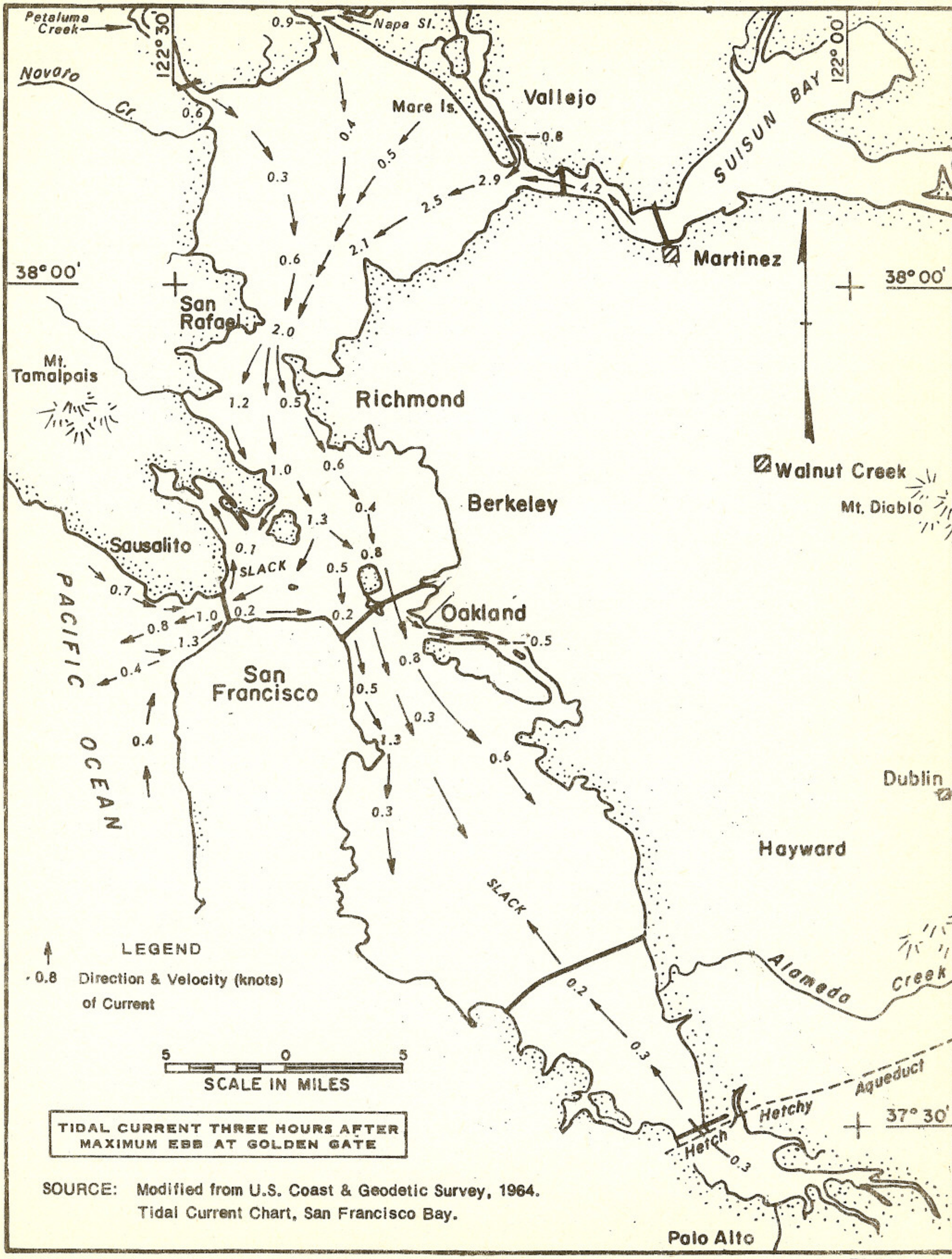

Petaluma Creek
Napa Sl.
Novato Cr.
122°30'
122°00'
Mare Is.
Vallejo
SUISUN BAY
Martinez
38°00'
San Rafael
Mt. Tamalpais
Richmond
Walnut Creek
Mt. Diablo
Berkeley
Sausalito
SLACK
Oakland
PACIFIC OCEAN
San Francisco
Dublin
Hayward
Alameda Creek
Hetch Hetchy Aqueduct
37°30'
Palo Alto
LEGEND
0.8 Direction & Velocity (knots) of Current
5 0 5
SCALE IN MILES
TIDAL CURRENT THREE HOURS AFTER MAXIMUM EBB AT GOLDEN GATE
SOURCE: Modified from U.S. Coast & Geodetic Survey, 1964. Tidal Current Chart, San Francisco Bay.

PLATE II- 18

2.070 (3) Depths. The large deep channels within San Francisco Bay provide inherent deep draft navigational advantages which, with the exception of Puget Sound, are only approximated in other west coast bays and harbors. For example, the Columbia River estuary has a continuing entrance-bar shoaling problem, and the first deep draft port is located 100 miles inland at Portland. The deep draft harbor at Los Angeles has only breakwater protection from the open sea and thus does not have a comparable wind or storm protection of the coastal mountain range that San Francisco Bay has.

2.071 Although necessarily augmented by dredging, San Francisco Bay has extensive natural areas of deep and shallow water. The natural depth over the crest of San Francisco Bar, eight miles radially offshore from the Golden Gate, is 30 feet (MLLW). From the Bar's crest this depth progressively increases to the deepest point in the Bay at the Golden Gate where 384-foot soundings have been recorded. Central Bay has depths ranging from 212 feet off Belvedere's Peninsula Point in Raccoon Strait, 183 feet deep off Point Blunt (Angel Island), 160 feet off Alcatraz Island, and 124 feet off Yerba Buena Island to 50 feet off Hunter's Point. South of Hunter's Point the Bay has a relatively small natural channel, 50 to 30 feet deep, that extends to the Dumbarton Bridge. The area south of the San Mateo-Hayward Bridge is quite shallow with more than half of it less than 10 feet deep. The north reach of Central Bay increases from about 40 feet off Richmond to 80 feet off Point San Pablo. The depths decrease in San Pablo Bay to 25 feet in the natural channel extending to Carquinez Strait. In Carquinez Strait depths range from 40 to over 130 feet. Mare Island Strait has a maintained depth of 30 feet. Suisun Bay is relatively shallow with a natural channel ranging from 20 to 50 feet deep.

(4) Submarine Geology of the Bay.

2.072 (a) Geological formations. San Francisco Bay is situated over two distinct geological units: the bedrock unit consisting of the Franciscan Formation, and the overlying sediment unit called Recent Bay sediments. The Francisan Formation has already been briefly described under Basic Geology.

2.073 Overlying the Franciscan Formation are Recent Bay Sediments deposited since the formation of the Bay 15,000 to 25,000 years ago during the late Pleistocene. These recent sediments are principally fluviatile and originating from upland erosion of parent formations situated in watershed tributary to the Bay. The thickness of sediment deposits in the Bay exceeds 300 feet in certain areas.

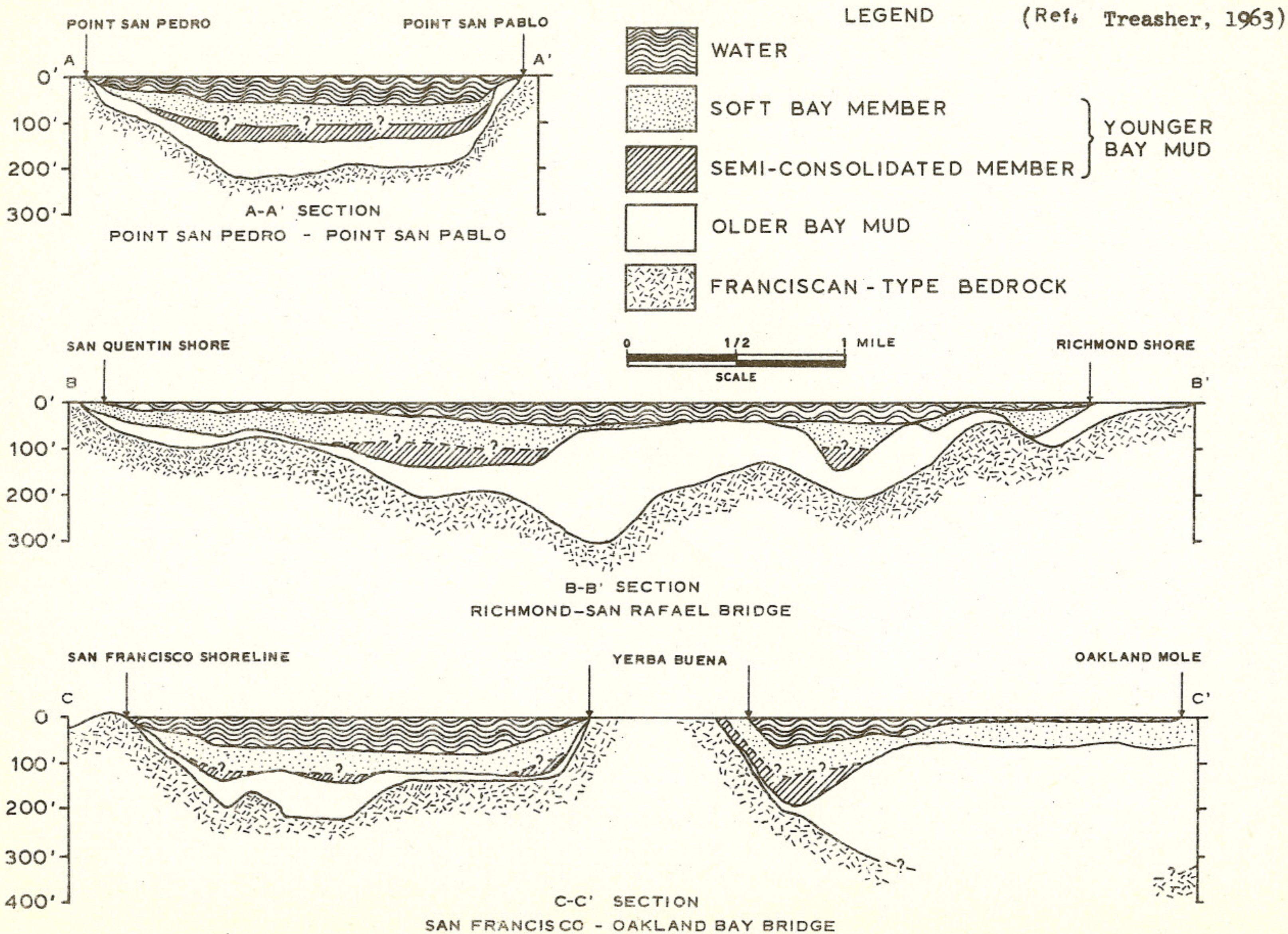
2.074 These deposits have been subdivided into three stratigraphic units based on degree of consolidation and vertical location of the stratum and are referred to as Older Bay Mud, Sand Deposits and Younger Bay Mud (218). The Younger Bay Mud can be further subdivided into a Semi-consolidated Bay Mud member and a Soft Bay Mud member. Plate II-19 shows the divisions of Recent Bay Sediments into the stratigraphic units used in this report.

2.075 (b) Older Bay Mud. Older Bay Mud is composed of firm, dark, gray-green clay with varying amounts of silt, sandy clay, sand and small gravel lenticularly bedded. This layer also contains shell lenses which range from five to 50 feet thick. In general, Older Bay Mud ranges from 0 to 200 feet thick in the Bay and the thickest layer appears to be in the central portion of the Bay floor and is either very thin or absent along the shoreline.

2.076 The term "Older Bay Mud" includes alluvial deposits known as the Merritt Sand, Posey Formation, San Antonio Formation and Alameda Formation described by Louderback (278). These geologic units were identified, described and extrapolated from data secured by dry land explorations. Corps of Engineers' studies of over 3,000 borings conducted throughout the Bay did not confirm or deny the grouping, naming or location of these formations under the Bay floor (218). Therefore, for the purpose of this EIS, the geologic units used are those employed by the Corps of Engineers.

2.077 There is no evidence that the Santa Clara formation is situated beneath sediments deposited in San Francisco Bay.

2.078 What differentiates this layer from the other two sediment layers is its physical properties. Aside from its characteristic grain-size composition, Older Bay Mud contains less moisture and is preconsolidated to a degree greater than would result from the weight of overlying sediments. Wet weight of Older Bay Mud is greater than 90-110 pounds per cubic foot and is less than 40 percent moisture.




# STRATIGRAPHY OF RECENT BAY SEDIMENTS