June 13, 1996

Subject: **Sediment Transport in Francisco Bay as it Relates to Site Investigated Under the IRP at NAS Alameda**
Naval Air Station Alameda, California
Navy CLEAN Contract No. N62474-88-D-5086, Contract Task Order 0107

The following is a summary describing the results of a literature search to evaluate sediment transport, erosion, and deposition in the vicinity of NAS Alameda. Several resources (Conomos 1979; Cloern 1984) have yet to be evaluated; these resources were not yet available through inter-library loan. However, historic and current research consistently suggest that the shoreline around NAS Alameda receives sediment transported from areas outside of the property boundaries.

This summary does not imply that the Navy has not contributed sediment from overland erosion and storm sewer effluent, rather it is intended to show the difficulties in assessing the extent of any impacts to the in situ sediment as a result of Navy activity versus sediment transported from other places as a result of resuspension and circulation during dredging or tidal current movement.

In some cases, the San Francisco Bay Regional Water Quality Control Board, U.S. Environmental Protection Agency (Region IX), and the California State Water Resources Board participated in the research and preparation of documents reviewed for this summary, which indicates their awareness of the challenge to identify the extent of individual impacts on bay sediments; for the Navy this challenge is in identifying how sites investigated under the IRP may have impacted near shore sediments.

The summary is organized as follows: first, a general discussion of sediment transport in the San Francisco Bay is provided, followed by general information about the effects of dredging in the San Francisco Bay; then, information about sedimentation is presented as it relates to specific locations around NAS Alameda, such as the Oakland Inner Harbor, the Western Bayside, and the turning basin.

Attached to this summary are several figures excerpted from the literature cited; in some cases, several pages of excerpted text where a figure was cited have been included. The first figure is not cited in the text, but shows NAS Alameda and the surrounding water areas discussed in this summary. Also attached are reference lists excerpted from various documents used in this research; these are attached because in many cases, the text referenced in this summary cites other references.

Sediment Transport in San Francisco Bay

The San Francisco Bay estuarine system is divided into three distinct regions: (1) the Delta, at the confluence of the Sacramento and San Joaquin River systems; (2) the northern reach of the Bay, which extends south and westward from the Delta through the broad and shallow Suisun and San

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Pablo Bays; and (3) the south bay, which extends southeastward toward San Jose (Krone 1979) (see attached reference list from U.S. ACOE Dredge Disposal Study). The northern and southern reaches meet in the central Bay (not well defined or agreed upon by researchers as a distinct region), where NAS Alameda is located.

The San Francisco Bay receives runoff from over 40 percent of the land area of California; the silty runoff mixes with the saline water of the Pacific Ocean (U.S. EPA, U.S. ACOE, San Francisco Bay Conservation and Development Commission, San Francisco Bay RWQCB, and California State Water Resources Control Board, 1996). The U.S. Army Corps of Engineers (U.S. ACOE) in 1967 studied the historical sedimentation patterns in the Bay system using hydrographic surveys for a 101-year period from 1855 to 1956. The results of the study show an average annual net deposition of 5.2 million cubic yards for the years studied (U.S. ACOE 1979). In separate studies cited U.S. ACOE (1979), Krone (1966 and 1974) and the California State Water Resources Board estimated that between 2.1 and 2.4 million cubic yards annually is deposited in the Bay.

At least as early as 1931 the U.S. ACOE studied currents and silt movement in San Francisco Bay (Grimm 1931) (see attached reference list from U.S. ACOE Dredge Disposal Study). Since that time, several researchers have studied the horizontal and vertical mixing of silt-laden water with saline water of the Pacific Ocean within San Francisco Bay (Carlson and McCulloch, 1974; Conomos and Peterson, 1977 [see attached reference list from U.S. ACOE Dredge Disposal Study]; Smith, 1987).

Conomos and Peterson (1977) [see attached reference list from U.S. ACOE Dredge Disposal Study] found that water movement within the central portion of San Francisco Bay is dominated by mixed and semidiurnal tidal flows, and that annual riverine flows that are three times the total Bay volume from the Delta impose a seasonal variation on the daily tidal influence

Carlson and McCulloch (1974) used aerial photography to provide a synoptic view of discrete water masses that can be differentiated by suspended sediment load. They observed that during periods of high riverine discharge (typically winter and spring flow) from the Sacramento-San Joaquin River system, a distinct plume of high-turbidity brown water flowed into south San Francisco Bay. Using in-situ measurements of suspended sediment and salinity, they were able to relate the plumes' suspended sediment load to seasonal variation in fresh water inflow and to tidal state (See attached Figure 6).

> *"The higher concentrations of suspended sediment (30 to 40 mg/l over ambient concentrations) in the incoming plume of flood water make it* [sediment plume] *easily visible. The turbid brown water assumes a lobate front that maintains its integrity as it moves to approximately 15 km (9.3 mi) south of the Bay Bridge. If it is assumed that in situ measurements which indicate a minimum thickness of about 2 m (6.6 ft), are representative throughout the area covered by the plume, the calculated volume is 120,000,000 cubic meters (4,240,000,000 cubic feet). Dye movement, monitored over a period of 2 h by a radar-tracked helicopter, showed that the plume front moved south at a rate of 125 cm/s (2.5 knots)."* (Carlson and McCulloch, 1974)

Smith (1987) identified net current patterns in the shallows and channels of the San Francisco Bay estuary called gravitational circulation. Gravitational circulation, induced by fresh water inflow from the rivers, is characterized by sediment-laden saline water of the bay bottom moving landward while less saline river water moves seaward near the surface. This results from density differences in the mixing waters, and is believed to increase the ebb tidal currents (seaward) near the water surface and the flood tidal currents (landward) near the bay bottom.

The implications of gravitational circulation near NAS Alameda are that the density driven bottom currents may contribute to the transport of sediment from the bay into deep dredged channels such as the Oakland Inner Harbor and the Navy's turning basin on the south side of NAS Alameda.

The Effects of Dredging on Sediment Transport in San Francisco Bay

In a study to evaluate the potential disposal requirements for dredging in the San Francisco Bay, the U.S. ACOE reported that approximately 10 million cubic yards of Bay sediment are dredged annually by the Federal Government and private concerns in the Bay system (U.S. ACOE, 1979). Regarding the fate of dredged and wave generated suspended sediments, U.S. ACOE reports:

> *"The majority of this material is released in Bay waters at one of three disposal sites. Assuming that these sites received dredged sediments over a 250-day period and that the material disperses over a 100-square mile are, 400 cubic yards of dredge material would be placed in suspension per square mile per day of dredging. In contrast, Krone estimated the amount of material suspended by wave action in a square mile of shallow area by conservatively using an average suspended sediment concentration of .5 grams per liter over five-foot water depth when the wind blows over 10 knots. Using the value of 220 days per year when the wind velocity is 10 knots or greater, Krone estimated that each square mile of shallow area suspends 2,200 tons of sediments per day. Using the value of 25 pounds per cubic foot for sediments brought into suspension by wind and wave forces, the 2,200 tons may be converted to cubic giving a total of 6,500 cubic yards per square mile per day as the volume of sediment resuspended by wind driven waves. Figure 11 is a summary of sedimentation in the San Francisco Bay system."* (U.S. ACOE, 1979) (Figure 11 is attached to this summary for reference.)

The U.S ACOE Waterways Experiment Station (WES) modeled the dispersion of dredged sediments that are disposed at existing in-Bay sites, and estimated that in all cases, the disposed sediment could migrate into "virtually every major sub-basin of the Estuary" (U.S. EPA, U.S. ACOE, San Francisco Bay Conservation and Development Commission, San Francisco Bay RWQCB, and California State Water Resources Control Board, 1996). In addition, U.S. ACOE conducted a tracer study in the mid-1970s and *"confirmed that as much as 10 percent of the sediments accumulating in the Mare Island Strait were in fact dredged material recirculated from the Carquinez disposal site (USACE 1976b)"* (U.S. EPA, U.S. ACOE, San Francisco Bay Conservation and Development Commission, San Francisco Bay RWQCB, and California State Water Resources Control Board, 1996).

The implications of these findings is that at locations around NAS Alameda, such as the Oakland Inner Harbor, the turning basin, and the beach to the east of the turning basin, could be accumulating previously dredged material that was discharged at an erosional in-Bay site. Further, it is possible that the sediment accumulating in such areas was exposed to pollutants from places other than NAS Alameda.

Oakland Inner Harbor - Sediment Transport and Deposition

The Oakland Inner Harbor area is situated in a boundary zone separating South Bay from Central Bay and is exposed to the circulation patterns peculiar to each. In the U. S. ACOE *Dredge Disposal Study, San Francisco Bay and Estuary* (U.S. ACOE 1979), generalized surface flow patterns during typical flood and ebb tidal conditions in this area are represented on a figure include with this summary for reference (Figure 40). Flood currents are southeast trending currents that generally move parallel to the eastern shore and then turn and flow in an easterly direction into the Oakland Inner Harbor navigation channel. Ebb currents move north through the same pass, drawing water out of the Oakland Inner Harbor. In this same report, it is stated that the flood current is predominately along the bottom of the channel, while the ebb current is predominately along the surface of the water. *"Normally, the bottom waters are heavily laden with suspended sediments which are brought into the navigation channels and deposited in these tranquil waters"* (U.S. ACOE 1979).

This report also states that

> *". . . sediments being deposited in the Outer and Inner Harbor navigation channels are derived in large part from sediments being resuspended elsewhere in the Bay system. Sediments of the Oakland Inner-Outer Harbor area are similar to those found elsewhere in San Francisco Bay. The sediment of the shallow periphery areas around Oakland are very similar to the sediments of Berkeley Flats. These sediments are a clayey silt and silt-sand-clay mixture. Sediment deposition occurs throughout the navigation channels, turning basins and berthing areas of the Oakland Inner-Outer Harbor area. Sediments settle to the bottom in low energy, quiescent portions of the channels. Areas highly susceptible to shoaling are situated around irregularities such as piers, jetties and breakwaters."* (U.S. ACOE 1979)

Western Bayside - Sediment Transport and Deposition or Erosion

In a study prepared for a 1992 Long Term Management Strategy (LTMS) for Bay area dredged material, net differences between high-resolution bathymetric surveys of San Francisco Bay were compared for two periods 35 years apart. This comparison identified large-scale areas of longer-term net deposition and erosion throughout San Francisco Bay; the shoreline bordering NAS Alameda was included in this study. Attached to this summary are Plates 6 and 7 showing the net erosional/depositional depths on the perimeter of NAS Alameda. The Western Bayside (western shore of NAS Alameda) shows net erosion ranging from 0 to 6 feet for most of its length; the northern portion (approximately 1,000 feet long) is an area where sediment deposition ranges from 0 to 1 foot (U.S. EPA, U.S. ACOE, San Francisco Bay Conservation and Development Commission, San Francisco Bay RWQCB, and California State Water Resources Control Board, 1996).

The net erosion of up to 6 feet of surface sediment along Western Bayside indicates that sampling sediment adjacent to Navy property may not effectively sample sediments that are related to current or past activities, because impacted sediments may have eroded.

Plates 6 and 7 show an area of deposition some distance from the shoreline. Yet, based on findings of other researchers discussed in this summary, it is not possible to conclude that the deposited sediments offshore of the Western Bayside are affected by activities at NAS Alameda. Net deposition in the offshore region of the Western Bayside may have migrated from other areas of the San Francisco Bay.

NAS Alameda Turning Basin - Sediment Deposition

The 1992 LTMS bathymetric surveys showed that the erosion occurring along the southern portion of the Western Bayside continues eastward along the southern coast of NAS Alameda nearly to the Runway Area wetlands (see Plates 6 and 7 from the LTMS). Also shown on these plates, is that further east (where the NAS Alameda turning basin is located), sediment deposition ranges from 1 to 3 feet. The Navy has, in the past, had to dredge this area on a regular basis to accommodate Navy ship traffic.

Other references presented in this summary support the fact that sedimentation occurs in the turning basin due to its quiescent environment. It is possible that density driven bottom currents push sediment-laden salt water into the turning basin area, as described by Smith (1987). Hence, the sediment found today in the turning basin and at the beach area were probably carried in from outside the NAS Alameda property.

Summary

The volume of sediment in runoff from the land surface of NAS Alameda is likely to be minimal compared to the volume deposited around the perimeter of NAS Alameda from other areas of the Bay due to current entrained transport as described in this summary. Using estimates of sediment load in runoff from industrial acreage and residential acreage of 1,500 and 2,050 pounds per acre per year, respectively (Corbitt 1989), and assuming 1,530 acres of Navy land, the greatest volume of sediment that could be deposited around NAS Alameda is 3.1 million pounds per year, or approximately 1,160 cubic yards per year. Clearly, this is much less sediment than that which was once dredged from the turning basin or Oakland Inner Harbor. Dredging around NAS Alameda has occurred since 1959. The average dredge volume from 1959 to 1992 was 670,300 cubic yards per year (U.S. Navy 1990).

The Navy's industrial activities have undoubtedly contributed some contamination to the Bay over the last 60 years through direct industrial wastewater discharges. Those wastewater discharges were released through outfalls that are underwater at high tide. The Navy impact on sediments can only be addressed qualitatively by attributing particular chemical usage at Navy activities on base to the types of contaminants found in the sediments near the outfalls.

The literature abounds with research indicating that sedimentation in quiescent areas, such as the Oakland Inner Harbor, turning basin, and the beach east of the turning basin, occurs as a result of current entrained sediment migrating in from the San Francisco Bay. Further, the literature indicates that sediments deposited in these areas of NAS Alameda have been exposed to pollutants in places other than NAS Alameda.

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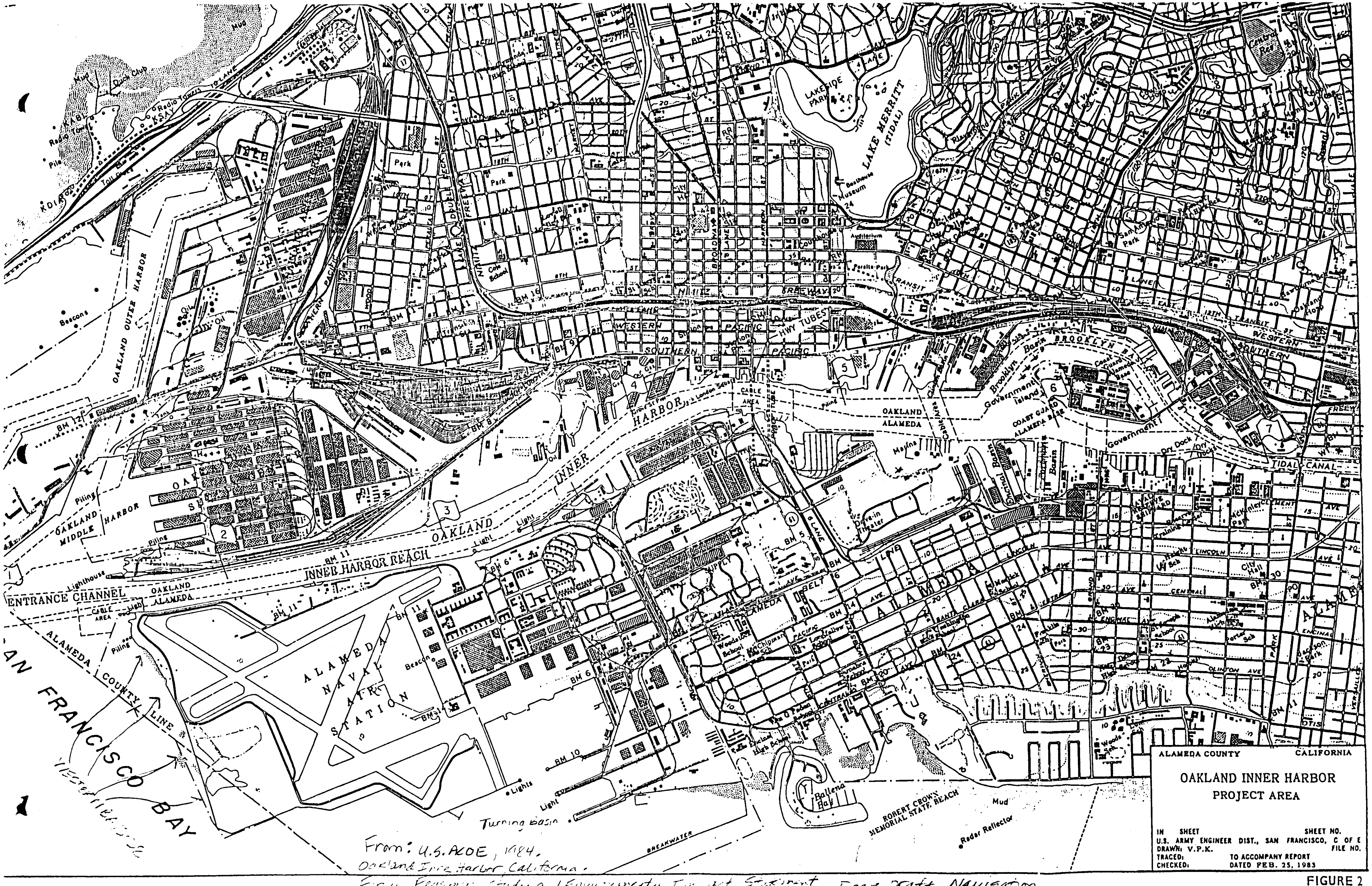
FIGURE

MAP SHOWING NAS ALAMEDA AND SURROUNDING WATER AREAS DISCUSSED IN THIS SUMMARY



Final Feasibility Study and Environmental Impact Statement Deep-Draft Navigation.

FIGURE 2

LIST OF REFERENCES FROM FINAL ENVIRONMENTAL IMPACT STATEMENT FOR PROPOSED NEW DREDGING

U.S. NAVY, 1990

FINAL ENVIRONMENTAL IMPACT STATEMENT FOR PROPOSED NEW DREDGING

U.S. NAVY MILITARY CONSTRUCTION PROJECTS: P-202 NAVAL AIR STATION ALAMEDA P-082 NAVAL SUPPLY CENTER OAKLAND

SAN FRANCISCO BAY, CALIFORNIA

AUGUST, 1990

Prepared by: United States Department of the Navy, Western Division Naval Facilities Engineering Command, Code 1833RH, P.O. Box 727, San Bruno, CA 94066-0720.

3.0 EXISTING ENVIRONMENT

This section describes the existing physical, biological, and socioeconomic environments of the dredging and potential disposal sites for the NAS Alameda and NSC Oakland projects. Existing data are used to provide the baseline descriptions of the sites.

3.1 PROPOSED DREDGING SITES

The Navy is proposing to dredge NAS Alameda and NSC Oakland to increase depths of berthing areas, turning basins, and entrance channels to allow the safe operation and maintenance of ocean-going vessels. Both of these dredging sites are located in Central San Francisco Bay in an area characterized by complex circulation and sedimentation processes. San Francisco Bay is an estuarine system where the fresh waters of the Sacramento and San Joaquin Rivers (the Delta) meet the saline water of the Pacific Ocean. The flows of the rivers, the tides, winds, and salinity gradients all affect the circulation patterns and sediment transport. The 1988 EAs stated that sediment quality at both dredging sites is similar to the quality of sediments found throughout the Central Bay (Environmental Science Associates, 1988a,b).

The NAS Alameda land area contains wetlands and associated biological resources. No undeveloped wetlands exist at NSC Oakland. The general marine areas around both NAS Alameda and NSC Oakland provide spawning areas for Pacific herring. Both bases have been extensively developed and contain structures such as buildings, piers, and maintenance facilities. Activities related to Navy operations are important to the local economy. The regional economy includes San Francisco and Oakland metropolitan area activities.

3.1.1 Physical Environment

3.1.1.1 Water Circulation and Sediment Transport

The San Francisco Bay estuarine system is geographically and hydrodynamically divided into three distinct regions: (1) the Delta, at the confluence of the Sacramento and San Joaquin River systems; (2) the northern reach of the Bay, which extends south and westward from the Delta through the broad and shallow Suisun and San Pablo Bays; and (3) the long shallow southern reach (also called the South Bay), which extends southeastward toward San Jose (Krone, 1979). The northern and southern reaches meet in the Central Bay. The two reaches exhibit distinctive characteristics of circulation and sedimentation, but their mutual boundary within the Central Bay is neither clearly delineated, nor agreed upon by researchers. The two proposed Navy dredging sites would be within this transition zone of complex and poorly defined circulation regimes.

Water movement within this central portion of the Bay is dominated by mixed and semidiurnal tidal flows. High annual riverine flows (three times the total Bay volume) from the Delta impose a seasonal variation on the daily tidal influence (Conomos and Peterson, 1977). Net daily displacements from peak spring flows can reach ten to 20 km (six to 12 mi) through the channels of the northern reach and Central Bay. Tidal excursions, on the other hand, typically average ten km (six mi). The net movement over a complete tidal cycle can be small, however, returning a parcel of water close to its starting point (Conomos, 1979).

Estuarine circulation, the result of less dense freshwater on the surface mixing with the more dense and saline ocean waters beneath, produces another type of nontidal current. These density-salinity driven currents move upstream along the bottom, carrying sediment into the deeper natural and dredged channels, as the less saline waters flow toward the ocean on the surface.

During spring and summer, daily onshore winds superimpose another circulation pattern on the oscillatory tidal flows. In the Central Bay, these predominantly westerly winds produce easterly flowing wind-drift currents that bring surface water carrying sediment to the eastern shores (Sustar, 1982).

Horizontal circulation and vertical mixing of water control .... transport of sediments and organic and inorganic particulate matter from both the rivers and the ocean. The combination of the various current sources and the generally shallow topography of the Bay system results in high turbidity. The various currents tend to keep sediments suspended, or deposit sediments in the

8.0 REFERENCES

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FIGURE 6

FROM CARLSON & MC CULLOCH

ADVANCE OF LOW SALINITY, HIGH TURBIDITY WATER INTO SOUTH SF BAY

Figure 4.—Turbulent front of low-salinity water (lighter color) advancing into south San Francisco Bay. The dark elongate patch (center) is rhodamine WT dye dropped from a helicopter about 20 min earlier. View from a helicopter at an altitude of 150 m (500 ft), May 6, 1969, looking west toward Army Street Pier, San Francisco. Photograph by G. E. Stoertz. (See Stoertz and others, 1970, for locations of dye drops.)

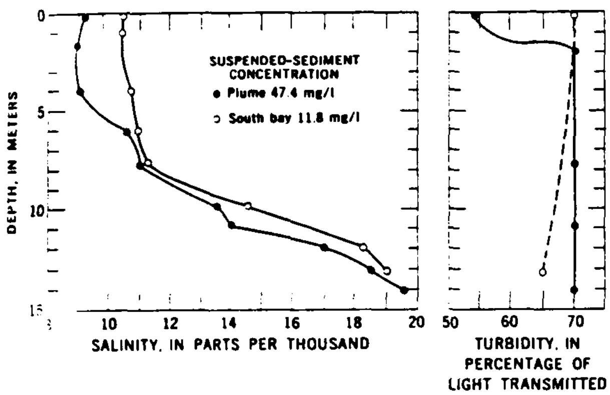

Figure 5.—Salinity, turbidity, and suspended-sediment concentration in front of and just behind the leading edge of the low-salinity, high-turbidity water plume shown in figure 3. Concentration of suspended sediment was measured from samples collected approximately 1 m below the water surface. Samples and measurements were taken January 27, 1970, at the same time in the tidal cycle as the aerial photograph (fig. 3).

Aerial observations (fig. 3) provide a basis for estimating the surface area covered by this turbid plume: the length was approximately 15 km (9.3 mi) and the width approximately 4 km (2.5 mi), a surface area of 60 km^2 (23.2 mi^2). If it is assumed that the in situ measurements (fig. 5), which indicate a minimum thickness of about 2 m (6.6 ft), are representative throughout the area covered by the plume, the calculated volume is 12×10^7 m^3 (424×10^7 ft^3).

Intermediate discharge conditions.

Discharge from the Sacramento–San Joaquin River system is high during the winter storm season and often remains relatively high during the spring snowmelt (March-June) (fig. 2). In May of 1969, the plume was tracked into the south bay to approximately 15 km (9.3 mi) south of the Bay Bridge (fig. 6). Also during May 1969, Rhodamine WT dye was dropped from a helicopter just behind the leading edge of the plume of low-salinity, high-turbidity water as it advanced into the south bay (Stoertz and others, 1970). Dye movement, monitored over a period of 2 h by a radar-tracked helicopter, showed that the plume front moved south at a rate of 125 cm/s (2.5 knots). The dye formed a circular patch upon impact with the water and quickly became elongate parallel to the flow of water toward the front of the plume (fig. 4), suggesting a flow of water within the plume toward the plume front. The water must then roll under as the plume overrides the south bay water.

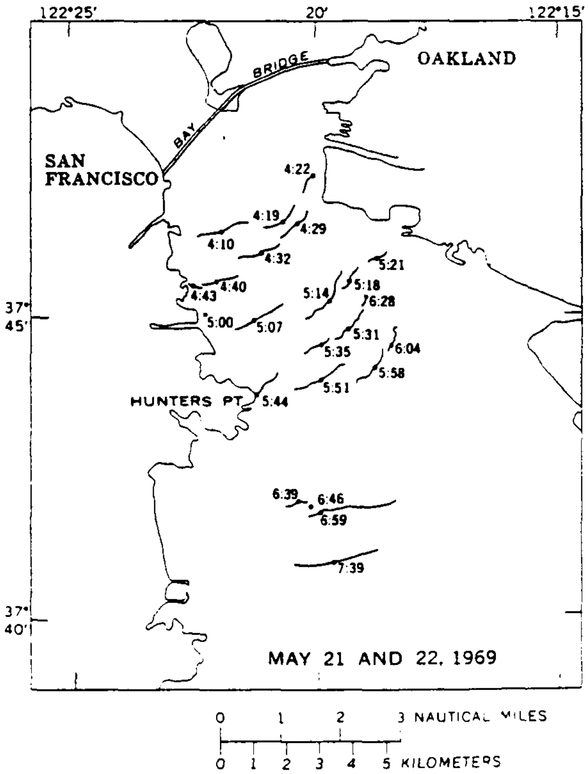

Figure 6.—Advance of low-salinity, high-turbidity water into south San Francisco Bay (average speed 100 cm/s or 2 knots). Dots, actual locations occupied by the vessel; positions determined by radar. Lines extending from dots, front of plume visible from bridge of vessel. Times for each location, hours and minutes after maximum ebb at the Golden Gate. Positions marked 4:10 through 6:59 occupied May 21, 1969, and position marked 7:39 occupied May 22, 1969.

FIGURES

FROM SMITH, 1987.

OCEAN - RIVER MIXING ZONE

CHARACTERISTIC SCALES OF CIRCULATION AND MIXING FOR SAN FRANCISCO BAY

Ocean-River Mixing Zone

A broad view of San Francisco Bay is as a body of water (fig. 1) in which ocean water is mixed landward and river water is mixed seaward, with a seaward flow equal to the sum of river inflows less evaporation. The characteristics of this mixing process are determined by the exchange process between the bay and the local coastal ocean and by the pattern of river inflows, as well as by circulation and mixing processes in the bay. Over a period of a few months these external and internal influences affect the entire bay (table 1), whereas tides and local bathymetry dominate within the bay for periods less than a few days. Any understanding of circulation and mixing within the bay requires description of these external influences over periods of a few days to a few months.

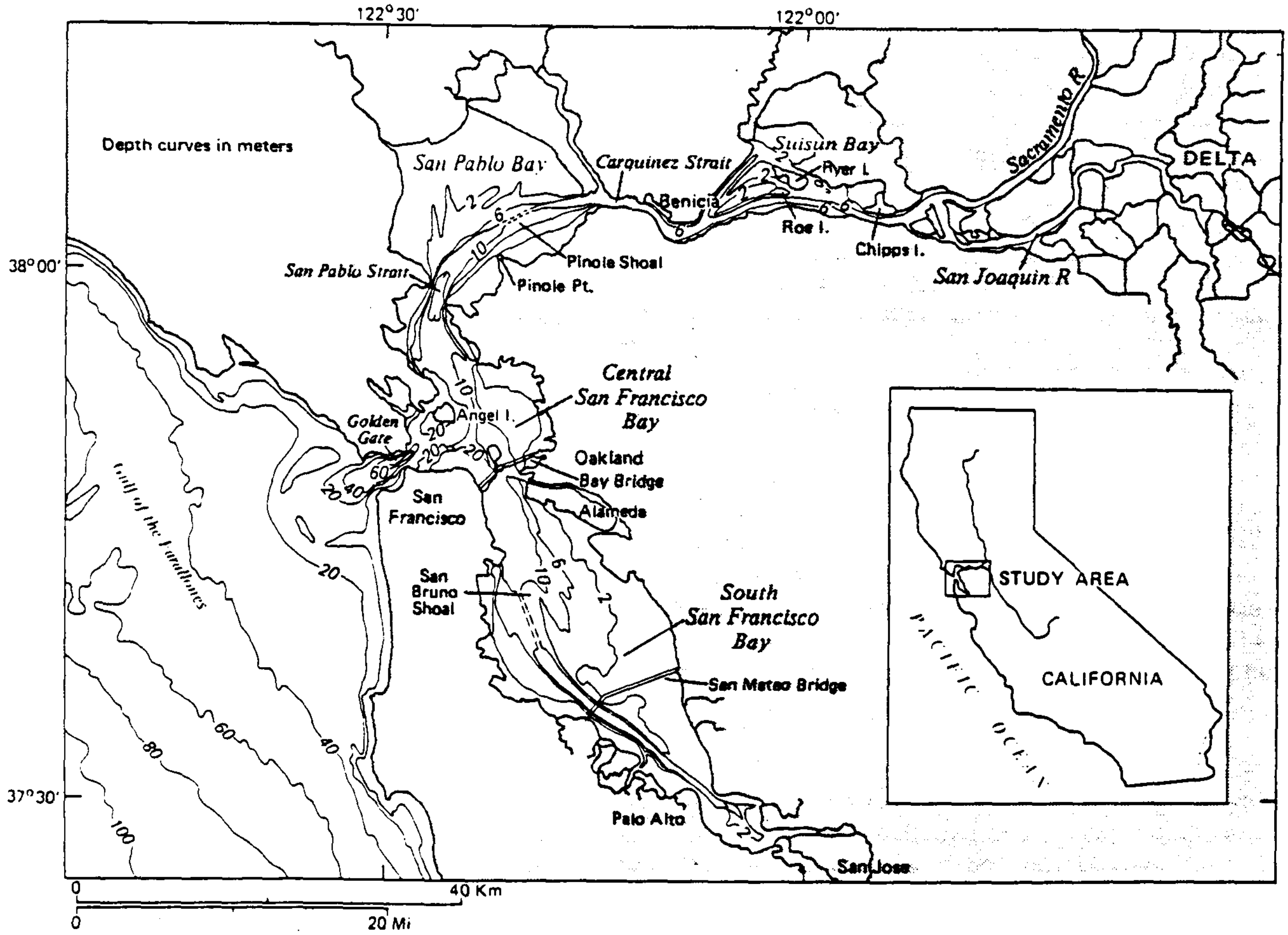

FIGURE 1.--Map of the San Francisco Bay region showing the adjacent coastal ocean and a portion of the Sacramento-San Joaquin Delta. Locations of place names mentioned in the text are shown. Depth contours shown are in meters.

 From: Smith, 1987.

Gravitational Circulation

In addition to inducing net seaward flow, freshwater inflows induce a net current pattern in the channels called gravitational circulation (fig. 3c). By gravitational circulation is meant a pattern of flow that in the mean is landward at the bay bottom and seaward at the water surface. It results from a significant difference in salinities in the landward-seaward direction, which enlarges ebb currents near the surface and flood currents near the bottom, and reduces ebb currents near the bottom and flood currents near the surface (fig. 7). The net result is a mean current that is seaward at the surface and landward at the bottom, and that is usually a small fraction of the tidal currents. Enhanced vertical mixing during spring tides weakens gravitational circulation in San Francisco Bay (Walters and others, 1985).

The magnitude of inflows determines how far landward the gravitational circulation mechanism penetrates. The most landward zone of gravitational circulation (fig. 7), where bottom ebb and flood velocities are approximately equal, is called the non-tidal current null zone (Peterson and others, 1975), and has been shown to accumulate high concentrations of plankton (Arthur and Ball, 1979).

Wind-Induced Currents

Wind-induced currents contribute to circulation and mixing in two major ways. First, the strong winds that occur daily during the summer and during the passage of winter storms have a pronounced effect in the shallows on resuspension of sediments and mixing of shallow water masses (Conomos and others, 1985). Second, persistent winds drive surface currents and compensatory counter-currents deep in the channels (Walters, 1982; Walters and others, 1985; Cheng and Gartner, 1985). These two effects are superimposed on the tide-induced currents and on gravitational circulation.

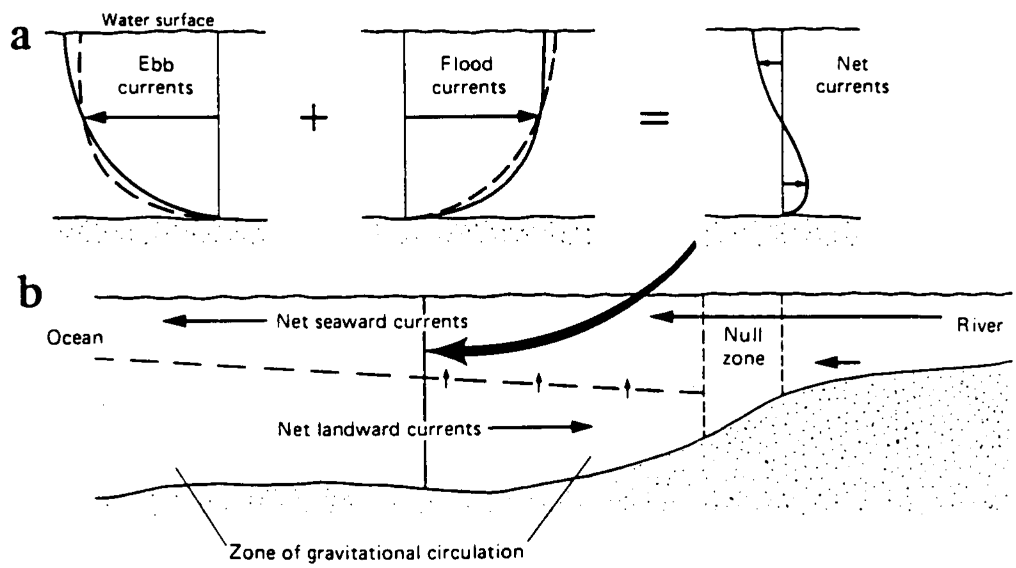

FIGURE 7.--(a) Idealized vertical profiles of tidal currents showing the effect of horizontal salinity differences (dashed profiles without salinity differences) that lead to a net current that is seaward at the surface and landward at the bottom (gravitational circulation), and (b) a landward-seaward section of an idealized estuary channel showing the spatial pattern of gravitational circulation and the nontidal current null zone.

FIGURES 1 and 7

FROM SMITH, 1987.

OCEAN - RIVER MIXING ZONE

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FIGURES 1 AND 7

OCEAN – RIVER MIXING ZONE

SUMMARY RESULTS OF THE EVALUATION OF SEDIMENT TRANSPORT, EROSION, AND DEPOSITION IN SAN FRANCISCO BAY

THE ABOVE IDENTIFIED FIGURES ARE NOT AVAILABLE.

EXTENSIVE RESEARCH WAS PERFORMED BY NAVFAC SOUTHWEST TO LOCATE THESE FIGURES. THIS PAGE HAS BEEN INSERTED AS A PLACEHOLDER AND WILL BE REPLACED SHOULD THE MISSING ITEMS BE LOCATED.

QUESTIONS MAY BE DIRECTED TO:

DIANE C. SILVA
RECORDS MANAGEMENT SPECIALIST
NAVAL FACILITIES ENGINEERING COMMAND SOUTHWEST
1220 PACIFIC HIGHWAY
SAN DIEGO, CA 92132

TELEPHONE: (619) 532-3676

FIGURES 11 and 40, AND REFERENCE LIST

FROM U.S. ACOE
DREDGE DISPOSAL STUDY

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DREDGE DISPOSAL STUDY

SAN FRANCISCO BAY AND ESTUARY

APPENDIX B

POLLUTANT DISTRIBUTION

MAY 1979

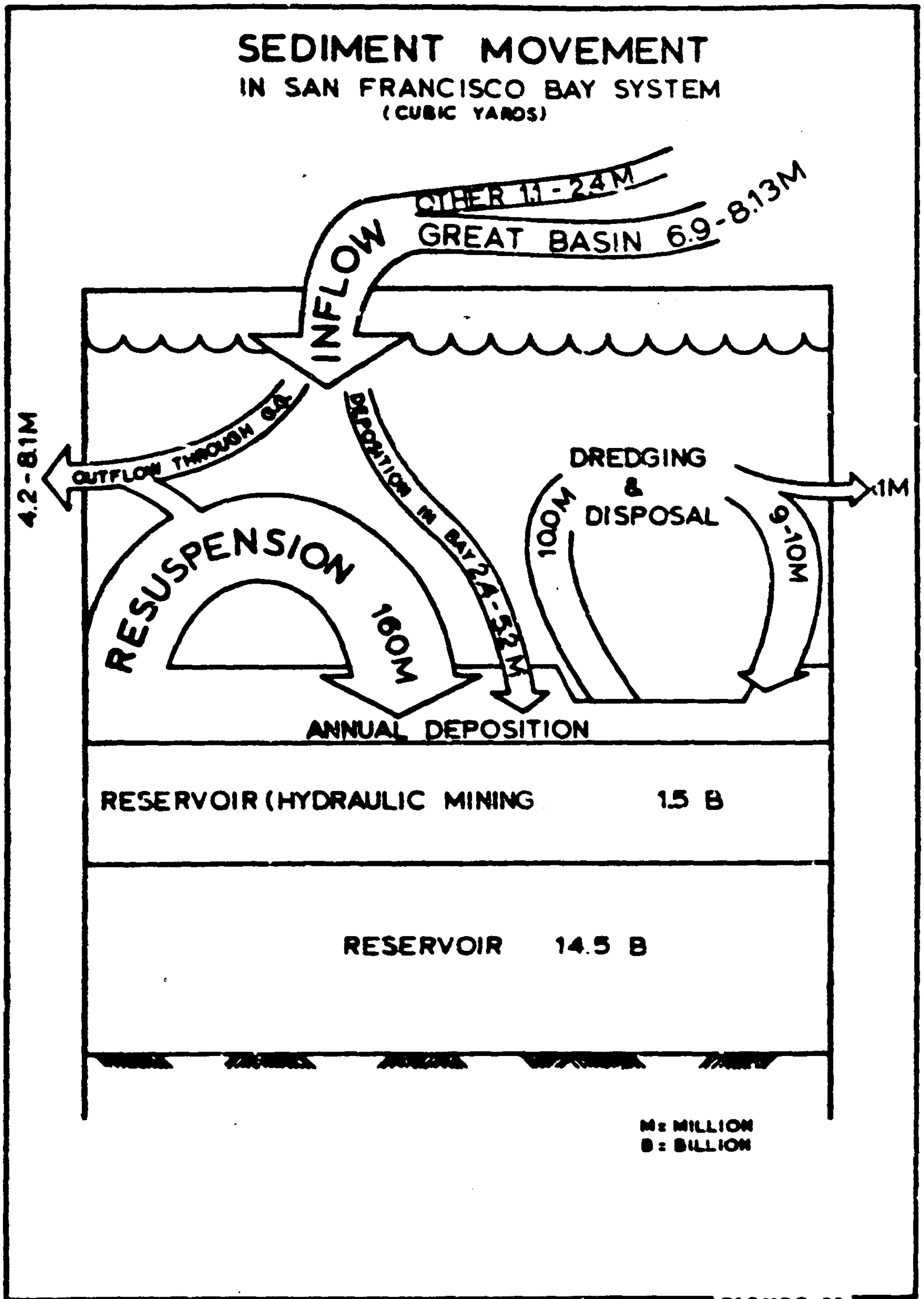
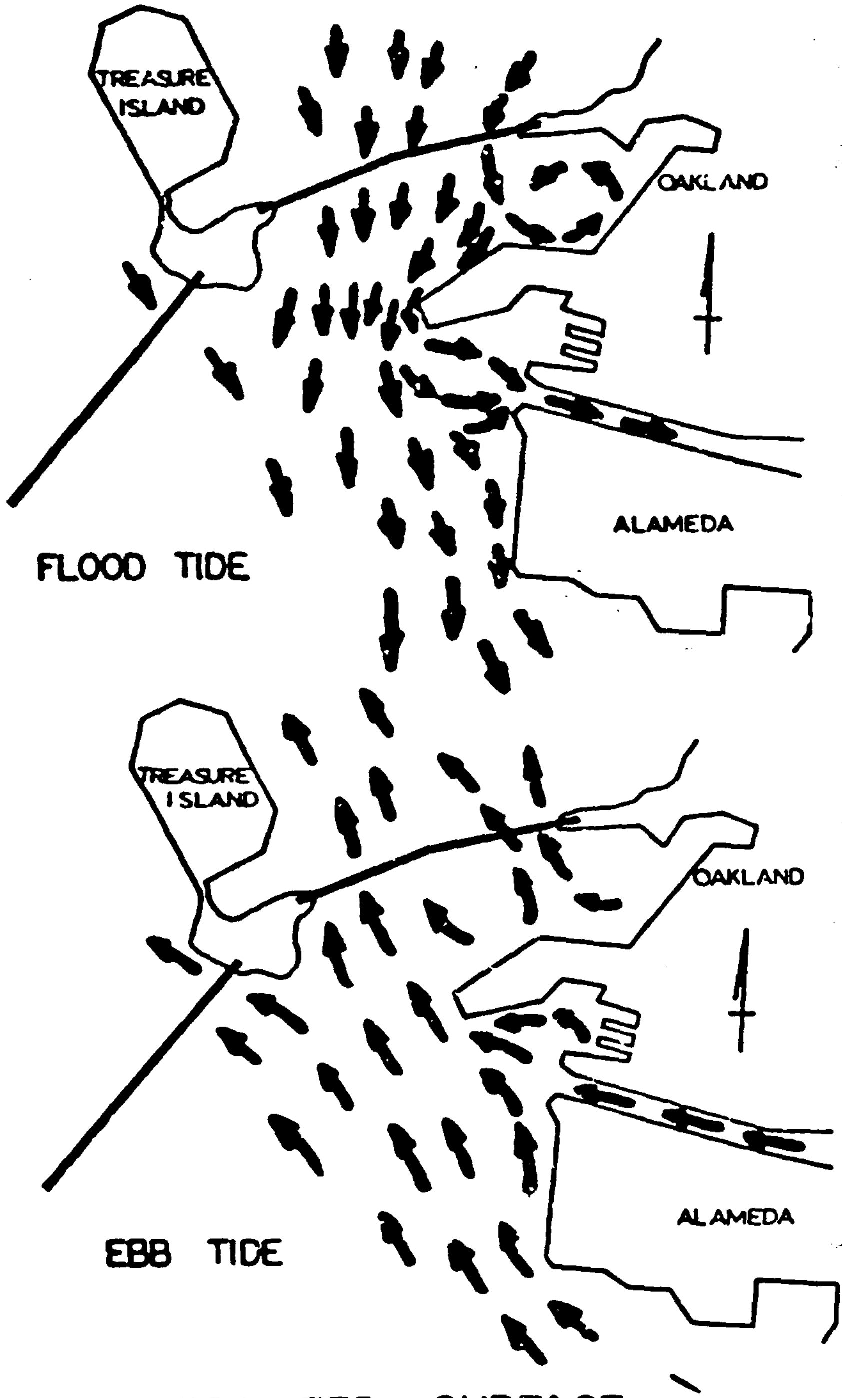


FIGURE 11

From: U.S. ACOE, 1979. Dredge Disposal Study for San Francisco Bay and Estuary



GENERALIZED SURFACE FLOW PATTERNS

FIGURE 40

From: Dredge Disposal Study, ~~San Francisco~~ Bay and Estuary, Appendix B. ACOE 1979

From: Dredge Disposal Study
SF Bay and Estuary
Appendix B
ACOE.

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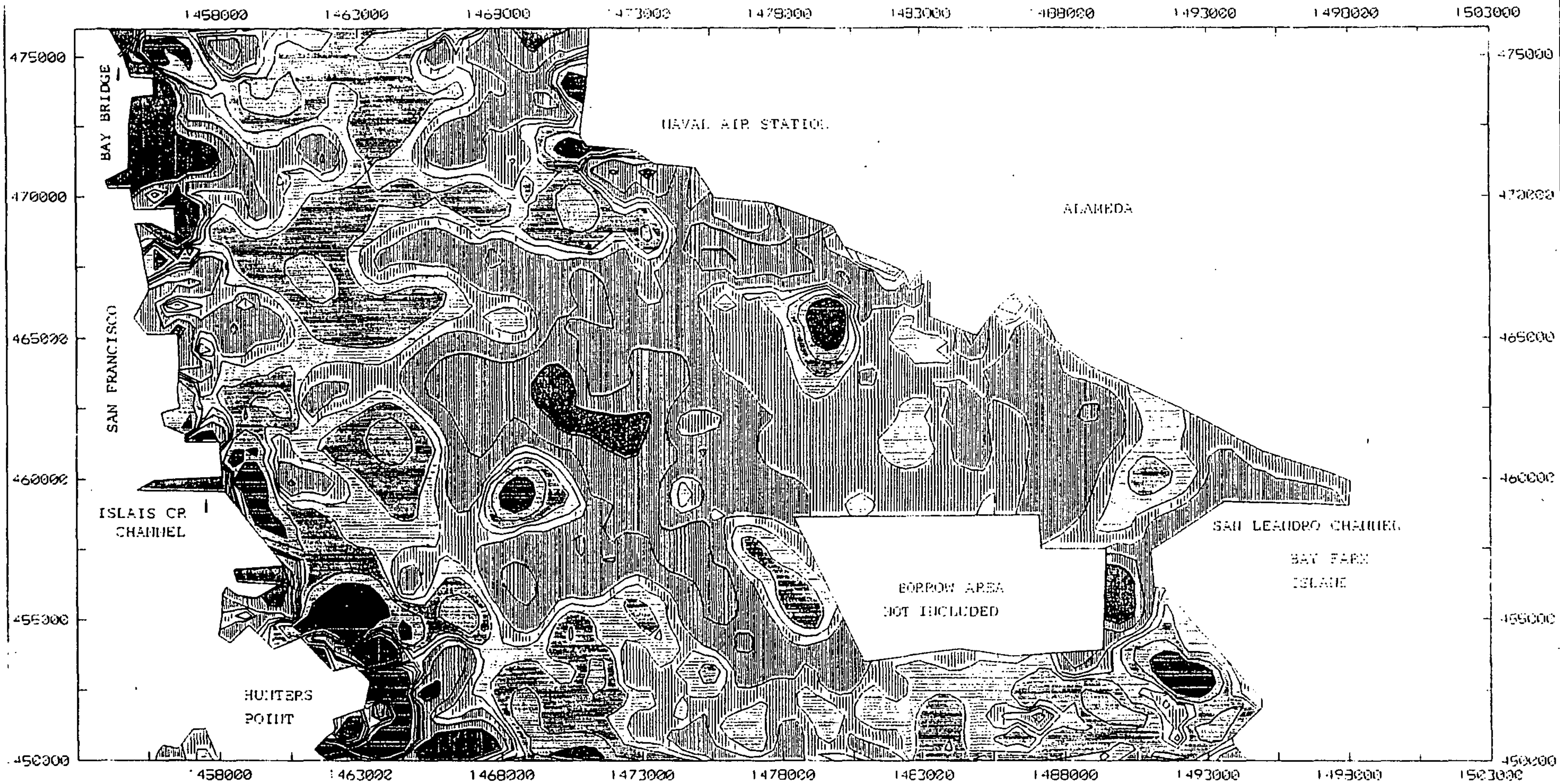
PLATES 6 AND 7

FROM LTMS, 1996

EROSION AND DEPOSITION AROUND NAS ALAMEDA

NORTH BAY 1955/1990 - Section 'A'



LEGEND

ACCRETION		EROSION	
0' TO 1'	3' TO 6'	0' TO -1'	-3' TO -6'
1' TO 3'	>6'	-1' TO -3'	<-6'

NORTH

SCALE IN FEET
0 5000 10000

PLATE 6

NORTH BAY 1955/1990 - Section 'B'

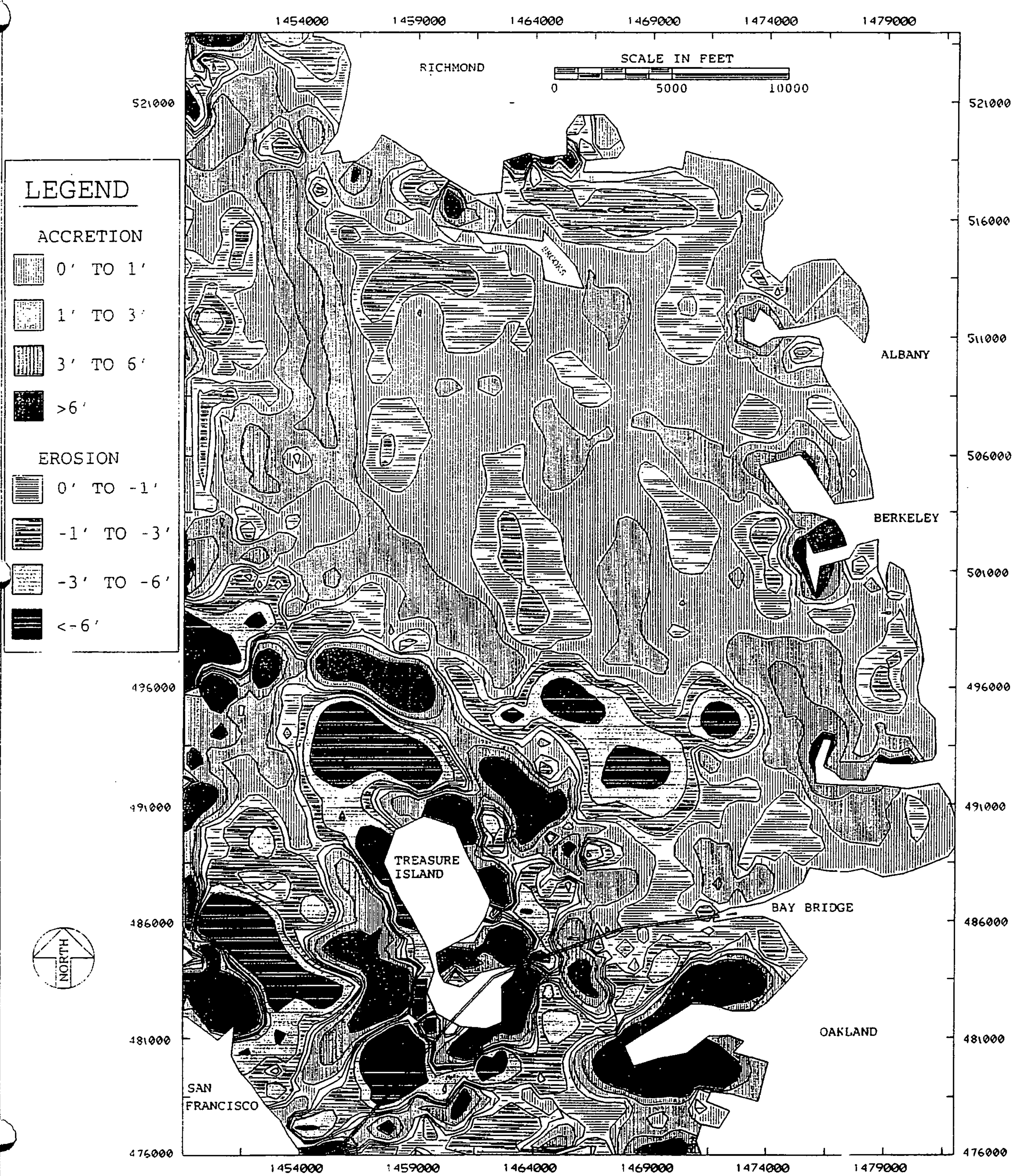


PLATE 7