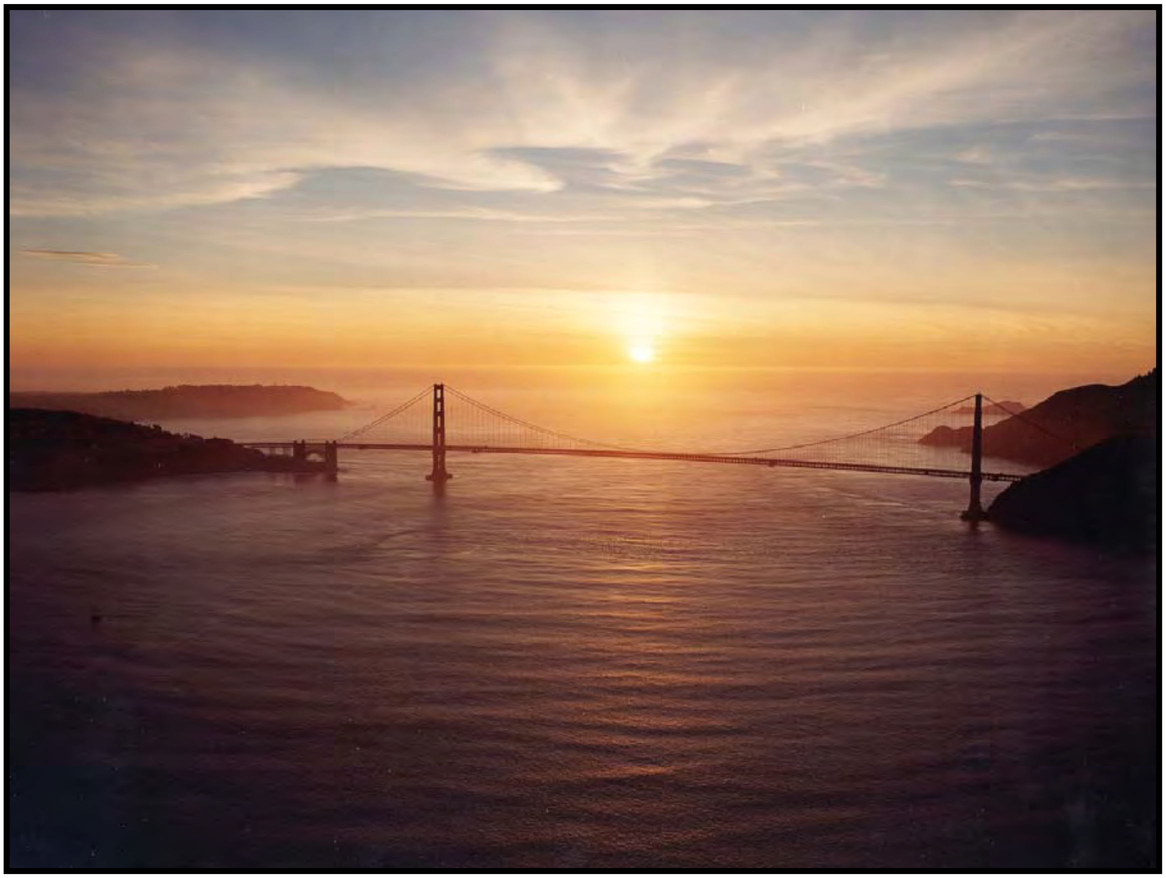
Programmatic Essential Fish Habitat (EFH) Assessment for the Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region



July 2009

US Army Corps of Engineers
San Francisco District

AR 0028384

Executive Summary

Programmatic Essential Fish Habitat (EFH) Assessment for the Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region

Pursuant to section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (16 U.S.C. §1855(b)), the United States Army Corps of Engineers (USACE) and the United States Environmental Protection Agency (USEPA), as the federal lead and co-lead agencies, respectively, submit this Programmatic Essential Fish Habitat (EFH) Assessment for the Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region. This document provides an assessment of the potential effects of the on-going dredging and dredged material placement activities of all federal and non-federal maintenance dredging projects in the action area (see Figure 1.1 located on page 3).

The SF Bay LTMS program area spans 11 counties, including: Marin, Sonoma, Napa, Solano, Sacramento, San Joaquin, Contra Costa, Alameda, Santa Clara, San Mateo and San Francisco counties. It does not include the mountainous or inland areas far removed from navigable waters. The geographic scope of potential impacts included in this consultation (action area) comprises the estuarine waters of the San Francisco Bay region, portions of the Sacramento-San Joaquin Delta (Delta) west of Sherman Island and the western portion of the Port of Sacramento and Port of Stockton deep water ship channels. It also includes the wetlands and shallow intertidal areas that form a margin around the Estuary and the tidal portions of its tributaries. Lastly, it includes the San Francisco Deep Ocean Disposal Site (SF-DODS), the San Francisco Bar Channel Disposal Site (SF-8) and the nearshore zone off Ocean Beach, as well as the waters that are used by vessels en route to these sites.

Within the action area, there are at least 13 federal (maintained by USACE), 105 non-federal maintenance dredging projects, four in-Bay disposal sites (SF-9, SF-10, SF-11 and SF-16), two ocean disposal sites SF-8 and SF-DODS, several beneficial use wetland restoration sites (the on-going Hamilton Wetland Restoration Project, Montezuma Wetlands and Bair Island), and privately-used beneficial use and upland sites.

The San Francisco Bay Long Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region (SF Bay LTMS) was formed in the early 1990s in response to the public's growing concern over the potential direct, indirect and cumulative effects of dredging and dredged material disposal activities on the already stressed resources of the San Francisco Bay/Estuary (Bay or Estuary). The 50-year SF Bay LTMS program is comprised of state and federal regulatory agencies with primary authority to review and permit dredging and dredged material disposal activities in the San Francisco Bay area. Partnering agencies include: United States Army Corps of Engineers (USACE), United States Environmental Protection Agency (USEPA), San

Francisco Bay Regional Water Resources Control Board (SFBRWRCB), State Water Resources Control Board (SWRCB), San Francisco Bay Conservation and Development Commission (BCDC) and State Lands Commission (SLC).

Formal implementation of the SF Bay LTMS began in 2001 with the adoption of the *Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region Management Plan* (LTMS Management Plan). The LTMS Management Plan was proceeded by an extensive eight-year federal and state planning effort which culminated in the *Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region Final Environmental Impact Statement/Environmental Impact Report* (EIS/EIR), finalized in October 1998. The SF Bay LTMS EIS/EIR and subsequent Management Plan called for reversing the historic practice of disposing 80 percent or more of all material dredged from the Estuary at in-Bay disposal sites and requires that at least 80 percent of all dredged material be placed at beneficial use sites, upland or at ocean disposal sites, with only limited volumes of material being placed at in-Bay disposal sites. Over the life of the SF Bay LTMS, the selected alternative aims to:

- Maintain in an economically and environmentally sound manner those channels necessary for navigation in San Francisco Bay and eliminate unnecessary dredging activities.
- Conduct dredged material disposal in the most environmentally sound manner.
- Maximize the use of dredged material as a resource.
- Maintain the cooperative permitting framework for dredging and disposal applications.

Prior to implementation of the SF Bay LTMS, an average of 6.0 million cubic yards of material dredged from the Estuary was placed back in Estuary at four in-Bay disposal sites. Since the SF Bay LTMS Management Plan was implemented in 2001, allowable in-Bay disposal has significantly decreased: from pre-LTMS quantities of over 6.0 million cubic yards per year to current quantities of less than 2.0 million cubic yards per year. Additionally, reductions will automatically occur in 2010 and 2013, until the final in-Bay disposal limit of 1.25 million cubic yards per year is reached. The reduction of in-Bay disposal to date is remarkable; but, even more important is the SF Bay LTMS goal to increase beneficial use of dredged material. Beneficial use of dredged material has been a success in restoring several important wetland ecosystems surrounding the Estuary, including Sonoma Baylands, Montezuma Wetlands, and the ongoing Hamilton Wetlands Restoration Project. These three projects alone total approximately 3,000 acres of restored and enhanced habitat that benefits all fish and wildlife species that depend on the Estuary. Further, these restoration sites provide a dredged material beneficial use capacity of approximately 27.5 million cubic yards. Other smaller beneficial use projects are currently being constructed and the SF Bay LTMS continues to look for beneficial use opportunities.

At times, beneficial use is not possible. When this occurs, rather than being disposed of in the Estuary, some dredged material is diverted to the environmentally superior SF-

DODS site. Since the 1995 designation of SF-DODS as a deep open ocean aquatic disposal site, approximately 15 million cubic yards of dredged material has been disposed there. This has significantly reduced and eliminated some of the effects of aquatic dredged material disposal on the Estuary's water and sediment quality, as well as direct effects (e.g., burial, abrasion, adhesion of particles to eggs) and indirect effects (e.g., ingestion of constituents of concern, bioaccumulation, reduced fitness) of disposal and subsequent increases in suspended sediment concentrations on aquatic organisms.

Most of the effects of dredging and dredging material placement are temporary and localized and, with the exception of impacts associated with a changed bottom topography (potential changes in local hydrodynamics and in the makeup of the benthic resources present in the dredged area), the impacts end when dredging ends. The most substantial impacts tend to be on water quality – the potential for resuspension of constituents of concern buried in the sediments – and the impacts on biological resources in the dredged and dredged material disposal areas.

Although there are adverse impacts associated with dredging and dredged material disposal, as presented in Section 8.0 of the attached EFH Assessment and summarized in Table 1.0 (below), it is clear that the SF Bay LTMS has brought about major improvements in the management of dredging and dredged material disposal in the San Francisco Bay area. These improvements have directly benefited EFH and EFH-managed species, as well as the overall ecosystem of the Estuary. Not only is the SF Bay LTMS directly responsible for improving the management of dredging and dredged material disposal; they are responsible for several other accomplishments that directly and indirectly benefit EFH, EFH-managed species and the Estuary, including:

- Expansion of the Hamilton Wetlands Restoration Project with the Bel Marin Keys "Unit V" property will increase established tidal wetlands restoration capacity to approximately 5,000 acres and 45 million cubic yards of dredged material.
- Subtidal aquatic habitat was enhanced in Oakland Middle Harbor through beneficial use of approximately 6 million cubic yards of dredged material.
- The Montezuma Project can accept some contaminated dredged material for capping and, therefore, removes some constituents of concern from the Estuary while also restoring habitat.
- A variety of other small or private beneficial use projects have occurred in the last several years.
- Environmental work windows for dredging and dredged material disposal activities were established to reduce the potential adverse effects on sensitive species. With assistance from NOAA-Fisheries, USFWS and California Department of Fish and Game, advanced planning has significantly reduced the amount of dredging conducted outside of the environmental work windows. In 2008, the inter-agency advanced planning resulted in only 10 percent of all Bay area dredging being conducted outside the environmental work windows.
- Environmental work windows continue to be refined through SF Bay LTMS funded studies, such as the *Juvenile Salmonid Outmigration and Distribution Study in the San Francisco Bay*.

- The SF Bay LTMS has an ongoing program to fund studies that will help increase scientific knowledge about the potential impacts of dredging and dredged material placement. This knowledge will help support regulatory guidance for dredging projects in the Estuary. To date, the SF Bay LTMS has provided over $7 million in funding to support a number of studies (including, but not limited to: *Framework for Assessment of Potential Effects of Dredging on Sensitive Fish Species in San Francisco Bay*; *Mercury Concentrations Bordering the Hamilton Airfield Remediation Site* [October 2002 and September 2003], *Assessment of Sediment Resuspension by Vessel Traffic at Richmond Longwharf/Characterization of Sediment Plumes during Knockdown Operations at Redwood City* [February 2005], *Mercury Cycle Studies Associated with the Hamilton Wetland Restoration Project*; *Pre-construction Biogeochemical Analysis of Mercury in Wetlands Bordering the Hamilton Airfield Wetlands Restoration Site – Interim Report*]September 2005], and *A Review of Scientific Information on the Effects of Suspended Sediment on Pacific Herring (Clupea pallasie) Reproductive Success – Final Report* [April 2005])

Through implementation of the SF Bay LTMS program, the risks to and effects on EFH and EFH-managed species resulting from dredging and dredged material disposal have been significantly reduced. In addition, substantial aquatic habitat restoration and enhancement has occurred throughout the Estuary. Over the life of the SF-Bay LTMS, reducing in-Bay disposal has the potential to improve the Estuary's overall water quality and benthic communities within and around dredging and disposal sites. Furthermore, utilizing dredged material for beneficial use projects has the potential to improve water quality as wetlands constructed or restored around the Estuary and its tributaries would filter pollutants out of the water. Based on the information provided in this document, the SF Bay LTMS agencies believe that the overall benefits of the program to EFH and EFH-manages species far outweigh the potential adverse effects of pre-SF Bay LTMS maintenance dredging and disposal activities, and that these benefits will continue over the coming years.

Table 1.0	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	Direct Effects		
8.1 - Direct Effects on EFH and EFH-Managed Species	• Direct removal (entrainment) of EFH and EFH-managed species during dredging.	**BMP 1.0** - Environmental Work Windows. **BMP 2.0** - Lower Hydraulic Dredge Heads. **BMP 2.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
	Water Quality		
8.2.1.3 - Potential Direct Effects of Suspended Sediment on EFH and EFH-Managed Species	***Adults and Juveniles:*** • Impair oxygen exchange rates. • Clogging and laceration of gills. • Increased coughing rates. • Avoidance of turbid areas. • Reduced spawning success. ***Eggs and Larvae:*** • Decreased gonad maturation. • Lack of adhesion of eggs to substrate. • Reduced egg viability. • Reduced hatching success. • Smothering of eggs. • Reduced larval feeding.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.1.4 - Potential Effects of Suspended Sediment on Foraging and Foraging	• Reduced ability of visual feeders to find food. • Reduced prey abundance (benthos and	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.

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Grounds	planktonic organisms) at dredging and aquatic disposal sites.	**BMP 4.0** - Limit Overflow Dredging.	
8.2.1.5 - Potential Effects of Suspended Sediment on Migration and Migratory Corridors	• Temporary blockage of safe passage to spawning grounds which cold inhibit or delay migration. • Reduction in cover/shelter during migration. • Reduced ability to feed during migration.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.1.6 - Potential Effects of Suspended Sediment on Spawning and Spawning Grounds	• Reduced egg survival (discussed in impact 8.2.1.3). • Reduce spawning success. • Reduce the quality and/or quantity of spawning ground within the Estuary and dredged tributaries.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.1.7 - Potential Effects of Suspended Sediment on Nursery Habitat of EFH-Managed Species	• Reduce the quality and/or quantity of nursery habitat critical for spawning success.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.2.3 - Potential Effects of Releasing Constituents of Concern on EFH-Managed Species	• Constituents of concern can become bioavailable and directly absorbed by EFH-managed species leading to direct mortality, reduced fitness, reduced fecundity and/or bioaccumulation.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.

Table 1.0	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	• Reduce the quality and/or quantity of prey (e.g., phytoplankton, zooplankton, benthic organisms and other fish prey).		
8.2.3 - Decreased Dissolved Oxygen	• Exposure of anoxic sediments (which contain oxygen-demanding substances) could temporarily reduce dissolved oxygen levels in dredged and dredged material disposal sites. • Reduced dissolved oxygen has the potential to reduce the fitness of EFH-managed species (should dissolved oxygen levels fall below 5.0 mg/l).	**BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.4 - Saltwater Intrusion	• Because the projects managed under the SF Bay LTMS are maintenance dredging projects, saltwater intrusion is not expected to occur with continued implementation of the SF Bay LTMS and maintenance dredging of the projects managed by the LTMS.	No BMPs or MMs proposed.	Not likely to substantially affect.
8.2.5 - Potential Effects on pH	• Continued implementation of the SF Bay LTMS and maintenance dredging of the projects managed by the LTMS are not expected to affect pH.	No BMPs or MMs proposed.	Not likely to substantially affect.
8.4.6 - Un-Ionized Ammonia Disturbance	• Continued implementation of the SF Bay LTMS and maintenance dredging	No BMPs or MMs proposed.	Not likely to substantially affect.

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	of the projects managed by the LTMS are not expected to affect pH.		
8.4.7 - Potential Cumulative Effects on Water Quality	• Dredging and aquatic dredged material disposal activities are known to temporarily degrade water quality and, generally, these impacts subside once the dredging activities cease. However, the purpose of the SF Bay LTMS is to manage dredging and dredged material disposal activities within the Estuary in such a way to minimize the potential adverse effects on water quality and aquatic resources. Further, BMPs already implemented by the SF Bay LTMS help protect water quality from the adverse effects of dredging and aquatic dredged material disposal.	No BMPs or MMs proposed.	Beneficial
Sediments			
8.3.1 - Potential Effects on Sediment Dynamics (Circulation, Currents and Bathymetry)	• Dredging and dredged material disposal can alter the bathymetry of the Estuary's floor in the immediate surrounding of dredging and dredged material disposal activities. Dredging can affect bathymetry by deepening	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.

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	areas of the Estuary and disposal can cause temporary mounding at in-Bay disposal sites (in-Bay disposal sites are managed to be dispersive; thus, any mounding is expected to be temporary). • Alterations to bathymetry can alter benthic communities and, therefore, EFH-managed species prey.		
8.3.2 - Potential for Accumulation of Constituents of Concern	• Disposal of dredged sediment has the potential to accumulate constituents of concern at in-Bay dredged material disposal sites. However, all in-Bay disposal sites are managed to be fully dispersive; therefore, it is unlikely that accumulation would occur. • Constituents of concern are often bound tightly to sediment particles and do not easily become dissociated and bioavailable.	**BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.3.3 - Potential for Cumulative Effects on Sediments	• Cumulative changes in bathymetry could alter benthic habitat and species composition. • Continued reduction in in-Bay disposal could result in small-scale changes in sediment cycling and	No BMPs or MMs proposed.	May affect, but not likely to substantially affect.

Table 1.0	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	possible erosion over time.		
	Biological Resources		
8.4.1 - Potential Effects on Phytoplankton and Zooplankton	• Dredging and dredged material sediment plumes can alter habitat in which phytoplankton and zooplankton grow. • Increased turbidity could reduce light penetration required for phytoplankton and zooplankton photosynthesis.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.4.2 - Potential Effects on Benthos	• Direct removal of benthic habitat and organisms during dredging. • Burial of benthic habitat and organisms during dredged material disposal. • Increased suspended sediment concentrations could adversely affect benthic organisms. • Reduced fitness due to potential release of constituents of concern.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.4.3 - Potential Effects on Eelgrass Bed Habitat	• Direct removal of eelgrass beds during dredging. • Siltation of eelgrass beds during dredging and dredged material disposal.	**BMP 1.0** - Environmental Work Windows.	May affect, but not likely to substantially affect.

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Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
8.4.4 - Potential Effects on Oyster Bed Habitat	• Effects related to increased suspended sediment, including: reduced ability to filter feed, clogging of gills, inability of eggs to adhere to substances and increased tissue concentrations of constituents of concern. Most of these potential effects would occur in the South Bay.	No BMPs or MMs proposed.	May affect, but not likely to substantially affect.
8.4.5 - Removal of EFH-Managed Species Resting and Foraging Habitat	• Dredging can directly remove foraging habitat and prey species. • Aquatic dredged material disposal could bury foraging habitat. • Dredging and dredged material disposal could reduce the fitness of prey species. • Increased suspended sediment generated by dredging activities could reduce the ability of visual feeders to locate prey.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.4.6.1 - Potential Cumulative Effects on Benthos	• Repeated removal of recolonized benthic communities resulting from repeated maintenance dredging episodes. • Repeated burial of recolonized benthic communities resulting from repeated in-Bay dredged material disposal	**BMP 1.0 -** Environmental Work Windows. **BMP 3.0 -** Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.

Table 1.0	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	activities. • Additional deepening projects and/or designation of another in-Bay disposal site could exacerbate these effects.		
8.4.6.2 - Potential Cumulative Effects on Eelgrass Bed Habitat	• During the life of the LTMS, eelgrass beds could be further degraded because several dredging projects exist along the periphery of the Estuary in close proximity to eelgrass meadows; however, current regulations mitigation of eelgrass removal. • Dredging and in-Bay disposal of maintenance dredged material can increase suspended sediment loads causing siltation of eelgrass beds and reducing light penetration in the water column. • Maintenance and new work dredging projects, as well as other projects that shade or fill the shallow margins of the Estuary could cumulatively affect eelgrass bed habitat or hamper eelgrass bed growth. It is expected that these effects would be exacerbated by new work dredging	Mitigation measures on new work dredging projects should occur on a case-by-case basis during project-specific EFH consultations.	May affect, but not likely to substantially affect.

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Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	projects.		
8.4.6.3 - Potential Cumulative Effects of Bioaccumulation of Constituents of Concern	• Over time, disposal of dredged material has the potential to bioaccumulate constituents of concern up the food chain. However, rigorous screening and monitoring is required prior to dredging and dredged material disposal.	**BMP 3.0 -** Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.4.6.4 - Potential Indirect Effects Related to Invasive Species	• Deep-draft ocean-going vessels are known to transport invasive species between aquatic environments, generally in ballast waters. California law mandates that ballast water be exchanged outside the EEZ to flush potential invasive organisms. • This SF Bay LTMS EFH Assessment is for maintenance dredging projects only. Maintenance dredging disturbs areas that are continually disturbed due to maintenance dredging and vessel traffic.	No BMPs or MMs proposed.	May affect, but not likely to substantially affect.
8.5 - Potential Effects of Dredged Material Disposal on Aquatic Resources at SF-DODS	• Although EFH consultation was not conducted as part of the designation process for SF-DODS, the USEPA's site designation process and	No BMPs or MMs proposed.	No Effect.

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	regulations (promulgated under the MPRSA and NEPA) independently require evaluation of a variety of factors that minimize the potential effects of disposal on EFH.		

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Appendices

1.0 Introduction

Pursuant to section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (16 U.S.C. §1855(b)), the United States Army Corps of Engineers (USACE) and the United States Environmental Protection Agency (USEPA), as the federal lead and co-lead agencies, respectively, have prepared this Programmatic Essential Fish Habitat (EFH) Assessment for the Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region. The state and federal interagency San Francisco Bay Long Term Management Strategy (SF Bay LTMS) program, which began in 1990, is a 50-year plan that covers all federal and non-federal operations and maintenance dredging and dredged material disposal activities in the San Francisco Bay region from the 1999 signing of the Record of Decision (ROD) until 2049 (USACE and USEPA 1999) (the ROD is available at: http://www.spn.usace.army.mil/ltms/rod799.pdf). This EFH Assessment provides an assessment of the potential effects of the on-going dredging and dredged material placement activities of all federal and non-federal maintenance dredging projects in the action area (see Figure 1.1).

1.1 San Francisco Bay Long Term Management Strategy for the Placement of Dredged Material

The San Francisco Bay Long Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region (SF Bay LTMS) was formed in the early 1990s in response to the public's growing concern over the potential direct, indirect and cumulative effects of dredging and dredged material disposal activities on the already stressed resources of the San Francisco Bay/Estuary (Bay or Estuary). The 50-year SF Bay LTMS program is comprised of state and federal regulatory agencies with primary authority to review and permit dredging and dredged material disposal activities in the San Francisco Bay area. Partnering agencies include: United States Army Corps of Engineers (USACE), United States Environmental Protection Agency (USEPA), San Francisco Bay Regional Water Resources Control Board (SFBRWRCB), State Water Resources Control Board (SWRCB), San Francisco Bay Conservation and Development Commission (BCDC) and State Lands Commission (SLC).

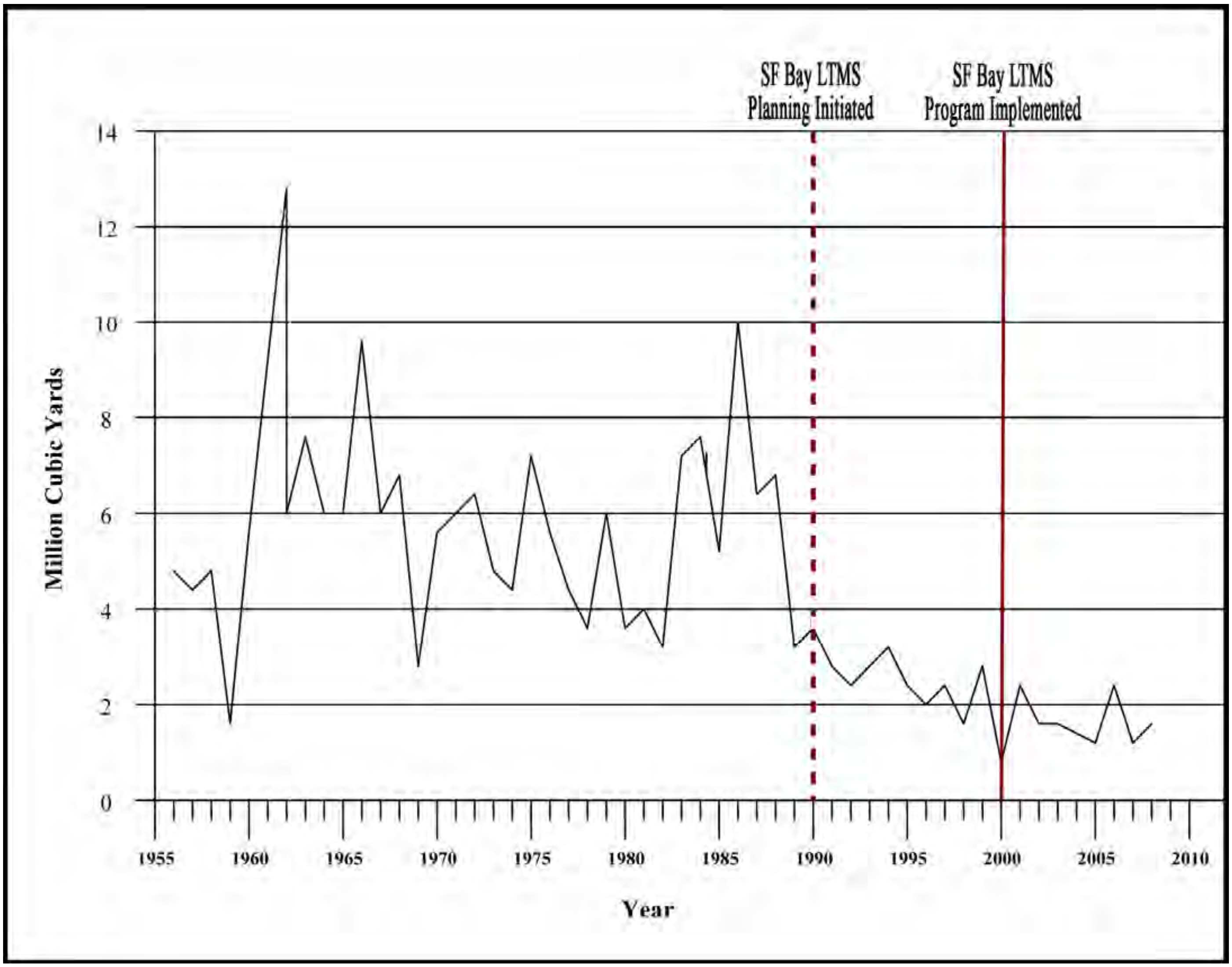
The SF Bay LTMS program area spans 11 counties, including: Marin, Sonoma, Napa, Solano, Sacramento, San Joaquin, Contra Costa, Alameda, Santa Clara, San Mateo and San Francisco counties. It does not include the mountainous or inland areas far removed from navigable waters. The geographic scope of potential impacts included in this consultation (action area) comprises the estuarine waters of the San Francisco Bay region, portions of the Sacramento-San Joaquin Delta (Delta) west of Sherman Island and the western portion of the Port of Sacramento and Port of Stockton deep water ship channels (see Figure 1.1). It also includes the wetlands and shallow intertidal areas that form a margin around the Estuary and the tidal portions of its tributaries. Lastly, it includes the San Francisco Deep Ocean Disposal Site (SF-DODS), the San Francisco Bar Channel Disposal Site (SF-8) and the nearshore zone off Ocean Beach, as well as the waters that are used by vessels en route to these sites. The action area defines the region where navigational dredging covered by the SF Bay LTMS program may occur, where dredged material disposal and beneficial use sites are located and where additional disposal or beneficial use sites may be feasible. In some cases, dredged material may be transported outside the region for use in landfills, levee repair or other beneficial use projects.

Figure 1.1 San Francisco Bay LTMS Action Area

1.2 The San Francisco Bay LTMS Management Plan

Since the 1970s and prior to the implementation of the SF Bay LTMS, disposal of the majority of dredged material in the San Francisco Bay area has taken place at four state and federally designated in-Bay disposal sites within the Estuary: Suisun Bay (SF-16), Carquinez Strait (SF-9), San Pablo Bay (SF-10) and Alcatraz (SF-11) and one deep ocean disposal site, SF-DODS, located approximately 55 miles east of the Golden Gate (see Figure 4.1, located in Section 4.0). Following establishment in 1990, the San Francisco Bay LTMS began studying dredging data from 1990 through 2000 (planning period) and determined that during this time an average of approximately 6.0 million cubic yards of dredged material was disposed of in-Bay (see Figure 1.2).

Figure 1.2 Pre- and Post- SF Bay LTMS In-Bay Disposal Volumes



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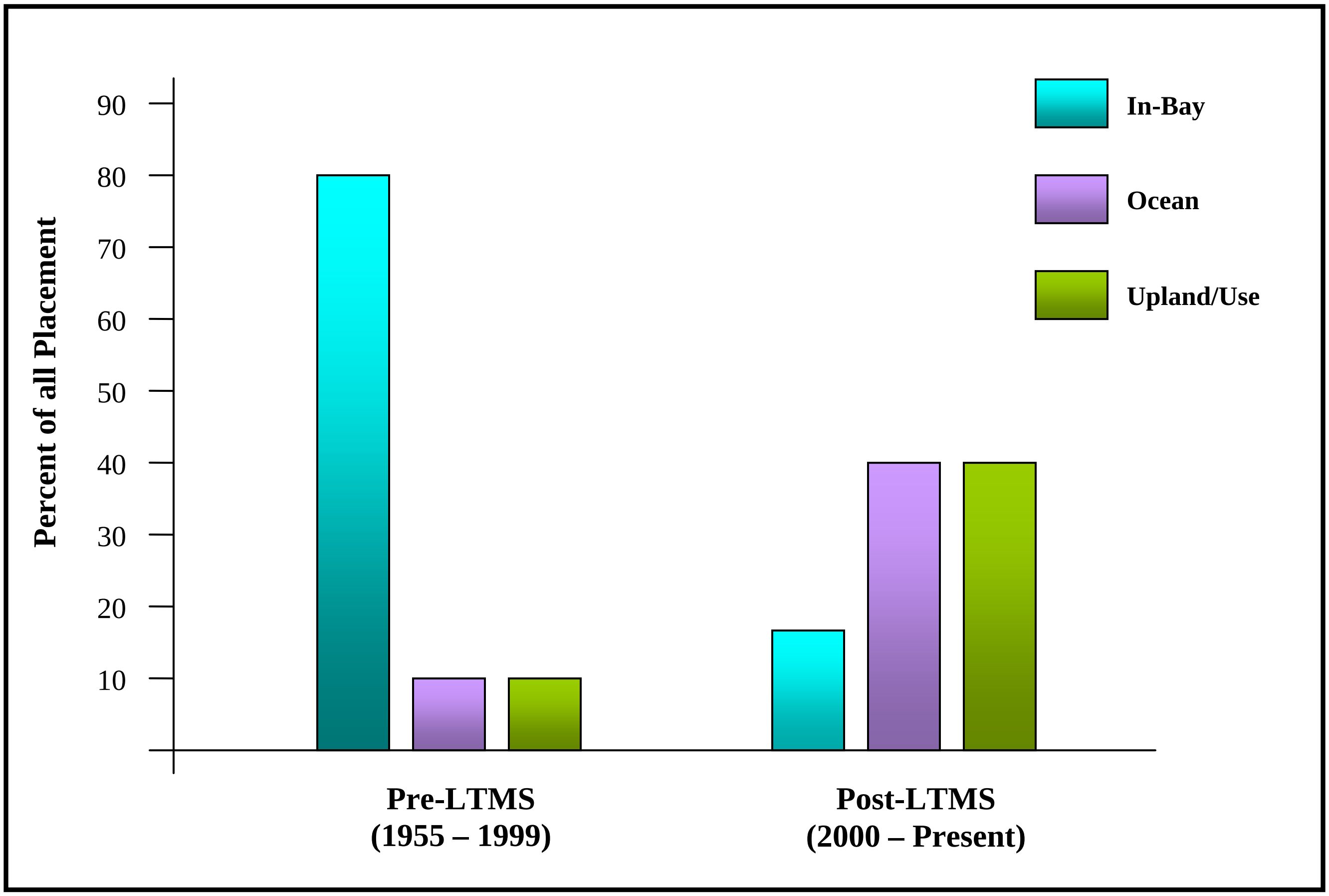
Formal implementation of the SF Bay LTMS began in 2001 with the adoption of the *Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region Management Plan* (LTMS Management Plan). The LTMS Management Plan was proceeded by an extensive eight-year federal and state planning effort which culminated in the *Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region Final Environmental Impact Statement/Environmental Impact Report* (EIS/EIR), finalized in October 1998 (both documents are available on the web at: http://www.spn.usace.army.mil/ltms/). The environmentally preferred alternative identified in the EIS/EIR includes: beneficial use of a minimum of 40 percent of material dredged in the San Francisco Bay region, a maximum of 40 percent disposed of at SF-DODS and a maximum of 20 percent disposed at in-Bay disposal sites. This is the main goal of the SF Bay LTMS program. The SF Bay LTMS program's initial planning was based on average annual dredged material disposal volumes from 1955 to 1999 (see Figure 1.3). The subsequent LTMS management plan called for reversing the historic practice of disposing 80 percent or more of all material dredged from the Estuary at in-Bay disposal sites and requires that at least 80 percent of all dredged material be placed at beneficial use sites, upland or at ocean disposal sites, with only limited volumes of material being placed at in-Bay disposal sites. Over the life of the SF Bay LTMS, the selected alternative aims to:

- Maintain in an economically and environmentally sound manner those channels necessary for navigation in San Francisco Bay and eliminate unnecessary dredging activities.
- Conduct dredged material disposal in the most environmentally sound manner.
- Maximize the use of dredged material as a resource.
- Maintain the cooperative permitting framework for dredging and disposal applications.

Figure 1.3 SF Bay LTMS Dredged Material Placement Management Strategy



1.2.1 Transition to the SF Bay LTMS Goals

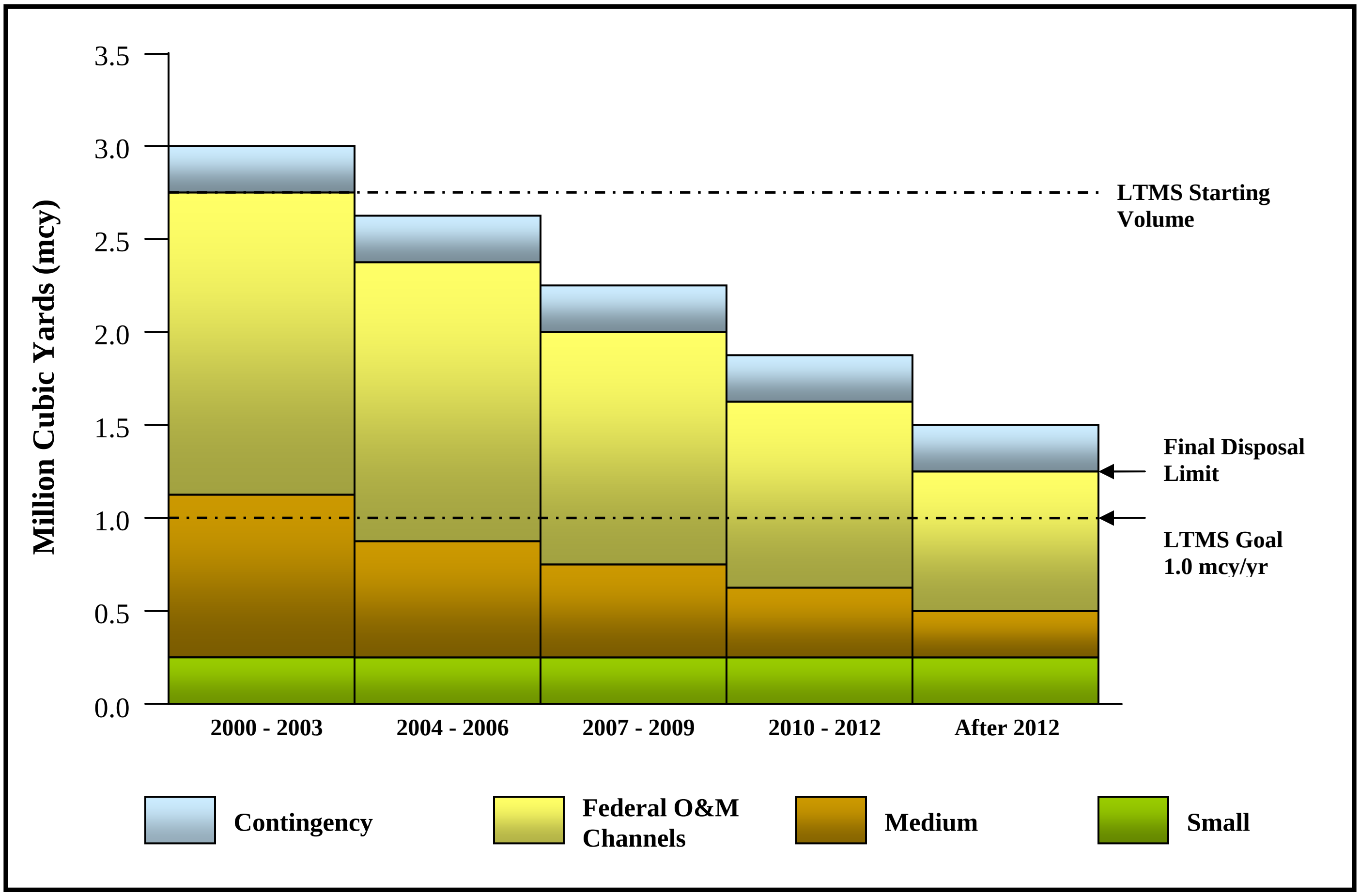
The EIS/EIR and Management Plan recognized that the San Francisco Bay dredging community could not feasibly reduce in-Bay disposal to 1.25 million cubic yards immediately, primarily because significant beneficial use site capacity did not yet exist and both planning and budgeting would need to take place. Consequently, the SF Bay LTMS agencies adopted a program that created a twelve-year transition period for reduction of in-Bay disposal and the development of dredged material beneficial use sites.

The transition period began in 2001 with an immediate reduction in the maximum allowable in-Bay disposal of over 50 percent from pre-SF Bay LTMS limits, from approximately 6.6 million cubic yards to 3.3 million cubic yards.[1] Every three years thereafter, automatic step-downs of the maximum allowable annual in-Bay disposal volumes were implemented until the final in-Bay disposal target limit is reached in 2012 (see Figure 1.4). Each three-year step-down reduces the allowable annual in-Bay

[1] In the years just prior to the adoption of the SF Bay LTMS Management Plan, limits were placed on total in-Bay disposal volumes: 6.7 million cubic yards could be disposed in-Bay during a "dry" year and 7.7 million cubic yards could be disposed in-Bay during a "wet" year.

disposal by a further 387,500 cubic yards. The purpose of the transition period is to allow time to plan (financially and otherwise) the utilization of beneficial use sites to the extent practicable. This program requires a commitment from all parties to increase availability of beneficial use sites. The automatic nature of the step-down assures that the agencies and the dredging community will work diligently to develop beneficial use sites as quickly as possible. The SF-DODS disposal site functions as a "safety valve" during the transition period by allowing in-Bay disposal to continue to be reduced even if beneficial use site development is delayed, and by providing another alternative for dredgers of whom ocean disposal is practicable. If the in-Bay disposal target limits are not met on average in any three year period, the LTMS management plan provides for project-specific disposal volume allocations to be implemented.

Figure 1.4 In-Bay Dredged Material Placement Transition



1.2.2 Progress Implementing the San Francisco Bay LTMS Management Plan to Date

Currently, the SF Bay LTMS transition plan is three-quarters complete – in-Bay disposal volumes are less than pre-SF Bay LTMS volumes, substantial volumes of dredged material is being used for beneficial use and the SF Bay LTMS has made significant progress addressing other San Francisco Bay area planning goals (e.g., the San Francisco Estuary Project's Comprehensive Conservation and Management Plan and San Francisco Bay's Baylands Habitat Goals). Additional accomplishments to date include:

- The initial SF Bay LTMS implementation immediately reduced maximum in-Bay disposal by over 50 percent (from 6.7 to 7.7 million cubic yards per year to approximately 3 million cubic yards). Since then, in-Bay disposal volumes have remained within the transition period target volume limits every year. This has already included two automatic step-downs that have reduced allowable in-Bay disposal by an additional 757,000 cubic yards per year.

- The designated deep-ocean disposal site, SF-DODS, has diverted over 10 million cubic yards of dredged material from in-Bay disposal sites to date. Extensive annual monitoring has confirmed the lack of any significant adverse impacts at SF-DODS, including impacts to EFH.

- The 300+ acre Sonoma Baylands wetland restoration project was constructed using over 2.5 million cubic yards of dredged material from deepening the Oakland federal navigation channels to -42 feet Mean Lower Low Water (MLLW).

- The approximate 1,800 acre Montezuma Wetlands Project is in operation, accepting both clean "cover" material and more contaminated "foundation" material.[2] Montezuma has a capacity of up to 17 million cubic yards and has already used over 3 million cubic yards of dredged material (mostly from the Port of Oakland -50 foot deepening project).

- The 988-acre Hamilton Wetlands Restoration Project (HWRP) is in operation. It has a capacity of approximately 10.6 million cubic yards of dredged material. As of March 2009, the site has already accepted approximately 2.9 million cubic yards from the Port of Oakland -50 Foot Navigation Improvement Project. The Hamilton Wetlands Restoration Project can only accept clean material.

- HWRP was expanded to approximately 2,600 acres with the addition of the Bel Marin Keys Unit V property, increasing the capacity of dredged material use to 24.4 million cubic yards.

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[2] "Cover" sediments refer to the top three feet of sediments, including the "biologically active" zone in contact with flora and fauna; whereas "foundation" sediments refer to sediments placed below the three-foot cover due to contamination issues. Screening guidelines for cover material are intended to be protective of the most sensitive potential biological receptors. Foundation material may be somewhat more contaminated, and must be covered by surface material placed in such a way that it is isolated from biological receptors.

- Approximately 1 million cubic yards of sand dredged from the Main Ship Channel has been used to directly nourish Ocean Beach and USEPA and USACE are planning to propose a permanent nearshore beneficial reuse site off Ocean Beach. Additionally, the portion of the SF-8 disposal site closest to shore was recently approved for the placement of sandy material from other Estuary dredging projects to add more sand to the littoral transport system feeding Ocean Beach.

- Environmental work windows (see Tables 1.1 and 1.2 below) were established to help protect sensitive species. The SF Bay LTMS "Short Term Solutions" work group (which includes NOAA Fisheries) coordinates directly with permittees to minimize dredging outside the windows, and since 2000 this advance planning has improved windows compliance (environmental work windows continue to be established or removed as species are listed and delisted). Species recently listed that may alter the existing work windows include Southern Distinct Population Segment green sturgeon (*Acipenser medirostris*), listed by NOAA Fisheries as threatened under the federal ESA on April 7, 2006 and the longfin smelt (*Spirinchus thaleichthys*), listed as threatened by the State of California on March 4, 2009.

- The interagency Dredged Material Management Office (DMMO) was established and continues to make joint decisions on sediment quality, disposal options, coordinate permit applications and improve consistency in decision making. DMMO is nationally recognized for its success.

- The SF Bay LTMS agencies meet regularly with stakeholders and support an ongoing research program to identify and understand impacts from dredging and dredged material disposal. To date, the SF Bay LTMS has funded approximately 5 million dollars in studies to better understand and avoid impacts to sensitive species and their habitats, including:

    - *Juvenile Salmonid Outmigration and Distribution Study in the San Francisco Bay* (initiated in fiscal year 2006);
    - *Characterization of Suspended Sediment Plumes Associated with Knockdown Operations at Redwood City, CA* (October 2005);
    - *Framework for Assessment of Potential Effects of Dredging on Sensitive Fish Species in San Francisco Bay*; *Mercury Concentrations Bordering the Hamilton Airfield Remediation Site* (October 2002 and September 2003);
    - *Mercury Cycle Studies Associated with the Hamilton Wetland Restoration Project*; *Pre-construction Biogeochemical Analysis of Mercury in Wetlands Bordering the Hamilton Airfield Wetlands Restoration Site – Interim Report* (2004 and September 2005);
    - *Effects of Suspended Sediment on Pacific Herring (Clupea pallasi) Reproductive Success – Final Report,* Bodega Bay Marine Lab (April 2005);
    - *Spatial Characterizations of Suspended Sediment Plumes during Dredging Operations Through Acoustic Monitoring* (January 2004); and

- *White Paper – Potential Impacts of Dredging on Pacific Herring in San Francisco Bay* (May 2005).

Ongoing work under the auspices of the SF Bay LTMS includes: literature reviews of fish behavior, review of tools for monitoring fish behavior, water quality and suspended sediment research, and a green sturgeon migration study.

Table 1.1 Existing Environmental Work Windows for San Francisco Bay Dredging Projects

Site	Species	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
		1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31
SF Bay Bridge to Sherman Island	Steelhead Trout																								
	Chinook Salmon Juveniles																								
Carquinez Strait to Collinsville	Delta Smelt Water </= 10 feet																								
	Delta Smelt Water > 10 feet																								
Napa and Petaluma Rivers, Sonoma Creek	Steelhead																								
Napa River	Delta Smelt																								
North Bay, San Pablo Bay and Shallow Berthing Areas	Dungeness Crab																								
Richardson Bay, North and South Bay	Pacific Herring																								
Waters of Marin County from the GG Bridge to Richmond-San Rafael Bridge	Coho Salmon																								
Berkeley Marina to San	California Least Tern																								

Table 1.1 Existing Environmental Work Windows for San Francisco Bay Dredging Projects

Site	Species	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
		1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31
Lorenzo Creek (within 1 mile of coastline)																									
Central Bay	Pacific Herring																								
South of Highway 92 (San Mateo-Hayward Bridge)	California Least Tern																								
In Areas with Eelgrass Beds	California Least Tern																								
Bay Wide in Areas of Salt Marsh Habitat	California Clapper Rail																								
Bay Wide within 250 feet of Salt Marsh Habitat	California Clapper Rail																								
In and Adjacent to Salt Marsh	Salt Marsh Harvest Mouse																								
Within 300 feet of Roost Site	California Brown Pelican																								

Work Window (no consultation required)

Consultation Required

AR 0028417

Table 1.2 Existing Environmental Work Windows for Disposal Sites in the San Francisco Bay

Location & Designation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bar Channel (SF-8)	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Work Window	Work Window	Work Window	Work Window	Work Window	Work Window	Work Window
Carquinez (SF-9)	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Work Window	Work Window	Work Window	Work Window	Work Window	Work Window	Work Window
San Pablo (SF-10)	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Work Window	Work Window
Alcatraz (SF-11)	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Minimize Disposal	Work Window	Work Window
Suisun (SF-16)	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required
Beneficial Use	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required	Consultation Required

Work Window (no consultation required) **Minimize Disposal** **Consultation Required**

2.0 Essential Fish Habitat

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) protects the *Essential Fish Habitat* (EFH) of species fished for fishery purposes. EFH is defined as "…those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity…" (16 U.S.C. 1802(10)). EFH for specific fishery-managed species on the West Coast of the United States is described in three Fisheries Management Plans (FMP): Pacific Groundfish FMP, Pacific Coast Salmonid FMP and Pelagic FMP. The MSFCMA requires federal agencies to consult with NOAA-Fisheries regarding the potential effects of an action proposed, funded or federally-permitted, on EFH.

In addition to FMPs, the MSFCMA requires NOAA-Fisheries to designate a Habitat Area of Particular Concern (HAPC) for each species. HAPC are subsets of EFH, which are rare, particularly susceptible to human-induced degradation, ecologically important or located in an environmentally stressed area. HAPCs are not afforded additional protection beyond that of the EFH; however, federal projects with potential adverse impacts to HAPCs will be given more scrutiny during the consultation process.

2.1 Pacific Groundfish Fishery Management Plan

The *Pacific Coast Groundfish FMP* provides protection for 82 groundfish species throughout the Pacific Coast of the United States. Because groundfish species are widely dispersed during certain life stages, EFH for groundfish species is correspondingly large. As such, EFH for Pacific Coast Groundfish includes: the entire Exclusive Economic Zone (EEZ) and all the waters from the mean higher high water line (MHHW) to the upriver extent of saltwater intrusion in river mouths along the coasts of Washington, Oregon and California, seaward to the boundary of the United States EEZ. The *Pacific Coast Groundfish FMP* describes seven composite units that comprise pacific groundfish EFH: estuarine, rocky shelf, non-rocky shelf, canyon, continental slope/basin, neritic zone and oceanic zone.

The overall extent of groundfish EFH includes all water and substrate in depths that are less than or equal to 11,483 feet (3,500 meters or 1,914 fathoms) to the mean higher high water level (MHHW) or the upriver extent of saltwater intrusion (upstream area and landward where waters have salinities less than 0.5 parts per thousand), seamounts in depths greater than 11,483 feet and areas designated as HAPCs (for pacific groundfish, HAPCs include estuary, seagrass, kelp canopy and rocky). The action area, including SF-DODS, is within pacific groundfish EFH, and the San Francisco Estuary includes estuarine and eelgrass (*Zostera* spp.) bed HAPCs.

2.1.1 Groundfish Species in San Francisco Bay

Of the 82 groundfish species identified in the Pacific Groundfish FMP, 76 have the potential to occur in the action area (either in the Estuary or outside the Golden Gate) and 22 are present in the Estuary during part of their life history. Table 2.1 provides the groundfish species that may be present in the SF Bay LTMS action area and includes a brief discussion of species life histories (e.g., range, spawning and prey). Further life history details of Pacific groundfish species can be found in Appendix B.2 of the Pacific Groundfish FMP, available at: http://www.pcouncil.org/groundfish/gffmp/gfa19/GF_FMP_App_B2.pdf.

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
FLATFISHES							
Arrowtooth Flounder	*Atheresthes stomias*	ND	Range from the Bering Sea to Santa Barbara, California. Densities are low south of Cape Blanco, Oregon.	Winter. Spawning occurs off Washington in waters deeper than 1,640 feet.	Eggs and larvae are pelagic.	Juveniles and adults are demersal and sublittoral-bathyal, found id depths ranging from 29 - 2,953 feet.	Arrowtooth Flounder feed on copodes and their eggs and copepod nauplii. Juveniles and adults feed on crustaceans.
Curlfin Sole	*Pleuronichthys decurrens*	ND	Range from the Bering Sea to Baja California. They are considered a moderately important in the California trawl fishery.	Late Apr. - Aug.	Eggs and larvae are pelagic.	Prefers soft bottoms and water depths between 24 and 1,746 feet deep.	Polychaete worms, nudibranches, echiurid proboscises, crustacean eggs (possibly crab) and brittle star fragments.
Butter Sole	*Isoptsetta isolepis*	May be present outside San Francisco Bay: eggs, larvae, juveniles and adults.	Range from the Bering Sea to Ventura, California.	Winter through Spring Spawning occurs offshore.	Eggs and larvae are planktonic, floating near the surface. Settling occurs in May through August and juveniles migrate offshore.	Common in shallow water and occasionally deep water on muddy or silty bottoms in coast waters within 11.2 miles of the shore.	Butter sole feed on amphipods, cumaceans, decapods, polychaetes, mollusks and sea stars.
Dover Sole	*Microstomus pacificus*	Outside San Francisco Bay: eggs,	Range from the Bering Sea to Baja California;	Nov. - Apr. Spawning	Eggs and larvae are generally found in the	Juveniles and adults are demersal; juveniles prefer	Dover sole feed diurnally by sight and smell. Larvae eat copepods, eggs

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
		larvae, juveniles and adults.	they are a major target of the deep-water trawl fishery.	occurs in waters 260 to 1,800 feet deep.	upper 164 feet of the water column up to 520 miles offshore.	waters deeper than 2,152 feet. Adults are found in waters 33 to 5,250 feet deep; however, a majority of individuals inhabit waters deeper than 1,640 feet. They prefer soft bottoms with fine sand and mud.	and nauplii, as well as other plankton. Juveniles and adults feed on polychaetes, bivalves, brittlestars and small benthic crustaceans.
English Sole	*Parophrys vetulus*	Juvenile Adult are abundant.	Range from the Bering Sea to Baja California.	Nov. - May. Spawning takes place offshore over soft-bottom substrates at depth between 164 - 230 feet.	Larvae and eggs float near the surface with zooplankton in nearshore coastal waters. Once juveniles settle to the benthos, they move into the Estuary. Larvae metamorphose into juveniles in spring and early summer, when they migrate to the Estuary.	Juvenile and adults prefer soft bottoms of fine sands and mud at depths 0 to 1,800 feet. Generally, juveniles prefer shallow-water coastal bays and estuaries; as they grow, they move to deeper water (generally in the fall/winter time). They are also known to occur in eelgrass beds.	Larvae are planktivorous and eat copepods and other small planktonic organisms. Juveniles and adults feed on harpacticoid copepods, gammarid amphipods, cumaceans, mysids, polychaetes, small bivalves, clam siphons and other benthic invertebrate. English sole feed during the day using sight and smell; occasionally, they dig.
Flathead Sole	*Hippoglossoides elassodon*	Not expected to be the	Distributed along Pacific coast of	May - June.	Eggs and larvae are pelagic and	Juvenile nursery habitat is found in	Flathead sole are opportunistic predators

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
		Estuary.	North America from Monterey Bay northward through the Gulf of Alaska and across the Bering Sea.	Spawning occurs in waters that are 240 - 420 feet deep.	prefer the upper portion of the water column. Juveniles metamorphose and settle in the late summer.	shallow estuaries and bays less than 328 feet deep. Prefer silty or muddy substrates; but can occur in areas with mixed gravel or sand.	that feed on a variety of small mobile prey from the water column and the benthos. Young flathead sole feed on amphipods, bivalves, mysids and shrimp; older fish feed on fishes, polychaetes and clams as well.
Pacific Sanddab	*Citharichthys sordidus*	ND	Range from Baja California to Alaska.	Jul. - Sep.	Eggs are pelagic and planktonic.	Juveniles prefer soft sand, silt or mud bottoms in bays and estuaries and shallow waters along the continental shelf. Eggs are pelagic. Prefers waters 30 to 1,000 feet; most abundant in waters 120 to 300 feet.	Juveniles and adults are carnivorous. Large sanddabs feed on crab larvae, squids, octopi and northern anchovy. Smaller fish eat euphausiids, amphipods, copepods, shrimp, mysids and some fish.
Petrale Sole	*Eopsetta jordani*	ND	Range from Cape St. Elias, Alaska to Coronado Island, Baja California.	Dec. - Apr. Spawning occurs off the continental shelf and slope.	Eggs are pelagic.	Juveniles and adults are demersal and common along the outer shelf in waters 328 - 492 feet deep. Juveniles prefer waters 18 - 489 feet deep. Adults are found from the surf line to 1,804 feet	Larvae are planktivorous, feeding on all stages of copepods. Juveniles feed on mysids, sculpins and other juvenile flatfish, adults eat shrimp and other decapod crustaceans, euphausiids, pelagic fishes, ophiuroids and juvenile petrale sole.

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
						deep and migrate seasonally between deep water spawning areas to shallow water feeding areas.	
Rex Sole	*Errex zachirus*	ND	Low inside the Estuary.	Jan. - Jun. Spawns in depths between 328 – 984 feet over soft bottoms.	Eggs and larvae are pelagic. Larvae are widely distributed offshore 28 - 131 miles offshore.	Widely distributed along the continental shelf and upper slope on sand and muddy bottoms in waters 60 – 2,790 feet deep (most abundant between 600 – 1,500 feet). Eggs and larvae are pelagic; adults are shelf-mesobenthal.	Rex sole feed almost exclusive on benthic invertebrates. Small fish feed on amphipods and other crustaceans, larger fish feed on polychaetes.
Rock Sole	*Lepidopsetta bilineata*	ND	Range from Baja California to the Bering Sea.	Nov. - Mar. Spawning occurs off the coast.	Eggs are demersal and adhesive. Larvae are pelagic and found in the upper 98 feet of water. Small juveniles settle along the coast, with larger populations settling up north.	Adult rock sole are found in intertidal waters to depths of 2,400 feet. They overwinter on the edge of the continental slope and occupy the shelf during the summer months. Adults and juveniles prefer sandy or gravel substrata along the Pacific	Larvae are planktivorous; juveniles and adults carnivorous and all life stages feed during the day.

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
						coast.	
Sand Sole	*Psettichthys melanostictus*	Juvenile and adults are found in the Estuary.	Range from Redondo Beach, California to the Bering Sea.	Jan. - Apr. Spawning occurs in shallow, nearshore waters.	Eggs are pelagic. Larvae occur in most estuaries along the West Coast.	Sand soles are considered inner shelf-outer shelf species. Adults prefer sandy habitats, from near shore to 600 feet; generally prefers shallow waters.	Larvae and small juveniles feed on copepods and nauplii, juveniles feed on small crustaceans, worms and mollusks and adults feed on speckled sanddabs, herring, anchovies, crustaceans, worms and mollusks.
Starry Flounder	*Platichthys stellatus*	Juvenile and adults are abundant in the Estuary.	Range from the Bering Sea to Avila Beach, California.	Nov. - Feb. Spawning occurs offshore in deeper waters.	Eggs and larvae are eplipelagic. Eggs occur at or near the surface and larvae are found in estuaries and offshore.	Starry flounder are found along the inner continental shelf and shallow sublittoral zones in areas with mud, sand or gravel bottoms in water depths ranging from 0 to 1,230 feet. Generally prefers nearshore waters.	Larvae are planktivorous and juveniles and adults are carnivorous. Larvae eat copepods, eggs and nauplii, as well as barnacle larvae and diatoms. Juveniles feed on copepods, amphipods and annelid worms. Adults feed on a wide variety of aquatic species, including crab. Starry flounder do not feed during spawning or coldwater periods.
ROCKFISHES							
Aurora Rockfish	*Sebastes aurora*	ND	Range from British Columbia to Baja California	Mar. - May.	Larvae are pelagic and occur	Common offshore in waters 210 - 2,930 feet deep (most occur	ND

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
						in waters 984 - 1,640 feet deep) on soft bottom habitats along the continental slope/basin.	
Bank Rockfish	*Sebastes rufus*	ND	Range from Fort Bragg, California southward to Central Baja California.	Dec. - May.	ND	Bank rockfish occur offshore in waters less than 810 feet deep. Juveniles are pelagic and occur in waters 82 - 262 feet deep. Juveniles and adults prefer rocky reefs, boulder fields, cobble, mixed mud-rock, non-rocky shelves and canyons along the continental shelf.	Bank rockfish are midwater feeders, eating planktonic organisms and preying on small fish and krill.
Black Rockfish	*Sebastes melanops*	ND	Range from southern California to the Aleutian Islands; common from San Francisco, California northward.	Jan. - May. Spawning sites are unknown; they are expected to be offshore, however.	Larvae are pelagic and occur offshore.	Black rockfish inhabit surface waters to 1,200 feet deep; however, they prefer waters shallower than 180 feet deep. Juveniles migrate nearshore in shallow kelp beds (19 - 39 feet deep) and sometimes in	Larvae feed on nauiplii, invertebrate eggs and copepods. Adults prey on small fishes, euphausiids, amphipods, crustaceans, polychaetes, cephalopods, chaetognaths and jellyfish.

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
						estuaries.	
Black and Yellow Rockfish	*Sebastes chrysomelas*	ND	Range from Cape Blanco, Oregon to Baja, California	Jan. - early Feb.	Females carry eggs internally - they hatch between Mar. - May. Planktonic larvae settle in their adult habitats in early summer.	Black and yellow rockfish are relatively immobile. They inhabit holes and crevices in rocky reefs and kelp beds and are demersal, usually in waters less than 60 feet. They can be found in depths up to 120 feet. Prefers in coastal intertidal and shelf waters.	Black and yellow rockfish pick zooplankton out of the water column.
Blackgill Rockfish	*Sabastes melanostomus*	Blackgill rockfish inhabit coastal waters outside of the Estuary.	Range from British Columbia to Baja California.	Jan. - June. Spawn off southern California.	Larvae are pelagic.	Adults are found offshore in waters 755 - 1,854 feet deep; juveniles are found in waters greater than 590 feet deep. They inhabit rocky- or hard-bottom habitats along steep drop-offs.	Blackgill rockfish primarily feed on planktonic prey.
Blue Rockfish	*Scorpaenidae mystinus*	Larvae are present in the Estuary; there is a slight chance of juveniles	Range from Baja California to Alaska.	Dec. – Jan.	Larvae and early juveniles are pelagic.	Juveniles and adults are demersal. They prefer rocky structures, such as jetties in waters from 0 to 1,800 feet deep	Blue rockfish feed on tunicates, hydroids, jellyfishes, calps, crustaceans and larval and juveniles fish species.

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
		or adults being present.				(prefer depths between 16 and 297 feet). Found only in the outer portions of Central Bay (near Golden Gate).	
Bocaccio	*Sebastes paucispinis*	Larvae and adults are found in the Estuary; however, they are rare.	Range from the Gulf of Alaska to Baja California; most abundant from Oregon south.	Viviparous; a nearly 10 year spawning period.	Larvae and small juveniles are pelagic. Larvae generally occur over the continental shelf and juveniles settle over rocky areas associated with algae or eelgrass in the upper 328 feet of water.	Rocky outcrops and soft ocean bottoms in waters up to 1,560 feet deep; prefers depths between 240 and 1,050 feet. Juveniles prefer the upper portion of the water column.	Larvae eat diatoms, dinoflagellates, tintinnids and cladocerans. Juveniles eat copepods and euphausiids. Adults eat small fishes.
Bronzespotted Rockfish	*Sebastes gilli*	ND	Range from Baja California to Eureka, California	ND	ND	Historically found in deeper waters off southern California.	ND
Brown Rockfish	*Scorpaenidae auricultus*	Juveniles are found in the Estuary	Range from Baja California to southeast Alaska.	Dec. - Jul.	ND	Shallow waters and bays in waters less than 175 feet deep (sometimes found in waters 420 feet deep). Prefer hard bottoms or sand. Aggregate	Brown rockfish eat small fishes, crabs, shrimp, isopods and polychaetes; juveniles feed on small crustaceans, amphipods and copepods.

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
						near rocks, oil platforms and sewer pipes. Sub-adults occupy bays and coastal areas in eelgrass and other vegetation.	
Calico Rockfish	*Sebastes dalli*	ND	Range from Baja California northward to San Francisco, California.	Dec. - Mar.	Calico rockfish release pelagic larvae from Jan. - May.	Adults inhabit sand-rock substrate in waters with depths ranging from 60 – 840 feet. Juveniles are found in areas of soft sand-sit at sand-rock interfaces over a wide depth of range, including intertidal areas.	Juveniles feed on zooplankton and larval fish; adults feed on larger crustaceans, fish, gammarid amphipods, bivalves and cephalopds.
Canary Rockfish	*Sebastes pinniger*	ND	Range from Baja California to the western Gulf of Alaska.	Nov. - Mar.	Larvae transform to pelagic juveniles then to benthic juveniles from June to August.	Canary rockfish inhabit water depths from the surface (juveniles) to 1,394 feet. Adults move into deeper waters and are associated with pinnacles and sharp drop-offs. Young juveniles have been observed near the bottom at the	Juveniles and adults primarily feed on crustaceans, and occasionally fish.

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
						seaward sand-rock interface off the shores of central California.	
Chilipepper	*Sebastes goodei*	ND	Range from Baja California to Pratt and Durgin Seamounts in the Gulf of Alaska; most commonly found between Cape Mendocino and northern Baja California.	Viviparous; fertilization of eggs begins in Oct. and spawning occurs from Sep. - Apr.	Larvae and small juveniles are associated with kelp canopies. Pelagic juveniles are found in 98 - 164 feet deep water.	Adults and older juveniles occur over the continental shelf and slope. Adults form schools over boulders and rock structures.	Larvae and juveniles feed on all life stages of copepods and euphausiids; adults prey on large euphausiids, squid and small fishes.
China Rockfish	*Sebastes nebulosus*	Present.	Range from the western Gulf of Alaska south to Redondo Beach, California.	Jan. - Jul.	ND	Occur both inshore and along the open coast in waters from 10 - 420 feet deep. Juveniles are pelagic, inhabiting shallow subtidal waters during the summer and early fall; adults are sedentary, associated with rock reefs or cobble.	China rockfish larvae are planktivores, eating invertebrate eggs and nauplii and copepods. Juveniles eat crustaceans and adults prey on crustaceans, octopi, abalones, chitons, fishes and brittle stars.
Copper Rockfish	*Sebastes caurinus*	ND	Range from the western Gulf of Alaska south to Baja California.	Feb. - Mar. Copper rockfish move inshore to	Larvae and small juveniles are pelagic for several months	Occur in nearshore waters from the surface to 600 feet deep. Adults prefer	Copper rockfish are opportunistic carnivores. Juveniles feed on planktonic crustaceans and

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
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			Common in Puget Sound, the San Juan Islands and Straits of Juan de Fuca, and in southern California.	release young on reefs once a year.	to a year and associated with surface waters containing surface-forming kelp beds.	rocky areas and rock-sand bottoms in shall waters; near SF Bay, juveniles inhabit kelp beds (*Macrocycitis* spp.).	switch to larger crustaceans as they grow; adults eat fish, crustaceans and mollusks.
Cowcod	*Sebastes levis*	ND	Range from Guadalupe Island, Baja California north to Newport, Oregon. The most preferred habitat is the Southern California Bight.	ND	ND	Adults are found at depths ranging from 498 - 800 feet over high-relief rocky areas and juveniles prefer depths of 65 - 328 feet over low-relief rocks and soft bottom habitats.	Juveniles eat shrimp and crabs; adults eat fish, octopus and squid.
Darkblotched Rockfish	*Sebastes crameri*	ND	Range from Santa Catalina Island, California to the eastern Bering Sea.	Insemination occurs from Aug. - Dec. and fertilization from Dec. - Mar.	ND	Pelagic juveniles are found in depths ranging from 65 - 148 feet. Most adults prefer depths ranging from 164 - 1,312 feet. Juveniles prefer soft substrata and low-relief reefs, whereas adults are associated with rocks, boulders and cobble surrounded by mud.	Adults feed on macroplanktonic organisms and occasionally, Crangon shrimp, squid, amphipods, small salps and small octopi.

Table 2.1	**Pacific Groundfish of the San Francisco Bay Area**						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
Flag Rockfish	*Sebastes rubrivinctus*	ND	Range from Oregon to Baja California.	Mar. - June in southern California and Apr. - May in northern California.	ND	Adults prefer depths ranging from 98 - 600 feet; however, they can occur in waters 990 feet deep. Juveniles are found in shallow waters and surface waters associated with algal mats and plant debris, generally off the coast.	Flag rockfish predominately eat bottom dwelling organisms, such as crabs, shrimp, fish and octopus.
Gopher rockfish	*Sebastes carnatus*	ND	Range from Cape Blanco Oregon to Baja California.	Mar. - May	Larvae and young juveniles are planktonic and associated with kelp canopies.	Gopher rockfish rarely inhabits waters less than 98 feet deep; however, they can occupy waters ranging from intertidal to 282 feet deep. They are shallow-water benthic fish that inhabits rocky reefs, kelp beds and sandy areas near reefs. Young prefer low-relief rock or sand substrates and are associated with kelp canopies.	Gopher rockfish are diurnal planktivores preying on nauplii eggs, invertebrate eggs and copepods during daylight hours. Juveniles also feed on copepods, shrimp, brachyurans and algal-associated prey.

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Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
Grass Rockfish	*Sebastes rastrellinger*	ND	Range from Baja California to Yaquina Bay, Oregon; most common south of southern Oregon.	Jan. - Mar.	ND	Shallow water fish, found from intertidal zones to 184 feet. Juveniles and older adults are commonly associated with kelp and eelgrass beds, nearshore rocky areas (e.g., jetties).	Larvae feed on nauplii and invertebrate eggs and copepods; juveniles and adults prey on crustaceans, fish, crabs, shrimp, cephalopods and gastropods. Adults feed at night.
Greenblotched Rockfish	*Sebastes rosenblatti*	ND	Range from Baja California to northern California; most common from central California south.	Dec. - July. Spawning occurs two or more times per season.	Larvae are pelagic.	Greenblotched rockfish prefer depths ranging from 180 to 1,611 feet; adults prefer deeper waters than juveniles.	Juveniles and adults feed on planktonic prey (euphausiids and pelagic tunics), fish (hake, anchovies and lanternfish) and squid.
Greenspotted Rockfish	*Sebastes chlorostictus*	ND	Range from Copalis, Washington south to Baja California; they are most abundant south of Monterey Bay, California.	Apr. - Sep. Spawning occurs two or more times per season.	ND	Adults prefer waters with depths of 295 - 1,191 feet; juveniles prefer depths of 98 - 292 feet. They spend most of their time on or near the bottom in caves or crevices; juveniles are associated with rock outcrops, soft bottoms and oil platforms.	Benthic feeder that prey on planktonic euphausiids, pelagic tunicates, fish and squid.
Greenstriped	*Sebastes*	ND	Range from Baja	May - Jul.	ND	Greenstriped rockfish	Juveniles and adults prey

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Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
Rockfish	*elongatus*		California to the Gulf of Alaska; most common between British Columbia and Punta Colnett, Baja California.	Spawns multiple times per year.		are widely distributed over rocky and soft bottoms in waters ranging from 170 - 2,717 feet deep. Juveniles prefer shallower water than adults.	on planktonic euphausiids and copepods, pelagic tunics, small fish, shrimp and squid.
Kelp Rockfish	*Sebastes atrovirens*	ND	Range from Albion, California south to Baja California.	May - Jun. Eggs are internally fertilized.	Larvae are planktonic.	Prefers kelp (*Macrocystis*) bed habitat in shallow waters with depths ranging from 59 - 79 feet.	Kelp rockfish are carnivorous, preying on a variety of free-swimming organisms.
Longspine Thornyhead	*Sebastolobus altivelis*	ND	Range from Baja California to the Aleutian Islands.	Jan. - Apr. Spawning occurs in water depths ranging from 1,968 - 3,280 feet.	Eggs rise to the surface; eggs and larvae are pelagic.	Juveniles and adults are demersal and occupy soft bottom sediment surfaces along the continental slope. In California, they prefer waters ranging from 679 - 5,758 feet deep.	Longspine thornyhead prey includes fish fragments, crustaceans, bivalves and polychaetes. Pelagic juveniles prey on herbivorous euphausiids.
Olive Rockfish	*Sebastes serranoides*	ND	ND	Jan. - Mar.	Larvae are planktonic for 3 - 6 months.	Inhabit surface and intertidal waters over hard substrates up to 570 feet deep. Co-	Larvae are planktivorous and feed on nauplii, invertebrate eggs and copepods; juveniles feed

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Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
						exist with kelp rockfish and kelp bass in reefs and giant kelp.	on crustaceans, juveniles fishes, polychaetes, octopi and squid; adults and subadults feed on midwater fish, octopi and squid.
Pacific Ocean Perch	*Sebastes alutus*	ND	Range from La Jolla, California to the western boundary of the Aleutian Archipelago; however, most common from Oregon northward.	Jan. - Apr. Fertilization is internal. Spawning occurs among seamounts and other steep areas.	Larvae and juveniles are pelagic.	Adults and subadults are benthopelagic. Inhabit waters off the upper continental shelf in depths ranging from 82 - 2,707 feet. They are found along submarine canyons, seamounts, pinnacles and depressions.	Pacific ocean perch are carnivorous. Larvae eat small zooplankton, juveniles eat copepods, euphausiids and calinoid copepods; adults feed on euphausiids, calinoids copepods, mysids, shrimp, squid and small fish.
Pink Rockfish	*Sebastes eos*	ND	Range from Baja California northward to the central Oregon coast.	ND	ND	Common in waters ranging from 147 - 1,200 feet deep. Adults prefer boulder fields but rest on soft bottoms; juveniles prefer soft bottoms.	ND
Quillback Rockfish	*Sebastes maliger*	ND	Range from the Channel Islands, California north to the Gulf of Alaska; most common in the	Apr. - July	ND	Quillback rockfish are shallow-water benthic species that are found in water depths ranging from subtidal to 902 feet.	Quillback rockfish are generalists, feeding during mid-day. Larvae consume nauplii, invertebrate eggs and copepods; adults feed on crustaceans, small fish,

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			Strait of Georgia, San Juan Islands, the Puget Sound, Washington, and from southeastern Alaska to northern California.			Juveniles occur along shores in waters less than 197 feet deep.	bivalves, polychaetes and fish eggs.
Redbanded Rockfish	*Sebastes babcocki*	ND	Range from the Bering Sea to San Diego, California; uncommon south of San Francisco	Mar. - Apr. Give birth to life young.	ND	Occur in water depths ranging from 160 - 2,050 feet over hard-bottom subustrata.	ND
Redstripe Rockfish	*Sebastes proriger*	ND	Range from Baja California to the Bering Sea.	July - Sep.	Larvae and juveniles are pelagic to semi-demersal.	Inhabits the outer shelf and upper slope in water depths ranging from 39 - 1,394 feet, but are most common in depths ranging from 492 - 902 feet. Adults are semi-demersal. Juveniles are sometimes found in estuaries.	Larvae and juveniles feed on copepods, copepod eggs, copepod nauplii and euphausiids; adult feed on small fish (e.g., anchovies, herring and early stages of groundfish species) and squid.
Rosethorn Rockfish	*Sebastes helvomaculatus*	ND	Range from Baja California to the Gulf of Alaska.	May - June	Young are pelagic and occur off the west coast.	Prefers water depths ranging from 82 - 1,801 feet; most occur in depths	Rosethorn rockfish feed on euphausiids and other crustaceans.

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Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
						ranging from 328 - 1,148 feet. They are generally found in muddy areas, adjacent to boulders, cobble or rock.	
Rosy Rockfish	*Sebastes rosaceus*	ND	ND. Ranges from the Straits of Juan de Fuca to Baja California.	Apr. - July	ND	Rosy rockfish have been taken from waters with depths ranging from 23 - 860 feet; however, they prefer depths of 98 - 151 feet with hard, high-relieve and low-relief rocks and sand. Juveniles are found in water depths ranging from 98 - 200.	Feed on small, bottom-dwelling organisms.
Rougheye Rockfish	*Sebastes aleutianus*	ND	Range from Aleutian Island to San Diego, California; commonly caught off central California.	May off Oregon and February to June off British Columbia; no California data.	ND	Common in offshore waters, rare in nearshore waters. Prefers depths ranging from 82 - 2,871 feet.	Rougheye rockfish pre on fish, shrimps and crusteaceans.
Sharpchin Rockfish	*Sebastes zacentrus*	ND	Range from San Diego, California to the Aleutian Islands, Alaska; less common	May - June.	ND	Sharpchin rockfish is an outer shelf-mesobenthal fish that occupies waters ranging from 82 -	Sharpchin rockfish feed on euphausiids, shrimp, amphipods, copepods and small fishes.

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
			south of Monterey, California.			1,558 feet deep, most of them are found in depths from 328 - 820 feet.	
Shortbelly Rockfish	*Sebastes jordani*	ND	Range from Baja California to British Columbia.	Jan. - Apr. Spawning occurs off California.	Larvae are found up to 173 miles from shore, but are generally within 12 miles of shore.	A middle shelf-mesobenthal species found in waters ranging from 164 - 1,148 feet deep. They occur over the continental shelf and upper slope.	Primarily feed on various life stages of euphausiids and calanoids.
Shortraker Rockfish	*Sebastes borealis*	ND	Range from Japan, to the Bering Sea, through the Aleutian Islands, to Point Conception, California. Commonly caught off central California.	Mar. - July Females release larvae.	ND	Occur offshore from the shore to 2,871 feet deep, primarily inhabit the middle shelf of the mesobenthal slope in waters ranging from 164 - 2,133 feet deep.	Shortraker rockfish feed on shrimp, cephalopods, mysids, bathylagids and myctophids.
Shortspine Thornyhead	*Sebastolobus alascanus*	ND	Range from Baja California to the Bering Sea; common from Southern California northward.	Dec. - May Spawning occurs in water depths ranging from 1,969 - 3,281 feet.	Gelatinous egg masses float to the surface; larvae and young juveniles are pelagic.	Inhabit areas over the continental shelf and slope and are common in waters ranging from 328 - 2,789 feet. Juveniles prefer depths between	Shortspine thornyhead are benthic feeds that prey on shrimp, crabs, amphipods, fishes and worms.

Table 2.1				Pacific Groundfish of the San Francisco Bay Area			
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
						328 - 1,969 feet over muddy bottoms near rocks.	
Silvergray Rockfish	*Sebastes brevispinis*	ND	Range from Santa Barbara Island, California to the Bering Sea.	Apr. - Aug.	ND	Silvergray rockfish inhabit the outer shelf-mesobenthal zone in depths ranging from shore to 1,430 feet; they prefer depths ranging from 323 - 984 feet.	ND
Speckled Rockfish	*Sebastes ovalis*	ND	Range from northern Washington to Baja California; most common from central California southward.	Sep. - May. Spawns multiple times.	ND	Adults inhabit water depths ranging from 149 - 499 feet; juveniles prefer depths ranging between 98 - 292 feet deep. They occur in midwater over rocks and near the bottom of reefs and among boulders.	Speckled rockfish feed on plankton and small fish.
Splitnose Rockfish	*Sebastes diplorproa*	ND	Range from Alaska to Baja California.	July and Oct. - Dec. off British Columbia; mid-May - June off Oregon; June 0 July off Washington.	Larvae and early juveniles are pelagic.	Splitnose rockfish inhabit the outer shelf-mesobenthal zone in water depths ranging from 262 - 2,625; most occur in depths ranging from 492 - 1,476 feet.	Adult feed on midwater plankton; juveniles feed on planktonic organisms and switches to epibenthic prey when they become benthic.

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Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
				No data for California.		Older juveniles are benthic.	
Squarespot Rockfish	*Sebastes hopkinsi*	ND	Range from Baja California and Guadalupe Island to the southern Oregon coast.	Feb. - Mar. (Central California) Females spawn larvae.	Known to spawn off central California.	Occur in waters ranging from 59 - 800 feet deep, but are most common in waters ranging from 98 - 492 feet. Juveniles occupy the shallower portions of their depth range.	Squarespot rockfish feed entirely on plankton (copepods, krill and crab larvae).
Starry Rockfish	*Sebastes constellatus*	ND	Range from San Francisco southward.	Apr. - May	ND	Starry rockfish have a depth range of 78 - 810 feet, but are most often found at depths ranging from 196 - 292 feet. They are exclusively found over hard bottoms, generally large rocks and boulders.	Starry rockfish feed on small fishes, crabs, shrimp and other small invertebrates.
Stripetail Rockfish	*Sebastes saxicola*	ND	Range from Baja California to southeast Alaska.	Nov. - Mar.	Females release live young; juveniles are pelagic.	Stripetail rockfish inhabit depths ranging from 32 - 1,795 feet over the outer shelf-upper slope.	Prey on pelagic organisms such as euphausiids.
Tiger Rockfish	*Sebastes nigrocinctus*	ND	Range from southern California to	May - Jun. (Puget Sound)	ND	Occur in shallow waters from intertidal to 900 feet deep;	Rockfish feed in the evening on caridean shrimp, crabs, amphipods

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			Alaska; most common from northern California to southeast Alaska.			generally occur in waters depths from 180 - 900 feet. Juveniles are pelagic and commonly drift with algal mats and plant debris.	and small fishes.
Treefish	*Sebastes serriceps*	ND	Range from San Francisco to Baja California; most common south of Santa Barbara, California.	Late winter.	ND	Found in depths up to 318 feet; prefer depths less than 197 feet. Adults are found on shallow rocky reefs; pelagic juveniles often drift with kelp mats.	Treefish feed on benthic invertebrates and small fish during the night.
Vermilion Rockfish	*Sebastes miniatus*	ND	Range from Alaska to Baja California; most abundant from northern California to Baja California.	Sep. is the peak spawning month in California.	Females release larvae that are pelagic and found near the surface. They settle to the floor in three to four months in waters ranging from 16 - 98 feet deep.	Juveniles prefer shallow water; adults inhabit deeper water in areas with high-relief rocky reefs.	Adults and benthic juveniles feed on fish (anchovies, lanternfish and small rockfishes); pelagic young feed on crustaceans.
Widow	*Sebastes*	ND	Range from Baja	Mating occurs	Larvae and	Adults are sublittoral	Widow rockfish are

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
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Rockfish	*entomelas*		California to Kodiak Island.	in Sep. off the coast of California (Dec. off Oregon). Larvae are released from Dec. - Feb. in California.	small juveniles are neritic and epipelagic in nearshore waters to 186 miles offshore.	and bathyal over depths ranging from 79 - 1,801 feet.	carnivorous. Adults eat pelagic crustaceans, midwater fish, salps, cardean shrimp and small squids; pelagic juveniles feed on various life stages of calonoid copepods and sub-adult and egg euphausiids.
Yelloweye Rockfish	*Sebastes ruberrimus*	ND	Range from Alaska to northern Baja California; most common from central California to Alaska.	Young are released from Apr. - Sep.	ND	Yelloweye rockfish inhabit water depths ranging from 82 to 1,558 feet and is a middle shelf-mesobenthal spcies.	Yellowfish rockey are large predatory reef fish that feeds close to the bottom; they are also opportunistic feeders, consuming fish, crabs, shrimp and snails.
Yellowtail Rockfish	*Sebastes flavidus*	ND	Range from Alaska to La Jolla, California.	Mating occurs from Oct. - Dec.; birth occurs from Jan. - May	ND	Associated along steep sloping shores or above rocky reefs in waters depths from 0 to 1,800 feet. Juveniles are pelagic and found around floats and pilings.	Yellowtail rockfish feed on pelagic organisms and, occasionally, benthic species.
ROUNDFISH							
Lincod	*Ophiodon elongatus*	Present.	Range from Baja California to the Gulf of Alaska.	Dec. - Apr.	Eggs occur in nests; deposited on bottom in association with	Adults are demersal and prefer rocky reefs and banks with seaweed, kelp or	Larvae are zooplanktivores feeding on copepods, amphipods, euphausiids and decapod

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
					rocky reefs and swift currents.	eelgrass in waters up to 1,380 feet deep. Juveniles prefer sand or mud on the bottoms of bays and inshore areas.	larvae; juveniles prey on copepods, shrimp and other small crustaceans; adults feed on demersal fish, squids, octopi and crabs. Licond are a visual predator, feeding during the day.
Cabezon	*Scorpaenichths marmoratus*	Juvenile are rare in the Estuary.	Range from southeast Alaska to Baja California.	Late Oct. - Mar.	Eggs laid on intertidal and subtidal, algae free rocky surfaces, in crevices and under rocks.	Adults inhabit kelp beds, jetties, rocky reefs, shallow tide pools and isolated rock reefs and pinnacles estuaries in water depths from 0 to 335 feet.	Larvae are plaktivorous, feedingon copepods, barnacle larvae and fish larvae and eggs; juveniles are opportunistic carnivores; adults feed on crabs, small lobsters, mollusks, small fish and fish eggs.
Kelp Greenling	*Hexagrammos decagrammus*	ND	Range from the Aleutian Islands to La Jolla, California.	Late Fall - Early Winter.	Eggs are laid on or between rocks, in algae beds.	Adults prefer rocky reefs of shallow nearshore areas; areas with rock banks near dense algae or kelp beds. Larvae move to open seas and return to bays and estuaries as demersal juveniles.	Pelagic kelp greenling larvae and juveniles feed on copepods and copepod nauplii, amphipods, brachyuran larvae, euphausiids and larval fish; adult feed on shrimp, crab, works, octopi, brittle stars, snails and small fishes. Feeding occurs during the day.
Pacific Cod	*Gadus macrocephalus*	ND	Range from Alaska to Santa	Late fall - early spring (Puget	Eggs are demersal,	Adult Pacific cod are inner shelf-	Young juveniles ate copepods, small shrimp

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Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
			Monica, California.	Sound); winter - spring (Gulf of Alaska and Bering Sea). Spawning sites are located on the outer shelf and upper slope.	adhesive; eggs and juveniles are found in polyhayline to euhaline waters.	mesobenthal fish that inhabit shallow, soft bottoms in water depths up to 2,871 feet; they prefer depths of 164 - 984 feet.	and amphipods; adults prey on eat whatever prey is most abundant, they prefer shrimp, mysids, amphipods, crabs and sandlance.
Pacific Hake (Pacific Whiting)	*Merluccius productus*	Rare.	Range from Baja California to the Gulf of Alaska.	Dec. - Mar.	Adults spawn several hundred miles out at sea. Eggs and larvae are pelagic and found in the upper 148 feet of water up to 600 miles offshore.	Inhabit oceanic and coastal areas, but mainly on the continental shelf; near bottom or higher in the water column (largely pelagic existence) in waters up to 3,000 feet depth (most abundant in waters 164 – 1,640 feet deep). Adults form large schools.	All life stages feed late night / early morning near the surface. Larvae eat calanoid copepods, their eggs and nauplii; juveniles and small adults feed on euphausiids; large adults eat amphipods, squid, herring, smelt and crabs.
Pacific Flatnose (Fincescale Codling)	*Antimora microlepsis*	ND	Range from Japan through the southeastern Bering Sea to the Gulf of California.	ND	ND	Pacific flatnose are mesobenthal-bathybenthal inhabiting depths ranging from 574 - 10,000 feet.	Pacific flatnose probably feed on benthic macrofauna.
Pacific Grenadier	*Corphaenoids acrolepis*	ND	Range from the northeast Pacific	Late winter to early spring in	Larvae are pelagic and	One of the world's most abundant fishes	Stomach contents of adults contain remnants of

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			Ocean off Japan to Baja California.	California.	inhabit the upper 656 feet of the water column.	off the continental slope and abyssal waters. They are found at depths ranging from 508 - 12,549 feet. Juveniles inhabit waters less than 1,640 feet deep.	cephalopods and other demersal fishes.
Sablefish	*Anoplopoma fimbria*	ND	Abundant in the north Pacific, from Japan to the Bering Sea, south to Baja California.	Late fall - early winter in waters greater than 984 feet deep.	Eggs and larvae are pelagic; juveniles become benthic after 1 - 2 years.	Sablefish is an inner shelf-bathybenthal species. Adults occupy waters up to 9,843 feet deep, but are most common at 656 - 3,281 feet.	Sable fish prey on copepods and copod nauplii. Pelagic juveniles feed on small fishes, copepods and sephalopods; demersal juveniles eat small demersal fish, apmphipods and krill. Adult feed on fishes.
SHARKS, SKATES & CHIMAERAS							
Leopard Shark	*Triakis semifasciata*	Juveniles and adults are present.	Range from Oregon to Baja California. Leopard sharks reside in the Estuary during March through September and outside from	Jan. - Feb. Spawning takes place at depths greater than 984 feet.	Eggs, larvae and young juveniles are pelagic. Eggs are usually found in waters deeper than 984 feet. Larvae and young are found offshore up to	Prefers enclosed muddy bays in waters less than 12 feet deep; can be found in waters up to 300 feet deep. Leopard sharks are active during the day.	Leopard sharks are generalists and do not depend on any specific food source. In the Estuary, the feed on crabs and shrimp. Depending on the size of the shark, diets consist of echiuroid worms, crabs, clam

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
			October to February.		230 miles offshore.		siphons, fishes and fish eggs.
Soupfin Shark	*Galeorhinus zyopterus*	ND	Range from British Columbia to Baja California.	Spring.	Females move to bays to birth live young after an approximate 1-year gestation. San Francisco Bay is sometimes use as nursery grounds.	Adult males favor deeper waters off Northern California; females prefer waters closer to the shore off Southern California; they mix in the waters off Central California. Prefer depths up to 1,350 feet.	Soupfins sharks are opportunistic and carnivorous. They feed throughout the water column on pelagic and benthic organisms. They feed on boney fish and invertebrates.
Spiny Dogfish	*Squalus acanthias*	Present.	Range from the Bering Sea to Baja California.	Mar. - Jun.	Adult females move inshore to shallow waters in the spring to release young. Small juveniles are pelagic.	Benthopelagic; oceanodromous; brackish and marine in water depths between 0 – 4,790 feet.	Spiny dogfish are carnivorous scavengers. Their diet consists of herring, sandlance, smelts, cods, capelin, hake, ratfish, shrimp, crab, worms, krill, squid, octopus, jellyfish and sea cucumbers.
Big Skate	*Raja binoculata*	Present.	Range from the Bering Sea to southern Baja California.	Jan. - Dec.	Egg capsule deposition on bottom substrate in inland sea and shelf.	Found along the coast in estuaries, bays and over the inner and outer continental shelf in water depths up to 330 feet. Juveniles are benthic.	Big skate feed on crustaceans, small benthic fishes, polychaete worms and mollusks.
California	*Raja inornata*	ND	Range from Baja	ND	The eggs are	California skates	California skate feed on

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**
Skate			California northward to the Straits of Juan de Fuca. Common off the shore of California.		laid in a smooth-surfaced case with horns.	prefer depths ranging from 55 - 2,201 feet over muddy bottoms.	shrimp and other invertebrates.
Longnose Skate	*Raja rhina*	ND	Range from the Bering Sea to Baja California.	ND	Eggs are enclosed in a rough, leathery shell covered with fibers and short horns. Egg cases generally hold only one egg.	Common on the bottom along the inner and outer shelf areas depths from 0 - 3,507 feet.	Smaller longnose skate feed on crustaceans; larger skate feed on bony fishes.
Spotted Ratfish	*Hydrolagus colliei*	ND	Range from western Gulf of Alaska to Baja California.	Spawning occurs throughout the year, but appears to peak in late summer - early fall. One or two egg cases are produced per year.	Eggs are attached to rocks or placed upright in the sand, generally in deeper waters.	Spotted ratfish are a middle shelf-mesobenthal species inhabiting waters from 0 - 3186 feet deep. All live forms are free-swimming and share the same habitat type. During the winter, spotted ratfish move into shallow nearshore waters and estuaries to feed and mate selection.	Spotted ratfish are opportunistic feeders and commonly prey on isopondylous fishes, mollusks, squid, nudibrances, opisthobranches, annelids and small crustaceans.

Table 2.1	Pacific Groundfish of the San Francisco Bay Area						
Common Name	**Scientific Name**	**Life Stage Presence in the Estuary**	**Range**	**Spawning**	**Early Life Stages**	**Adult and Juvenile Habitat Preferences**	**Prey**

[1]Groundfish Species that occur in San Pablo Bay occur in the Central Bay and may occur in other embayments.
ND: No Data.
Sources: Milton 2002; NOAA-Fisheries (available at: http://swr.nmfs.noaa.gov/hcd/loclist.htm); Pacific Groundfish FMP Appendix B.2 (available at: http://www.pcouncil.org/groundfish/gffmp/gfa19/GF_FMP_App_B2.pdf).

2.2 Coastal Pelagics Fisheries Management Plan

The *Coastal Pelagics FMP* delineates EFH for five pelagic fish species: Pacific sardine, Pacific (chub or blue) mackerel, northern anchovy, jack mackerel, and market squid (invertebrate). Coastal pelagic finfish live in the water column, near the surface, in waters with temperatures ranging between 10 to 26 degrees Celsius, and are not associated with the substrate. Generally, they occur above the thermocline in the upper mixed layer. The EFH for coastal pelagic finfish and market squid is defined as all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington, offshore to the limits of the EEZ and above the thermocline where the sea surface temperatures range between 10 to 26 degrees Celsius, and south to the United States-Mexico maritime boundary. Generally, sea surface temperatures and habitat boundaries for coastal pelagic finfish extend farther to the north during the summer than during winter months. The action area, including SF-DODS, is within EFH for coastal pelagic species.

2.2.1 Coastal Pelagic Species in the San Francisco Estuary

All five coastal pelagic species managed under the MSFCMA can be found in the San Francisco Bay region; however, only three are known to enter the Estuary during portions of their life cycle: northern anchovy, pacific sardine and jack mackerel. Table 2.2 provides information regarding these species, life stages and relative abundance that exist in the San Francisco Bay region.

Table 2.2 Pelagic Fish Species of San Francisco Bay

Common Name	Scientific Name	Life Stage in the Estuary	Range	Spawning	Habitat Preferences
Northern Anchovy	*Engraulis mordax*	Juveniles and adults are abundant in the Estuary.	Distributed from British Columbia to Baja California.	Spawn each month of the year; peaking Feb. -Apr. Eggs are found near surface.	Adults are pelagic; found in estuaries and nearshore (up to 98 miles off shore) waters up to 984 feet deep. Juveniles are pelagic; found in nearshore waters and estuaries.
Pacific Sardine	*Sardinops sagax caerulea*	Juveniles and adults are present in the Estuary.	Found in the Atlantic and Pacific, and in the western boundary of currents of the Indo-Pacific Oceans.	Year-round; peaking Apr. - Aug. Spawn in loosely aggregated schools in upper 164 feet of the water	Schools inhabit coastal subtropical and temperate waters. Larvae are pelagic.

Table 2.2	Pelagic Fish Species of San Francisco Bay				
Common Name	**Scientific Name**	**Life Stage in the Estuary**	**Range**	**Spawning**	**Habitat Preferences**
				column.	
Jack Mackerel	*Trachurus symmetricus*	Present in the Estuary.	Range from Baja California to the Aleutian Islands, Alaska.	Feb. - Oct.	Occurs in schools over rocky bottoms, reefs and shallow rocky coastal areas. Remain near bottom or under kelp canopies during daylight and deeper areas at night. Juveniles school under floating kelp and debris in the open sea.
Pacific (Chub) Mackerel	*Scomber japonicus*	ND	Range from Banderas Bay, Mexico to southeastern Alaska. Most common south of Monterey Bay.	Span from Eureka, California south to Baja California between 1.8 - 199 miles offshore.	Adults are found near shallow banks. Juveniles are found off sandy beaches, around kelp beds and in open bays.
Market Squid	*Loligo opalescens*	Not likely.	Range from Alaska to Baja California; they are most abundant between Monterey Bay and Baja California.	Spawning occurs year-round, peaking in the fall-spring. They spawn in shallow, semi-protected nearshore areas with sandy or mud bottoms adjacent to submarine canyons.	Market squid are pelagic and are found over the continental shelf from surface depths to depths of at least 497 feet. They are rarely found in bays, estuaries or river mouths.

[1]Coastal Pelagic Species that occur in San Pablo Bay occur in the Central Bay and may occur in other embayments.
Sources: Milton 2002; NOAA-Fisheries Coastal Pelagic FMP (available at: http://www.pcouncil.org/cps/cpsfmp/a8apdxa.pdf).

2.3 Pacific Salmon Fisheries Management Plan

The current Pacific Salmon Fisheries Management Plan provides management protection for the coast-wide aggregate of natural and hatchery salmon species within the EEZ that are fished off the coasts of Washington, Oregon and California. These species include Chinook, Coho, pink (only in odd-numbered years) and all salmon protected under the Endangered Species Act (ESA). The Pacific Salmon FMP also contains requirements and recommendations for the EFH for the managed salmon species. The EFH includes marine waters within the EEZ, and estuarine and freshwater habitat within Washington, Oregon, California and Idaho. The action area is within designated EFH for Pacific salmon species. Chinook salmon (Central Valley spring-run and Sacramento River Run Chinook salmon) are the only Pacific Salmon FMP salmonid that exists in San Francisco Bay (coho salmon is believed to be extirpated).

The Central Valley spring-run Chinook salmon ESU consists of populations from Redwood Creek, Humboldt County, south through the Russian River. Currently, only three naturally spawning populations are known to exist in Deer, Mill and Butte Creeks, which are tributaries to the Sacramento River. Historically, this ESU ranged from Ventura River, California to Point Hope, Alaska, and in northeastern Asia from Hokkaido, Japan to the Anadyr River in Russia. Chinook salmon exhibit two generalized freshwater life histories, stream-type and ocean-type. Stream-type juveniles reside in freshwater for a year or more before migrating to marine environmental, whereas ocean-type migrate within their first year of life (70 FR 37160).

The life history, habitat requirements and threats to the Sacramento River winter-run Chinook Salmon ESU are similar to that of the Central Valley spring-run Chinook salmon ESU and are discussed above. The primary difference, however, is that adults migrate to spawning grounds between December and July, peaking in March, and spawn from early March through July, peaking in May through June. Juveniles begin migrating to marine environments between July and October, residing in estuarine waters from five to ten months prior to entering the ocean (Fisher 1994).

3.0 The San Francisco Bay LTMS Maintenance Dredging Projects

The projects covered under the SF Bay LTMS and subject to this consultation include all operations and maintenance dredging and dredged material placement/disposal projects within the SF Bay LTMS geographic area (see Figure 1.1) conducted by USACE (federally-authorized dredging projects) or by non-federal entities which USACE and USEPA review for authorization under section 10 of the Rivers and Harbors Act (RHA), section 404 of the Clean Water Act (CWA) and/or section 103 of the Marine Protection Research and Sanctuaries Act (MPRSA). This consultation does not directly apply to "new work" dredging projects or projects to deepen existing channels, ports or marinas beyond their currently authorized depths, although maintenance dredging of these areas following completion of the "new work" or deepening projects will be considered part of this consultation.

3.1 Dredging Project Description

Maintenance dredging typically involves four steps: 1) testing for sediment quality; 2) removing recently shoaled sediment from the dredging site to restore authorized widths and depths; 3) transporting the dredged material via scows, hopper dredges or pipeline to the disposal, placement or beneficial use site; and 4) placing the dredged material at the designated site.

Typical methods of maintenance dredging include hydraulic dredging, mechanical dredging and knockdowns. Hydraulic dredging usually involves hopper dredges (with a hopper bin in the midsection to store and transport material dredged) or suction/cutterheads attached to hydraulic pipelines that convey the dredged material to a scow or directly to an upland site. Mechanical dredging usually involves bucket or clamshell dredges which scoop material directly into a scow for transport to a placement site. Knockdowns use a clamshell or an I-beam dragged behind a vessel to smooth local high spots into immediately adjacent deeper areas, without transport to an offsite placement location. The various methods of dredging and equipment used are discussed in Section 5.0.

Once the material is dredged, it is transported to a designated dredged material placement site and either disposed of, stored or beneficially used. Dredged material placement in the San Francisco Bay area includes the aquatic in-Bay disposal sites SF-9, SF-10, SF-11 and SF-16; the ocean disposal sites SF-8 and SF-DODS; rehandling facilities (e.g., Port of Oakland Berth 10), or beneficial use sites (e.g., Montezuma Wetlands, Hamilton Wetlands Restoration Project, Winter Island levee rehabilitation). Dredged material placement sites are discussed in Section 4.0.

Within the action area, there are at least 13 federal (maintained by USACE) and 105 non-federal maintenance dredging projects (see Figures 3.1 through 3.7, located at the end of this section). For USACE federal dredging projects, Table 3.1 provides the authorized depths, dimensions, type of dredge equipment commonly used, frequency of dredging, last fiscal year the project was dredged, and the historic dredged material placement site for each federal navigation project. Appendix A provides an in-depth description of each of the federally-authorized maintenance dredging projects and Appendix B provides the quantities of material dredged from the channels from fiscal years 1997 through 2008. Hydrosurveys of the federal navigation channel conducted before and after dredging are available at: http://www.spn.usace.army.mil/hydrosurvey/. The surveys provide information regarding where shoaling occurred and where dredging was conducted. Raw data can be provided to NOAA Fisheries upon request.

For non-federal dredging projects, Table 3.2 provides the approximate latitude and longitude, authorized depth and area, type of dredge equipment commonly used, and the historic dredged material placement site. For organizational purposes, Table 3.2 is broken up into non-federal dredging projects located within the various embayments (Suisun Bay, Carquinez/Mare Island Strait, San Pablo Bay, Central Bay and South Bay) and, within these embayments, further divided into smaller bays and tributaries. Further, each non-federal dredging project is numbered and corresponds to the numbered dredging project located on Figures 3.1 through 3.7. The information provided on Table 3.2 is derived from USACE and BCDC maintenance dredging permit files.

For larger non-federal project, the frequency of dredging is provided in Table 3.2. For projects where the frequency of dredging is difficult to predict, the quantities of material dredged from these projects between fiscal years 1997 through 2008 is provided in Appendix C; these data should provide the reader with an idea of how often projects are dredged over a thirteen-year period.

Whether dredging is required at these sites is dependant on two factors, shoaling and funding. Neither funding nor shoaling is consistent; different areas of the Estuary will experience sedimentation at different rates and sedimentation in any one area will be different from year to year. As such, it is difficult to predict the frequency of dredging for medium and smaller dredging projects. Further, dredging projects are not limited to using historic dredged material placement sites or dredging equipment.

Prior to conducting dredging activities, sediment that will be dredged from a site must be sampled and analyzed to determine the potential impacts of placing dredged sediment on the aquatic or upland environment. Sediment sampling results are reviewed by the Dredged Material Management Office (DMMO) to determine if the sediment is suitable for aquatic or upland disposal or beneficial use (sediment testing requirements are discussed in Section 6.0).

3.2 Federally (USACE) Maintained Maintenance Dredging Projects

USACE currently maintains 13 federally-authorized navigation projects in the Estuary. Table 3.1 provides an overview of the authorized dimensions, frequency of dredging, last fiscal year dredged and the dredged material placement site commonly used. Figures 3.1 through 3.7 show the locations of the federally maintained navigation channels.

Table 3.1	**USACE Maintained O&M Dredging Projects Located in the San Francisco Bay**							
Dredge Location	**Authorized Depth (MLLW)** [1]	**Length (feet)**	**Width (feet)**	**Area (acre)**	**Dredge Type**	**Frequency (years)**	**Last Dredged (FY)**	**Historic Placement Site**
Richmond Harbor [2]								
Southampton Shoal	-45	600	6,000	550	Bucket/ Clamshell/ *Essayons*	1	2006	Montezuma/ SF-DODS/ SF-11
Outer Harbor at Longwharf	-45	1,260 ft radius turning basin	500 - 600	--		1	2006	
Inner Harbor Entrance Channel	-41	20,000	500 - 1,500	459		1	2006	
Inner Harbor Approach Channel	-41	8,000	500 - 600	101		1	2006	
Santa Fe Channel	-30	1,000	200	4.59		12	1999	
Pt. San Pablo Channel	-20	2,000	150	6.89		ID	--	
San Francisco Harbor								
Bar Channel	-55	16,000	2,000	734.62	*Essayons*	1	2006	SF-8
Islais Creek Shoal	-40	2,000	500	22.96	--	ID	1977	
Presidio Shoal	-40	Varying widths and lengths		--	--	--	--	
Black Point Shoal	-40			--	--	--	--	
Alcatraz Shoal	-40			--	--	--	--	
Point Knox Shoal	-35			--	--	--	--	
Napa River Channel								
Mare Island Strait Causeway to Asylum Slough	-15	84,480	100	193.94	Cutterhead/ Pipeline	6	1999	Upland
Asylum Slough to Third Street	-10							

Table 3.1 USACE Maintained O&M Dredging Projects Located in the San Francisco Bay

Dredge Location	Authorized Depth (MLLW) [1]	Length (feet)	Width (feet)	Area (acre)	Dredge Type	Frequency (years)	Last Dredged (FY)	Historic Placement Site
Petaluma River Channel								
Across the Flats	-8	25,000	200	114.8	Cutterhead/ Pipeline	3	1998	SF-10
River Channel	-8	77,000	200	353.5		4	2003	Upland
San Rafael Creek								
Across the Flats	-8	10,000	100	23.0	Clamshell/ Hopper	7	1998	SF-11
Inner Canal Channel	-6	8,900	60	12.26		4	2003	SF-11/ Winter Island
Turning Basin	-6	200	100	0.46				
Pinole Shoal/Mare Island Strait								
Pinole Shoal	-35	40,000	600	798.9	*Essayons/* Clamshell/ Hopper	2	2005	SF-10
Mare Island Strait	-35	17,000	700 – 1,000	331.7		ID	1994	
Suisun Bay Channel *(and upper portion of New York Slough)*								
Main Channel	-35	25,000	300	172.2	Clamshell/ Hopper/ *Yaquina*	Annual	2006	Upland/ Levee/ SF-9/ SF-16
South Seal Island Channel	-25	5,600	250	32.1		Infrequent	1994	
Suisun Slough Channel								
Suisun Slough Channel	-8	68,640	125	197.0	--	8	--	Upland/ SF-9
Oakland Harbor [2]								
Outer Harbor	-50	9,000	600 - 800	144.63	Cutterhead/	1	2006	SF-11/

Table 3.1 USACE Maintained O&M Dredging Projects Located in the San Francisco Bay

Dredge Location	Authorized Depth (MLLW)[1]	Length (feet)	Width (feet)	Area (acre)	Dredge Type	Frequency (years)	Last Dredged (FY)	Historic Placement Site
Main Channel and Turning Basin	-50	8,000	600 - 950	146.9	Pipeline	1	2006	SF-DODS/ Upland/ Hamilton/ Montezuma
Inner Harbor Channel	-50	37,000	700	594.58		1	2006	
North Channel	-25	6,000	300	4.1		--	--	
San Leandro Marina (Jack D. Maltester Channel)								
Main Access Channel	-8	11,088	200	50.9	Cutterhead/ Hopper	4	2005	Upland
Interior Access Channel	-8	2,112	140	6.79		4	2001	Upland
North and Eastern Auxiliary Channels	**Deauthorized (Water Resources Development Act, 1992).							
Redwood City Harbor								
Entrance Channel	-30	13,900	300 - 350	103.71	Bucket/ Clamshell	2	2005	SF-11
Outer Turning Basin	-30	2,200	400 - 900	30.3		2	2005	
Connecting Channel	-30	1,300	400	11.94		2	2005	
Inner Turning Basin	-30	1,700	900	35.12		2	2005	
Inner Channel	-30	7,000	150	24.1		1	2005	
San Bruno Channel	-30	1,800	510	21.07		Infrequently	2005	
Sacramento River Deep Water Ship Channel (western portion)[3]								
Sacramento River DWSC	-30	22,176	600 - 1000	522	Hydraulic/ Clamshell	Annual	2008	Upland
San Joaquin River Deep Water Ship Channel (Reach 5 - between Pittsburg and Antioch through New York Slough)[4]								
San Joaquin River DWSC	-35	47,520	400	436.36	Hydraulic	4	--	Upland

Notes:
--: Information not available; however, the SF Bay LTMS is working to provide missing information.
ID: Indefinite Deferral
[1] Many federally-authorized channels are not maintained to their authorized depth.

Table 3.1	USACE Maintained O&M Dredging Projects Located in the San Francisco Bay							
Dredge Location	**Authorized Depth (MLLW)[1]**	**Length (feet)**	**Width (feet)**	**Area (acre)**	**Dredge Type**	**Frequency (years)**	**Last Dredged (FY)**	**Historic Placement Site**

[2] Dredged material is expected to go to HWRP and BMKV.
[3] A Supplemental EIS/EIR is being prepared to deepen the existing -30 foot Sacramento River DWSC to -35 feet MLLW. Information can be found at: http://www.sacramentoshipchannel.org/. Only a small portion of this project is located in the SF Bay LTMS action area.
[4] A Supplemental EIS/EIR is being prepared to deepen the existing -30 foot San Joaquin River DWSC to -40 feet MLLW in the West Richmond and Pinole Shoal portions of the channel and -45 feet MLLW for the remaining segments of the channel. Only a small portion of this project is located in the SF Bay LTMS action area.

3.3 Non-Federal Maintenance Projects

More than 100 non-federal marinas, ports and berthing slips are maintenance dredged within the Estuary. Most of the non-federal maintenance projects are located along the shorelines and within the tributaries of the Estuary. Table 3.2 provides an overview of the non-federal dredging projects, including dimensions, last fiscal year dredged, the dredge type commonly used and the historic dredged material placement site; Figures 3.1 through 3.7 provide maps showing the locations of the non-federal maintenance navigation channels.

Table 3.2			Non-Federal Dredging Projects Located in the San Francisco Bay						
No.	**Project**	**Latitude / Longitude**	**Depth (feet MLLW)**		**Area (acre)**	**Frequency[1]**	**Sediment Type**	**Dredge Commonly Used[2]**	**Historic Placement Site[2]**
			Suisun Bay						
1	USS Posco	38°01'50.23"N 121°51'44.98"W	Dock Intake Pipe	-35 -15	0.5 0.05	--	Sand	Clamshell	Winter Island
2	Pittsburg Marina	38°02'10.88"N 121°52'54.76"W	Marina Boat Launch	-7 -3	38.8 0.34	5 yrs	Silt/Clay/Sand	Clamshell	Winter Island
3	Ryer Island Boat Harbor (Venoco)	38°04'28.84"N 122°00'42.69"W	-6		0.3	5 yrs	Silt/Clay	Clamshell	SF-9
4	Montezuma Harbor	38°11'16.96"N 121°58'34.72"W	-2.5		--	--	Mud	Clamshell	Upland
5	Suisun City Marina	38°14'15.43"N 122°02'18.80"W	Main Channel Docks	-8 -6	12	5 yrs	Clay/Silt	Hydraulic	Pierce Island
6	City of Suisun Pierce Island Boat Ramp	38°13’59.25” N 122°02’15.58” W	-6		<1.0	--	Mud	Hydraulic	Upland
7	Tosco Refinery	38°02'56.86"N 122°05'28.46"W	-38		2.3	--	Silt/Clay	Clamshell	SF-9
8	Martinez Shore Terminal	38°02'45.29"N 122°06'3.64"W	-40		3.3	--	Sand/Silt	Clamshell	SF-9
			Carquinez Strait						
9	Valero Refinery Company - Benicia Crude Dock - Crude Wharf Tug Mooring Area	38°02’37.10” N 122°07’48.17” W	Crude Wharf Tug Mooring Area	-42 -10	0.06 0.03	Quarterly	Clay/Silt	Clamshell	SF-9/ SF-11

Table 3.2 Non-Federal Dredging Projects Located in the San Francisco Bay

No.	Project	Latitude / Longitude	Depth (feet MLLW)		Area (acre)	Frequency[1]	Sediment Type	Dredge Commonly Used[2]	Historic Placement Site[2]
10	Benicia Port Terminal (Amports)	38°02’23.53”” N 122°08’10.24” W	-41		6.5	--	Clay/Silt	Clamshell	SF-9 SF-11
11	Shell Terminal	38°02'3.76"N 122°07'32.49"W	--		--	--	--	--	--
12	Martinez Marina	38°01’40.41”” N 122°08’18.39” W	-8		11.5	4 yrs	Clay/Silt	Hydraulic	Upland Site
13	Benicia Marina	38°02’36.77”” N 122°09’27.10” W	Outer Channel	-11	2.4	1 - 3 yrs	Sand	Clamshell	SF-9
			Inner Channel & Turning Basin	-9	2.3		Sand/Silt		
			Berthing	-7	9.5				
14	Glen Cove Marina	38°04’00.14”” N 122°12’47.27” W	-5		0.83	8 - 10 yrs	Clay/Silt	Clamshell	Winter Island
15	C&H Sugar	38°03’27.56” N 122°13’13.29” W	-36		0.2	--	Mud	Clamshell	SF-9
16	Conoco Philips, Rodeo Terminal	38°03'25.25” N 122°15'43.08” W	Area 1	-40	16.7	Annual	--	Clamshell/ Hydraulic	SF-8/ SF-9/ HWRP
			Areas 2 & 3	-22					
					Napa River & Mare Island Strait				
17	Napa Valley Marina	38°13'14.61"N 122°18'45.46"W	-10		8.7	3 yrs	Mud	Hydraulic	Napa Sea Ranch
18	Vallejo Marina	38° 6'30.17"N 122°16'12.90"W	-12		29.9	--	Silt/Clay	Clamshell	SF-9
19	Vallejo Yacht Club	38° 6'12.13"N 122°15'57.91"W	Channel	-8	4.4	3 - 5 yrs	Mud	Clamshell/ Hydraulic	SF-9
			Marina	-10					
20	Vallejo Ferry Terminal	38° 5'58.99"N 122°15'47.43"W	-15		2.75	5 yrs	Clay/Silt	Clamshell	SF-9
21	Mare Island Shipyard	38° 5'45.71"N 122°15'51.28"W	-32		16.53	Annual	Clay/Silt	Clamshell	SF-9 / HWRP

No.	Project	Latitude / Longitude	Depth (feet MLLW)	Area (acre)	Frequency[1]	Sediment Type	Dredge Commonly Used[2]	Historic Placement Site[2]
Table 3.2	**Non-Federal Dredging Projects Located in the San Francisco Bay**							
22	Kiewit Pacific Company	38° 5'27.32"N 122°15'14.54"W	-15	38	--	Clay/Silt/Sand	Hydraulic	SF-10/ Kiewit Property
23	U.S. Army Reserve Center, Mare Island	38° 5'17.82"N 122°15'24.92"W	-10	4.7	--	Clay/Silt	Clamshell	SF-9
San Pablo Bay & Tributaries								
Petaluma River								
24	Petaluma River Turning Basin	38°14'7.59"N 122°38'16.30"W	-6	.01	-	Mud	Hydraulic	Upland
25	Shamrock Materials	38°13'47.70"N 122°37'29.61"W	-8	0.25	--	Mud	Clamshell	Upland
26	Petaluma Marina	38°13'43.26"N 122°36'48.07"W	-8	9	5 yrs	Mud	Hydraulic	Upland
27	Black Point Boat Launch Ramp	38° 6'52.56"N 122°30'21.91"W	Ramp -2 Approach Channel -14	0.091	Annual	Mud	Clamshell	SF-10/ SF-11
28	Port Sonoma Marina	38° 7'0.30"N 122°30'0.76"W	-8	16.4	5 yrs	Mud	Hydraulic	Carneros River Ranch/ On Site Ponds
Novato Creek								
29	Bel Marin Keys Community Services District[3]	38° 5'1.38"N 122°30'55.85"W	North Lagoon -3.5 South Lagoon -1.8 Novato Creek Entrance -5	28	10 yrs	Clay/Silt	Hydraulic	Upland/ HWRP

Table 3.2	Non-Federal Dredging Projects Located in the San Francisco Bay								
No.	**Project**	**Latitude / Longitude**	**Depth (feet MLLW)**		**Area (acre)**	**Frequency[1]**	**Sediment Type**	**Dredge Commonly Used[2]**	**Historic Placement Site[2]**
Gallinas Creek									
30	Gallinas Creek	38° 0'58.43"N 122°30'4.59"W	-7		17.2	Infrequent	--	Clamshell/ Hydraulic	SF-10/ SF-11/ Upland
San Pablo Bay									
31	San Rafael Rock Quarry	37°59'34.68"N 122°26'56.82"W	-16		9.8	--	Silt/Clay	Clamshell	SF-10
32	Point San Pablo Yacht Club	37°57'52.43"N 122°25'5.30"W	-7		8.0	5 yrs	Clay/Silt	Clamshell/ Excavator	SF-10
San Rafael Creek and Bay									
33	Loch Lomond Marina	37°58'17.34"N 122°29'1.83"W	-10		18.4	5 yrs	Clay/Silt	Clamshell	SF-10/ SF-11
34	Marina Vista Canal & Homeowners Association	37°58'16.10"N 122°29'43.48"W	Channel	-6	3.0	2 - 5 yrs	Silt/Clay	Clamshell/ Excavator	SF-10/SF-11
			Docks	-5					
35	Marin Yacht Club	37°58'13.68"N 122°29'58.84"W	-8		8.3	5 yrs	Silt/Clay	Bucket	SF10/ SF-11
36	San Rafael Creek, Residential Berths	37°58'4.76"N 122°30'16.02"W	-7		5.6	3 - 4 yrs	Silt/Clay	Bucket/ Clamshell	SF-10
37	Lowrie Yacht Harbor	37°58'0.57"N 122°30'28.11"W	-7		3.0	5 yrs	Silt/Clay	Bucket	SF10/ SF-11/ Winter Island
38	High Tide Boat Sales	37°58'2.83"N 122°30'38.99"W	-7		<1.0	--	Silt/Clay	Bucket	SF10/ SF-11
39	San Rafael Yacht Harbor	37°58'1.95"N 122°30'48.21"W	-6		4.5	--	Clay/Silt/Sand	Bucket	SF-10

Table 3.2	Non-Federal Dredging Projects Located in the San Francisco Bay								
No.	**Project**	**Latitude / Longitude**	**Depth (feet MLLW)**		**Area (acre)**	**Frequency[1]**	**Sediment Type**	**Dredge Commonly Used[2]**	**Historic Placement Site[2]**
				Central Bay & Embayments					
				Corte Madera Creek & Bay					
40	Larkspur Landing Ferry Terminal	37°56'41.49"N 122°30'29.34"W	Turning Basin	-15	0.87	--	Silt/Clay	Clamshell	SF-11
			Channel, Berths 1, 2 & 3	-17	3.6				
41	Larkspur Marina	37°56'38.53"N 122°30'30.17"W	--		6.3	--	Silt/Clay	Clamshell	SF-11
42	Larkspur Sea Scout Base	37°56'38.53"N 122°30'30.17"W	-8		0.05	5 yrs	Mud	Excavator	SF-10
43	Marin Rowing Association	37°56'33.54"N 122°31'0.37"W	-5		0.04	5 yrs	Clay/Silt	Excavator	SF-10/ SF-11
44	Greenbrae Marina Neighborhood	37°56'29.88"N 122°31'21.85"W	-10		2.1	3 - 4 yrs	Mud	Excavator	SF-11
				Keil Cove, Northwest Shore					
45	Paradise Cay Yacht Club	37°54'56.59"N 122°28'30.29"W	-10		9.9	10 yrs	Silt	Excavator mounted	SF-11
46	Paradise Cay Homeowners Association	37°54'33.12"N 122°28'27.16"W	South Cay Area	-8	5.8	4 yrs	Silt	Clamshell	SF-11
			Entrance Channel	-9	0.3				
47	Timmers Landing	37°54'30.52"N 122°28'20.35"W	-7		1.2	--	Mud	Clamshell	SF-11
				Belvedere Cove					
48	Corinthian Yacht Club	37°52'20.15"N 122°27'19.54"W	Basin 1	-8	0.4	7 yrs	Silt/Clay	Clamshell/ Hydraulic	SF-11
			Basin 2	-11	1.1				
			Basin 3	-13	1.8				

Table 3.2	Non-Federal Dredging Projects Located in the San Francisco Bay								
No.	**Project**	**Latitude / Longitude**	**Depth (feet MLLW)**		**Area (acre)**	**Frequency[1]**	**Sediment Type**	**Dredge Commonly Used[2]**	**Historic Placement Site[2]**
49	Bellevue Channel (Belvedere Cove)	37°52'21.16"N 122°27'34.33"W	-6		0.61	10 yrs	--	Clamshell	SF-11
50	Johnson Property	37°52'24.93"N 122°27'38.88"W	-6		<1.0	--	Silt/Clay	Clamshell/ Bucket	SF-11
51	Belvedere Land Company	37°52'22.58"N 122°27'42.87"W	-10		--	--	--	--	SF-11
52	San Francisco Yacht Club	37°52'21.02"N 122°27'39.90"W	-13		13.25	10 yrs	Silt/Clay	Clamshell/ Hydraulic	SF-11
Richardson Bay									
53	Strawberry Recreation District	37°53'10.12"N 122°29'55.00"W	-6		20.5	3 yrs	Silt	Clamshell	SF-11
54	Kappas Marina	37°52'36.01"N 122°30'10.80"W	-9.5		3.8	10 yrs	Clay/Silt	Clamshell/ Hydraulic	SF-11
55	Clipper Yacht Harbor	37°52'12.06"N 122°29'42.73"W	-11		13.3	3 yrs	Silt/Clay	Clamshell	SF-11
56	Arques Shipyard and Marina	37°52'3.33"N 122°29'43.96"W	-8		2.8	5 yrs	Silt/Clay	Clamshell	SF-11
57	Marina Plaza Harbor	37°52'0.42"N 122°29'43.37"W	-8		2.7	Annual	Mud	Clamshell	SF-11
58	Schoonmaker Point Marina	37°51'51.42"N 122°29'14.81"W	-13		9.1	10 yrs	Silt/Clay	Clamshell	SF-11
59	Galilee Harbor	37°51'46.44"N 122°29'16.39"W	Basins 1, 2 & 4	-8	11.6	5 yrs	--	Bucket/ Clamshell	SF-11
			Basin 3	-10					
60	Sausalito Marina Properties	37°51'38.88"N 122°29'3.01"W	-12		1.1	--	Clay/Silt	Clamshell	SF-11
61	Sausalito Yacht Club	37°51'34.87"N 122°28'42.61"W	-10		25.7	--	Silt/Clay	Clamshell	--

Table 3.2	Non-Federal Dredging Projects Located in the San Francisco Bay								
No.	Project	Latitude / Longitude	Depth (feet MLLW)		Area (acre)	Frequency[1]	Sediment Type	Dredge Commonly Used[2]	Historic Placement Site[2]
					Horseshoe Cove				
62	Coast Guard Station, Golden Gate	37°49'57.85"N 122°28'39.00"W	Berthing	-10	1.2	--	Sand/Gravel	Bucket/ Clamshell	SF-11
			Access Channel	-12					
					Central San Francisco Bay, Southwest Shore				
63	San Francisco Marina (includes Golden Gate Yacht Club and St. Francis Yacht Club)	37°48'26.95"N 122°26'26.20"W	Marina	-12	26.8	5 yrs	Silt/Sand/Gravel	Clamshell	SF-11
			Sand trap near Jetty	-55	2.8		Sand		Upland (construction)
64	Port of San Francisco (encompasses the southwest shoreline of Central Bay and the northwest shoreline of South Bay)	37°48'40.89"N 122°24'52.83"W	Berth 9S	-22	3.9	Annual	--	Clamshell	SF-11/ Berth 94 POSF/ Winter Island/ SF-DODS
			Berth 9N	-37	3.0		--		
			Piers 15 & 17	-42	2.7		--		
			Pier 45	-22	16.1		Clay/Silt		
			Pier 47	-14	3.8		Clay/Silt		
			Pier 45E	-37	2.8		Clay/Silt		
			Pier 45E	-14	2.3		Clay/Silt		
			Pier 43	-19	6.6		Clay/Silt		
			Pier 39	-14	17.1		Clay/Silt		
			Pier 35W	-37	7.3		Sand		
			Pier 35E	-37	11.3		Sand		
			Piers 31 & 33	-37	4.7		Sand		
			Pier 29	-37	2.8		Sand		
			Pier 27	-37	4.9		Silt/Clay		
			Ferry Terminal	-22	17.5		Mud		

Table 3.2	Non-Federal Dredging Projects Located in the San Francisco Bay								
No.	**Project**	**Latitude / Longitude**	**Depth (feet MLLW)**		**Area (acre)**	**Frequency[1]**	**Sediment Type**	**Dredge Commonly Used[2]**	**Historic Placement Site[2]**
			Piers 30 & 32	-40	9.4		Mud		
			Piers 48 &50	-37	21.9		Silt/Clay		
			Pier 50S	-44	5.2		Silt/Clay		
			Pier 50S	-37	4.5		Silt/Clay		
			Piers 52 & 54	-22	8.5		Silt/Clay		
			Central Basin	-37	36.1		Silt/Clay		
			Piers 80, 90 – 96	-44	135.9		Silt/Clay		
			China Basin	-22	13.2		Silt/Clay		
Central Bay, Eastern Shore (includes: Santa Fe Channel, Lauritzen Canal & Harbor Channel)									
65	Chevron, Richmond Longwharf	37°55'30.71"N 122°24'49.79"W	Longwharf	-52	25.5	Annual	Clay/Silt	Clamshell	SF-11/ SF-10/ Winter Island
			Berth 5	-21	1.8				
66	Richmond Yacht Club	37°54'28.29"N 122°22'58.52"W	-10		8.2	15 yrs	Clay/Silt	Clamshell/ Excavator	SF-11
67	Brickyard Cove Homeowners Association	37°54'29.38"N 122°22'51.87"W	--		--	--	--	Clamshell	SF-11
68	Castrol North American Consumer's Berth	37°55'21.35"N 122°22'26.96"W	-41		<10	--	Mud	Clamshell	SF-11/ SF-10
69	Levin-Richmond Terminal Corporation	37°55'17.19"N 122°22'0.99"W	Berth A	-41	0.5	--	Silt/Clay	Clamshell	Port of Richmond Parking Lot
			Berth B	-39	1.1				
70	Time Oil Terminal	37°55'4.93"N 122°21'52.31"W	-36	<10	--	Mud	Clamshell	SF-10/SF-11	
71	Conoco Philips, Richmond	37°54'47.83"N 122°21'53.26"W	Terminal Wharf	-42	8.2	--	Sand/Mud	Clamshell/ Hydraulic	SF-9/ SF-10

Table 3.2 Non-Federal Dredging Projects Located in the San Francisco Bay

No.	Project	Latitude / Longitude	Depth (feet MLLW)		Area (acre)	Frequency[1]	Sediment Type	Dredge Commonly Used[2]	Historic Placement Site[2]
	Terminal		Areas 4 & 5	-24					
72	Port of Richmond	37°54'35.44"N 122°21'39.70"W	Marina Entrance Channel	9.2	9.2	10 yrs	Silt/Clay	Clamshell	SF-10/ SF-11
			Terminal 3	2.88	2.88		Silt/Clay		
			Berth 8	-37	2.77		--		
			Berth 9	-37	3.25		--		
			Berth 10 (Rehandling Facility)	-36	1.89		--		
			Berths 20 – 21	-42	3.71		Silt/Clay		
			Berth 22	-50	2.79		--		
			Berth 23	-50	2.58		Clay/Sand		
			Berth 24	-50	3.7		Clay/Sand		
			Berths 25 – 26	-50	3.27		--		
			Berth 30	-50	3.47		--		
			Berths 32 – 33	-50	5.82		Silt/Clay		
			Berth 34	-38	2.67		--		
			Berth 35	-50	3.31		Clay/Sand		
			Berth 37	-50	3.32		--		
			Berth 38	-42	2.5		--		
			Berth 55	-50	3.69		--		
			Berth 56	-50	3.57		--		
			Berth 57	-50	4.48		Silt/Clay		
			Berth 58	-50	4.48		Clay/Sand		
			Berth 59	-50	3.4		Clay/Sand		
			Berths 60 – 61	-42	4.14		Mud		
			Berths	-42	3.89		Mud		

Table 3.2 Non-Federal Dredging Projects Located in the San Francisco Bay

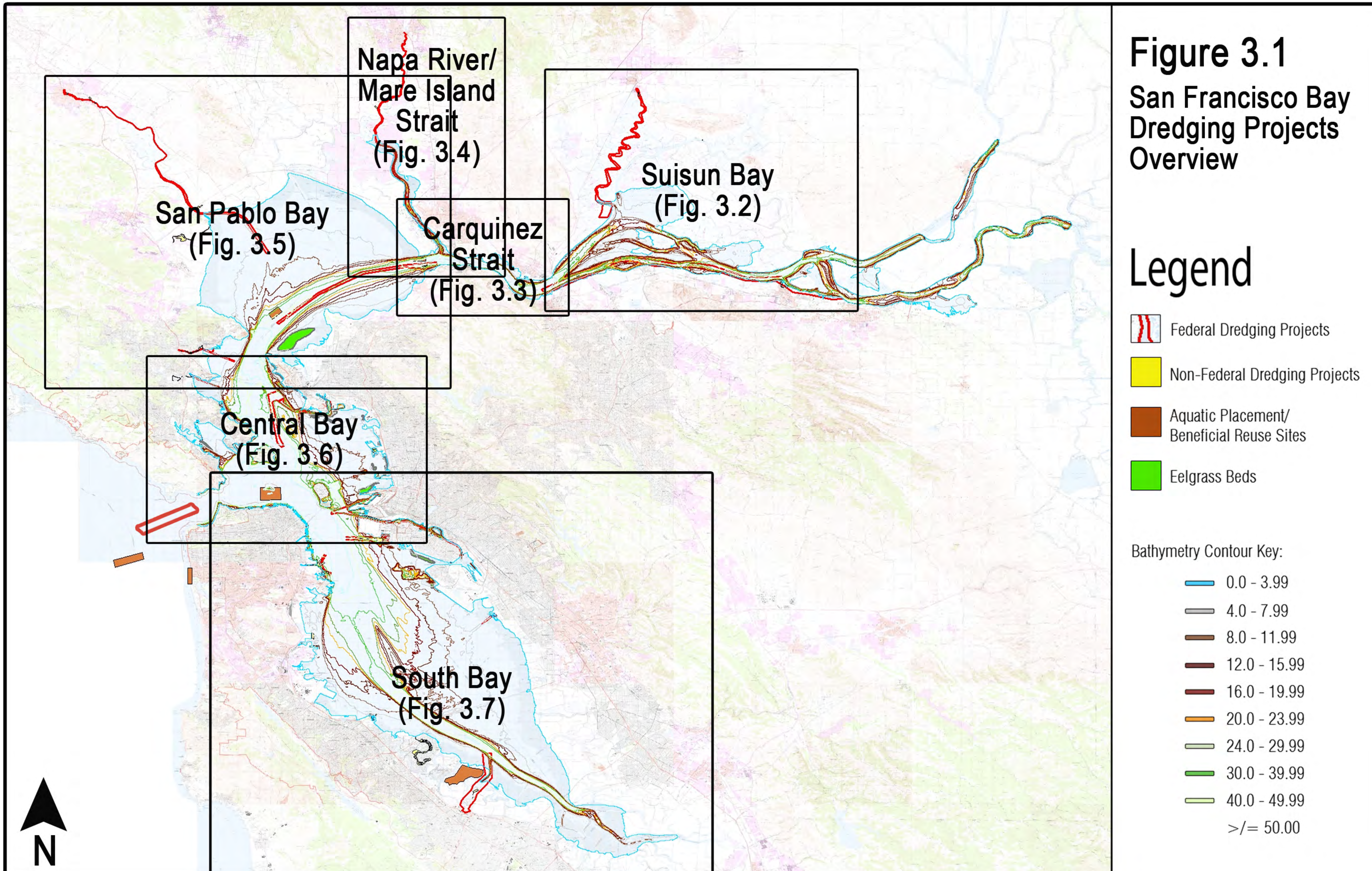
No.	Project	Latitude / Longitude	Depth (feet MLLW)		Area (acre)	Frequency[1]	Sediment Type	Dredge Commonly Used[2]	Historic Placement Site[2]
			62 – 63						
			Berth 67	-42	2.64		Silt/Clay		
			Berth 68	-42	3.54		Silt/Clay		
			Berth 82	-35	2.82		Mud		
			Berths 83 – 84	-35	3.29		Mud		
73	BP, Richmond Terminal	37°54'28.33"N 122°21'49.26"W	-41		2.2	3 - 4 yrs	Mud	Clamshell	SF-10
74	Berkeley Marina	37°51'59.98"N 122°19'4.19"W	-8		52	3 yrs	Mud	Clamshell	SF-11
75	Emery Cove Yacht Harbor	37°50'25.92"N 122°18'35.56"W	-8.5		<20	6 yrs	Clay/Silt/Sand	Clamshell	SF-11
76	City of Emeryville Marina	37°50'25.92"N 122°18'35.56"W	-8		22.3	3 yrs	Clay/Silt/Sand	Clamshell/ Excavator	SF-11
77	Emery Cove Marina	37°50'25.92"N 122°18'35.56"W	-9.5		55.3	5 yrs	Silt/Clay	Clamshell/ Excavator	SF-11
South Bay									
South Bay, Yerba Buena Island									
78	Coast Guard Station, Yerba Buena Island	37°48'39.41"N 122°21'38.45"W	Area A	-10	3.5	--	Clay/Silt	Clamshell	SF-11
			Area B	-14					
			Area C	-18					
South Bay, Western Shore									
79	South Beach Yacht Club	37°46'56.24"N 122°23'5.65"W	-16		24.9	--	Silt	Clamshell	SF-11
80	San Francisco Dry Dock	37°45'52.29"N 122°22'57.09"W	Areas A & B	-28	1.5	--	Silt/Clay	Clamshell	SF-11
			Area C	-34	0.9				
81	Brisbane Marina at Sierra Point	37°40'9.77"N 122°22'40.91"W	-8		39.6	5 yrs	Silt/Clay	Clamshell	SF-11

Table 3.2	Non-Federal Dredging Projects Located in the San Francisco Bay								
No.	**Project**	**Latitude / Longitude**	**Depth (feet MLLW)**		**Area (acre)**	**Frequency[1]**	**Sediment Type**	**Dredge Commonly Used[2]**	**Historic Placement Site[2]**
82	Oyster Cove Marina	37°40'9.77"N 122°22'40.91"W	-8		29.2	3 yrs	Clay/Silt/Sand	Clamshell	SF-11
83	Oyster Point Marina	37°40'9.77"N 122°22'40.91"W	-8		29.8	10 yrs	Mud	Clamshell	SF-11
84	Candlestick Point	37°36'22.24"N 122°22'0.24"W	-8		--	5 yrs	--	--	SF-11
85	Coyote Point Marina	37°35'26.83"N 122°18'58.46"W	Entrance Channel	-10	2.6	8 yrs	Mud	Clamshell	SF-11
			Basins 1 & 2	-8	8.2				
South Bay, South of Dumbarton Bridge									
86	Foster City Lagoon[3]	37°33'14.63"N 122°16'16.21"W	-7		60	5 yrs	Mud	Pipeline	Upland (Foster City)
87	Redwood Shores Lagoon[3]	37°32'20.94"N 122°14'40.64"W	+93		8.2	--	Silt/Clay	Hydraulic	Preserve at Redwood Shores (wetland)
88	RMC Lonestar Cement Marina Terminal	37°30'54.28"N 122°12'25.57"W	-35		<10	--	--	Clamshell	SF-11
89	Port of Redwood City	37°30'18.14"N 122°13'9.05"W	-34		7.17	4 - 5 yrs	Mud	Clamshell	SF-11
90	Redwood City Marina	37°30'6.60"N 122°13'20.12"W	--		--	--	--	--	--
91	Alvisio Marina Boat Ramp	37°25'34.06"N 121°58'45.55"W	--		--	--	--	--	--
92	City of Sunnyvale Boat Ramp	37°25'58.98"N 122° 5'19.94"W	--		0.57	--	Mud	Excavator	Upland

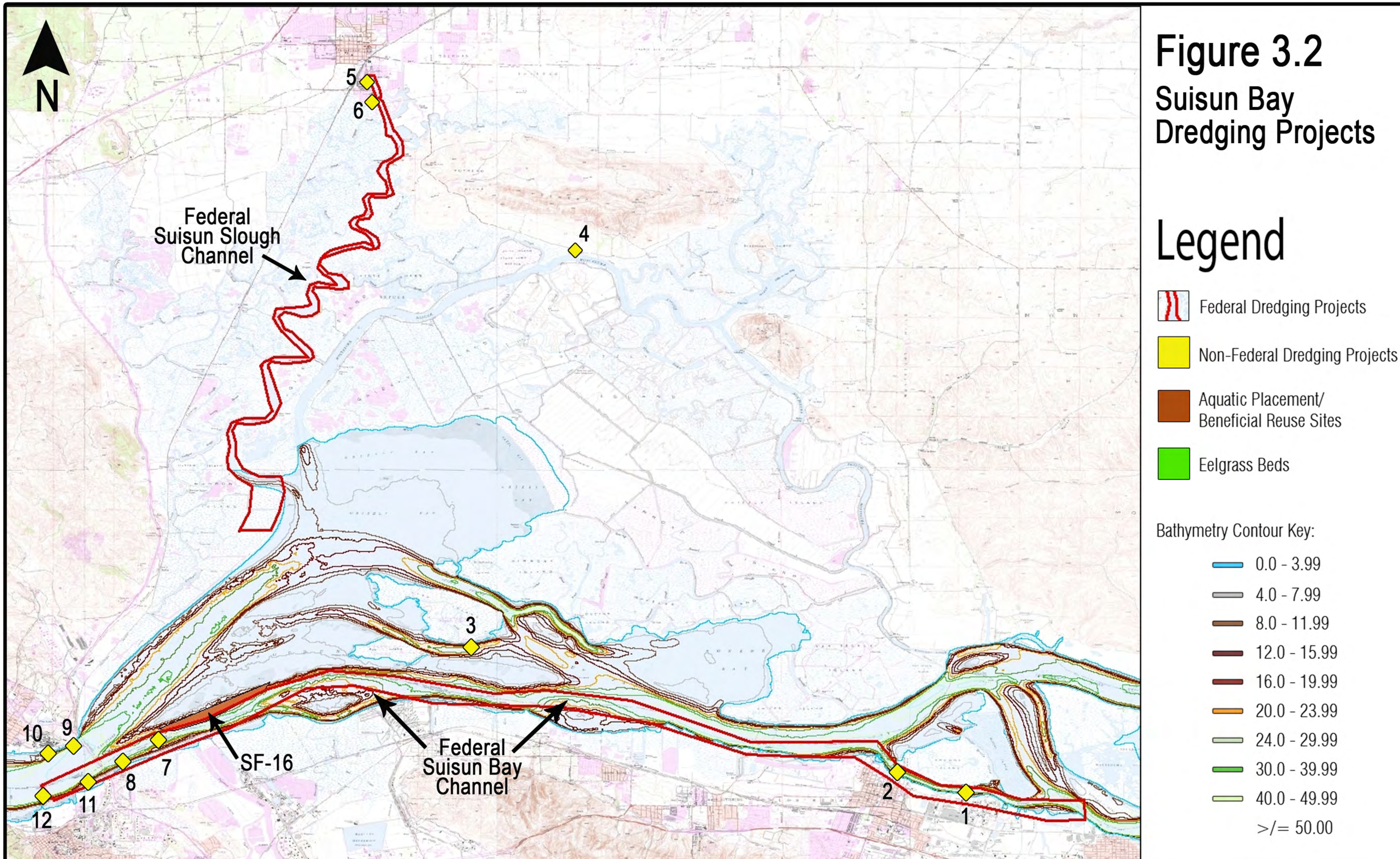
Table 3.2	Non-Federal Dredging Projects Located in the San Francisco Bay								
No.	**Project**	**Latitude / Longitude**	**Depth (feet MLLW)**		**Area (acre)**	**Frequency[1]**	**Sediment Type**	**Dredge Commonly Used[2]**	**Historic Placement Site[2]**
South Bay, East Shore									
93	Port of Oakland	37°49'13.65"N 122°18'44.62"W	Berth 7	-37	4.23	Annual	--	Clamshell/ Hydraulic	NSC Naval Center/ SF-11/ B40 (South Buttress)/ Berth 10, POO/ Berth 94, POSF/ MHEA/
			Berth 8	-37	2.77		--		
			Berth 9	-37	3.25		--		
			Berth 0	-36	1.89		--		
			Berths 20 – 21	-42	3.71		Silt/Clay		
			Berth 22	-50	2.79		--		
			Berth 23	-50	2.58		Clay/Sand		
			Berth 24	-50	3.7		Clay/Sand		
			Berths 25 – 26	-50	3.27		--		
			Berth 30	-50	3.47		--		
			Berths 32 – 33	-50	5.82		Silt/Clay		
			Berth 34	-38	2.67		--		
			Berth 35	-50	3.31		Clay/Sand		
			Berth 37	-50	3.32		--		
			Berth 38	-42	2.5		--		
			Berth 55	-50	3.69		--		
			Berth 56	-50	3.57		--		
			Berth 57	-50	4.48		Silt/Clay		
			Berth 58	-50	4.48		Clay/Sand		
			Berth 59	-50	3.4		Clay/Sand		
			Berths 60 – 61	-42	4.14		--		
			Berths 62 – 63	-42	3.89		--		
			Berth 67	-42	2.64		Silt/Clay		
			Berth 68	-42	3.54		Silt/Clay		
			Berth 82	-35	2.82		--		
			Berths	-35	3.29		--		

Table 3.2	Non-Federal Dredging Projects Located in the San Francisco Bay							
No.	**Project**	**Latitude / Longitude**	**Depth (feet MLLW)**	**Area (acre)**	**Frequency**[1]	**Sediment Type**	**Dredge Commonly Used**[2]	**Historic Placement Site**[2]
			83 – 84					
94	Schnitzer Steel	37°47'41.26"N 122°17'21.75"W	-37	2.0	--	Silt/Clay	Clamshell	SF-11
95	Oakland Yacht Club	37°47'2.59"N 122°15'51.83"W	-10	<10	--	Mud	Clamshell	SF-11
96	Coast Guard, Alameda Station	37°46'47.01"N 122°14'59.90"W	-29	7.1	--	Silt/Clay	Clamshell/ Hydraulic	SF-11/ POO Berth 10/ Upland
97	Alameda Point Channel	37°46'26.05"N 122°19'1.55"W	-32	18.2	--	Clay/Silt	Clamshell/ Hydraulic	SF-11
98	Ron Valentine Boat Dock	37°46'4.83"N 122°17'19.65"W	-4	0.01	--	Mud	Clamshell	SF-11
99	Ballena Isla Marina	37°45'56.86"N 122°16'55.06"W	-9	--	4 yrs	Fines/ Shell-hash	Clamshell	SF-11
100	Ballena Isla Townhomes	37°45'56.86"N 122°16'55.06"W	Dock -3 Channel -8	3.8 2.5	8 yrs	Fines/ Shell-hash	Clamshell	SF-11
101	Hanson Aggregates	37°45'48.47"N 122°13'26.21"W	-14	.30	--	Sand/Gravel	Clamshell/ Excavator	SF-11/ Winter Island
102	Corona Del Mar Homeowners Association	--	-6	0.05	5 yrs	Mud	Clamshell	SF-11
103	Aeolian Yacht Club	37°44'59.05"N 122°14'5.12"W	-9	2.9	7 yrs	Clay	Clamshell/ Hydraulic	SF-11
104	Harbor Bay Ferry Channel	37°44'10.52"N 122°15'27.04"W	-10	2.43	--	--	--	SF-11
105	San Leandro Marina	37°41'41.19"N 122°11'31.64"W	-7	20	5 yrs	Fines/Silt/Clay	Hydraulic	SF-11

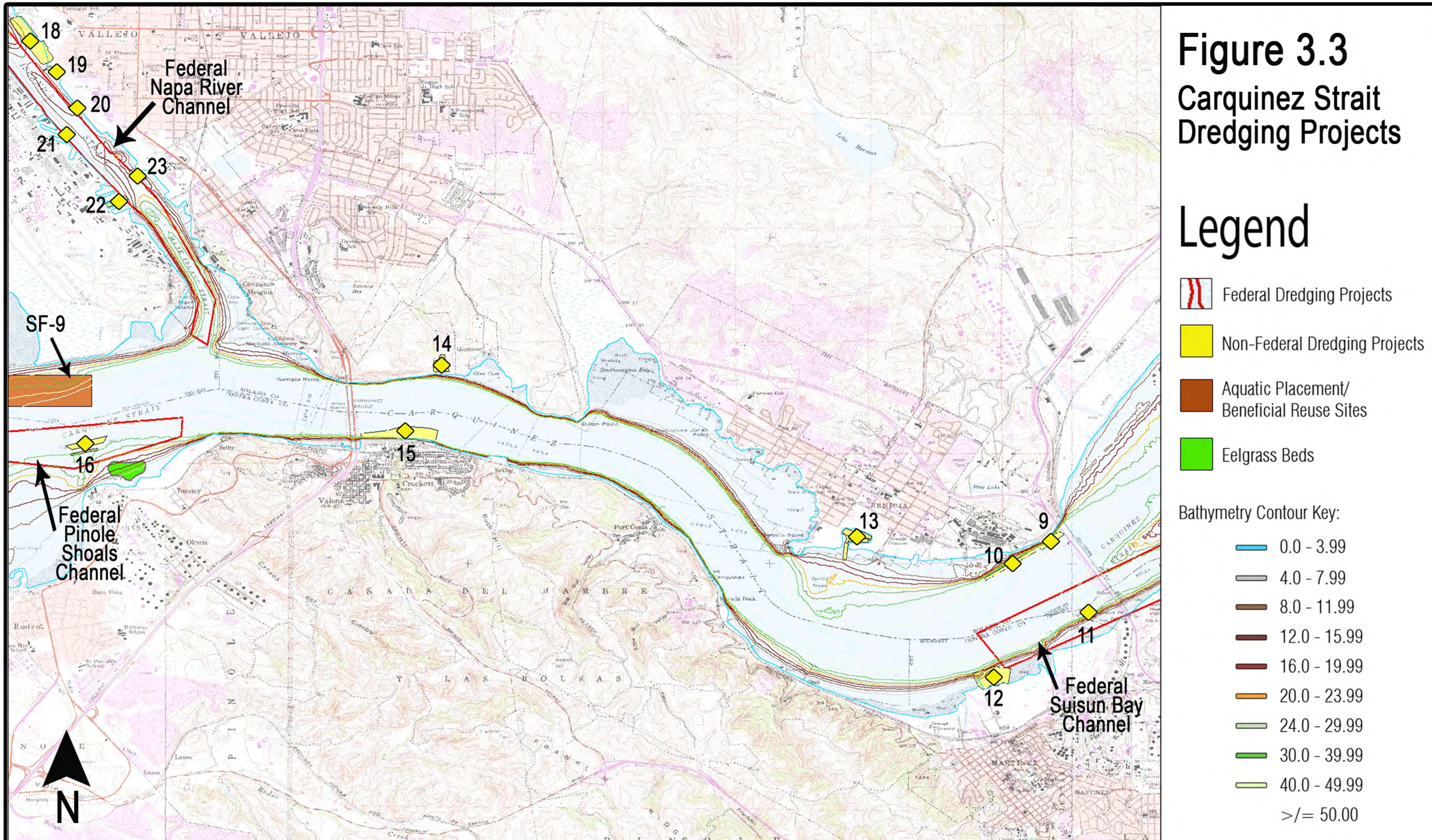
Source: DMMO and BCDC maintenance dredging permit files.
(--): Data not available.
[1]The frequency of dredging depends on shoaling rates and funding.
[2]Projects are not constrained to historic dredging or dredged material placement methods
[3]Dredging and dredged material placement occurs outside of the Estuary and its tributaries; therefore, these projects are not expected to result in impacts on EFH or EFH-managed species.



Source: Created by USACE 2009.
Not to scale



Source: Created by USACE 2009.
Not to scale



Source: Created by USACE 2009.
Not to scale

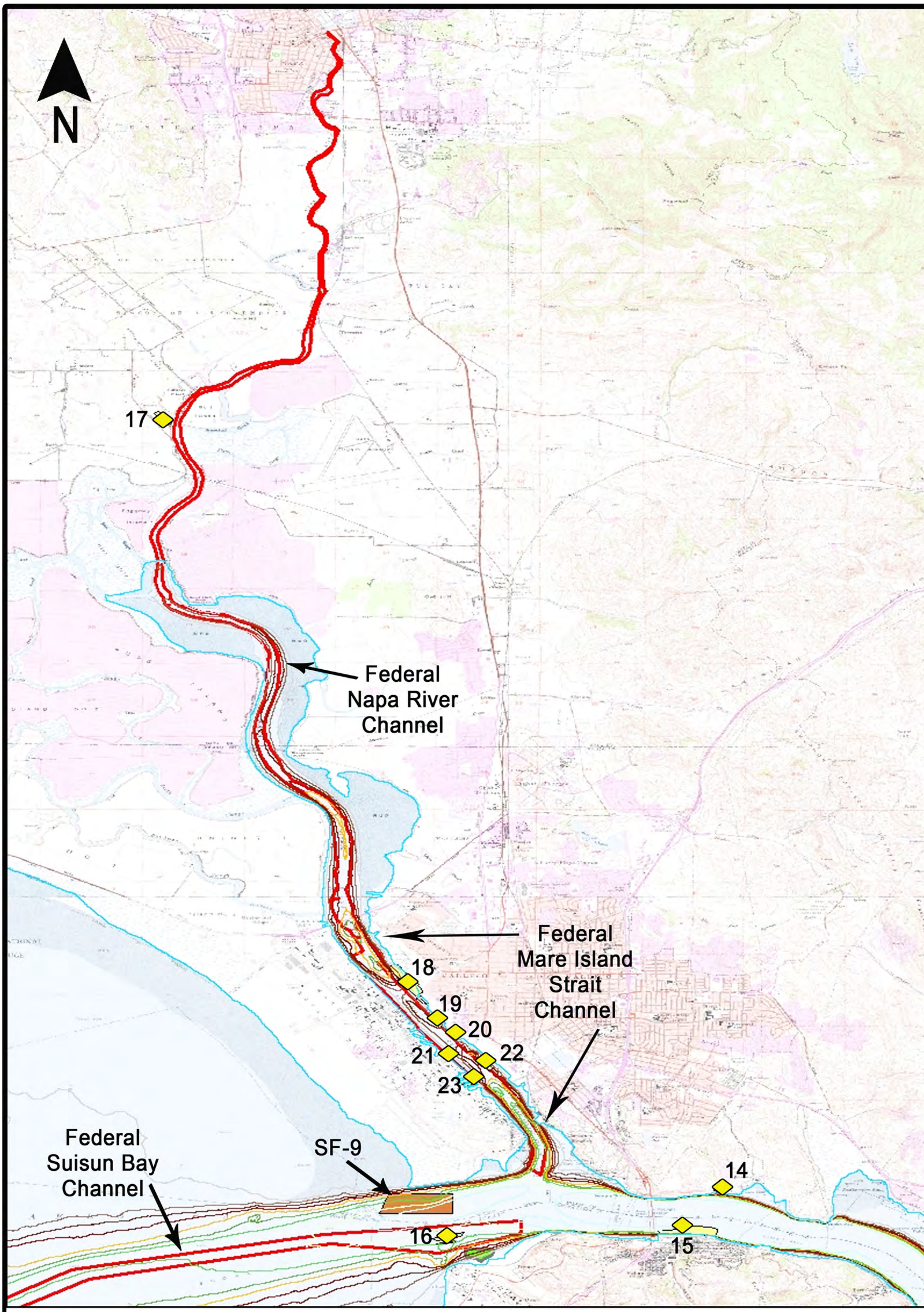


Figure 3.4

Napa River & Mare Island Strait Dredging Projects

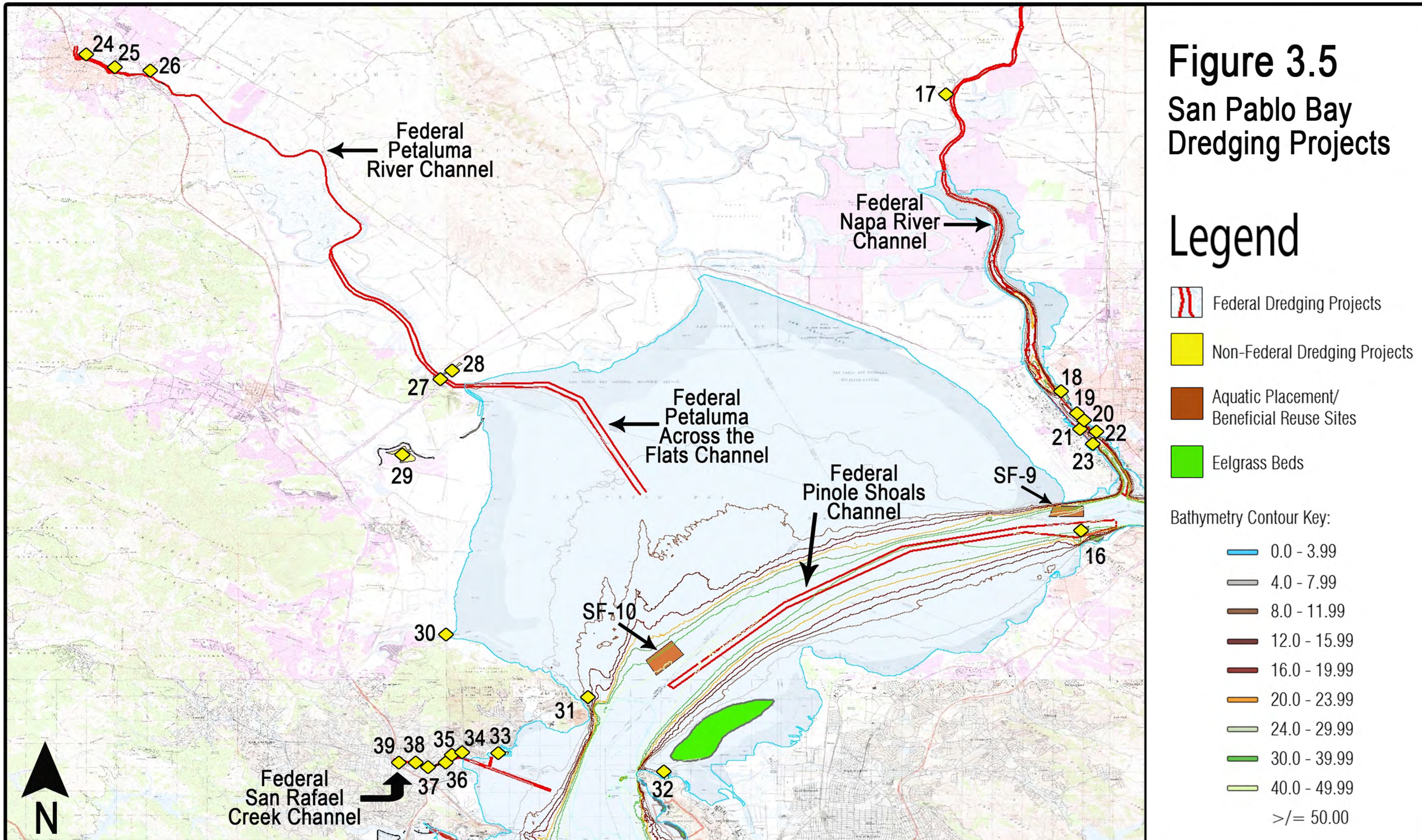
Source: Created by USACE 2009.
Not to scale

Legend

- Federal Dredging Projects
- Non-Federal Dredging Projects
- Aquatic Placement/ Beneficial Reuse Sites
- Eelgrass Beds

Bathymetry Contour Key:

- 0.0 - 3.99
- 4.0 - 7.99
- 8.0 - 11.99
- 12.0 - 15.99
- 16.0 - 19.99
- 20.0 - 23.99
- 24.0 - 29.99
- 30.0 - 39.99
- 40.0 - 49.99
- >/= 50.00



Source: Created by USACE 2009.
Not to scale

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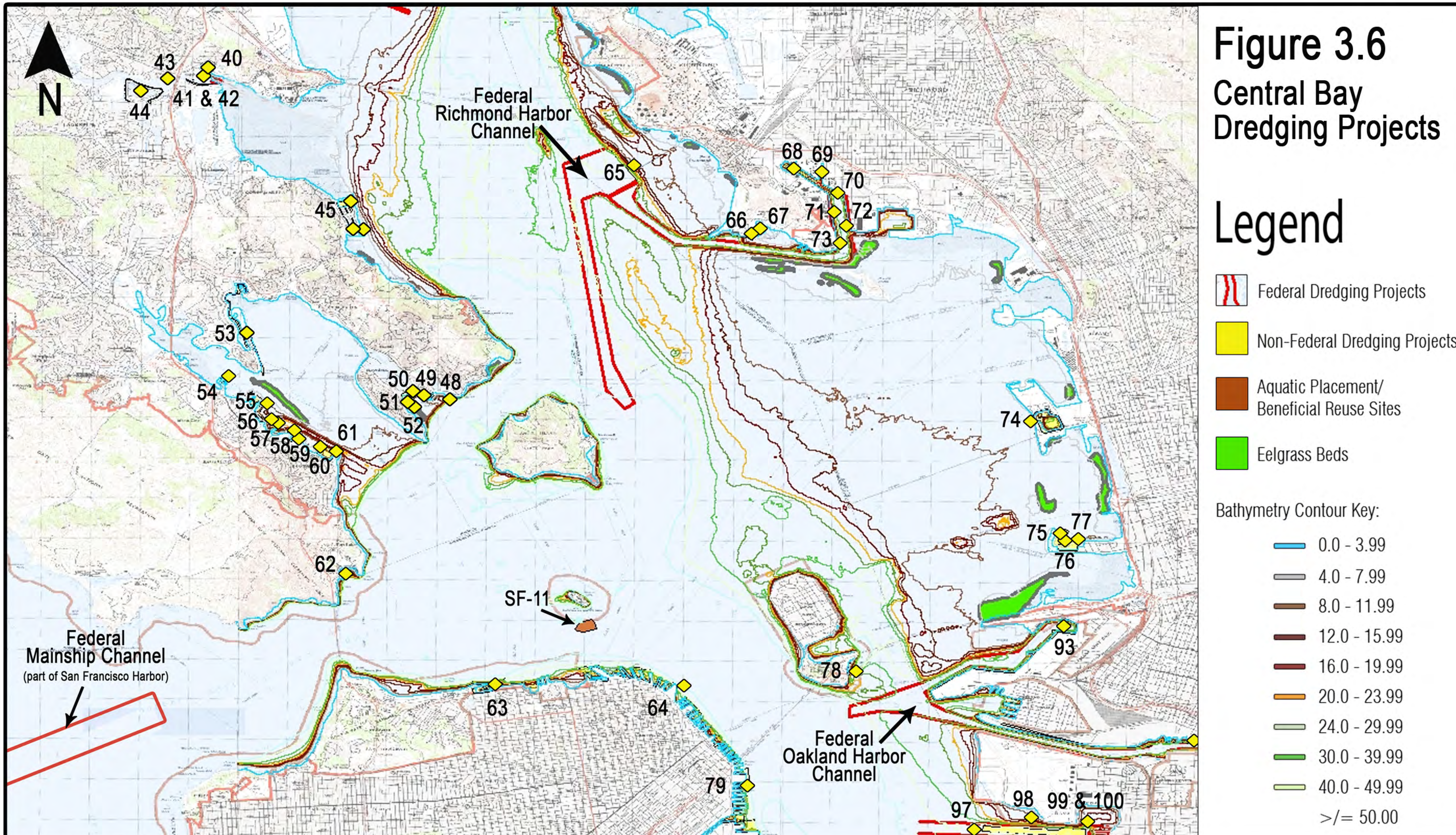

Source: Created by USACE 2009.
Not to scale

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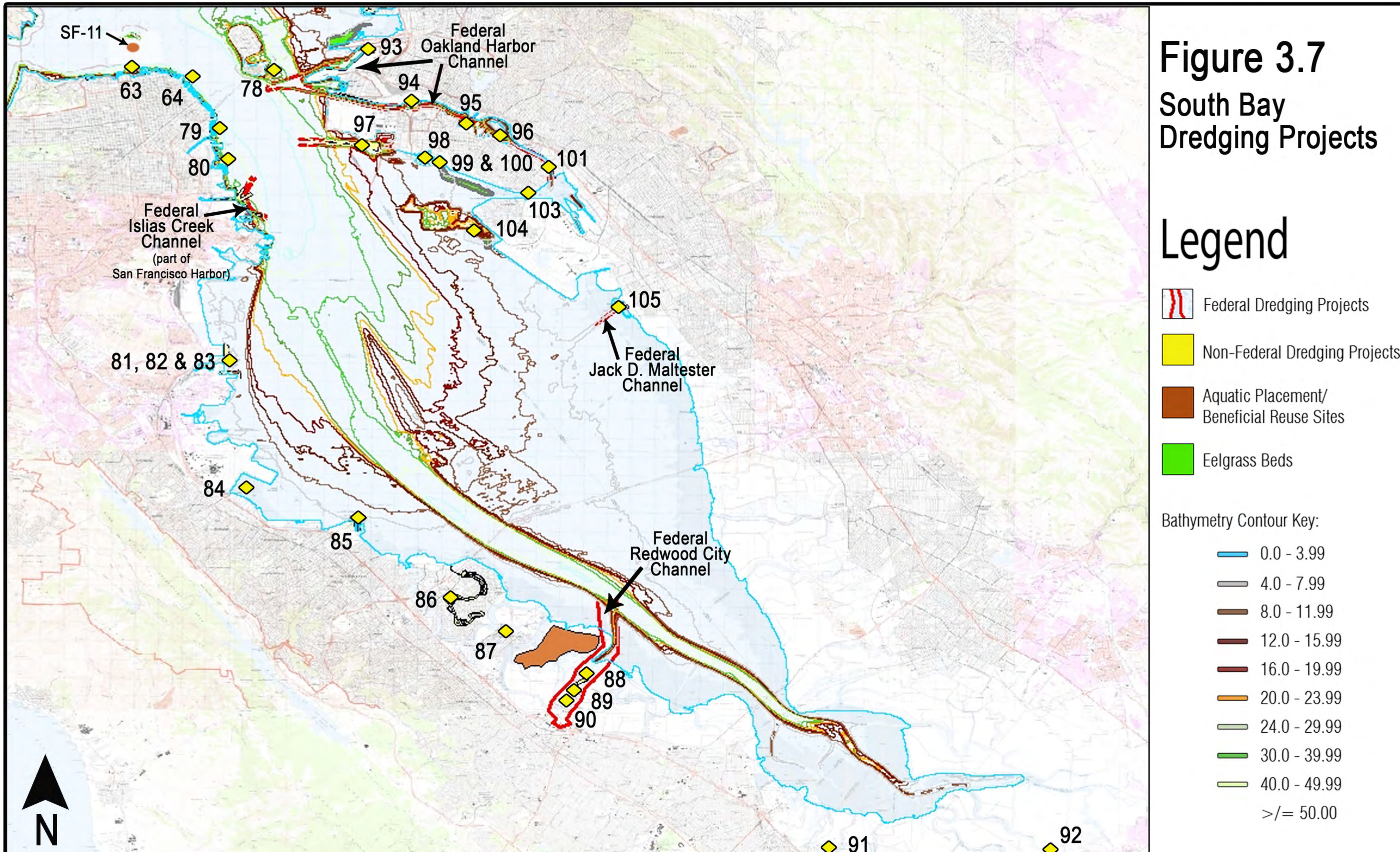


Source: Created by USACE 2009.
Not to scale

4.0 Dredged Material Placement Locations

This section provides a discussion of the various locations currently authorized for dredged material placement in the San Francisco Bay region. Table 4.1 and Figure 4.1 present the dredged material placement options for material dredged from the Bay. In addition to the dredged material placement options listed on Table 4.1, there are limited private and project-specific dredged material placement sites that are not listed here.

Table 4.1 Dredged Material Placement Locations within the San Francisco Bay Area

Name	Type	Location
SF-09 Carquinez Strait	In-Bay, unconfined	Carquinez Strait
SF-10 San Pablo Bay	In-Bay, unconfined	San Pablo Bay
SF-11 Alcatraz	In-Bay, unconfined	Alcatraz Island
SF-16 Suisun Bay	In-Bay, unconfined	Suisun Bay
SF-DODS	Ocean, unconfined	55 miles west of Golden Gate
SF-08 San Francisco Bar Channel	Ocean, unconfined	Adjacent to SF Bar Channel
Hamilton Bel Marin Keys-V[1]	Beneficial use	Marin County
Carneros River Ranch	Beneficial use	Sonoma County
Montezuma	Beneficial use	Solano County
Winter Island	Beneficial use	Delta island
Van Sickle Island	Beneficial use	Delta island
Sherman Island	Beneficial use	Delta island
Bair Island	Beneficial use	Near Redwood City Harbor
Demonstration Site at Ocean Beach	Beneficial use	Near shore
Pierce Island Disposal Ponds	Upland	Near Suisun City, Solano County
Schoellenberger Park	Private, upland	Petaluma, Sonoma County
San Leandro Marina	Private, upland	San Leandro, Alameda County
Lorenzi Property	Private, upland	Near Bel Marin Keys, Marin County
Martinez Marina Disposal Ponds	Private, upland	Martinez Marina, Martinez, Contra Costa County

[1]Project expansion authorized in WRDA 2007.

Figure 4.1 San Francisco Bay Beneficial Use and Disposal Sites

4.1 Aquatic Dredged Material Placement Sites

Open water dredged material placement sites provide for the placement of dredged material in the Estuary (in-Bay) or ocean via pipeline or release from hopper dredges or scows. Dredged material placement volume history per disposal site is presented in Appendix D. In San Francisco Bay, most aquatic disposal occurs via hopper dredges or scows.

4.1.1 In-Bay Dredged Material Placement Sites

SF-11 Alcatraz

The SF-11 disposal site is a 1,000-foot radius circular disposal area (72 acres), approximately 40 to 70 feet deep, located approximately 0.3 miles south of Alcatraz Island in the Central Bay. Since at least 1972, SF-11 has been the most heavily used disposal site in the Bay (center at 37°49'17" N, 122°24'88" W). SF-11 is a mound cresting at approximately -40 feet MLLW, over what was historically a scour hole 165 feet deep. This mound developed through the 1970s and 1980s when disposal volumes were higher. Today the site is managed to be fully dispersive for material continuing to be placed there, so that the mound does not grow. Now disposal is limited to 400,000 cubic yards of dredged material per month during the October through April timeframe and 300,000 cubic yards per month during the May through September timeframe. In addition to these monthly limits, total annual disposal is capped at 4 million cubic yards (however, this is further limited by the overarching LTMS limit on in-Bay disposal at all sites combined, which is currently 2.03 million cubic yards/year). Since the implementation of the SF Bay LTMS (2001 - 2008), actual disposal at SF-11 has ranged from 700,000 to 1,817,000 cubic yards per year, averaging 1.2 million cubic yards per year.

SF-10 San Pablo Bay

The SF-10 disposal site is a 1,500 by 3,000 foot rectangle (103 acres), approximately 30 to 45 feet deep, located 3.0 miles northeast of Point San Pedro in southern San Pablo Bay, Marin County (center at 38°00'28" N, 122°24’55" W). Depths at this disposal site range from approximately -35 to -40 feet MLLW. Disposal is limited to 500,000 cubic yards of dredged material per year; all 500,000 cubic yards can be placed there in a month. Since the implementation of the SF Bay LTMS (2001 - 2008), actual disposal at SF-10 has ranged from 6,000 to 378,000 cubic yards per year, averaging 201,000 cubic yards per year. SF-10 is a fully dispersive disposal site; therefore, all material placed at the site is re-deposited throughout the Estuary.

SF-9 Carquinez Strait

The SF-9 disposal site is a 1,000 by 2,000 foot rectangle (46 acres), approximately 10 to 55 feet deep, located 0.9 miles west of the entrance to Mare Island Strait in eastern San

Pablo Bay, Solano County. Depths at this disposal site range from approximately -30 to -60 feet MLLW. Disposal is limited to 1.0 million cubic yards of dredged material per month and a maximum of 2.0 million cubic yards per year during wet years and 1.0 million cubic yards per year during dry years. Since the implementation of the SF Bay LTMS (2001 - 2008), actual disposal at SF-9 has ranged from 39,000 to 320,000 cubic yards per year, averaging approximately 151,000 cubic yards per year. SF-9 is a fully dispersive disposal site; therefore, all material placed at the site is re-deposited throughout the Estuary.

SF-16 Suisun Bay

The SF-16 disposal site is a single-user in-Bay unconfined disposal site reserved for sand dredged from the USACE's Suisun Channel and New York Slough projects only. It is a 500 by 11,200 foot rectangle (129 acres) located adjacent to the north side of Suisun Bay Channel, approximately one mile upstream of the Interstate 680 Bridge (center at 38°03'05" N, 122°05'35" W). The depth at this site is approximately -30 feet MLLW. Currently, the site is authorized to receive 200,000 cubic yards of dredged material per year. Since the implementation of the SF Bay LTMS (2001 - 2008), actual disposal at SF-16 has ranged from 111,000 to 320,000 cubic yards per year, averaging 214,000 cubic yards per year. SF-16 is a fully dispersive disposal site; therefore, all material placed at the site is re-deposited throughout the Estuary.

4.1.2 Ocean Dredged Material Placement Sites

SF-8 Bar Channel

The SF-8 is a 15,000 by 3,000 foot wide rectangle (1,033 acre) disposal site located 7,500 feet south of the San Francisco Bar Channel in the Pacific Ocean (first Corner: 37°44'55", 122°37'18" W, second Corner: 37°45'45" N, 122°34'24" W, third Corner: 37°44'24" N, 122°37'06" W and fourth Corner: 37°45'15" N, 122°34'12" W). Depths at SF-8 range from approximately 30 to 45 feet MLLW. This offshore site is mainly under the jurisdiction of the MPRSA, and disposal is limited to sandy material dredged by USACE from the Main Ship Channel. However, the eastern most portion of SF-8 is within the 3-mile limit, and sand from other dredging projects in the Bay can be permitted there as beneficial use to nourish Ocean Beach. The trapezoidal portion of SF-8 that is within the three-mile limit is approximately 3,000 feet long by 430 feet at its northern end and 1,000 feet wide at its southern end. There is no set limit on disposal at SF-8; however, since the implementation of the SF Bay LTMS (2001 - 2008), actual disposal at SF-8 has ranged from 60,000 to 378,000 cubic yards per year, averaging 204,000 cubic yards per year.

SF-DODS (San Francisco Deep Ocean Disposal Site)

Located approximately 49 nautical miles west of the Golden Gate Bridge, the SF-DODS is the farthest offshore and deepest (8,000 to 10,000 feet) dredged material disposal site in the Nation (center point at 37°39'00" N, 123°29'00" W). The USEPA designated SF-DODS for dredged material disposal in a Final Rule published August 11, 1994 (59 FR

41243, 40 CFR 228.15(1)(3)), amended in 1996 and 1999. The Final Rule contains a Site Management and Monitoring Plan (SMMP) that describes the management and monitoring activities necessary to assess any potential adverse impacts resulting from disposal of dredged material at SF-DODS. Unlike the in-Bay disposal sites discussed above, SF-DODS is in a depositional environment. Disposal is limited to 4.8 million cubic yards of dredge material per year. Since the implementation of the SF Bay LTMS (2001 - 2008), actual disposal at SF-DODS has ranged from 78,000 to 1,109,000 cubic yards per year, averaging 534,000 cubic yards per year. Extensive annual monitoring has confirmed that this disposal has occurred without causing any significant impacts to the ocean and the marine biology in and around SF-DODS.

Nearshore Beneficial Use Demonstration Site (Near Ocean Beach)

Because the sandy material placed at the Nearshore Beneficial Use Demonstration Site is used to nourish Ocean Beach in San Francisco, California, it not considered a dredged material disposal site; rather, it is a beneficial use site. Clean sandy material is being placed within an area approximately three-quarters of a mile offshore of Sloat Boulevard, San Francisco County. The Demonstration Site is discussed in further detail below in Section 4.2.2.

4.2 Upland/Beneficial Use Dredged Material Placement Sites

This section discusses the placement/beneficial use of dredged material in the uplands, diked former baylands and wetlands surrounding the margins of the Estuary. Dredged material placement in the upland/beneficial use environments includes confined disposal facilities (CDF), rehandling facilities and beneficial use sites. Beneficial use includes habitat development (restoration and enhancement), levee maintenance and rehabilitation, various uses at existing sanitary landfills, and general construction uses. Use categories other than habitat restoration or levee maintenance and stabilization often require dredged material processing at a rehandling facility prior to use. Rehandled/processed dredged material can be used for habitat restoration and levee maintenance and rehabilitation when direct barge access is not possible or material stockpiling capacity is limited. Detailed guidelines for various beneficial use applications are provided in EM 1110-2-5026 (USACE 1987a).

The amount of dredged material beneficially used varies greatly from year to year; however, one of the main goals of the SF Bay LTMS is to maximize beneficial use of dredged material in the Bay area. Projects proposed to maximize beneficial use of dredged material include the HWRP Aquatic Transfer Facility; which could beneficially use approximately 2.5 million cubic yards of material annually. It is anticipated that the SF Bay LTMS member agencies will continue to seek restoration and levee maintenance projects to continue beneficially using sediment dredged from the Bay area.

4.2.1 Habitat Restoration

For the purposes of this assessment, habitat restoration involves use of dredged material for various wetland and aquatic restoration and enhancement and beach nourishment purposes. Table 4.2 provides an overview of existing and potential habitat restoration sites evaluated as part of the SF Bay LTMS EIS/EIR (SF Bay LTMS 1994b, 1994c). All sites considered for wetland use, rehandling facilities and levee restoration were ranked as having low to high restoration or use potential. If some sites considered in this evaluation are not actually restored, other sites with lower use potential could be used.

Table 4.2 Feasible Habitat Development Sites from the SF Bay LTMS EIS/EIR

Name	General Location	Ranking
Bel Marin Keys V Expansion Project*	San Pablo Bay, Marin County	High
HWRP*	San Pablo Bay, Marin County	High
Sonoma Baylands*	San Pablo Bay, Sonoma County	
North Point	San Pablo Bay, Sonoma County	High
Middle Harbor Enhancement Area*	Alameda County	High
Skaggs Island	Sonoma County	High
Montezuma Wetlands*	Solano County	High
Bair Island *****	San Mateo County	Medium
Camp Islands	San Pablo Bay	Medium
Hog Islands	Sonoma County	Medium
Sherman Island	Western Delta	Medium
Tubbs Island	Sonoma County	Medium
Adjacent to Days Island	Marin County	Low

* Indicates that the project already exists.
Source: LTMS 1995d.

Prior to the implementation of the SF Bay LTMS, tidal marsh was established at three former dredged material disposal sites within the Bay: Muzzy Marsh in Corte Madera, Marin County, Farber Tract in Palo Alto, Santa Clara County and Salt Pond No. 3 in Fremont, Alameda County. Dredged material was also used successfully to enhance natural resource values and management capability at managed wetlands in the Suisun Marsh. Since the SF Bay LTMS began, dredged material generated from deepening Oakland Harbor was beneficially used for wetland restoration at the Sonoma Baylands site in Sonoma County, Montezuma Wetlands Restoration Project site in Solano County, Middle Harbor Enhancement Area in Alameda County, and sandy material was beneficially used to nourish Ocean Beach San Francisco. Other habitat restoration projects currently underway include the HWRP and Bel Marin Keys Unit V Expansion Project in Marin County, Bair Island Project in San Mateo County and the ongoing Ocean Beach Pilot Project in San Francisco County.

Within the upland portion of the eleven county SF Bay LTMS planning area, dredged material beneficial use for habitat restoration and enhancement is most likely to affect habitats located between MLLW and the historic inland boundary of the Bay's tidal marshes. These areas support a diversity of habitats, including intertidal mudflats, tidal marsh, seasonal wetlands, rocky shorelines, salt ponds and riverine habitats.

4.2.1.1 Wetland Restoration

Several activities (e.g., agriculture, salt mining and urban development) over many years have caused diked marshes along the Estuary to subside such that current land elevations behind dikes are many feet below sea level, far below the elevation necessary to support most marsh vegetation. Placing dredged materials on subsided, diked former baylands can accelerate the tidal marsh restoration process by raising ground level to the appropriate height for establishment of marsh vegetation. Dredged material can also be used to create higher areas within tidal wetlands that would be inundated only by the highest tides (spring tides in the winter and storm-related extreme high tides) and would pond water from infrequent tidal inundation and rainfall. Additionally, dredged material can be used to construct berms to separate tidal and seasonal wetlands at a site (without raising the elevation of the seasonal wetlands) and to create areas for ponding and drainage control on sites not associated with tidal wetland creation projects.

The following wetland restoration projects are currently accepting dredged material from dredging projects within the San Francisco Bay area:

Montezuma Wetlands

The Montezuma Wetlands Project is a privately owned and operated site that began accepting material in July 2003. The approximately 1,800-acre site is located adjacent to Montezuma Slough in Solano County, and has a capacity of approximately 14 million cubic yards of material. The imported material from various dredging sites is being used to create wetlands and the site will be accepting material for many years. The site has all required permits and can accept both cover and foundation quality material (as described in the SFBRWQCB's Draft Beneficial Use Guidelines). The site has deep-water access, as well as a docking area and dredged material off-loading equipment. The off-loading equipment is designed for large dredged material transport scows and is not suitable for hopper dredges and small shallow-draft barges. However, currently the offloader is in use at the Hamilton Wetland Restoration Project. It is anticipated that either a secondary offloader will be developed for this site, or if only one offloader is provided, the two projects would have to share the equipment adding delays and expense to both dredging projects and restoration projects. To date, Montezuma Wetlands has accepted a total of approximately 3 million cubic yards in both cover and foundation quality material.

Hamilton Wetland Restoration Project (HWRP)

The 988-acre HWRP is located 25 miles north of San Francisco in the City of Novato, Marin County, on the western shore of San Pablo Bay. The adjacent Bel Marin Keys Unit V site, authorized by Water Resources Development Act (WRDA) of 2007, expanded HWRP by 1,576 acres, for a total of nearly 2,600 acres of restored wetlands. As of May 2009, the site has accepted approximately 2.9 million cubic yards of dredged material. Ultimately, HWRP with the expansion of Bel Marin Keys V parcel, will beneficially use approximately 24.4 million cubic yards of dredged material. The statement above regarding the offloading equipment holds true for Hamilton as well.

Bair Island

Bair Island is located in South San Francisco Bay across Redwood Creek from the Port of Redwood City in San Mateo County. The 31-acre site is now owned by public agencies and is being managed for habitat restoration. Bair Island's total capacity of 1,500,000 cubic yards can be filled with construction dirt, dredged material or a combination, approximately 228,000 cubic yards has been placed at the site from maintenance dredging of the Redwood City federal channel in late 2008/early 2009.

4.2.2 Other Beneficial Use Sites

Winter Island

Winter Island is a privately owned and operated site located at the confluence of the Sacramento and San Joaquin Rivers and Suisun Bay in Contra Costa County. Dredged material is imported onto the site to re-nourish the island and maintain five miles of perimeter levees. Although the wetland portion of this site is currently closed, it has the capacity to take up to 200,000 cubic yards of material a year, but only 50,000 cubic yards can be sand. Currently, a smaller upland portion of the site can take dredged sediment.

The site is permitted by the RWQCB and has specific dredged material acceptance criteria established in its Waste Discharge Requirement (WDR). The WDR allows for placement of dredged material having some levels of constituents of concern not normally suitable for unconfined aquatic placement in this area.

Van Sickle Island

Van Sickle Island is a 2,362-acre island located on the eastern edge of the Sacramento-San Joaquin Delta, north of the Stockton Deep Water Ship Channel and within Suisun Marsh in Solano County. The site is privately owned and operated by Reclamation District 1607 and is currently authorized to accept approximately 6,000 to 8,000 cubic yards of dredged material per year for levee restoration. The owners of the site are requesting permission to expand the operation to accept 500,000 to 1,000,000 cubic yards of dredged material over a ten year period to rehabilitate failing portions of the 7.1 miles of levees surrounding the island. If approved, the expansion would greatly enhance the potential of this use option.

Carneros River Ranch

Carneros River Ranch is an approximate 540-acre site located near the mouth of the Petaluma River, in the Sears Point area of unincorporated Sonoma County. The area was formerly part of the Bay, but was diked and drained in the late 1800's. Material dredged from Port Sonoma and Bel Marin Keys North Lagoon has been placed in the North West and North Central Fields to raise site elevations by approximately 2 feet. Once the material dries, hay and other crops are farmed. To date, approximately 600,000 cubic yards of dredged material was beneficially used at Carneros River Ranch.

The owners of this site are currently seeking permits for placement of an offloader which would be capable of offloading dredged sediments from small dredging projects of up to 100,000 cubic yards per year.

Oakland Harbor Middle Harbor Enhancement Area (MEAH)

The Middle Harbor Enhancement Area Project (MHEA) is located at the Port of Oakland's Middle Harbor in Oakland, California. This approximately 190 acre site is being managed as an ecological reserve of shallow bay and shoreline habitats that support commercial species such as Dungeness crab, bottom fish, anchovy, herring and perch, and also the endangered, least tern. Approximately 5.5 million cubic yards of material from the Port of Oakland -50 foot Deepening Project were placed to create this habitat at MHEA. The site is currently in the consolidation phase and eelgrass will likely be planted in the next two years.

Nearshore Beneficial Use Demonstration Site (Near Ocean Beach)

Although SF-8 was established to retain material dredged from the San Francisco Main Ship Channel within the littoral cell for nearshore beneficial use, sufficient material has not reached the southern reaches of Ocean Beach to protect infrastructure from storm damage. Capacity concerns at SF-8 have also arisen in recent years. As an alternative, USACE is demonstrating the potential for a viable long-term dredged material beneficial use site in the nearshore zone to re-nourish the shore of Ocean Beach. Material is being placed within an area approximately three-quarter mile offshore of Sloat Boulevard, San Francisco County. To date, USACE has completed three pilot projects to date, totaling approximately 825,000 cubic yards of dredged material.

Currently the USEPA and USACE are investigating the potential for permanently designating this site as dredged material beneficial use site for sandy sediments.

Project-Specific Beneficial Use Sites

Several project-specific dredged material beneficial use sties exist in the Bay area; these include:

- San Leandro Marina Ponds. The 100-acre San Leandro Marina Ponds are located near the City of San Leandro Marina, Alameda County, is reserved for placement of material dredged from the federal San Leandro Channel and the San Leandro Marina;
- Upper Petaluma Ponds. The 210-acre Upper Petaluma Ponds is located on the east side of the Petaluma River near Highway 101 and Lakeville Highway accepts dredged material from the federal Petaluma River Channel and the City of Petaluma's dredging projects. Once the material dries, it is used as landfill cover.
- Sea Cloud Phase II. Located near Foster City, San Mateo County, this 18.65-acre site is used for the placement of material dredged from Foster City Lagoon.
- City of Martinez. The city of Martinez, Contra Costa County, owns and operates this upland dredged material placement site for the placement of material dredged from the Martinez Marina. Once dried, this material is used for construction and landfill cover.
- Port of Oakland, Berth 10. The Port of Oakland's rehandling facility accepts dredged material from the Port's large and small dredging operations. Once the material is dried, it is used by the Port for construction or as landfill.
- Pierce Island. Pierce Island is located in Suisun Slough south of the Suisun City, Solano County. With a capacity of 660,000 cubic yards, the site is used for the placement of material dredged from the federal Suisun Bay Channel and the Suisun City Marina.
- Napa Marina Ponds. The seven-acre Napa Marina Ponds are located adjacent to the Napa Valley Marina across from Carneros Creek. The site holds approximately 57,000 cubic yards of dredged material. Once dried, the material is used as a soil amendment at Napa Sea Ranch.
- South Bay Salt Ponds. The South Bay Salt Ponds are located in the southern portion of the South Bay near the cities of Union City, Palo Alto and Milpitas.

4.2.2.1 Levee Maintenance and Stabilization

Vast tracts of reclaimed land in the San Francisco Bay/Sacramento-San Joaquin Delta are protected from inundation by levees. Dredged material often has similar properties as existing levee soils; as such, it can be used to improve levee stability and structural strength. Implementation of this aspect of the SF Bay LTMS would prevent additional materials from being disposed of in-Bay. However, the distance from dredging sites and limited barge access to the levees make this beneficial use difficult and costly.

4.2.2.2 Landfill Use

The clay and fine silt particles that comprise most material dredged from the Bay are often suitable at landfill sites (once dried) for use as cover, on-site construction, capping or lining material. Landfills possess several characteristics ideal for the use of dredged material. Daily operations and closure procedures require substantial amounts of cover and capping material; as such, there is the potential for utilizing a significant portion of material dredged annually from the Bay area. Because landfills are designed to contain pollutants and manage runoff, they have the added benefit of being able to accept some contaminated material that is not suitable for unconfined aquatic disposal.

4.2.2.3 Rehandling Facilities

Rehandling facilities are mid-shipment points for dredged material that cannot be hauled directly to a site where it will be ultimately used, such as landfills. They are also locations where dredged material can be dried or treated to remove or reduce salinity or constituents of concern. Typically, rehandling facilities accept relatively small volumes of material originating from specific dredging projects. In the San Francisco Bay area, rehandling facilities are located at Port Sonoma-Marin, near the mouth of the Petaluma River; the City of Petaluma, Sonoma County; Port of San Francisco Berth 94/96 (POSF), San Francisco County; Port of Oakland Berth 10, Alameda County; and the City of San Leandro, Alameda County. Some of the privately operated upland sites, such as Schoellenberger Park and San Leandro, must be emptied of dredged material prior to using the site again; therefore, these sites become de-facto rehandling facilities. Once dredged material placed at these sites is dried, it can be used for a variety of purposes.

4.2.2.4 Confined Disposal Facilities (CDF)

Confined disposal is placement of dredged material within diked nearshore or upland CDFs via pipeline or other means. CDFs may be constructed as upland sites, nearshore sites with one or more sides in water (sometimes called intertidal sites) or as an island containment facility. There are several CDFs in the San Francisco Bay area and most are containment facilities for clean dredged material.

5.0 Dredge Equipment and Methods

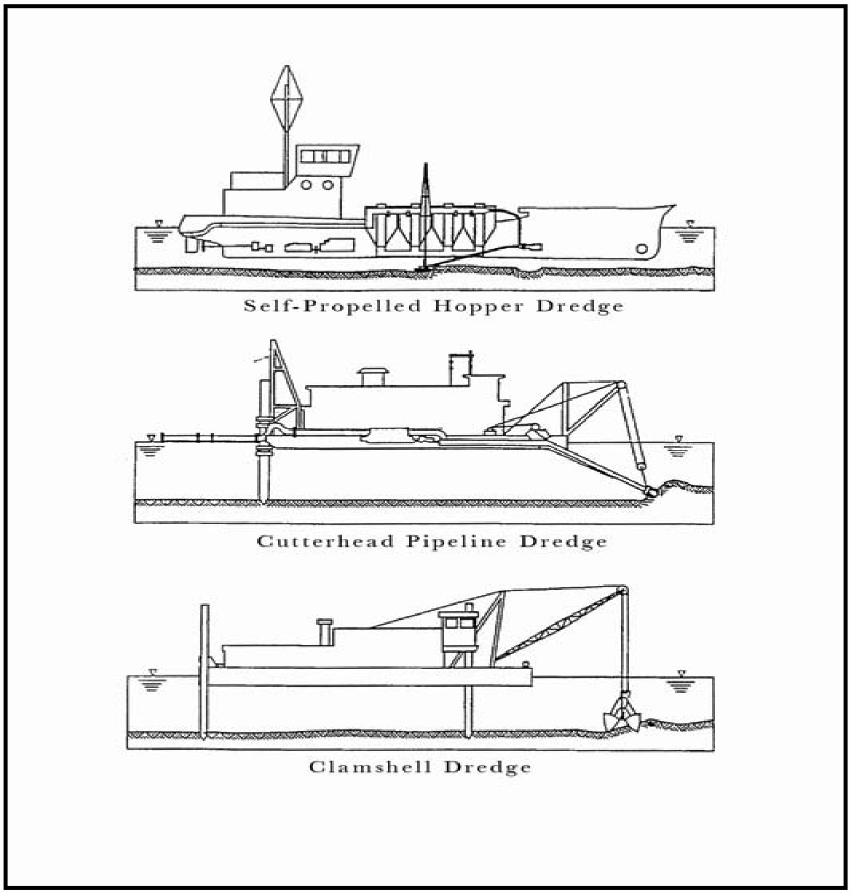
The dredging process involves the removal or excavation of sediment from aquatic environmental and the subsequent transportation and placement of the sediment. Dredging methods for a specific area are typically based upon site specific characteristics, such as substrate type, water quality, site bathymetry, wave energy, dredging depth, desired production rate (i.e., cubic yards per hour), method of disposal, distance to disposal area, levels of constituents of concern and spatial feasibility. Additionally, costs and availability of dredge equipment factor into which type of dredging method to employ. Dredging equipment and techniques vary; however, for the purposes of this analysis, dredging equipment is categorized by two mechanisms:

- Hydraulic dredging – Removal of loosely compacted materials by cutterheads, dustpans, hoppers, hydraulic pipeline, plain suction and sidecasters, usually for maintenance dredging projects. The use of hydraulic dredging generally reduces the resuspension of dredged material along the floor of dredging site, compared to mechanical dredging. However, hopper dredges, such as the federally-owned *Essayons* and *Yaquina*, utilize overflow dredging to achieve economic loads of dredged material. Overflow dredging releases water and fine-grained sediments back into the water column. Overflow dredging practices in the Estuary are limited to a maximum of 15 minutes, regardless if an economic load of dredged material is attained or not.

- Mechanical dredging – Removal of loose or hard compacted materials by clamshell, dipper or ladder dredges. Unlike hydraulic dredging, mechanic dredges use mechanical force to remove sediments from the floor of the dredging site. As a result of mechanical force against the substrate, sediment is resuspended along aquatic floor, thus increasing suspended sediment around dredging activities. Further, as the dredge is raised through the water column, sediment laden water can leak from the clamshell, dipper or other type of bucket if it is not tightly closed, thus generating increased suspended solids throughout the vertical water column.

The schematics of the various dredge types are presented in Figure 5.1 and further discussed below.

Figure 5.1 Typical Dredge Equipment



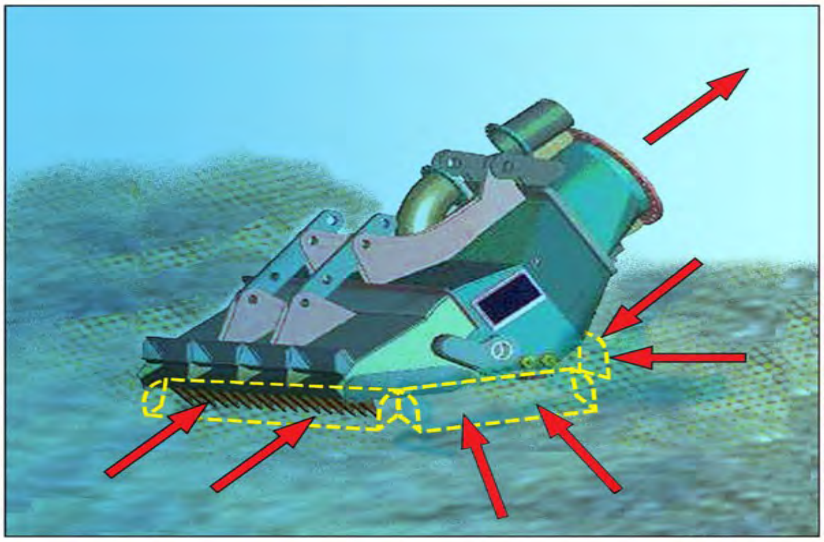
5.1 Hydraulic Dredges

Hydraulic dredges remove and transport sediment in liquid slurry form (generally a ratio of 80 percent water and 20 percent sediment). They are usually barge-mounted and carry diesel or electric-powered centrifugal pumps with discharge pipes ranging in diameter from 6 to 48 inches. The pump produces a vacuum on its intake side, which forces water and sediments through the suction pipe. The slurry is then transported by a pipeline or scow to the dredged material placement site. Hopper dredges are included in the category of hydraulic dredges for this report even though the dredged material is simply pumped into the self-contained hopper within the dredge rather than through a pipeline to a scow.

5.1.1 Hopper Dredges

Hopper dredges are sea going vessels designed to dredge *and* transport material from navigation channels to open water disposal areas. Hopper dredges are equipped with a drag arm on each side of the dredge. The drag arms are long suction pipes with drag heads attached to their ends (see Figure 5.2). During active dredging, the drag arms are lowered into the water column until the drag heads are on the channel bottom, next the suction is turned on and the drag heads are slowly dragged across the shoaled material by the forward motion of the vessel. Sediment and water slurry is drawn up through the drag heads and drag arms by on-board pumps and deposited within the hopper bin located in the vessel's midsection. When the hopper bin is full, the dredge raises the drag arms and moves to a designated disposal area to empty the dredged material through large doors located at the bottom of the dredge.

Figure 5.2 Hopper Draghead Schematic



It is often advantageous to overflow excess water from hopper dredges to increase the sediment load carried; however, due to water quality concerns near the dredging site, hopper dredges may not always be acceptable. Overflow dredging occurs when the hopper is full of sediment slurry, pumping continues to fill the hopper with water and sediment, the heavier, coarser material settles out to the bottom of the hopper and lighter, finer sediments remain suspended in the water. As dredging continues, excess water begins to fall into overflow weirs (tubes that span from the top of the hopper bin to the bottom of the vessel) and into the water column at the level of the draft of the vessel. This excess water is called overflow and is where fine material is returned to the water column. The amount of fine-grained material that is returned to the water is dependant on the type of sediment being dredged. For hopper maintenance dredging in the Estuary, overflow dredging is limited to 15 minutes at all times for fine-grained sediments and overflow is not allowed for sandy sediments.

5.1.1.1 Federally-Owned Hopper Dredges

USACE utilizes two federal hopper dredges in the San Francisco Bay area, the *Essayons* and the *Yaquina*. Table 5.1 provides the specifications of the USACE's hopper dredges.

Table 5.1 Federally-Owned Hopper Dredges		
Parameter	***Essayons***	***Yaquina***
Length	350 feet	200 feet
Drag arm extension	-94 feet MLLW	-45 to -55 feet MLLW
Hopper capacity	6,000 cubic yards	1,050 cubic yards
Draft (when fully loaded)	-27 feet MLLW	-14 feet MLLW
Max speed (when fully loaded)	13.5 knots	10.5 knots
Size of intake pipe	28 inches	20 inches
Size of draghead	100 x 100 inches	54 x 54 inches
Pump size (gpm)	2 @ 28,500	2 @ 15,000
Water:Sediment	80:20	80:20
Production Rate[1]	43,000 cy/day	13,000 cy/day
Locations dredged Annually	• San Francisco Harbor (Main Ship Channel) • Richmond Outer Harbor • Pinole Shoal/Mare Island Strait • Suisun Bay	[2]Varies annually
Volume dredged Annually	800,000 – 1,000,000 cubic yards (annual average)	[2]Varies annually

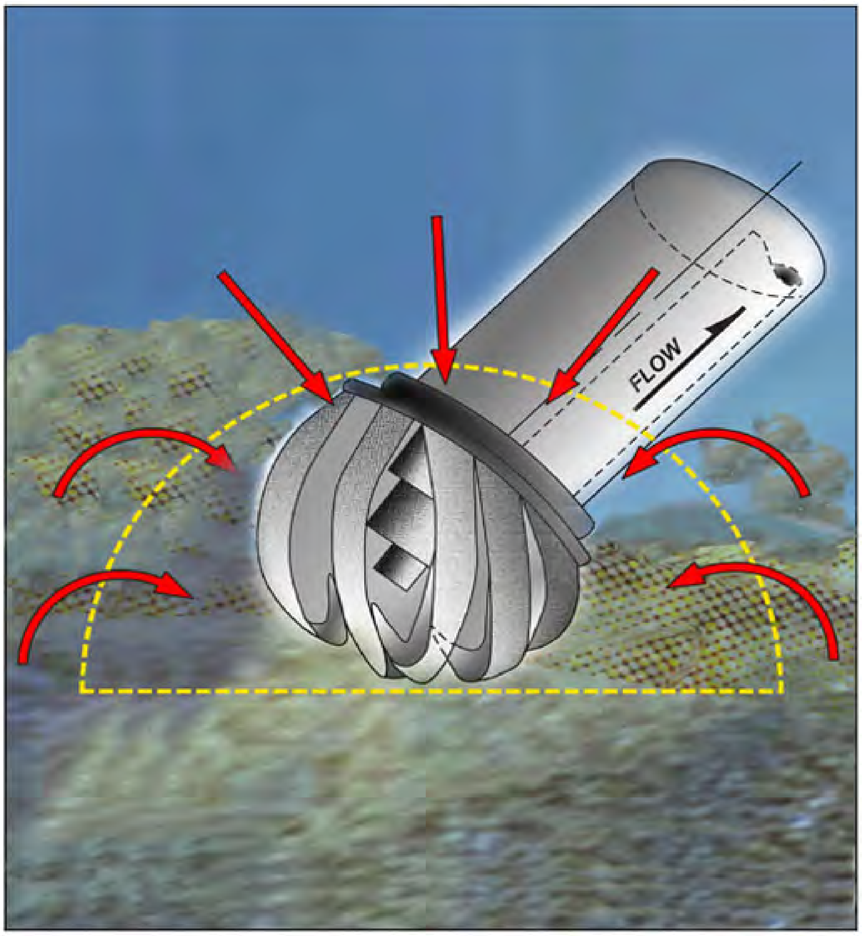
[1]Average Daily Production Rate.
[2]The *Yaquina* does not often dredge within the San Francisco Bay Area. At times it is scheduled to dredge the Federal navigation channels. As such, volumes of dredged material vary annually.

Unlike the *Yaquina*, the *Essayons* is equipped with an anti-turbidity valve on its overflow weirs that may reduce the environmental impacts caused by the dredging overflow process. Once the hopper is filled with water and sediment slurry, water and fine-grained sediment falls into the overflow weirs, taking a lot of air into the overflow tubes. The air becomes entrained with the material that did not settle into the hopper bin. The anti-turbidity valve restricts the volume of water that can pass through the overflow tube and causes the water level within the weir to back up the tube, over the top of the weir, and back into the hopper bin. Therefore, instead of the water falling uncontrolled down the overflow weir and into the water column during overflow, the weir becomes filled with water. The water then runs down the side of the overflow weir more evenly, without entraining excessive amounts of air. Anti-turbidity valves may greatly reduce the amount of turbidity in the water around the dredge during the overflow dredging operations by reducing the amount of air that is entrained in the overflow slurry.

5.1.2 Pipeline Dredges

Pipeline dredges typically utilize a cutterhead at the end of a pipeline (see Figure 5.3). The size of the cutterhead is determined by the size of the discharge pipeline, which has an internal diameter of 8 to 42 inches and is most commonly 18 to 36 inches. Typically, to dredge sediment, pipeline dredges suction up a slurry of approximately 80 percent water and 20 percent sediment. The typical production rate for a 30 inch pipeline dredge is approximately 2000 cubic yards of dredged material per hour.

Figure 5.3 Cutterhead Dredge Schematic



5.2 Mechanical Dredges

Mechanical dredges remove bottom sediments by direct application of mechanical force to dislodge *in situ* sediments, scooping the sediments from the bottom and placing them into barge or scow for transport to a dredged material placement site. Mechanical dredges can work in tightly confined areas, as they are mounted on a large barge, towed to the dredging site and secured in place by anchors or anchor piling, called spuds. They are often used in harbors, around docks and piers, and in relatively protected channels, but are not suited for areas of high traffic or rough seas.

Generally two or more dump scows are used in conjunction with the mechanical dredge. While one barge is being filled, another is being towed to the dredged material placement site. Using numerous barges, work can proceed continuously, only interrupted by changing dump scows or moving the dredge. This makes mechanical dredges particularly well-suited for dredging projects where the disposal site is many miles away.

Often water quality at dredging and disposal sites is a particularly important consideration in the choice of dredge equipment used. Hydraulic dredging can reduce disturbance and resuspension of sediments at the dredging site, and is often the first choice when dredging occurs in enclosed water bodies or in locations near aquatic resources that are especially sensitive to temporary increases in suspended solids or turbidity. However, because hydraulic dredging typically entrains additional water that is many times the volume of sediment removed, water management and water quality must be controlled at the placement site (rather than overflowing excess water to the water column, water is retained in the scow and placed of with the dredged material). In contrast, mechanical dredging creates little additional water management concern at the disposal site because little water is entrained by mechanical dredging equipment; therefore mechanical dredging is usually the first choice when disposal site capacity limitations are a primary concern. However, typical mechanical equipment often creates more disturbance and resuspension of sediment along the floor of the dredging site.

5.2.1 Clamshell Dredge

A clamshell dredge employs a vertical loading grabber connected to a wire rope (bucket, dipper and backhoe dredges are also considered mechanical dredges and operate similarly to clamshell dredges) (see Figure 5.4). Clamshells have the capability of utilizing several diverse bucket configurations that optimize removal of different sediment types (e.g., silt, mud, clay, sand, gravel, rock and boulders). The dredge operates by lowering the vertical loading grabber in the open position; the weight of the grabber penetrates the substrate; the bucket is closed around the material, raised above the level of the scow or barge and placed inside.

Figure 5.4 Clamshell Dredge

The loading grabbers/buckets can be sized up to 50 cubic yards; however, most often 10 to 20 cubic yard grabbers are utilized and 1 cubic yard buckets can be used for smaller projects. Larger, custom fabricated sizes exist for special dredging projects. The depth a clamshell dredge can operate is dependant on the length of the wire rope. Production rate is generally determined by cycle time, bucket size, dredging depth, type of material, thickness of cut and transport equipment.

Advantages of utilizing a clamshell dredge include:

- Sediment water content is minimized during the dredging process;
- Dredging is uninterrupted since the scow/barge is not part of the actual dredge; thus, the dredge does not have to transport dredged material to the disposal site this proves practical when the disposal site is a long distance from the dredge site);
- Accuracy of positioning and cut;
- Effectively excavates moderately compacted materials and can pick up large particles and debris; and
- Can effectively work in confined areas;

Disadvantages of utilizing a clamshell dredge include:

- Requires sufficient cut-face thickness to efficiently fill the clamshell;
- Inefficient and unsuitable for light, free-flowing materials;
- Unable to dig in relatively hard material;
- Oversized debris and shattered rock may keep bucket from closing/operating properly; and
- Unstable in heavy swell conditions.

5.2.2 Excavators

Some smaller projects utilize backhoe excavators mounted to a barge. The excavator bucket is lowered to the bay floor where it scoops up sediment with its open bucket, bringing the sediment up through the water column as an open bucket-type dredge and placing it in a scow or other vessel for transport.

5.3 Knockdowns

In addition to dredging, knockdowns provide an additional method to alleviate shoaling in marinas, ports and in some navigation channels. Knockdowns are generally used both for smoothing the bottom following conventional mechanical or cutterhead dredging, and for managing localized mounds without the need to mobilize a full maintenance dredging episode. Since knockdowns typically create less resuspension than full dredging episodes (especially in the upper water column) they have at times been approved in the Bay area to minimize necessary work outside environmental windows. Generally, knockdowns are accomplished with the use of an I-beam or other equipment to redistribute shoaled sediment into deeper areas within the dredging site. The knocked down sediment is then dredged during future standard maintenance dredging episodes.

6.0 Regulation of Dredged Material

In 1996, the Dredged Material Management Office (DMMO) was created to establish a comprehensive and consolidated approach to eliminate redundancy and delays in the dredged material disposal permitting process (Memorandum of Understanding 1998). The DMMO is a joint program composed of USACE, USEPA, BCDC, SFBRWQCB and the State Lands Commission. Participating agencies include the California Department of Fish and Game, NOAA-Fisheries and USFWS.

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6.2 USACE Headquarters Overdepth Dredging Guidance

Recent USACE nation-wide guidance, dated January 2006, clarified the requirements for characterization and evaluation of all sediment that may be removed from the dredging prism, including advanced maintenance, allowable overdepth and non-pay dredging. Thus, the sediment sampling and analysis plans must reflect the maximum depth that material can reasonably be expected to be excavated, intentionally or otherwise.

For some projects, overdepth dredging can account for a substantial proportion of the total quantity dredged, while for other projects it may be relatively minor. In all cases, overdepth dredging should only be approved to the extent necessary to ensure that a project's design depth ("authorized dimensions" as outlined below) will be achieved given the equipment to be used and the conditions at the dredging site. In the Bay area, this is generally a total of 2 feet beyond design depth. The volume represented by overdepth material is fully accounted for in both pre-dredge testing, and in disposal tracking and disposal site management. The following bullets provide an overview of the various terms described in the January 2006 Memorandum.

- **Authorized Dimensions:** Authorized dimensions include the depth, width and length of a navigation channel to be constructed, maintained or permitted by USACE).

- **Advance Maintenance Dredging:** Advance maintenance dredging is dredging to a specified depth and/or width beyond the authorized channel dimensions in critical and fast-shoaling areas to avoid frequent re-dredging and ensure the reliability and least overall cost of operating and maintaining the project's authorized dimensions.

Advance maintenance dredging must be justified, and approved by the appropriate USACE Division Commander.

- **Paid Allowable Overdepth Dredging:** Paid allowable overdepth refers to dredging that occurs beyond the authorized dimensions (or advance maintenance prism) to account for physical conditions and inaccuracies in the dredging process that may otherwise result in authorized dimensions not being fully achieved. In other words, this represents material that the contractor will be paid to remove in order to ensure that authorized dimensions are fully achieved. District Commanders may authorize paid overdepth dredging to a maximum of -2 feet beyond the authorized dimensions.

- **Non-Pay Dredging**: Non-pay dredging, also known as non-paid overdepth, is dredging beyond the paid allowable overdepth to account for unanticipated variation in substrate, incidental removal of submerged objects or wind and wave conditions that reduce the dredge operators' ability to control excavation; however, it is within the permitted depth. Non-pay overdepth also provides a disincentive for the contractor to remove any more material than is necessary to fully achieve authorized dimensions.

- **Characterization Depth**: Characterization depth represents the depth to which material is reasonably expected to be removed given the substrate and the conditions specific to the dredging project. It is the depth to which sediments must be sampled and evaluated for all project environmental documents and permits, and is typically the same as the paid plus non-pay dredging and over depth allowance. For projects within the LTMS area, overall characterization depth is generally no more than 2 feet below a project's authorized dimensions.

6.3 Testing Requirements for Placement and Beneficial Use of Dredged Material

The Clean Water Act (CWA), Marina Protection Research and Sanctuaries Act (MPRSA or Ocean Dumping Act) and California's Porter-Cologne Act are the primary laws regulating aquatic dredged material placement. These laws require that the physical and chemical properties of sediment, as well as the sediment's potential toxicity to aquatic organisms be tested prior to dredging and dredged material placement. The USACE and USEPA have jointly developed national effects-based sediment testing manuals applicable under both the CWA and MPRSA. Under both laws, sediment quality assessment is performed in order to identify appropriate disposal sites and controls that may be required to minimize potential adverse effects associated with dredging and dredged material placement.

Dredged material proposed for ocean disposal must undergo testing to determine the potential effects of disposal on the surrounding environments. For ocean disposal (disposal at SF-DODS), testing and management requirements are regulated under section 103 of the MPRSA and the regulations at 40 C.F.R. 227-228. Current guidance on implementing these requirements is provided in *Evaluation of Dredged Material*

Proposed for Ocean Disposal - Testing Manual (USEPA and USACE 1991), referred to as the *Ocean Testing Manual*.

For placement of dredged material in inland waters, including the Estuary, section 404 of the CWA and the regulations at 40 C.F.R 230 define the basic national testing requirements. Current guidance is provided in *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual* (USEPA and USACE 1998) referred to as the *Inland Testing Manual* or ITM. Additional specific testing requirements for the San Francisco Bay area are published by the DMMO in regional guidance, available on the DMMO web site.

The ITM and OTM focus on direct effects-based testing of dredged material, rather than more general standards-based assessment. This is because, unlike other kinds of discharges such as those from permitted outfalls for which water quality criteria apply, there are for the most part no numeric sediment quality criteria that apply to the regulation of dredged material discharges[3]. Where relevant chemical-specific regulatory limits exist, they are applied *in addition to* the effects-based testing of the ITM and OTM.

Also, unlike other programs that only assess surficial sediments, dredged material evaluation requires that the sediment be representatively characterized to the anticipated maximum depth of the proposed dredging. In applying the OTM and ITM, the USEPA and USACE devote considerable effort toward ensuring that sampling, compositing, and testing of sediments from a proposed dredging area are conducted in such a way that potential areas of contamination are targeted and tested separately from areas known or expected to be relatively uncontaminated.

The OTM and ITM recognize distinct aquatic exposure pathways for evaluation: water column toxicity, benthic toxicity, and benthic bioavailability (bioaccumulation). The potential for effects via these primary exposure pathways is evaluated directly via standardized bioassays using sensitive aquatic indicator organisms, including national benchmark species. The species, and tests, are selected to cover a range of exposure types including filter feeders, deposit feeders, and burrowers. They are also selected so that test results can be reasonably compared from year-to-year and between areas, including other areas of the country.

[3] There are no national sediment quality standards for the discharge of dredged material at aquatic disposal sites. The State of California is promulgating Sediment Quality Objectives (SQOs) for its waters, but these focus on surface sediments and identifying cleanup needs; they do not specifically apply to dredged material suitability determinations. However, chemical-specific numeric guidelines can apply to aquatic discharges of dredged material in certain circumstances. For example, a TMDL for mercury has been established for San Francisco Bay by the state and approved by USEPA, which places a limit on the mercury concentration in dredged material allowed to be discharged back into the Estuary (that limit is currently 0.53 ppm dry weight). A TMDL for PCBs has also been proposed for San Francisco Bay, but is not yet approved by USEPA. Both TMDLs specifically recognize that by reducing in-Bay disposal and emphasizing beneficial reuse, the SF Bay LTMS is a net remover of contaminants from the Estuary and will speed its ecological recovery.

6.3.1 Water Column Exposure Pathway

Water column exposure to dredged material can occur both at the dredging site (due to resuspension of sediment from physical disturbance during dredging operations or for hopper dredges due to overflow) and at the disposal site (due to stripping of particles from the descending mass of dredged material from bottom-dump vessels or via return water flow from contained disposal sites). State water quality criteria, both chemical-specific numeric criteria and the "narrative" criterion for non-toxicity, must be met after allowing for initial mixing.

Chemical-specific numeric water quality criteria are compared against the worst-case concentrations of contaminants estimated (from the bulk chemistry measurements) to remain in the water column after initial mixing. However, for the narrative (toxicity) water quality criterion, direct bioassay testing is conducted on the liquid-suspended phase of the dredged material. Since water column exposure to suspended sediments from dredging and disposal operations is typically short-term (minutes to hours), the ITM and OTM use relatively short-term acute toxicity bioassays to assess this pathway. Sensitive life history stages (generally larvae) of one to three species of aquatic organisms relevant to the conditions at the dredging and/or disposal sites are exposed to a series of concentrations of suspended sediment elutriates for 24 to 96 hours (depending on the organism), so that LC50 or EC50 concentrations may be determined. Then a 100-fold safety factor is applied: the suspended sediment elutriate concentration remaining in the water column after initial mixing must be less than one percent of the LC50 or EC50, or else the material is defined as being toxic and violating the narrative water quality criterion.

6.3.2 Benthic Exposure Pathway

Aquatic organisms are much more likely to experience longer-term exposures to sediments that have settled on the bottom following disposal operations. Therefore the ITM and OTM specify that longer-term biological testing be conducted on solid phase sediments. Acute toxicity exposures last for 10-days, and employ sensitive aquatic species that live in intimate contact with the sediments. In the San Francisco Bay and estuary, these typically include an amphipod and a polychaete. The potential for toxicity is evaluated based on the survival of these organisms after 10 days of exposure, compared to the same species' survival in appropriate reference sediment. If the dredged material being tested causes significantly more mortality than the approved reference sediment, it is considered potentially toxic and cannot be discharged back into the water.

The potential for impacts, including food-web effects, to be associated with still longer-term exposures is evaluated when necessary by measuring the bioavailability of contaminants to accumulate in organism's tissues. Bioaccumulation exposures typically last for 28 days. After that time, the concentrations of contaminants in the tissues are measured. Interpretation of bioaccumulation test results is less prescriptive than for acute toxicity. Other than FDA Action Limits, there are no set "standards" for determining when bioavailability of contaminants from sediment samples is too great. Instead case-by-case determinations of suitability must be made, taking into account **a**ll the available information. This typically includes comparison against tissues from organisms exposed to approved reference sediments, and to an array of other human and ecological toxicity reference values (TRVs). In some cases, detailed risk assessment procedures must be followed.

6.3.3 Dredged Material Aquatic Disposal and Beneficial Use Suitability Determinations

Sediments proposed to be dredged must pass all of the appropriate testing steps listed above to be defined as suitable for unconfined aquatic disposal (SUAD). However, being defined as SUAD does not guarantee that the dredged material will be disposed of at an in-Bay site. As described elsewhere, the main goal of SF-LTMS program focuses on facilitating beneficial reuse of as much dredged material as possible, and most of the dredged material in the region is SUAD.

When the testing program identifies any sediment as not suitable for unconfined aquatic disposal (NUAD), disposal at in-Bay sites is not an option and some reuse alternatives may also be limited. However, it is important to point out that NUAD sediments may nevertheless still be suitable for beneficial reuse. In the San Francisco Bay area, NUAD material has been reused for wetland restoration (Montezuma Wetlands Restoration Project), and as an alternative source of daily cover at landfills. In some cases, NUAD material may also be isolated in construction fills.

Management of NUAD material at upland or confined disposal or reuse sites typically involves a different set of potential contaminant exposure pathways that need to be evaluated. These can include surface runoff, groundwater infiltration, wind-blown particulates, etc. The appropriate testing for upland and confined sites is not discussed further here, but USACE has published a national guidance manual titled *Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities — Testing Manual* (2003), known as the Upland Testing Manual or UTM. The UTM is available at: http://el.erdc.usace.army.mil/elpubs/pdf/trel03-1.pdf.

Pursuant to Section 303(d) of the Clean Water Act, the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) has adopted total maximum daily loads (TMDLs) for several constituents of concern exceeding water quality standards in San Francisco Bay. A TMDL is the maximum quantity of a pollutant that can enter a water body and attain water quality standards. To date, TMDLs that affect dredged material suitability determinations are mercury and PCB. These particular constituents of concern tend to partition to sediment rather than the water column. The SF Bay LTMS goal of reducing in-Bay disposal of dredged material could result in a net loss of mercury and PCBs from the Estuary, as these constituents of concern are removed from the Estuary's system.

The SFBRWQCB's implementation plans for mercury and PCB TMDLs state that in order to ensure that buried mercury and PCBs are not spread throughout the Estuary via dredged material disposal at dispersive sites; sediments disposed of in-Bay should have total mercury and PCBs concentrations no greater than that in ambient surface sediments in the Estuary.

7.0 Environmental Baseline Conditions of the San Francisco Estuary

With a surface area of 1,631 square miles, the San Francisco Bay is the largest estuary on the Pacific Coast of North and South America (SFEI 1994a). The Estuary is located at the mouth of two major rivers, the Sacramento and the San Joaquin, which carry approximately 60 percent of the State's runoff from tributary rivers and streams, thus draining about 40 percent of California's surface area (Conomos *et al.* 1985; Nichols and Pamatmat 1988).

Water quality, sediment contamination and estuarine toxicity data presented in this document are taken from the Regional Monitoring Program (RMP). Spearheaded in 1989, the RMP is a collaborative effort between the scientific community, the SFBRWQCB and the regulated discharger community (regulators include the USEPA and USACE). Water quality, sediment and toxicity data collection for the RMP began in 1993 and includes data from five hydrographic regions of the Bay: Suisun Bay, San Pablo Bay, Central Bay, South Bay and the Lower South Bay (south of Dumbarton Bridge). The RMP monitors water quality throughout the Bay and determines spatial patterns and long term trends in contamination through sampling of water, sediment, bivalves and fish, and further evaluates toxic effects on sensitive organisms and chemical loading.

This section begins with a description of the various embayments within the Bay, beginning with a detailed discussion of the environmental conditions within the Bay, the locations of dredging projects and disposal sites within the embayments, the associated essential fish habitat and general environmental conditions. For purposes of this document, discussions of the dredging projects within each embayment and the associated essential fish habitat and environmental conditions follow the northeast to south pattern within the Estuary – Suisun Bay, Carquinez/Mare Island Strait, San Pablo Bay, Central Bay and South Bay.

7.1 Embayments

As shown in Figure 7.1 the Estuary can be divided into several segments: Suisun Bay, Carquinez Strait (including Mare Island Strait), San Pablo Bay, Central Bay and South Bay. The most upstream portion of the Bay, the Sacramento-San Joaquin Delta (Delta), is a 1,150-square-mile, triangular-shaped region of land and water at the confluence of the Sacramento and San Joaquin Rivers. The Delta's western segment is subject to the greatest tidal effects. The central Delta includes many channels where waters from all four rivers — the Sacramento, San Joaquin, Cosumnes and Mokelumne rivers — mix. The Delta's rivers, sloughs and excavated channels comprise a surface area of about 75 square miles (SFEP 1992b).

Figure 7.1 San Francisco Bay Embayments

At the very northeast point of the Estuary, the waters of the Delta flow into the Suisun Bay. The Suisun Bay is a shallow embayment between Chipps Island at the western boundary of the Delta and the Benicia-Martinez Bridge at the eastern end of Carquinez Strait. Adjacent to Suisun Bay is Suisun Marsh; with over 55,000 acres, this is the largest brackish marsh in the United States (SFEI, 1992a).

Just west of Suisun Bay, the narrow, 12-mile-long Carquinez Strait connects Suisun Bay to San Pablo Bay. The Carquinez Strait area also includes the Napa River and Mare Island Strait, which flow into the western end of the Carquinez Strait.

San Pablo Bay is a large, open bay that extends from Carquinez Strait to the San Pablo Strait near the Richmond-San Rafael Bridge. Adjacent to San Pablo Bay lays the northern part of the Central Bay; it is bounded by the San Pablo Strait (which flows beneath the Richmond-San Rafael Bridge) to the north, the Golden Gate Bridge to the west, and the Oakland-San Francisco Bay Bridge to the south. The southern part of the Bay, known informally as the South Bay, includes all estuarine waters south of the Oakland-San Francisco Bay Bridge and extends to the most southern reaches of the Bay to include Coyote Creek and tributaries.

7.2 San Francisco Estuary - Wide Physical Conditions

The northern reaches of the Estuary (comprised of Suisun Bay, Carquinez Strait, and San Pablo Bay) is geographically distinct from the Central and South Bays, with different sediment types and hydrology distinct from the Central and South Bays. The South Bay is a tidally oscillating, lagoon-type bay where variations are determined by water exchange between the northern reaches and the ocean. Water residence times are much longer in the South Bay than in the North Bay; whereas, the northern reach is a partially to well-mixed bay (depending on the season) and is dominated by seasonally varying river inflow. The timing and magnitude of the highly seasonal river inflow modulates permanent estuarine circulation, which is largely maintained by salinity-controlled density differences between river and ocean waters.

Freshwater inflows, tidal flows and their interactions largely determine hydrologic variations of the Bay/Delta system. Hydrology has profound effects on all species that live in the Bay/Delta because it determines the salinity in different portions of the Bay and controls the circulation of water through the channels and bays.

7.2.1 Freshwater Flows from the Sacramento-San Joaquin Delta

Sacramento River flow dominates the northern Delta, while waters of the San Joaquin River dominate the southern Delta, and waters of the Cosumnes and Mokelumne rivers dominate the eastern Delta. The Estuary receives 90 percent of its fresh water inflows from streams and rivers of the Central Valley and about 10 percent from tributaries and other sources surrounding Estuary. Of the fresh water flows entering the Estuary from the Central Valley, the Sacramento River typically accounts for 80 percent, the San Joaquin River accounts for 15 percent, and smaller rivers and streams make up the remainder. However, the total volume of water flowing into the Delta and subsequently into the Estuary's system (discussed below) is extremely variable on both a seasonal and annual basis, due to natural variation and water control structures.

7.2.2 San Francisco Estuary Circulation

Water flows in the Estuary follow complex daily and seasonal patterns. Circulation is affected by tides, local winds, basin bathymetry and the local salinity field (Cloern and Nichols 1985).

The Estuary generally has two low tides and two high tides every 24.8 hours. During each tidal cycle, an average of about 1.3 million acre-feet of water, or 24 percent of the Estuary's volume, moves in and out of the Estuary. On the flood tide, ocean water moves through the Golden Gate and into the Estuary's southern and northern reaches, raising the water level at the end of the South Bay by more than 8 feet and raising the height of the Sacramento River at the upstream edge of the Estuary by about 3 feet. It takes about 2 hours for tidal influence to reach the end of South Bay and 8 hours to reach Sacramento.

Under today's flow regime, freshwater flowing from the Delta usually meets saltwater from the ocean in the vicinity of Suisun Bay. Because freshwater is less dense than saltwater, when they meet, freshwater tends to flow over the surface of the saltwater before the two are partially mixed by tidal currents and winds. The separation of fresh and salt water results in a vertical salinity gradient that may occur over an area extending several miles in length. The salinity gradient is most prominent when Delta outflow is high; when outflow is low, the waters are well-mixed, with only a small salinity gradient.

The downstream flow of the freshwater surface layer induces an upstream counter-current flow of saltier water along the bottom in a pattern known as gravitational circulation. The most landward zone of gravitational circulation, where bottom ebb and flood currents are nearly equal, is called the null zone. The location of the null zone is influenced mainly by Delta outflow. A moderate Delta outflow of about 10,000 cubic feet per second positions the null zone at the upstream end of Suisun Bay. A flow greater than about 20,000 cubic feet per second positions it in San Pablo Bay, and a flow of less than 5,000 cubic feet per second positions it in the upstream waters of the Sacramento River. Tidal currents also influence the location of the null zone, moving it upstream and downstream 2 to 6 miles twice each day.

Associated with the null zone is a region just downstream where gravitational circulation concentrates suspended materials such as nutrients, plankton and very fine sediments in what is called the entrapment zone. In this zone, suspended materials are circulated as they settle out of the upper water layer and are carried upstream by bottom currents and toward the surface by vertical currents near the null zone. In this way, the entrapment zone concentrates phytoplankton, zooplankton and nutrients, providing a rich habitat thought to be important for the rearing of young striped bass and other fish species.

Concentrations of suspended sediments and plankton are often many times higher in the entrapment zone than upstream or downstream of the entrapment zone. Suisun and San Pablo Bays receive the majority of freshwater input. There, density/salinity-driven currents show ebb dominance of surface waters and flood dominance of the bottom waters. Thus, waters in these embayments are characterized as being well oxygenated with low- to moderate-salinity and high suspended sediment concentrations. The residence time of water in the Estuary's northern reach, particularly in Suisun and San Pablo Bays, is strongly influenced by Delta outflow.

During the low flow period of the year (late summer), the residence time of freshwater moving from the Delta to the ocean can be relatively long (on the order of months) compared to when outflow is very high (winter), when freshwater can move from the Delta to the ocean in a matter of days. Water residence time affects the abundance and distribution of many estuarine organisms, the amount of production by phytoplankton and some of the chemical and physical processes that influence the distribution and fate of constituents of concern.

The Central Bay is most strongly influenced by tidal currents due to its proximity to the Pacific Ocean. The Central Bay is characterized by Pacific waters that are cold, saline and low in total suspended sediment. Water quality parameters fluctuate less than in other sectors of the Bay due to the predominance of ocean water. Net exchanges of ocean and estuarine waters depend on net freshwater flow in the Estuary, tidal amplitude and longshore coastal currents.

The South Bay receives less than 10 percent of the freshwater budget of the Estuary. It also receives the majority of wastewater discharged to the Estuary (>75 percent). During the summer, treated sewage discharge exceeds freshwater in-flow in this area. The South Bay waters are influenced by Delta outflow during the winter months, when a low-salinity water moves into the southern reaches displacing the saline, denser water northward. In the summer months, the South Bay currents are largely influenced by wind stress on the surface; northwest winds transport water in the direction of the wind and the displaced water causes subsurface currents to flow in the opposite direction. Because the South Bay receives only minor amounts of freshwater in-flow from the surrounding watershed, it is essentially a tidal lagoon with a relatively constant salinity.

Deep-draft navigation channels affect circulation by increasing gravitational circulation and can enhance salinity intrusion (Nichols and Pamatmat 1988). Because the existing deep-draft navigation channels were constructed more than 100 years ago, they are considered part of the baseline conditions. Deepening projects, such as the current Oakland -50 Foot Navigation Improvement Project, have the potential to increase gravitational circulation and salinity in portions of the Central Bay where the deepening occurs.

7.2.3 San Francisco Estuary Currents

Currents created by tides, freshwater inflows and winds cause erosion and transport of sediments. Tidal currents are usually the dominant form of observed currents in the Bay. There is more intense vertical mixing and reduced vertical stratification during spring tides than during neap tides (Cloern 1984). Tidal currents are stronger in the deeper channels, weaker in the shallows and tend to parallel the bathymetry of the Estuary (Cheng and Gartner 1984). These processes enhance exchange between shallows and channels during the tidal cycle and contribute significantly to landward mixing of ocean water and seaward mixing of river water. Also, the South Bay begins flooding while San Pablo Bay is still ebbing, making it possible for South Bay to receive some water from the northern reaches (Smith 1987).

Generally, tides appear to have a significant influence on sediment resuspension during the more energetic spring tide when sediment concentrations naturally increase and during the ebbs preceding lower low water when the current speeds are highest (Cheng and McDonald 1994). The substantial increase in suspended sediment concentrations following a lower low water ebb on a spring tide may be due to the longer duration of higher currents as well as a greater absolute current velocity. Powell *et al.* (1989), however, observed no correlation between tidal cycle and suspended sediment loads or distribution in the South Bay, although tidal cycling may have an impact on sediment resuspension at times of the year, other than winter/spring high-water flows. Their conclusion was that winds were the most important factor in resuspending sediments in the South Bay and that local sources of sediments were more important than the import of sediment resuspended from elsewhere (Reilly *et al*. 1992).

As described earlier, freshwater inflows from the Delta induce gravitational circulation within the water column where salinity/density differences result in ebb currents near the surface and flood currents near the bottom. Although gravitational currents are generally weaker than tidal currents, they contribute significantly to the sediment cycle within the Estuary. Freshwater inflow carries sediment loads downstream via surface currents. Suspended sediments settle out as mixing occurs and salinity concentrations increase. The fine sediments that settle out near the bottom are carried back upstream by the counter-flowing gravitational circulation near the bottom. The sediment cycle begins again as the fine suspended sediments are entrained in the freshwater flow and carried back downstream (Cheng and McDonald 1994). The landward extent of gravitational currents is determined by the magnitude of inflows.

Strong seasonal winds create circulation and mixing patterns and add to tide- and river-induced current forces. Wind-induced currents have a significant effect on sediment transport by resuspending sediments in shallow waters (Krone 1979; Cloern *et al.* 1989). It has been estimated that 100 to 286 million cubic yards of sediments are resuspended annually from shallow areas of the Estuary by wind-generated waves (Krone 1974; SFEP 1992b).

In summary, net circulation patterns within the Estuary are influenced by Delta inflows, gravitational currents and by tide- and wind-induced horizontal circulation and local tributaries. The cumulative effects of the latter three factors on net circulation within the embayments tend to dominate over that of freshwater inflows except during short periods after large storm events (Smith 1987). Circulation between embayments is influenced both by mixing patterns and by the magnitude of freshwater inflows (Smith 1987).

7.2.4 San Francisco Estuary Bathymetry

With the exception of portions of Central Bay nearest the Golden Gate, the San Francisco Bay is very shallow, with wide intertidal and subtidal regions cut by narrow, mid-bay channels (Nichols and Thompson 1985). Greater than 40 percent of the Estuary is less than 6.5 feet deep and over 70 percent is less than 16.5 feet deep (Nichols et al. 1986; Wright and Phillips 1988). The average depth of the Estuary is about 19 feet at mean lower low water while median depth is about 6 feet (Conomos *et al*., 1985) (see Figure 7.2). The Bay's deepest areas, at the Golden Gate (360 feet) and the Carquinez Strait (88 feet), are topographic constrictions where scouring by strong tidal currents contributes to maintaining these depths. Table 7.1 and Figure 7.2 show average depths within different embayments of the Estuary.

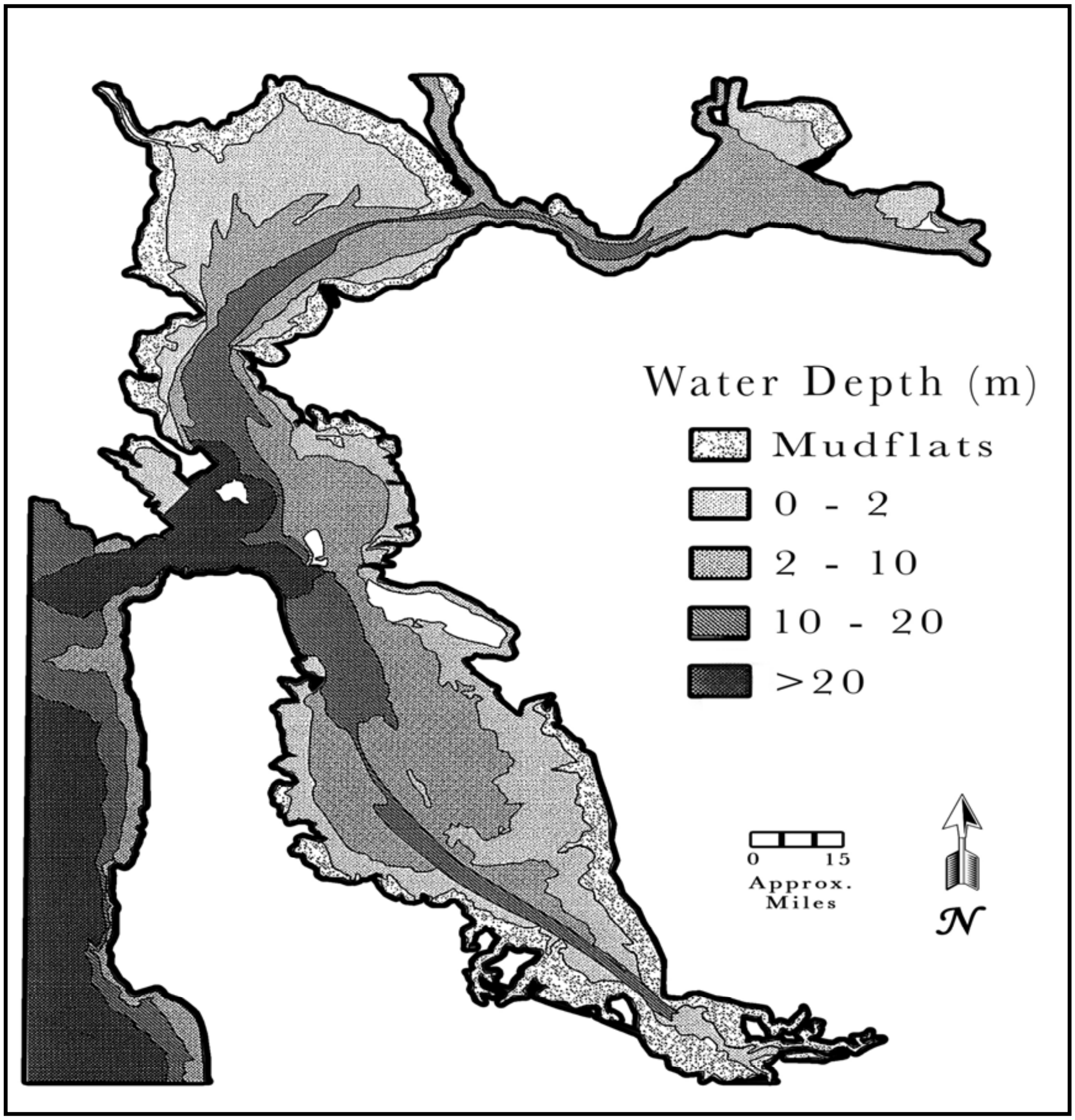
The bathymetry of the Estuary is an important factor affecting sediment dynamics. San Pablo, Suisun and South Bays are characterized by broad shallows that are incised by narrow channels, which are typically 33 to 66 feet deep. These shallower areas are more prone to wind-generated currents and sediment resuspension than deeper areas such as the Central Bay.

Table 7.1 Bathymetric Data for San Francisco Bay

Region	Surface Area (square mile)	Mean Depth (feet MLLW)	Mean Volume (acre feet)
Suisun Bay	36	14	323,000
Carquinez Strait	12	29	233,000
San Pablo Bay	105	9	605,000
Central Bay	103	35	2,307,000
South Bay	214	11	1,507,000

Source: SFEP 1992a; USGS 2006

Figure 7.2 Bathymetry of San Francisco Bay



*Bathymetry map taken from San Francisco Bay LTMS EIS/EIR.

7.2.5 Physical Characteristics of San Francisco Estuary's Sediments

The trough-like depression that underlies the Estuary is formed by Franciscan sandstone and shale bedrock. This trough has been nearly filled with sediments, some of which has come from erosion of surrounding hills and some consists of later marine deposits. For example, the marine clay-silt deposit termed "old Bay mud" is present throughout most of the Bay, several feet beneath the soft, more recently deposited "young bay muds". An ancient fine-grained sand deposit known as "Merritt Sand" occurs in the vicinity of Oakland and Alameda, in places relatively close to the sediment surface. Natural peat deposits can be found underlying more recent estuarine sediments in some areas of the North Bay and Delta. The thickness of the various historic sediment formations varies throughout the Bay/Delta, but they can be several hundred feet thick overall.

Whether of terrestrial or marine origin, the older deposits that pre-date European settlement in California generally are very hard-packed, low in moisture content, low in organic carbon (except for peat deposits) and have low concentrations of chemicals, such as heavy metals and organic compounds. The chemical levels that are measurable in these historic deposits represent natural "background" levels for the sediment type. Table 7.2 shows typical levels of heavy metals and organic compounds measured in old Bay mud and Merritt Sand deposits. These deposits are not typically dredged during maintenance dredging, but are often encountered during new work dredging (dredging of new navigation channels or channel deepening projects).

Table 7.2 Levels of Heavy Metals and Organic Compounds in Old Bay Mud and Merritt Sand Deposits

Sediment Chemistry	Merritt Formation Sediment (a)	Old Bay Mud Sediment (b)
Silver (mg/kg)	0.023 – 1.08	0.11
Arsenic (mg/kg)	2.93 – 12.60	3.28
Cadmium (mg/kg)	0.02 – 0.18	0.56
Chromium (mg/kg)	164 – 823	142
Copper (mg/kg)	8.9 – 43.8	27.4
Mercury (mg/kg)	0.0003 – 0.088	0.044
Nickel (mg/kg)	41.7 – 117.1	62.7
Lead (mg/kg)	3.5 – 10.4	10.6
Selenium (mg/kg)	0.07 – 0.42	0.17
Zinc (mg/kg)	33.7 – 100.5	68.3
Total PAH (µg/kg)	0.5 – 217	57
Tributyltin (µg/kg)	0.6 – 3.2	0.48 (U)
PCB (µg/kg)	2.3 – 4.0	20 (U)
Total DDT (µg/kg)	0.04 – 6.22	0.22 (U)

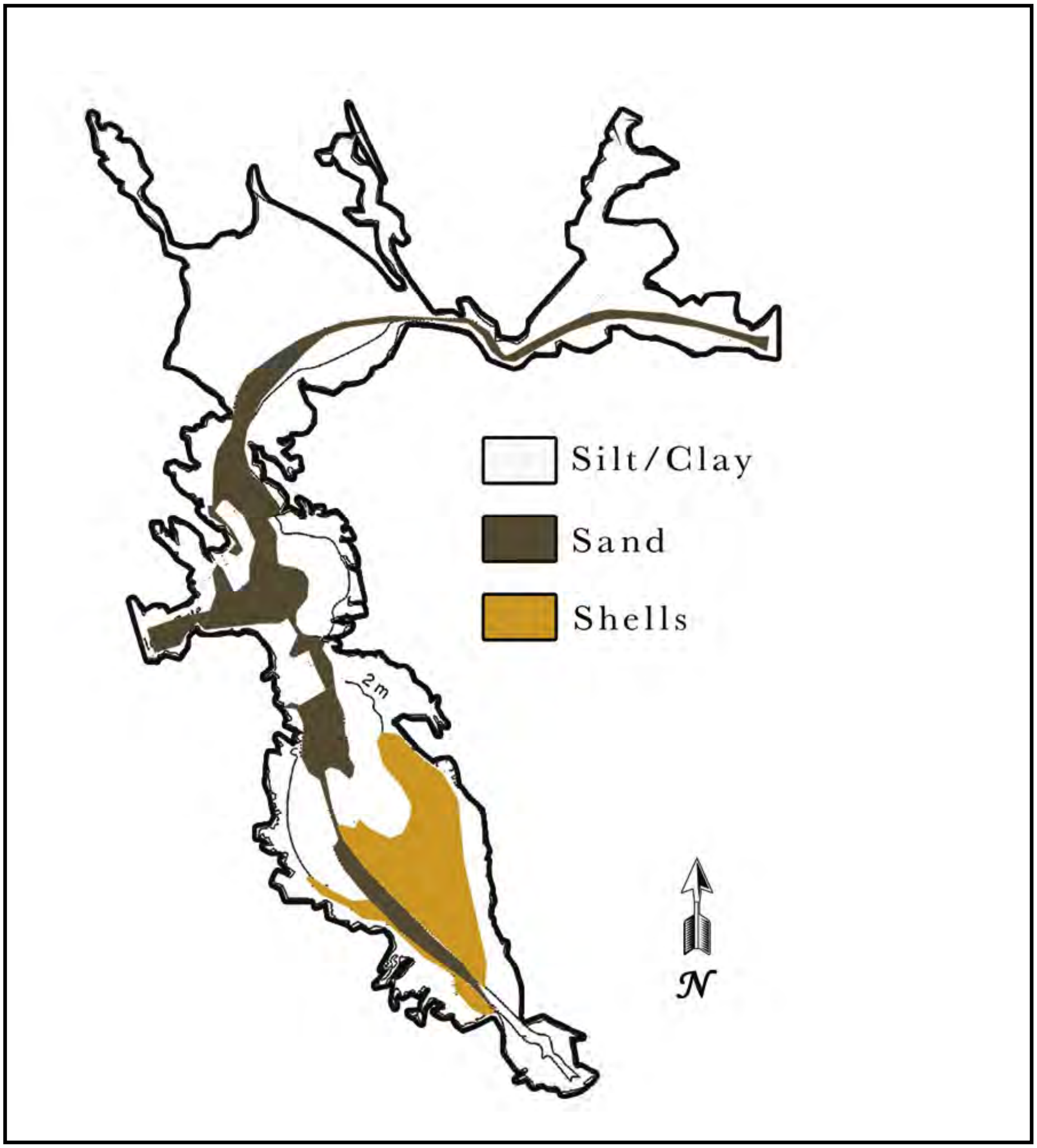
*All values expressed in dry weight.
(a) Ranges represent 13 stations with Merritt sand from the Port of Oakland Deepening Project (*Final Supplemental EIR/EIS Oakland Harbor Deep-Draft Navigation Improvements*, June 1994).
(b) Old Bay mud composite is comprised of OBM sediment from four stations in the Richmond Harbor Turning Basin (*Ecological Evaluation of Proposed Dredged Material from the Richmond Harbor Deepening Project and the Intensive Study of the Turning Basin*, June 1995)
(U) Undetected at or above detection limit.

The upper several feet of the sediment profile in most locations consists of more recently deposited marine and riverine sediments. The SFEP (1990) presented the following description of the classification and distribution of surficial (geologically recent) sediment deposits in the Bay:

- Sandy bottoms in the channels over much of the Central Bay;
- Shell debris over a wide expanse of the South Bay (derived from remnants of oyster beds (Wright and Phillips 1988); and
- Soft deposits (known as "Bay mud") underlying the vast expanses of shallow water.

Regions of the Estuary where currents are strong, including the deep channels of the Bay and the central channels of the major rivers in the Delta, generally have coarser sediments (i.e., fine sand, sand or gravel). Areas where current velocities are lower, such as the shallow fringes of each embayment of the Estuary are dominated by Bay mud (USACE 1976a). Bay mud is comprised of silt and clay particles deposited as a result of flocculation, or "salting out," a process in which particulate matter in fresh water aggregates when mixed with more saline waters. The settling velocity of the aggregates is much greater than that of the original clay or silt particles, increasing particle deposition. The distribution of surface sediment types in the Estuary is shown in Figure 7.3.

Figure 7.3 General Distribution of Surface Sediment Types in the San Francisco Bay/Delta



The surface Bay muds ("young Bay mud") and recent sand deposits tend to be much less densely packed and higher in moisture content and organic carbon than the underlying ancient sediment formations. Sand, on the other hand, has a low organic carbon content.

Silt particles are readily resuspended and redistributed by even fairly low energy currents and ultimately settle in quieter environments where constituents of concern and organic matter may also tend to accumulate. Clay has an even higher surface area for adsorption of constituent of concerns and tend to be charged; thus, facilitating bonding of additional contaminants to their surfaces. However, their charged nature also gives them a propensity to stick together in clumps. Factors such as the concentration of organic carbon and acid volatile sulfides (AVS) affect the degree to which constituents of concern may be associated with sediments. Organic carbon can readily adsorb a variety of constituents of concern, including many that would not otherwise have a high affinity to attach to the surface of sediment particles. Surface sediments, particularly the finer silts and clays, can accumulate organic carbon from a variety of sources including the water column and organisms living within the sediments. Whatever the source, the carbon content is generally higher in finer-grained sediments found in depositional areas (including portions of some navigation channels), where constituents of concern tend to accumulate. The concentration of AVS in sediments is defined as the concentration of solid phase sulfide compounds associated with metal sulfides (primarily iron and manganese monosulfides). In marine and freshwater sediments, sulfides of divalent metals form very insoluble compounds. It is hypothesized that the quantity of AVS represents a "reactive pool" of sulfides that are able to bind and reduce the bioavailability and toxicity of the metals in sediments (DiToro *et al*. 1990).

7.2.5.1 Movement and Fate of Sediments in the San Francisco Estuary

The primary source of new sediment into the Estuary's system is the Sacramento and San Joaquin Rivers, which flow through Suisun Bay to Carquinez Strait and into the northeastern end of San Pablo Bay. Other important, but much smaller sources include: Napa, Sonoma and Petaluma Rivers. A variety of smaller streams and other drainages (including storm drains and flood control channels) can be locally important for adding new sediment to the system. Overall, these sources provide an estimated 8 million cubic yards per year of new sediment to the Bay/Delta system (LTMS 1992; USACE 1965).

The Sacramento and San Joaquin Rivers account for approximately 89 to 92 percent of the total input of sediment to the Estuary's sediment budget; however, studies indicate that the amount of sediment input from the Central Valley is decreasing (Krone 1979, Conner and Oram 2007). Conner and Oram (2007) discuss the erosional nature of the Estuary and shows that the Suisun, San Pablo, Central and Upper South Bays are continuing to show a net erosional pattern while the Lower South Bay (south of Dumbarton Bridge) has continued to show a net deposition.

Decreases in sediment loads may be a result of several things: McKee, *et al.* (2006) suggests that in 2005 only 57 percent of the Estuary's sediment budget was derived from the Central Valley and the decreasing sediment budget may be a result of a lack of change in the sediment input from the local watersheds within the nine Bay area counties and the erosional nature of shallow areas of San Pablo and Suisun Bays that has occurred since the 1950s. Erosion of San Pablo and Suisun Bays may also be a result of reduced sediment supply from the Central Valley (Conner and Oram 2007). Hydraulic mining once dominated the Estuary's sediment budget; however, this practice was outlawed in 1884 and sediment loads from this practice appear to be reducing (Conner and Oram 2007).

Within the Estuary, surface sediments are continually re-suspended and re-deposited throughout the system. Deposits of typical fine-grained surface sediments in the extensive shallow areas are subject to hydraulic movement (resuspension) by riverine, tidal and wind-driven currents; it is estimated that 100 million cubic yards (Krone 1974) to 286 million cubic yards (SFEP 1992a) is resuspended annually, or perhaps 10 to 30 times greater than from all the "new" sediment sources combined. These resuspended sediments account for the vast majority of suspended particulate matter and turbidity throughout the Estuary.

SFEP (1990) included the following basic description of the dynamic environment experienced by surface sediments in the Estuary:

> The sediments of San Francisco Bay change on a time scale of days to months. The dynamic nature of the sediment compartment of the Bay was demonstrated by the sediment survey of SAIC (1987). Most of the site studied by these investigators showed evidence of recent sediment erosion, redistribution or deposition. On a short-term basis, Nichols and Thompson (1985) noted that sand waves standing from 20 centimeters to 8 meters in height move with the ebb and flow of tide, resulting in a continual sediment turnover to a depth of about 40 centimeters every few days. On a time scale of weeks, the intertidal mud-flat environment of the Bay may show rapid changes in elevation (Luoma and Bryan 1978; Nichols and Thompson 1985), as well as changes in sediment grain size.

Dredging and dredged material placement can also affect sediment transport within the Estuary. Dredging can resuspend in-situ sediments that can redistribute to other parts of the Estuary; in-Bay dredged material disposal can redistribute sediment from one area of the Estuary to another; the four in-Bay disposal sites (SF-9, SF-10, SF-11 and SF-16) are managed to be erosional, meaning that all dredged material placed at these sites redisperses completely over time; and, depending on where sediment is exported to, beneficial reuse and upland placement can completely remove dredged sediment from they Estuary's sediment budget.

For the most part only fine-grained particles are redistributed during the dredging process, as areas within the Estuary that have sandy bottoms are relatively deep and are not maintenance dredged (except for areas in the Main Ship Channel and portions of the Pinole Shoal Channel). Sand mining activities dredge for sand; however, these projects are not considered maintenance dredging projects and require their own environmental compliance.

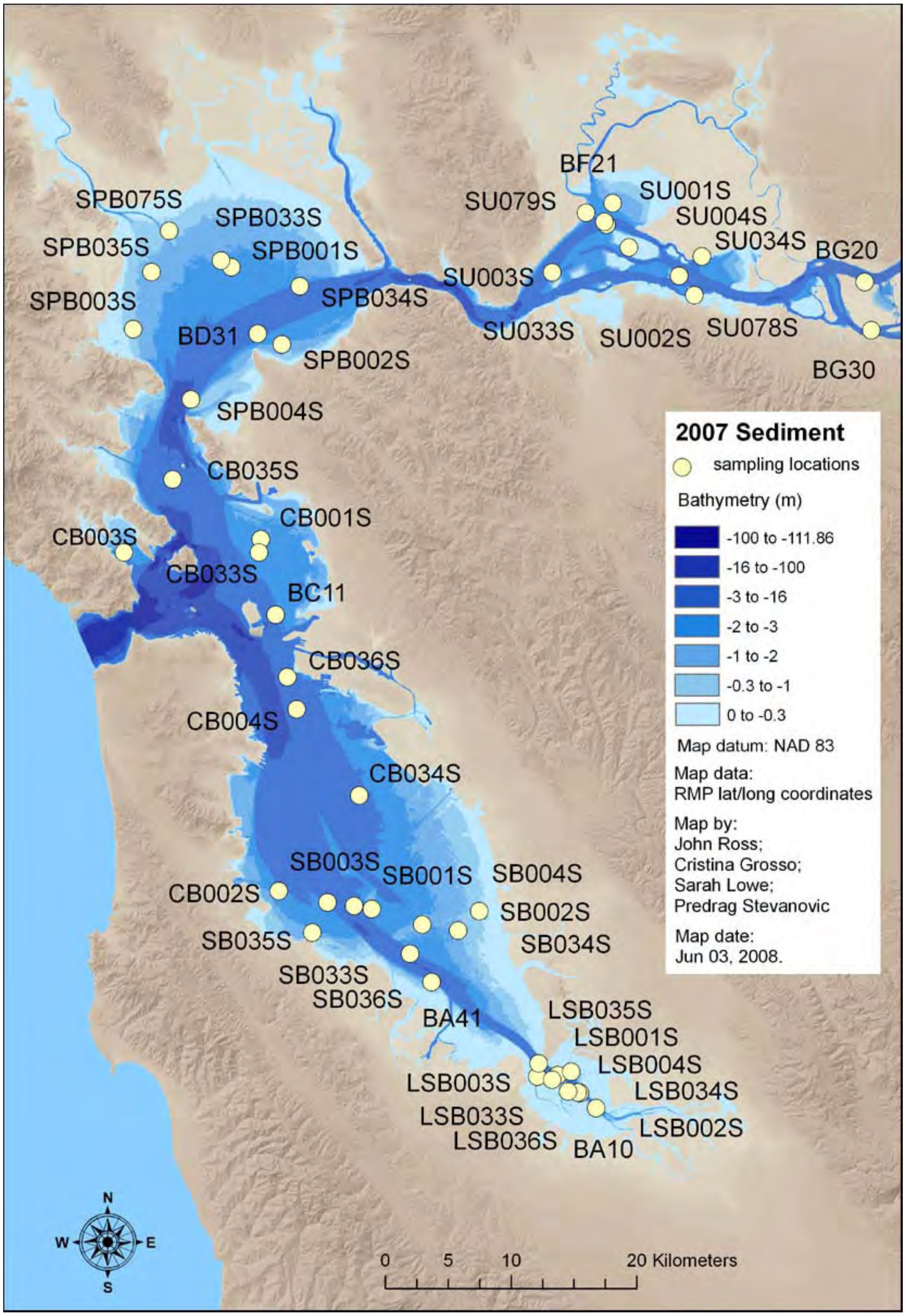
7.2.6 Sediment Quality

Sediments are a fundamental component of estuarine ecosystems, they provide habitat for several aquatic organisms and provide a source and sink for several constituents of concern within the water column. Sediment quality in the Estuary varies greatly according to the physical characteristics of the sediment, proximity to historical waste discharges, the physical/chemical condition of the sediment and sediment dynamics that vary with location and season. The Estuary's sediments generally contain elevated levels of constituents of concern compared to coastal reference sites. Currently, there are 270 sites within the Estuary and its tributaries identified on the federal Clean Water Act 303(d) list of impaired waters (SFEI 2005). Generally, concentrations of constituents of concern at a given location will vary depending on the rate of sediment deposition, which varies with seasons and tides (Luoma *et al.* 1990). Current and past data indicate that the margins of the Estuary may contain higher concentrations of constituents of concern than deeper areas (SFEI 2005). Chemical constituent of concern dynamics in bays are closely associated with the dynamics of suspended and deposited sediments. Overall, the physical and chemical characteristics and the bioavailability and toxicity of sediment-associated chemicals to aquatic organisms are particularly important in determining their potential impact on environmental quality.

While pollutant loading to the Estuary from point and non-point sources has declined dramatically over the past two decades and surface sediment contamination may be declining from historical highs, the Estuary's sediments are still an important source and sink of constituents of concern.

Much of the data documenting concentrations of trace metals and organics in the Estuary's sediments are found in the historical summary of Long and Markel (1992) and in the more recent monitoring efforts by the State's Bay Protection and Toxic Cleanup Program (BPTCP) (SFBRWQCB 1994) and RMP (SFEI, 1994, 1995, 2002, 2005, 2006 and 2007). As discussed above, much of the sediment data is taken from the most recent RMP quality checked monitoring, which occurred in 2004 and 2007. This data is considered by regulators' as the Estuary's ambient conditions; however, the data does not necessarily represent the data from the specific areas dredged. Figure 7.4 provides a map of the RMP sediment sampling sites throughout the Estuary.

Figure 7.4 2007 RMP Sediment Sampling Locations in the Estuary



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7.2.6.1 Concentrations of Metals in San Francisco Bay Sediments

The mean concentrations of metals in sediments vary according to grain size, organic carbon content and seasonal changes associated with riverine flow, flushing, sediment dynamics and anthropogenic inputs. Anthropogenic inputs appear to have the greatest effect on sediment levels of copper, silver, cadmium, and zinc; but, they also can contribute to elevated concentrations chromium, nickel and cobalt (SFBRWQCB). Metals that continue to be a concern in the Estuary include nickel, selenium and mercury (and methylmercury). For the most part, dredging does not occur in areas known to contain elevated levels of metals; however, should dredging occur in these areas, some of metals could be exposed to the water column. The following sediment quality data is provided from the RMP and can be accessed at: http://www.sfei.org/rmp/annualmonitoringresults/index.htm.

Arsenic

The ambient concentration of arsenic in the Estuary's sediments is 13.5 mg/kg for sediments with less than 40 percent fines and 15.3 mg/kg for sediments with 40 to 100 percent fines (SFBRWQCB 2000). Arsenic concentrations in the Estuary's sediments range from 2.60 to 24.10 milligrams per kilogram (mg/kg), with the highest reported concentrations found in San Pablo and Suisun Bays (SFEI 2007). The effects range low (ERL)[4] for arsenic in the Estuary is 8.2 mg/kg (SFEI 2006b).

Cadmium

Sediment cadmium levels measured in the Estuary range from 0.7 to 0.55 mg/kg; however, none of the total sampled area in the Estuary had sediment cadmium levels above the ERL guideline of 1.2 mg/kg (SFEI 2006b). Concentrations of cadmium in sediments taken from harbors and other enclosed areas around the Bay margins exhibit higher concentrations than those found in the main embayments (Long and Markel, 1992).

Chromium

Chromium levels throughout the Estuary range from 0.2 to 1.6 mg/kg, with the highest levels found in the San Pablo Bay, Central Bay and the Lower South Bay (SFEI 2006b). Approximately 95 percent of the total sampled area in the Estuary had sediment chromium concentrations above the ambient sediment concentration of 0.64 mg/kg (SFEI 2006b). Concentrations of chromium in known impacted areas along the periphery of the Bay can be much higher; levels in Islais Creek were found to average 140 parts per million (Long and Markel 1992) and sediments from the Oakland Inner Harbor ranged from 289 to 368 parts per million (USACE and Port of Oakland 1994). The ambient concentration of chromium in the Estuary's sediments is 91.4 mg/kg for sediments with

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[4] Effects range low (ERL) value is the concentration of a constituent equivalent to the lower 10th percentile of the constituent's concentration within a study area (e.g., San Francisco Bay). Sediment constituent concentrations below the ERL are interpreted as being rarely associated with adverse effects.

less than 40 percent fines and 112 mg/kg for sediments with 40 to 100 percent fines (SFBRWQCB 2000).

Copper

Copper concentrations in the Estuary's sediments are generally much lower in the central area of each embayment compared to levels found in samples taken from harbors and enclosed areas along the periphery. The RMP's 2007 monitoring of sediment copper revealed that concentrations of copper in the Estuary's sediments range from 12.2 to 83.6 mg/kg, with the highest concentrations found in San Pablo and Suisun Bays and the lowest concentrations found in the Central Bay (SFEI 2007). The ambient concentration of copper in the Estuary's sediments is 31.7 mg/kg for sediments with less than 40 percent fines and 68.1 mg/kg for sediments with 40 to 100 percent fines (SFBRWQCB 2000). The ERL guideline for copper in the Estuary is 34 mg/kg (SFEI 2006b)

Lead

Concentrations of lead in the Estuary's sediments range from 3.4 to 35.2 mg/kg and appear to be relatively spread evenly throughout the embayments (SFEI 2007). None of the total sampled area in the Estuary had led concentrations above the ERL guideline of 46.7 mg/kg (SFEI 2006b) and, compared to 2005 RMP results of 5 to 45 mg/kg, lead concentrations appear to be reduced. The ambient concentration of lead in the Estuary's sediments is 20.3 mg/kg for sediments with less than 40 percent fines and 43.2 mg/kg for sediments with 40 to 100 percent fines (SFBRWQCB 2000).

Mercury

Mercury is present in the environment in many forms; total mercury is the sum of all the different forms of mercury in the environment and is much easier to monitor than the various forms. Total mercury concentrations in the Estuary (and Delta) are abundant and widely distributed; so much so that it may take decades for total mercury concentrations to decline enough to reduce the Estuary's impairment (SFEI 2008). Mercury concentrations in the Estuary's sediments range from 0.1 to 0.5 mg/kg with the highest levels found in the San Pablo Bay (SFEI 2009). The lowest levels were observed in Central Bay near the Golden Gate. The ambient concentration of mercury in the Estuary's sediments is 0.25 mg/kg for sediments with less than 40 percent fines and 0.43 mg/kg for sediments with 40 to 100 percent fines (SFBRWQCB 2000).

Methymercury

Although mercury is often sequestered or immobilized by adsorption to soil particles, it can be biologically transformed into toxic methylmercury. Methylmercury is more water soluble, volatile and bioavailable than inorganic mercury; it is bioaccumulated and bioconcentrated by aquatic organisms and biomagnified in the food chain (Agency for Toxic Substances and Disease Registry 1999).

Mercury is converted to methylmercury in sediment by bacteria; however, this pathway is poorly understood (SFEI 2006b and 2008). Disturbance of sediments containing biologically unavailable mercury has the potential to release mercury to the water column. In addition, oxidizing conditions can cause inorganic mercury sequestered in sediments to be released into overlying waters. Once released, these mercury cations become available for methylation by sulfate-reducing bacteria (Compeau and Bartha 1985). The resultant concentration of methylmercury depends on numerous variables: salinity, pH, vegetation, sulfur concentration, dissolved organic carbon, oxidation/reduction potential, sulfide-reducing bacteria, and seasonal variations in each of the identified variables. The quantity of inorganic mercury present in sediments does not imply high rates of methylmercury formation (Marvin-DiPasquale et al. 2003).

Since the 1970s, the concentrations of methylmercury in the Estuary have been relatively constant. Results from the 2007 RMP indicate methylmercury concentrations in the Estuary ranging from 0.017 to 2.07 µg/kg with the highest concentrations found in the shallow areas of northern San Pablo Bay and the lower South Bay (SFEI 2007).

Nickel

Concentrations of nickel in the Estuary's sediments range from 25.5 to 133.03 mg/kg, with the highest levels found in Suisun, San Pablo, South and Lower South Bays; these concentrations are increased from the 2006 results of 20 to 125 mg/kg (SFEI 2007 and 2006b). The ambient concentration of nickel in the Estuary's sediments is 92.9 mg/kg for sediments with less than 40 percent fines and 112 mg/kg for sediments with 40 to 100 percent fines (SFBRWQCB 2000). The ERL guideline for nickel in the Estuary is 20.9 mg/kg (SFEI 2006b).

Selenium

Selenium concentrations measured in the Estuary in 2007 range from 0.031 to 1.6 mg/kg (SFEI 2007), a slight decrease from the 2006 measurement of 0.1 to 1.7 mg/kg. Generally, the highest concentrations of selenium are found in the South Bay and San Pablo Bay (SFEI 2007). The ambient concentration of selenium in the Estuary's sediments is 0.59 mg/kg for sediments with less than 40 percent fines and 0.64 mg/kg for sediments with 40 to 100 percent fines (SFBRWQCB 2000).

Silver

Silver concentrations in the Estuary's sediments range from 0.02 to 0.5 mg/kg in 2007; similar to the 0.05 to 0.5 mg/kg concentrations measured in 2006 (SFEI 2007 and 2006b). The highest concentrations found in the lower South Bay where maintenance dredging does not generally occur. The ambient concentration of silver in the Estuary's sediments is 0.31 mg/kg for sediments with less than 40 percent fines and 0.58 mg/kg for sediments with 40 to 100 percent fines (SFBRWQCB 2000). The ERL guideline for silver in the Estuary is 1 mg/kg (SFEI 2006b).

Zinc

Sediment concentrations of zinc in the Estuary range from 32.2 to 219.6 mg/kg in 2007; slight down from the 2006 measured concentrations of 50 to 225 mg/kg. The 2006 and 2007 sampling efforts revealed that the highest concentrations of zinc occur in the Lower South Bay (where maintenance dredging generally does not occur) and in Suisun Bay (SFEI 2007 and 2006b). The ambient concentration of zinc in the Estuary's sediments is 97.8 mg/kg for sediments with less than 40 percent fines and 158 mg/kg for sediments with 40 to 100 percent fines (SFBRWQCB 2000). The ERL guideline for zinc in the Estuary is 150 mg/kg (SFEI 2006b).

7.2.6.2 Concentrations of Organic Constituents of Concern in San Francisco Bay Sediments

Numerous organic contaminants are found in the Estuary's sediments. These include the following major classes of compounds: polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) and pesticides.

PAHs

Several areas in the Estuary are listed on the CWA 303(d) list for being impaired by polycyclic aromatic hydrocarbons (PAH) (SFEI 2008). Great differences are observed in sediment concentrations between Estuary's basins and shoreline margins, with higher concentrations being higher along the margins, often three to ten times greater (SFEI 2006b and 2008). In 2006, average Estuary-wide PAH concentrations were 2.0 parts per million (ppm), with the highest concentrations found in sediments located along the northwest shoreline of the upper portion of the South Bay (SFEI 2006b). In 2007, average concentrations of PAHs measured 1.8 ppm, a slight decrease from the previous years. Measuring 3.3 ppm, the western shoreline of the Central Bay continues to have the highest concentrations of PAHs (along the City of San Francisco's shoreline). The South Bay measured 1.9 ppm, San Pablo Bay measured 0.9 ppm and Suisun Bay 0.4 ppm (SFEI 2008). The ERL guideline for concentrations of PAHs is 4,033 µg/kg (SFEI 2006b).

PCBs

Polychlorinated biphenyls (PCBs) are synthetic chemicals associated with runoff from urbanization and industrialization. PCBs were heavily used during the 1930s to 1970s; as a result of increasing PCB concentrations in water bodies, the federal government put a ban on the sale and production of the substance in 1979. Since the ban, concentrations within the Estuary have declined; however, they are still a major concern in the Bay area, since they are a highly potent toxicant resistant to degradation and tends to bioaccumulate in organisms (SFEI 2006a). Due to the reservoir of PCBs that persist in the Estuary's sediments and the influx of PCBs that continue to enter the Estuary through urban runoff, Delta outflow, erosion and remobilization of buried sediments, it is expected to take more than 35 years to eliminate PCB impairment of the Estuary (SFEI 2006a).

Concentrations of PCBs in the Estuary increased slightly over the previous RMP sampling efforts; in 2007, the average Estuary-wide sediment PCB concentration was 8.7 ppb, compared to the long-term average of 5.7 ppb (SFEI 2008). The 2007 RMP measured the average concentration of PCBs in the sediments of each embayment with the following results: Lower South Bay - 7.5 parts per billion (ppb); South Bay - 6.5 ppb; Central Bay - 6.9 ppb; San Pablo Bay - 4.2 ppb and Suisun Bay - 2.0 ppb.

The SFBRWQCB has identified several PCB hotspots in the Estuary, including: Mare Island Strait, one area in Richardson Bay, along the eastern shoreline of the Central Bay and the northwest shoreline of the South Bay (Davis, *et al.* 2006). Currently, areas near the western entrance of Carquinez Strait (near SF-9 disposal site), the western portion of the Central Bay (Richmond Harbor area), the southern portion of the Central Bay / northern portion of the South Bay (Port of San Francisco area), areas within the central South Bay (near Coyote Point Marina) and southern South Bay (SFEI 2008). The ERL guideline for PCBs in the Estuary is 22.7 µg/kg (SFEI 2006b).

Pesticides

Historical use of the pesticides dieldrin, DDT and chlordanes has resulted in impairment of the Bay's waters; however, monitoring of sportfish and mussels indicate that concentrations of these pesticides are declining.

State monitoring programs typically test for a variety of chlorinated pesticides and pesticide derivatives. However, only a handful of these compounds are detected on a regular basis. Generally, pesticide concentrations in sediment are directly related to sediment type and are significantly correlated to the percent fines and total organic carbon content of a sample.

Concentrations of DDT in the Bay's sediments range from 1 to 14 µg/kg, with the highest concentration found near the mouth of the Carquinez Strait in San Pablo Bay (14 µg/kg) and the lowest concentrations found in the South Bay (SFEI 2006b). Approximately 55 percent of the total sampled area in the Bay has sediment sum of DDT concentrations above the ERL guideline of 1.58 µg/kg and all regions of the Bay have concentrations 50 percent or above the ERL guideline (SFEI 2006b).

Sediment concentrations of chlordane measured in the RMP are generally low for both basin and peripheral sediments. Concentrations of chlordane measured in Suisun, San Pablo, Central and South Bays are less than 0.3 µg/kg and one area in the Lower South Bay has chlordane concentrations of 0.9 µg/kg, which is above the ERL guideline of 0.5 µg/kg for chlordane (SFEI 2006b).

Concentrations of dieldrin in the Bay's sediments range from 0.02 to 0.22 µg/kg, with the highest concentrations found in the South Bay. Approximately 98 percent of the total sampled area has sediment dieldrin concentrations above the ERL guideline of 0.02 µg/kg (SFEI 2006b).

PBDEs

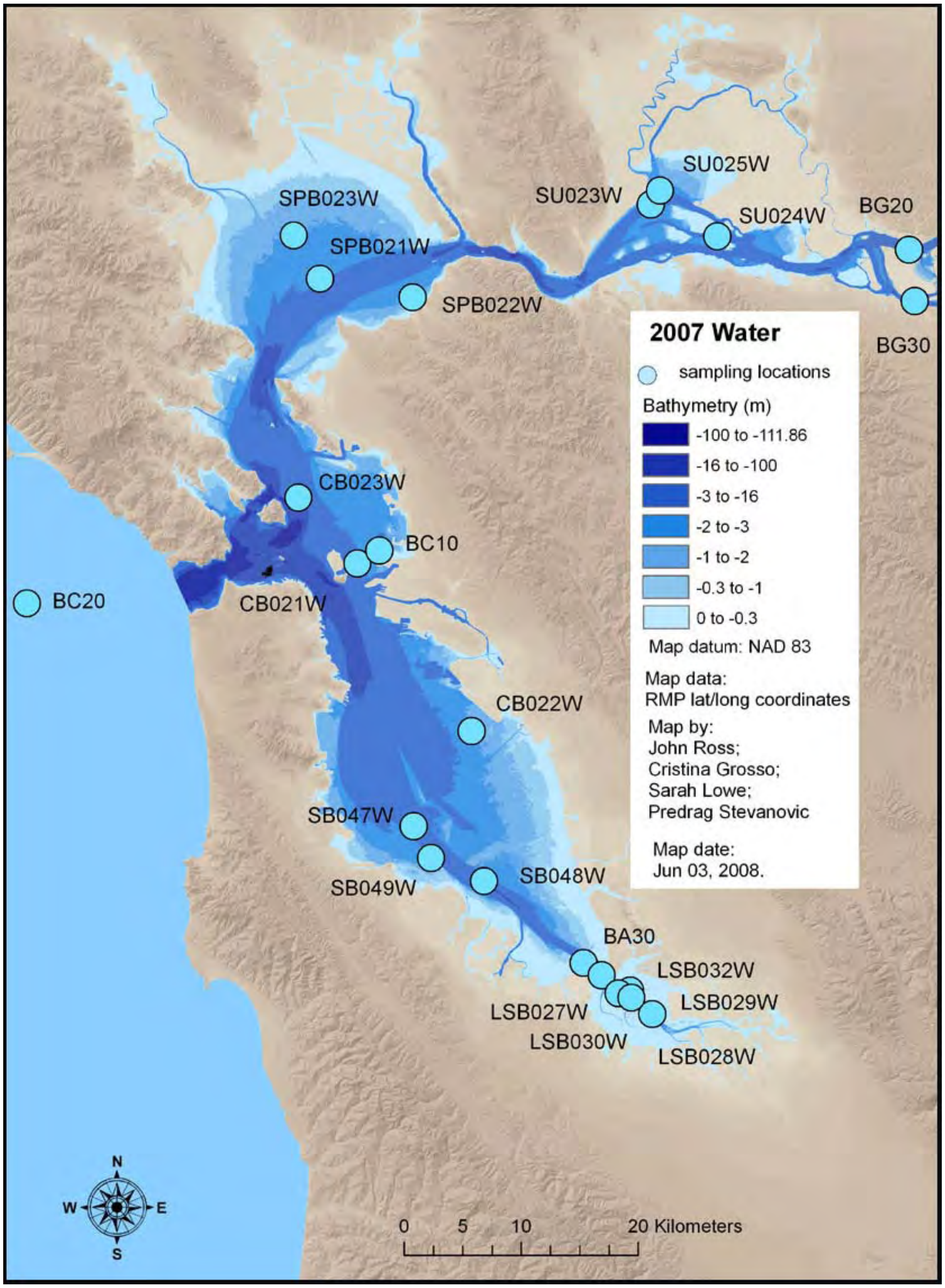
Polybrominated diphenyl ethers (PBDEs) are a class of bromine-containing flame retardants that has become a concern in the San Francisco Bay area and are currently on the SFBRWQCB's watch list of potential threats to the Estuary's water quality (SFEI, 2006). PBDEs also bioaccumulate in organisms. Although several forms of PBDEs are measured in the Estuary's sediments by the RMP, only PBDE 47 and PBDE 209 are still used in the Bay area. PBDE 47 concentrations ranged from 2004 through 2007 ranged from 0.81 ppb in the lower South Bay and 0.46 ppb in the Suisun Bay (SFEI 2008). Average concentrations of PPDE 209 ranged from 5.7 ppb in the lower South Bay, 3.5 ppb in San Pablo Bay to 1.0 in Suisun Bay.

PBDE hot spots include: the lower South Bay, where maintenance dredging does not occur); the western shore of San Pablo Bay, south of the federally-maintained Petaluma Across the Flats Channel; in the northeastern areas of San Pablo and Suisun Bays, where maintenance dredging does not occur; Honker Bay (near the Suisun Bay Channel); the north western shore of the South Bay (near the Brisbane Marina and Oyster Point Marina); and the lower South Bay (where dredging does not occur) (SFEI 2008).

7.2.7 Water Quality

The most comprehensive data sets describing water quality in the Estuary come from the RMP managed by the San Francisco Estuary Institute (SFEI 2006a), the United States Geological Service's Water Quality for San Francisco Bay program and ongoing studies by the Interagency Ecological Program (IEP) focusing on parameters affected by water flow. In addition, numerous short-term studies that focus on specific sites, resources or pollutants are conducted on a regular basis by researchers and entities discharging permitted wastes. For the purpose of this analysis, where possible, water quality data is taken from the RMP. Figure 7.5 provides a map of the water quality sampling sites for the RMP data used in this document.

Figure 7.5 2007 RMP Water Quality Sampling Locations



AR 0028525

The primary water quality parameters discussed below include: total suspended solids (TSS) and turbidity, salinity, dissolved oxygen, pH, unionized ammonia and constituents of concern.

7.2.7.1 Total Suspended Solids and Turbidity

Turbidity is an optical property of water that causes light to be scattered and absorbed by suspended particles as it passes through a water column. Particle matter that can affect turbidity includes inorganic solids (clay, silt and sand), organic solids (algae and detritus) and living organisms (phytoplankton and zooplankton) (APHA 1992). Turbidity is expressed in Nephelometric Turbidity Units (NTU).

Total suspended solids (TSS), on the other hand, is a measure of the amount of dry-weight mass of non-dissolved solids suspended per unit of water (often measured in milligrams per liter (mg/l)). Total suspended solids includes inorganic solids (clay, silt and sand) and organic solids (algae and detritus) (ERDC 2000). In general, higher TSS results in more turbid water. For the purposes of this analysis, whenever possible, total suspended solids (mg/l) are used, rather than using turbidity (NTU).

The level of turbidity and TSS in estuarine waters is a function of composition and type of sediment and other material, wind-wave resuspension, currents, tides, freshwater sediment input and freshwater flow; as such, suspended sediment concentrations are different within different parts of the Estuary and at different times of the year. Regions of maximum suspended solids occur in the Suisun and San Pablo Bays in the area known as the null zone (generally 50 to 200 mg/l, but, can be as high as 600 mg/l TSS); which accumulates high concentrations of phytoplankton (Smith 1987). The specific location of the null zone changes depending upon freshwater discharge from the Delta. TSS levels in the Estuary vary greatly, depending on the season, ranging from 50 to 200 mg/l in the winter and summer, respectively (Nichols and Pamatmat 1988; Buchanan and Schoellhamer 1995). Shallow areas and adjacent channels have the highest suspended sediment concentrations. TSS levels vary throughout the Bay depending upon season, tidal stage and depth (Buchanan and Schoellhamer 1995).

Concentrations of suspended sediment in the Central Bay are generally less than other regions, due to depth, increased tidal exchange and sediment type; however, wind-driven wave action, tidal currents, as well as dredged material disposal and sand mining operations cause localized elevations of suspended solids concentrations throughout the water column.

Additionally, seasons play an important role in suspended sediment loads. During the winter when freshwater flow and corresponding “new” sediment loads are high and winds are generally weak, sediments tends to be deposited on the mudflats of northern San Pablo Bay and other quiescent locations. In the summer when river flows and “new” sediment loads decrease dramatically, strong, frequent westerly winds over the shallow mudflats resuspend sediments and, in conjunction with tidal currents, transport them throughout the system. Although most new sediment input occurs in San Pablo Bay and there is less overall water circulation in the South Bay, the information available today supports the presumption that sediments from any of the embayments of the Estuary can be resuspended and spread widely throughout the system. Some sediment leaves the Estuary's system by being transported out the Golden Gate; however, the quantity leaving the system during a typical year is thought to be relatively small (on average, less than the input of new sediment from rivers and other sources) compared to the total quantity cycling within the Estuary. Table 7.3 provides the average monthly suspended sediment concentrations, measured by USGS at specific stations.

Table 7.3	**Average Monthly Suspended Sediment Concentrations (mg/l)**												
Site	**Dates**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Mallard Island	2/94-9/05	29	28	34	50	38	39	40	46	43	44	39	31
Martinez	2/94-1/96	41	40	43	121	61	70	54	53	59	64	53	46
Benicia Bridge	5/96-8/98,10/01-9/05	27	30	42	77	71	65	65	58	56	57	35	28
Carquinez Bridge	6/98-9/05	20	28	56	59	57	66	83	60	57	50	37	25
Mare Island Strait	10/98-9/05	37	44	58	60	89	58	82	78	59	59	48	42
Pt. San Pablo	12/92-9/05	38	47	59	82	75	65	78	79	61	62	50	28
Alcatraz	11/03-9/05	15	18	21	21	20	18	19	16	18	16	16	15
Pier 24	5/93-1/02	25	25	26	36	34	25	36	34	29	27	24	19
Golden Gate Bridge	1/96-8/97	23	--	--	17	24	16	16	17	21	19	18	33
Channel Marker 17	10/92-9/05	86	93	98	82	92	128	169	181	138	132	120	99
Dumbarton Bridge	10/92-9/05	86	76	89	73	71	92	126	82	74	71	62	58
San Mateo Bridge	12/92-9/05	48	43	59	52	46	48	52	45	51	54	65	42

* Data provide by USGS 2008.
** Monthly mean near surface or mid-depth suspended-sediment concentration, in mg/L.
*** -- indicates no data are available for that month.

7.2.7.2 Salinity

The salinity of water entering the Estuary from rivers varies greatly. The Sacramento River and eastside streams flowing into the Delta are low in salts, with salinity averaging less than 0.1 parts per thousand. San Joaquin River water is more saline than these tributaries and, since the 1930s, its average salinity has increased from less than 0.2 parts per thousand to about 0.4 parts per thousand, primarily as a result of increased agricultural drainage.

The salinity of the Estuary's northern reach varies considerably and increases along a gradient from the Delta to Central Bay. At the mouth of the Sacramento River, for example, the mean annual salinity averages slightly less than 2 parts per thousand; in Suisun Bay it averages about 7 parts per thousand; and at the Presidio in San Francisco near the Golden Gate, it averages about 30 parts per thousand. The entrapment zone is generally located where the surface salinity is between 1 and 6 parts per thousand and the near-bottom salinity is 2 parts per thousand. In the southern reaches, salinities remain at near-ocean concentrations (32 parts per thousand) during much of the year. However, during the summer, high evaporation rates may cause salinity in South Bay to exceed that of ocean water.

Seasonal changes in the salinity distribution within the Estuary are controlled mainly by the exchange of ocean and bay water and by river inflow. River inflow has the greatest influence on salinity distribution throughout most of the Bay because inflow varies widely, while ocean input varies relatively little. In winter, high flows of freshwater from the Delta lower the salinity throughout the Estuary's northern reaches. High Delta flows also intrude into the South Bay, lowering salinities for extended periods. In contrast, during the summer, when freshwater inflow is low, saline water from the Estuary intrudes into the Delta. The inland limit of salinity intrusion varies greatly from year to year. Salinity of one part per thousand has extended upstream of Rio Vista several times in the past 100 years (Nichols and Pamatmat 1988).

7.2.7.3 Dissolved Oxygen

Dissolved oxygen (DO) concentrations in estuarine waters can increase in several ways: by the mixing action of wind, waves and tides; by photosynthesis of phytoplankton and other aquatic plants; and by high dissolved oxygen levels in freshwater inflow. Dissolved oxygen concentrations are lowered by plant and animal respiration, chemical oxidation and bacterial decomposition of organic matter.

The Estuary's waters are generally well oxygenated, except during the summer in the extreme southern end of the South Bay where concentrations are reduced by poor tidal mixing and high water temperature. Typical concentrations of dissolved oxygen range from 9 to 10 milligrams per liter (mg/l) throughout the entire Estuary during periods of high riverine flow, 7 to 9 mg/l during moderate riverine flow and 6 to 9 mg/l during the late summer months when flows are the lowest. Unlike the 1950s and 1960s, when inadequately treated sewage and processing plant wastes depleted oxygen in parts of the Bay/Delta, today there are few reports of places where low oxygen concentrations adversely affect beneficial uses. Today, the lowest concentrations of dissolved oxygen in the Estuary are typically observed in the extreme South Bay, where concentrations range between 5 to 6 mg/l (SFEI 2007) (maintenance dredging does not occur in this area). In some instances, dissolved oxygen levels in semi-enclosed embayments, such as Richardson Bay, can be much lower than in the main water body (SFEI 2005).

7.2.7.4 pH

The pH of waters throughout the Estuary is relatively constant and typically ranges from 7.8 to 8.2 (SFEI 2007).

7.2.7.5 Nutrients

Nutrients in the Estuary are considered non-limiting due to high levels of nitrate, silicate and phosphate (resulting from riverine and agricultural inputs), as well as ammonium (resulting from anthropogenic inputs) (Wilkerson, *et al.* 2006).

7.2.7.6 Un-Ionized Ammonia

Ammonia is produces as a result of microbial breakdown of nitrogenous organic matter (e.g., plant and animal matter) or from anthropogenic sources (e.g., sewage). The toxicity of aqueous ammonia to aquatic organisms is primarily attributable to the un-ionized form.

Generally, concentrations of unionized ammonia are low in the Estuary's waters, with the highest levels typically found near the mouths of rivers and creeks during periods of high flow. Concentrations in the extreme South Bay and the mouth of the Napa River ranged from 0.18 to 0.30 mg/l during a period of high riverine flow in 1993, compared to levels ranging from 0.10 to 0.16 mg/l at most of the other monitoring stations (SFEI 1994). During periods of moderate and low riverine flow, ammonia levels were much lower, ranging from 0.001 to 0.01 mg/l throughout the Estuary.

7.2.7.7 Constituents of Concern

Increased concentrations of constituents of concern in the Estuary are one of the many factors that have stressed the environmental resources of the aquatic system. Constituents of concern enter the aquatic system through atmospheric deposition, runoff from agricultural and urbanized land and direct discharge of waste to sewers and from industrial activity.

The Estuary's sediments can be both a source of and a sink for constituents of concern in the overlying water column. The overall influx of constituents of concern from the surrounding land and waste discharges can cause increases in sediment pollutant levels. Natural resuspension processes, biological processes and other mechanical disturbances can remobilize particulate-bound pollutants.

Primary constituents of concern identified on the Clean Water Act 303(d) list by the State Water Resources Control Board include trace elements: mercury, nickel and selenium; pesticides: chlordane, DDT, diazinon and dieldrin; organic compounds: PAHs, PCBs, dioxin and furan compounds; as well as nutrients, pathogens and exotic species (SWRCB 2006).

7.2.7.8 Metals

Exposure to high levels of dissolved metals and other trace elements within the water column has the potential to harm aquatic life. Toxicity of many of trace metals is dependent on other water quality characteristics, particularly hardness (concentration of calcium carbonate). A number of trace elements, particularly mercury and selenium, are known to bioaccumulate in food webs (Bay Institute 2003).

Ten trace metals are monitored in the aquatic system and in waste discharged to the Bay on a regular basis. Total and dissolved fractions are sampled three times a year at RMP stations throughout the Bay. Table 7.4 presents typical trace metal concentration ranges taken from 2005 through 2007 RMP data (SFEI 2007).

Table 7.4 Ranges of Concentrations of Trace Metals in Water Samples (2005 - 2007)

Location	Ag µg/L	As µg/L	Cd µg/L	Co µg/L	Cu µg/L	Hg µg/L	MeHg ng/L	Ni µg/L	Pb µg/L	Se µg/L	Zn µg/L
South Bay	0.08 - 0.33	2.01 - 3.79	0.05 - 0.13	0.11 - 1.01	1.75 - 6.90	0.0031 - 0.0288	0.0419 - 0.2420	1.41 - 6.73	0.114 - 1.89	0.038 - 0.263	1.03 - 6.68
Average South Bay	0.015	2.92	0.07	0.37	3.39	0.0081	0.0899	2.81	0.505	0.14	2.50
Lower South Bay[1]	0.12 - 0.45	2.62 - 4.19	0.06 - 0.15	0.34 - 1.18	3.09 - 8.79	0.0045 - 0.0389	0.0063 - 0.2050	2.38 - 8.93	0.035 - 2.58	0.17 - 0.39	1.54 - 13.40
Average Lower South Bay[1]	0.021	3.45	1.32	0.69	4.90	0.0130	0.1239	4.60	0.92	0.26	4.81
Central Bay	0.50 - 0.20	1.23 - 2.68	0.04 - 0.12	0.03 - 0.41	0.35 - 4.18	0.0003 - 0.0099	0.0322 - 0.0773	0.030 - 3.74	0.016 - 0.731	0.04 - 0.12	0.38 - 2.83
Average Central Bay	0.08	1.77	0.07	0.18	1.56	0.0041	0.0520	1.35	0.226	0.08	1.20
San Pablo Bay	0.006 - 0.022	1.62 - 3.08	0.06 - 0.12	0.207 - 0.890	2.15 - 5.70	0.0030 - 0.0242	0.0390 - 0.0788	1.71 - 6.82	0.195 - 1.431	0.086 - 0.146	0.88 - 6.58
Average San Pablo Bay	0.014	2.20	0.08	0.533	3.99	0.0109	0.0651	3.77	0.778	0.117	3.12

Table 7.4 Ranges of Concentrations of Trace Metals in Water Samples (2005 - 2007)											
Location	**Ag µg/L**	**As µg/L**	**Cd µg/L**	**Co µg/L**	**Cu µg/L**	**Hg µg/L**	**MeHg ng/L**	**Ni µg/L**	**Pb µg/L**	**Se µg/L**	**Zn µg/L**
Suisun Bay	0.06 - 0.18	1.35 - 3.11	0.03 - 0.09	0.04 - 1.13	2.90 - 6.26	0.0042 - 0.0267	0.0250 - 0.1199	2.61 - 7.80	0.42 - 1.23	0.095 - 0.136	2.30 - 8.39
Average Suisun Bay	0.12	2.11	0.05	0.73	4.15	0.0119	0.0668	4.18	0.83	0.233	4.61

[1]Maintenance dredging does not occur in the lower South Bay (below Dumbarton Bridge).
Source: SFEI (2007).

7.2.7.9 Organic Constituents of Concern

Three general types of trace organic constituents of concern are measured in the Estuary on a regular basis: polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and pesticides (DDT, dieldrin and chlordane).

Several types of PAHs are measured in the Estuary, including low molecular weight PAHs (LPAH) (e.g., Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, and Anthracene) and high molecular weight PAHs (HPAH) (e.g., Fluoranthene, Pyrene, Benz(a)anthracene, Chrysene, Total Benzofluoranthenes, Benzo(a)pyrene, Indeno(1,2,3,-c,d)pyrene, Dibenzo(a,h)anthracene, and Benzo(g,h,i)perylene). For the purpose of this document, the total PAH measurements are provided. For the Central Bay, total PAHs ranged from 4,021 to 71,336 pg/l (average 33,924 pg/l.

Similar to PAHs, the RMP measures individual forms of PBDE and total forms. For the purpose of this document, total PBDEs are provided. This heist concentrations of PBDE 47, one of the most abundant in Suisun and San Pablo Bays, located north and east of maintenance dredging activities, respectively. Averaging 81 pg/l over the past six years, Suisun Bay has had the highest concentrations of PBDEs in the Estuary.

PCB concentrations measured throughout the Bay range from 10 to 250 pg/l, with areas in the South Bay having the highest concentrations and Suisun Bay the lowest (SFEI 2006b).

Measured water concentrations of pesticides were highest in the rivers and the extreme South Bay and lowest in the Central and San Pablo Bays. Concentrations of dieldrin range from 10 to 80 pg/l, with the highest concentrations found in the Suisun and Lower South Bays and the lowest concentrations found in the Central Bay. Concentrations of chlordane ranged from 10 to 50 pg/l, with the highest concentrations found in the Lower South Bay and Suisun Bay and the lowest found in the Central Bay (SFEI 2006b). The dissolved sum of DDT in the Estuary's water ranges from 20 to 190 pg/l, with the lowest concentrations found in the South Bay and concentrations increasing in the Central, San Pablo and Suisun Bays (SFEI 2006b).

7.2.8 Biological Resources of San Francisco Bay

The Estuary supports a strikingly complex array of biological resources. In addition to aquatic habitat types, the aquatic resources of the Estuary that are associated with the various embayments can be grouped into four categories: phytoplankton, zooplankton, benthos and fish. A similar but slightly different set of resources is associated with five distinct habitat types within the transition zones between the purely aquatic environment and upland areas (e.g., intertidal mudflats, rocky shore, salt marsh and ponds, and brackish marsh and freshwater marsh).

7.2.8.1 Phytoplankton and Zooplankton

Phytoplankton production is the major source of organic matter in the Bay, accounting for about 50 percent of the total (SFEP 1992b). In wet years, river transport of detrital material is another important source of organic matter, at least for the Delta and Suisun Bay. Phytoplankton dynamics are influenced by currents, light availability and aquatic organisms living in the system. Results from several studies suggest that much of the phytoplankton produced in the water column settles to the bottom where it is consumed by a variety of organisms, from bacteria to large clams and worms. Benthic diatoms growing on the sediment surface throughout the Estuary, together with temporarily or permanently settled phytoplankton, may represent the most readily available food resource for bottom-dwelling organisms.

The Estuary is not nutrient limited and has relatively high levels of nitrate, silicate, phosphate and ammonium within the water column. Generally, nutrient concentrations are highest in Suisun Bay, followed by San Pablo Bay and the Central Bay (Wilkerson 2006). Although the Estuary has high levels of nutrients; prior studies indicate that low primary production within the Estuary is attributable to light limitation (due to turbidity) and benthic grazing (especially by invasive species such as the Asian clam *Corbula amurensis*) (Wilkerson 2006), especially in Suisun Bay.

The organic matter produced in or transported to the Estuary is ingested directly by planktonic invertebrates (zooplankton) that digest and metabolize it to produce carbon dioxide, water and dissolved nutrients. There are estimated to be over 200 species of zooplankton in the Estuary, most of which are not well-studied. Important species include opossum shrimp (*Neomysis mercedis*) (ranges from Suisun Bay down into San Pablo Bay during periods of high riverine flow) and the copepod *Eurytemora* (resides in the northern reaches). Recently introduced species of copepod, *Sinocalanus doerri* and *Pseudodiaptomous forbesi*, are found in increasing numbers. Zooplankton are consumed by larval and juvenile stages of most fish species; by adult stages of fish species such as anchovy, smelt and shad; and by macro-invertebrates such as bay shrimp.

Phytoplankton is most abundant in the South Bay during the spring months and abundance decreases northward towards San Pablo and Suisun Bays. During the fall, primary production appears to be moderate throughout the Estuary, peaking in the Central Bay. During the winter months, phytoplankton abundance is low throughout the Estuary, also peaking in the Central Bay (Cole and Cloem 1997). Since the late 1990s, significant changes in phytoplankton biomass fluctuations in San Pablo, Central and South Bays have occurred, including larger spring blooms, blooms during other seasons and a progressive increase in annual minimum chlorophyll concentrations, thus resulting in an increase of approximately 100 grams per square meter per year from 1993 to 2004 (SFEI 2006a).

7.2.8.2 Benthos

Many EFH managed species forage on infaunal, epibenthic and benthic organisms. Benthic organisms dwell in the Estuary's mudflats, on the bottom of tidal marshes and open water areas, on hard surfaces below the intertidal zone and in eelgrass meadows. Benthic organisms have adopted a variety of life strategies – worms burrow into the bottom sediment; crabs and oysters live on the sediment surface (epibenthic) and mussels live on rock pilings or other hard objects. Most benthic species are either filter-feeders or grazers, although some are active predators. Benthic invertebrates are an important component of the food chain as they are an important food source for demersal fishes, invertebrates, crabs and shorebirds.

Key invertebrate functions include shredding, which breaks down and recycles organic matter; suspension feeding, which collects and transports sediments across the sediment-water interface; and bioturbating, which moves sediment into or out of the seabed. In addition, macrophytes regulate many aspects of nutrient, particle and organism dynamics above and below ground. Additionally, animals moving within or through the sediment are vectors that transport nutrients and organic matter across terrestrial, freshwater and marine interfaces.

The benthic ecology of the Estuary has undergone vast changes, historically and recently, due to natural and anthropogenic causes, including dredging projects. Many of the dredged locations, including many of the ports, marinas and federal navigation channels, are dredged on an annual basis. These areas are highly disturbed by dredging activities and by increased shipping vessel use.

As a result of commercial shipping, most benthic organisms in the Estuary are introduced species, arriving attached to imported commercial species, ship bottoms or in ballast water. New species entering the system have led to complete changes in community structure, particularly in San Pablo and Suisun Bays. The most striking (and recent) example of such an introduction is the Asian clam (*Potamocorbula amurensis*), which was first discovered in the Estuary in 1986. Since that time it has spread rapidly and now dominates most benthic communities in San Pablo and Suisun Bays (SFEP 1992a). The ecological and economic impacts of introduced species are extensive, ranging from reduced availability of food for higher trophic levels to damaging various water-related structures.

Factors affecting the abundance, composition and health of benthic communities include outflow from the Delta, substrate, salinity and pollution. In general, diversity is lowest in the Delta where, of the more than 82 benthic species recorded, only five species account for 90 percent of the individuals at most sites (SFEP 1992a). In the more saline waters of San Pablo Bay, the number of benthic species increases to more than one dozen. In the South Bay where there are several substrate types, diversity is even greater. Mollusks comprise the greatest biomass of larger benthic species in the Estuary (Thompson and Nichols, 1981), with the most abundant species being *Mytilus galloprovinciallis, Macoma balthica, Mya arenaria, Tapes japonica* and the recently introduced Asian clam. Other important components of the benthos include numerous polychaete and amphipod species as well as crabs and shrimp.

The following sections provide an overview of the various benthic species that inhabit the Estuary.

7.2.8.2.1 Phylum Porifera

Several species in the phylum porifera, commonly known as sponges, inhabit the Estuary. Species of sponges can sometimes be difficult to identify because they are differentiated on a microscopic level (California Academy of Sciences 2005). However, the following porifera are known to occur in the Estuary: *Clathria prolifera*, *Halichondria bowerbanki*, *H. panacea*, *Hailclona loosanoffi.*, *Leucilla nuttingi*, *Leucosolenia nautilia*, *Lissodenoryx topsenti*, *Mycale macginitiei*, *Myxilla agennes*, *Paresperella psila*, *Reneira spp.*, *Cliona spp.*, *Microciona prolifera,* and *Prosuberites spp.* (SFBMSI 2005).

Sponges are generally sessile, although they appear to be capable of minimal movement. Porifera feed by taking in water and food through their pores; as the water passes through their pores, they absorb bacteria and decaying organic matter. Feeding is regulated by adjusting the size of their pores. Sponges are common in the benthos throughout the South, Central and San Pablo Bays, as they require salinities of at least 15 parts per thousand (Cohen 2005), and are also a common dock fouling species.

7.2.8.2.2 Phylum Molluska

Mollusks include common species such as squid, octopi, snails, clams and mussels. Clams and mussels play an important role in the food-web of EFH-managed and ESA-listed species. The National Benthic Inventory for San Francisco Bay (NOAA-Fisheries 2001) documented the following molluska species:

- Bivalvia: several genuses in the Mytilidae and Lasaeidae families, *Mysella tumida*, *Mya arenaria*, *Macoma expansa*, *M. balthica*, *Musculista senhousia, Macoma spp.*, *Gemma gemma*, *Corbicula fluminea* (Asian clam), *Chione californiensis* and *Potamocorbula amurensis* (NOAA-Fisheries 2001).

- Gastropoda: several genuses in the Muricidae family, several orders and subclasses in the class *Gastropoda* (orders: *Archaeopulmonata*, *Basommatophora*, *Heterostropha*, *Neoptaenioglossa*, subclass *Opisthobranchia*, *Patellogastropoda*, subclass *Prosobranchia*, *Rhodopemorpha*, *Stylommatophora*, *Systellommatophora* and *Thecosomata*), *Dirona albolineata*, *Crepidula fornicata*, *Calyptraeidae spp.* and *Aglaja spp.*) (NOAA-Fisheries 2001).

Softshell Clam

Prior to the invasion of *Potamocorbula amurensis* in the late 1980s, the non-native softshell clams, *Macoma petaluma* and *M. arenaria*, were the dominant mollusks in the Estuary. During the wet years of 1982 to 1984, *Corbicula fluminea* abundance increased. Since the invasion of *P. amurensis*, all three mollusk species have been somewhat rare in Grizzly Bay. *M. arenaria* is distributed across the Bay. Large populations exist in the South Bay, San Pablo Bay, Carquinez Strait, Suisun Bay and various small bays and coves. Typically, the clam resides in the intertidal zone and shallow waters, though it has been observed in deeper waters. Adults survive in salinities as low as five parts per thousand and in temperatures between -2 and 28 degrees Celsius.

M. arenaria is typically 75 to 100 millimeters in length and filter feeds on plankton and organic detritus (NOAA Coastal Services Center 2003). Adults can filter up to 50 liters of water per day (Cohen 2005). *M. arenaria* spawns one to two times per year, producing up to one million eggs each time. Survival rate of eggs, however, is low, approximately 0.1 percent of eggs produced survive (NOAA Coastal Services Center 2003). Larvae float in the water column as plankton for approximately two to three weeks following hatching; they then settle onto the substrate surface as juveniles where they spend two to six weeks burrowing into the sediment, generally situating itself as deep as 30 centimeters below the substrate surface. Clams mature after one to four years and live for approximately 10 to 12 years.

M. arenaria are an important food source for snails, crabs, rays, sharks and flounders; larvae are prey for jellyfish, comb jellies and fish (Cohen 2005).

Tellinid Bivalve *(Macoma petulam or M. balthica)*

M. belthica was once thought to be native in San Francisco Bay; however, studies suggest that previously identified *M. balthica* is actually the non-native *M. petulam* (Thompson and Shouse 2004). This species is distinct from other clams in that it is both a filter feeder and a deposit feeder, meaning that each clam has a long intake siphon that scours the benthos for food and using its siphon to inhale it (Marine Organisms Database 2005). *M. balthica* spawns twice each year, during the late fall and in the spring. Population trends show that numbers peak in the spring and summer while dropping off during the winter months. Declines are thought to be due to physiological stressors and increased predation (Thompson and Shouse 2005).

M. balthica inhabits muddy substrate in the South, Central, San Pablo and Suisun Bays, and the Carquinez Strait. A 1996 study indicated that they are most abundant in San Pablo Bay (Thompson and Shouse 2005).

Amethyst Gem Clam *(Gemma gemma)*

Native to the Atlantic and Gulf Coasts, *G. gemma* was introduced to the Estuary in the 1890s along with the Atlantic Oyster (NOAA Coast Service Center 2003). At a maximum length of approximately five millimeters, it is one of the smallest known marine clams (NOAA Coastal Services Center 2003). It feeds on diatoms and organic detritus by filtering out particles near the surface of sediment beds (NOAA Coastal Services 2003).

Extremely high concentrations of *G. gemma* occur in South Bay south of the Dumbarton Bridge and sizable populations are found in San Pablo Bay. Elsewhere in the Bay, populations occur in a few small clusters. Generally, *G. gemma* utilize the intertidal zone to a depth of twenty feet (NOAA Coastal Services Center 2003). In the Bay, *G. gemma* is found in high intertidal and deep channel habitats in all sediment types, except shell hash and gravel. *G. gemma* is preyed upon by crustaceans and other invertebrates.

Eastern Mudsnail *(Ilyanassa obsoleta)*

I. obsoleta was first discovered in the Bay in 1907, likely introduced through the shipments of Atlantic oysters. Since this time it has become to most abundant species of snail in the mudflats of the Estuary, out competing the native hornsnail (*Cerithidea californica*) for habitat (Elkhorn Slough Foundation). The hornsnail now inhabits marsh channels and pools too saline for the mudsnail.

Although *I. obsoleta* is found throughout the Estuary, predominately in the South Bay, south of Dumbarton Bridge, Mare Island and Carquinez Straits. The snail prefers mudflats and salt marshes, occurs in salinities ranging from 10 to 32 parts per thousand and prefers temperatures ranging from 13 to 22 degrees Celsius (Cohen 2005).

I. obsoleta feeds on diatoms, algal detritus, worms, and on the remains fish, crabs and other animals (Cohen 2005). It lays its eggs in capsules on blades of eelgrass, shells, stones or other debris. Larvae float in the water column and feed on phytoplankton for up to a month before maturing to adults (Cohen 2005).

Olympia Oyster *(Ostrea lurida)*

O. lurida are native to the North American Pacific Coast and can be found along the eastern Pacific Coast, from Alaska to Baja, California, in channels, bays and estuaries. They form reefs in sub-tidal zones, often near eelgrass beds or mudflats. They prefer water with salinities of 25 parts per thousand; however, they do inhabit fresher water. Once abundant throughout the Estuary, they have rapidly declined due to exploitation and predation by non-native species (Couch and Hassler 1989). A 1986 study found that they still inhabit areas of the South and San Pablo Bays (Hopkins 1986).

O. lurida spawn during the spring, summer and fall in waters ranging from 13 to 16 degrees Celsius, depending on geography. Adult oysters grow as large as 45 millimeters in shell height (Couch and Hassler 1989). Like most oysters, *O. lurida* filter feeds on phytoplankton and are prey to Japanese oyster drill, the flatworm *Pseudostylochus ostreophagus*, rock crabs and bat rays (Couch and Hassler 1989).

Atlantic Oyster Drill *(Urosalpinx cinerea)*

U. cinerea was first observed in Estuary in 1890, likely introduced along with the Atlantic Oyster. Females lay eggs on hard surfaces in the spring and summer and each egg capsule contains 5 to 12 eggs. Juveniles feed on small invertebrates and reach maturity after two years (Cohen 2005). In the eastern portion of the Estuary, *U. cinerea* is known to prey on mussels and oysters, as it is able to penetrate the shell of its prey with its radula and a secretion that softens its prey's shell.

U. cinerea is distributed in low densities across the Estuary, especially in the South Bay (Hopkins, 1986). It inhabits intertidal and shallow subtidal waters to a depth of 50 feet and salinities ranging from 13 to 15 parts per thousand (Cohen 2005). It is often found on rocks and in oyster reefs.

Green Bagmussel *(Musculista senhousia)*

M. senhousia was first discovered in the Estuary in 1946, likely introduced with Japanese oysters or through ballast waters (California Academy of Sciences 2005). As larvae, they float in the water column for approximately two weeks to two months. As they reach maturity, they borrow into the substrate producing threads that bind them to the sediment and form a nest (Cohen 2005). The nests of adjacent mussels can create a mat of several thousand mussels per square meter over the substrate surface (Cohen 2005).

M. senhousia is found across the Estuary. High densities occur in San Pablo Bay, San Leandro Bay, South Bay and parts of Central Bay. Low concentrations inhabit areas within the Carquinez Strait and Suisun Bay. The mussel can survive on both hard and soft substrates, though it prefers soft surfaces, in the intertidal and shallow subtidal zones to a depth of about 65 feet (Cohen 2005). It can survive in waters with low salinity and dissolved oxygen levels. In the Bay, it inhabits waters with salinities between 17 and 33 parts per thousand and temperatures between 17 and 24 degrees Celsius (Cohen 2005).

M. senhousia is a filter feeder that is preyed upon by a variety of snails, crustaceans and fish.

7.2.8.2.3 Phylum Annelida

Annelids are segmented worms that include land worms, such as earthworms, and marine worm species known as polychaetes. In the Estuary, tubeworms are the most common annelids.

NOAA's 2001 National Benthic Inventory survey documented the following annelids in the Estuary: several genera and species in the *Tubificidae, Ampharetidae*, *Hesionidae*, *Maldanidae*, *Lumbrineridae*, *Cirratulidae*, *Chrysopetalidae*, *Enchytraeidae*, *Cossuridae*, *Capitellidae*, *Dorvilleidae* and *Eunicidae* families; *Exogon lourei*, *Streblospio benedicti*, *Pseudopolydora diapartra*, *Euchone limnicola*, *Mediomastus californiensis*, *Mediomastus spp.*, *Sobaco americanus*, *Cossura candida*, *Heteromastus filiformis*, *Schistomeringos annulata*, *Typosyllis spp.*, *Sphaerosyllis californiensis*, *Neanthes succinea*, *Harmothoe imbricate, Spiophanes berkeleyorum*, *Tharyx parvus*, *Microphthalums spp.*, *Melinna oculata*, *Marphysa sanguinea*, *Marenzelleria viridis*, *Malmgreniella macginitiei*, *Maldane sarsi*, *Magelona sacculata*, *Lysidice ninetta*, *Lysidice spp.*, *Lumbrineris tetraura*, *Lumbrinerides acuta*, *Lepidasthenia berkeleyae*, *Leitoscoloplos pugettensis*, *Leitoscoloplos spp.*, *Hypereteone lighti*, *H. fauchaldi*, *Heteropodarke heteromorpha*, *Heteromastus filobranchus*, *Heteromastus spp.*, *Hesionura coineaui*, *Harmothoe imbricate*, *Glycinde picta*, *G. armigera*, *Glycinde spp.*, *Exogone lourei*, *Exogone spp.*, *Eumida longicornuta*, *Eumida spp.*, *Eteone leptotes*, *Dipolydora socialis*, *Dipolydora caulleryi*, *Cossura pygodactylata*, *Cossura candida*, *Cossura spp.*, *Cirriformia spirabrancha*, *Cirratulus spectabilis*, *Chone duneri*, *Chaetozone spinosa*, *Chaetozone lunula*, *Chaetozone hedgpethi*, *Caulleriella spp.*, *Capitella ovincola*, *Capitella capitata*, *Capitella spp.*, *Autolytus spp.*, *Armandia brevis*, *Aricidea horikoshi*, *Prionospio pygmaea*, *Tharyx monilaris*, *Ancistrosyllis groenlandica* and *Amphiglena spp.* (NOAA-Fisheries 2001).

<u>Tubeworm *(e.g., Streblospio benedicti)*</u>

Like other polychates, *S. benedicti* is a filter feeder. It feeds by reaching into the water column or extending across the water column to obtain decomposed matter.

S. benedicti is found throughout most of the Estuary; however, it is not native. It most likely arrived in 1932 in ballast waters or with the Atlantic oyster. Since its arrival in the Bay, its population peaked and today it is no longer the dominant benthic species (Thompson and Shouse 2004). It spawns in the spring and fall. *S. benedicti* can survive at most depths and substrates and inhabits areas in the South, Central and San Pablo Bays and in the Carquinez Strait.

7.2.8.2.4 Phylum Arthropoda

Arthropods are vast in their number, location and diversity. They are generally characterized by segmented bodies with exoskeletons. In the Estuary, crabs, shrimp, crayfish and other arthropoda are found.

NOAA's 2001 National Benthic Inventory survey found the following arthropoda existing in the Estuary: *Ampelisca abdita*, *Photis brevipes*, *Leptochelia dubia*, *Leptocheliidae spp.*, *Polycirrus spp.*, *Sinocorophium alienense*, *Monocorophium acherusicum, M. insidiomsum, S. sinense, Eudorella pacifica, Grandidierella japonica, Americorophium stimpsoni, Mediomastus californiensis*, *Ampelisca spp.*, several genera in the *Corophiidae, Crangonidae*, *Caprellidae*, *Aoridae*, *Melitidae*, *Ampithoidae*, and *Munna*, families, *Caprella californica*, *Nippoleucon hinumensis, Synidotea laticauda*, several families in the *Collembola*, *Leptostraca*, *Cumacea*, and *Diptera* orders, *Munnogonium tillerae, M. tuberculatum, Corophium spp., Melita dentate, Melita spp., Lophopanopeus bellus, Listriella diffusa, Lamprops quadriplicatus, Hemigrapsus oregonensis, Grandidierella japonica, Gnorimosphaeroma oregonense, Gitana calitemplado, Gammarus setosus, Foxiphalus obtusidens, Eudorella spp., Dyopedos monacanthus, Dulichiella appendiculata, Diastylis spp., Cumella vulgaris, Cumella californica, Crangon alaskensis, Caprella spp., Atylus spp., Ampithoe valida, Ampelica spp., Americorophium stimpsoni, Americhelidium shoemakeri, Amaenana occidentalis* and *Pacifacanthomysis nephrophthalma* (NOAA-Fisheries 2001).

Dungeness Crab *(Cancer magister)*

C. magister larvae float in the water column of the ocean until about four to six months after birth when they settle to the bottom of the water column and make their way to estuarine environments. Juvenile and adult *C. magister* are bottom foragers, feeding on fish, clams and other crustaceans. In turn, *C. magister* are preyed upon by flounder, sole and other bottom-feeding fish species (Goals Project 2000).

Spawning generally takes place in early- to mid- spring and fertilized eggs remain in the female until hatching. Each female can produce up to two million eggs and may have four broods over her lifetime (Goals Project 2000).

The Estuary provides habitat for many life stages of the *C. magister*. Juveniles are most abundant in San Pablo Bay with abundance decreasing further south. Adults seek out structurally complex habitats, rather than exposed mud and sand, possibly due to protection against predation. However, almost any substrate can support the *C. magister* (Goals Project 2000).

Rock Crab *(C. antennarius and C. productus)*

The brown (*C. antennarius*) and red (*C. productus*) rock crabs begin their life cycle as fertilized eggs carried by the female for six to eight weeks before hatching in early summer. Females protect eggs by burrowing into the sand near the base of rocks. After hatching, crab larvae become epibenthic prior to becoming juveniles. In the Estuary, juveniles are most abundant during the summer. Red rock crab females produce up to 600,000 eggs per brood for an average of four broods; brown rock crabs produce about 5.3 million eggs for a brood average of 10 broods over seven years. Brown rock crabs reach up to 6.5 inches carapace width over their 5 to 6 year life span and red rock crabs reach approximately 8 inches.

Both species prey on hard-shelled benthic organisms at night. Juvenile rock crabs are preyed upon by macroinvertebrates and demersal fish; adults are preyed upon by marine mammals (Goals Project 2000).

Both species are common along the North American Pacific Coast and are known to inhabit the South, Central and San Pablo Bays. They prefer low intertidal zones with depths up to 300 feet. Brown rock crabs cannot tolerate brackish waters, while red rock crabs can tolerate waters with salinities as low as 13 parts per thousand. Both species inhabit rocky shores, reefs, gravel and sandy areas within the Estuary (Goals Project 2000).

Tube-dwelling Amphipod *(Ampelisca abdita)*

A. abdita was first discovered in the Bay in the 1950s and became a dominant species in some areas, including the Palo Alto mudflats in the South Bay. It was subsequently reported in the South, San Pablo and Suisun Bays. It is a semi-pelagic species in that many individuals abandon their tubes and swim, especially during spring tides. During reproduction, *A. abdita* increases swimming and invades new habitat. It is a filter feeder that filters out food from the water column and along the Bay floor (Thompson and Shouse 2004).

Franciscan Brine Shrimp *(Artemia franciscana)*

In the Estuary, *A. franciscana* was once limited to the few high-salinity locations available, such as salt panes and sloughs. Today its habitat has increased substantial in the Bay, predominately due to the presence of salt ponds that serve commercial salt production. As a result, *A. franciscana* has proliferated. A 1992 study revealed a winter population high of 40 billion and a low of 4.5 billion in the San Francisco Bay National Wildlife Refuge (Goals Project 2000).

A. franciscana occurs in the Bay where conditions are highly saline. Large populations are found in salt ponds in both the northern and southern portions of the Estuary. Shrimp can occur in salinities of 70 to 200 parts per thousand, but are typical in waters with salinities of 90 to 150 parts per thousand. *A. franciscana* feeds on phytoplankton and blue-green algae in salt ponds and is preyed upon by waterfowl and shorebirds (Goals Project 2000).

7.2.8.2.5 Phylum Chordata

Chordates include humans, sea squirts, giraffes and other vertebrates. In the Estuary, tunicates (sea squirts) are the most common chordata found. NOAA's 2001 National Benthic Inventory survey found the only chordate class *Ascidiacea* existing in the Estuary (NOAA-Fisheries 2001).

Sea Squirt *(Mogula manhattensis)*

Originating in the Atlantic Ocean, *M. manhattensis* is an important urochordate species inhabiting the Estuary. *M. manhattensis* and others like it are known as tunicates and nick-named 'sea squirts' for the squirting that results from squeezing a tunicate. Tunicate bodies are filled with water and have two siphons. Early in their life, they resemble tadpoles and later they resemble bags (University of Washington 2005). A tunicate matures in a matter of hours and attaches to rocks, docks and sometimes boats. They are filter feeders consuming mainly plankton. The plankton are filtered with sea water through a gill basket after entering the inflow siphon. *M. manhattensis* are known to exist in the South, Central and San Pablo Bays, as well as the Carquinez Strait. A 1986 study found *M. manhattensis* most abundant in the South Bay (Hopkins 1986).

7.2.8.2.6 Phylum Cnidaria

Cnidaria are characterized by stinging cells called cniddocytes and include jellyfish, sea anemones and corals. Within the Estuary, anemones and jellyfish are common. Approximately 20 different anemone species are known to exist within the Estuary. Like many other benthic invertebrates, anemones are difficult to differentiate due to their often minute and microscopic differences (California Academy of Science 2005).

NOAA's 2001 National Benthic Inventory survey found the following cnidaria classes existing in the Estuary: *Anthozoa* and *Actiniaria*; the following cnidaria (from most to least abundant): cnidaria from the order *Actiniaria* (suborders: *Endocoelantheae*, *Nyantheae*, *Protantheae*, *Ptychodacteae*); and several orders from the class *Hydrozoa* (orders: *Actinulida, Capitata*, *Chondrophora*, *Filifera*, *Hydroida*, *Siphonophora* and *Trachylina*).

Anemones *(Diadumene cincta, D. franciscana, D. leucolena, D. lineate)*

Anemones are planktivores that stun its prey with stinging tentacles and maneuvers it into its feeding orifice. They are known to occur throughout the Estuary and in brackish marshes. They commonly attach to rocks, docks, shells and sometimes mud (Cohen and Carlton 2005).

Jellyfish

Jellyfish have two basic life stages: polyp and medusa. Polyps are sessile with a linear core and tentacles facing up in the water column. Generally, they attach to the benthos while shedding discs before maturing to the medusa stage. Medusae are the drifters within the water column characterized by domes with downward-protruding tentacles. Jellyfish catch plankton or small fish in their tentacles and feed through their orifice.

Several species of jellyfish are exotic to the Estuary and its freshwater tributaries (e.g., San Joaquin, Napa and Petaluma Rivers). Various reports document several species of jellyfish in the South, Central and San Pablo Bays (Cohen and Carlton 1995).

7.2.8.2.7 Phylum Nemertea

NOAA's 2001 National Benthic Inventory survey found species in the family *Lineidae* existing in the Estuary (NOAA-Fisheries 2001).

7.2.8.3 Aquatic Habitats of the San Francisco Estuary

This section describes the aquatic habitats within the Bay, including intertidal mudflats, rocky shores, salt marsh, brackish marsh and freshwater marsh habitats.

7.2.8.3.1 Mudflats

Approximately 64,000 acres of mudflat habitat exist between the open water and the vegetated or rocky shoreline of the Estuary. Mudflats vary in composition from clay/silt to sand and include organic debris and shell fragments. Generally, these areas are exposed twice daily during the two low tides. Where tidal marshes adjoin mudflats, receding tides bring organic materials from the marshes to the mudflats, providing a food source for millions of detritus-feeding invertebrates, fish and birds.

The mudflats are a living system of diatoms, microalgae, protozoans and a multitude of arthropod, annelid and molluscan invertebrates. Emergent plants are uncommon in these habitat types; however, micro- and macro-algae form the basis of the food web. Micro-algae growing both in the shallow water column and on the sediment surface are transported across the intertidal and shallow subtidal mudflats by wind- and tide-induced currents, thus making them available to suspension or surface deposit feeding invertebrates. The benthic invertebrates are, in turn, eaten by large consumers such as shorebirds, demersal fishes, elasmobranchs and juvenile Dungeness crabs in the northern reaches of the Estuary and by human clam diggers.

The most notable consumers of this high secondary productivity are migratory shorebirds. The extensive intertidal mudflats of San Francisco Bay provide major feeding habitat for over-wintering shorebirds of the Pacific Flyway and are considered a key migratory staging and refueling area (SFEP 1991).

The organic material transported to mudflats by receding tides constitutes the base of the food web for both benthic and pelagic invertebrates. The distribution of benthic invertebrate species associated with mudflats and, to some extent, rocky shores is related to temporal variations in salinity and sediment stability (Nichols 1979). Depending upon salinity, common invertebrate species of intertidal mudflats include: clams (*Gemma gemma, Macoma balthica, Mya arenaria, Corbicula fluminea* and *Potamocorbula amurensis*); amphipods (*Ampelisca abdita, Corophium spinicorne* and *C. stimpsoni*); shrimp (*Crangon franciscorum* and *Palaemon macrodactylus*) and polychaetes (*Streblospio benedicti* and *Asychis elongata*) (Nichols and Pamatmat 1988; SFEP 1991). Except for the clam *Macoma balthica* and the shrimp *Crangon franciscorum*, all of these species are exotic in the Estuary. Since its discovery in the Bay in 1986, the Asian clam *Potamocorbula amurensis* has become the numerically dominant species in many mudflat habitats. Rocky shores are typically inhabited by hard-surface oriented marine taxa and the native cosmopolitan bay mussel *Mytilus galloprovinciallis* (formerly known as *Mytilus edulis*) (Nichols and Pamatmat 1988). Mudflat areas at the base of riprap dikes and breakwaters, where sediments contain cobbles and sand, are important habitat for the clams *Tapes japonica* and *Mya arenaria* (Nichols and Pamatmat 1988).

The distribution of fishes associated with these habitats varies in accordance with freshwater outflow and salinity. Both intertidal mudflat and rocky shore habitats serve as important forage habitats for a number of sportfish and special status species. These areas also provide important nursery habitat for native forage fish, such as Pacific herring and northern anchovy (SFEP 1991b). Important sportfish that forage and/or rear young in these areas include: native species such as Chinook salmon, white sturgeon, diamond turbot and a variety of sharks, in addition to the introduced striped bass.

Since pre-settlement conditions, mudflat habitat has declined throughout the Bay, with losses since 1958 in the South Bay alone estimated at approximately 500 acres (SFEP 1991). Within the planning area, general factors affecting mudflat habitats include the following: invading plants (smooth cordgrass and Chilean cordgrass), sea level rise, disturbance by boaters and fishermen and point and non-point sources of pollution (SFEP 1992c).

7.2.8.3.2 Rocky Shore Habitat

The rocky shore habitat in the Estuary occurs around the margins of Central and San Pablo Bays and is primarily found around Yerba Buena, Angel, and Alcatraz islands, the shoreline of the Tiburon peninsula and the rocky islands near the Richmond San Rafael Bridge. Vegetation along rocky shores is predominantly algae. Wildlife species that utilize these habitats include shorebirds, brown pelicans, cormorants, gulls and harbor seals.

7.2.8.3.3 Eelgrass Bed Habitat

Eelgrass (*Zostera marina*) meadows are among the most productive aquatic ecosystems known. Eelgrass meadows form complex, important and highly productive habitats. Eelgrass beds trap suspended materials and take up nutrients and other dissolved substances, help to stabilize sediment and prevent erosion, increase clarity and quality of estuarine waters, produce organic matter and export detritus (USFWS, *et. al.* 1984; Day, *et. al*. 1989). Eelgrass beds provide direct and indirect food sources for several marine food chains and a diverse habitat for several marine species (USFWS, *et. al.* 1984). In the Estuary, eelgrass is important habitat for Pacific herring (*Clupea pallasii*), which lay their eggs on the thin blades from November through April.

Light availability is crucial for the growth and survival of eelgrass; as such, eelgrass is generally is limited to depths ranging from MLLW to approximately -22 feet MLLW (in less turbid waters, eelgrass can grow in waters 100 feet deep). Other factors important to the growth, survival and reproduction of eelgrass include: temperature (optimum: 10° to 20° Celsius), salinity (10 to 30 parts per thousand), substrate (mixed sand and mud), pH (7.3 – 9.0) and water motion (little wave action) (USFWS, *et al*. 1984).

Eelgrass beds in the Estuary are restricted to a narrow intertidal range between approximately +1 to –6 feet MLLW. The range of depth eelgrass can grow is dependent upon the turbidity of water (Zimmerman, *et al*. 1991). Eelgrass is largely limited to the Central Bay region where salinity is highest. Eelgrass meadows are absent in waters that are more turbid where light availability is limited (e.g., Suisun Bay and north San Pablo Bay).

Eelgrass habitat in the Estuary is extremely dynamic; repeated surveys of eelgrass meadows at Point Molate, Richmond training wall and Emeryville Flats indicate that density and abundance fluctuate significantly from year to year (Merkel 2001). A 2003 eelgrass survey conducted by Merkel documented 2,880.5 acres of eelgrass habitat in the Estuary (Merkel 2004); whereas a 1989 study documented 316 acres (Wyllie-Echeverria and Rutten 1989). As shown in Figure 7.6, eelgrass is present within the intertidal and subtidal areas of southern San Pablo Bay, Central Bay and northern South Bay.

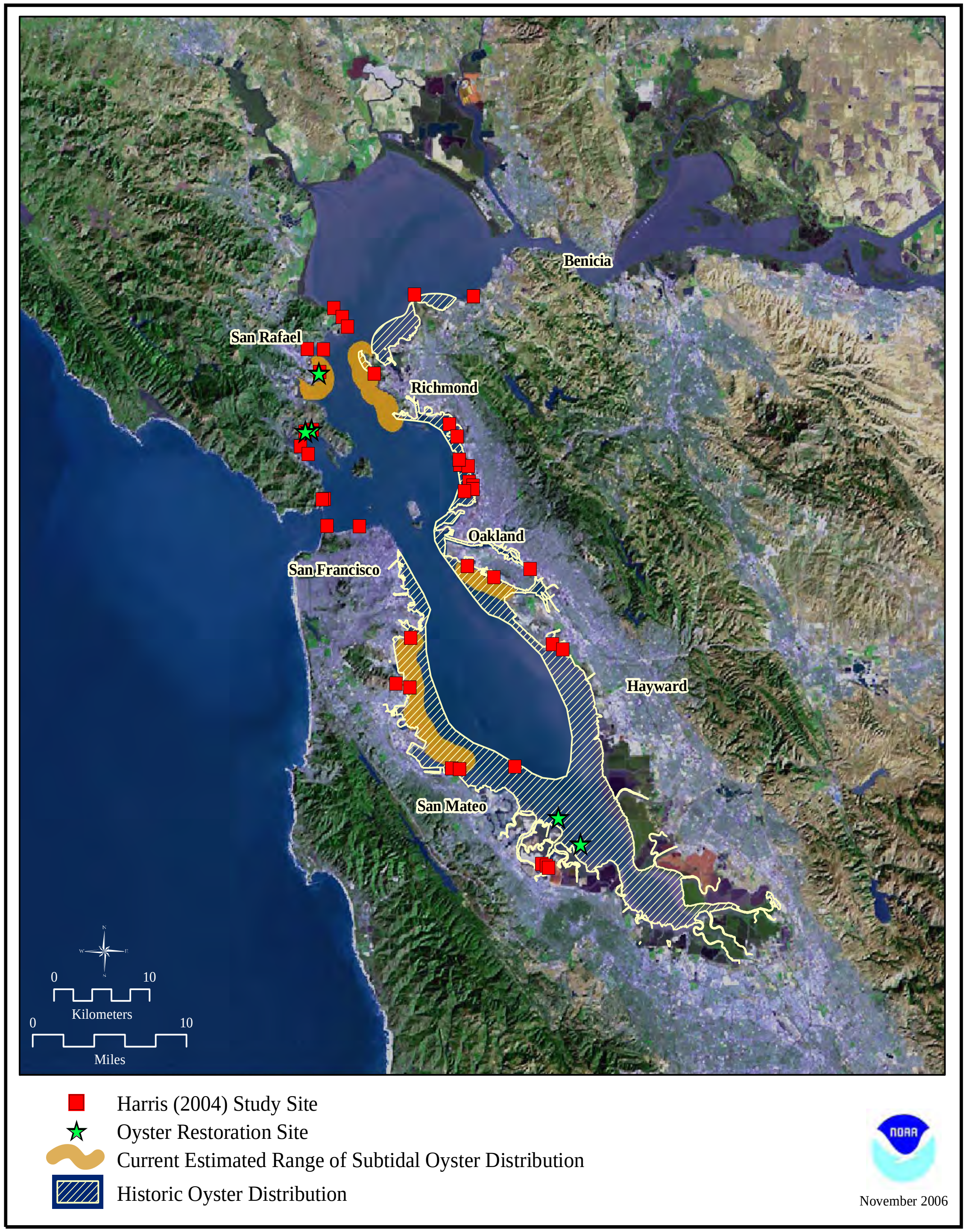
Figure 7.6 Eelgrass Habitat within San Francisco Bay

Source: Recreated from Merkel 2004.

7.2.8.3.4 Oyster Bed Habitat

Oyster beds provide habitat for several marine organisms. Live oysters and remnants of dead oysters form reefs in the intertidal zone of the Pacific Ocean, which provide food, protection and hard surface living habitat for fish and invertebrates. Oysters also act as filters by removing excess nutrients from water. Besides these ecological functions, oyster beds in the Estuary were once important commercially; however, intensive harvesting caused oyster populations to decline dramatically. Today oyster beds are threatened by heavy metal contamination and exotic species competition. As shown in Figure 7.7, oyster bed habitat exists along the margins of the northern portion of the South and Central Bays.

Figure 7.7 Oyster Bed Habitats within the San Francisco Bay



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7.2.8.3.5 Tidal Marshes

Tidal marshes are extremely productive and diverse ecological communities that provide important habitat and resources both to organisms that live solely within the marsh and to species more commonly found in upland and aquatic areas. Tidal marshes occur at scattered locations along the margins of the South Bay, along the waterways of the Delta, at the margins of San Pablo Bay and within Suisun Marsh. These marshes can be segregated into salt, brackish and freshwater types based on water and soil salinity. These marsh types can be further subdivided into 12 eco-geomorphic classes (LTMS 1994b).

The loss of tidal marsh habitat is well documented within the San Francisco Bay area (LTMS 1994b). Due to human activities, such as Gold Rush era (late 1800s) hydraulic mining activities in the Sierra, reclamation for agricultural uses and fill for development, over 479,000 acres of tidal wetland habitat has been lost or converted to other uses (SFEP 1992b). This decline is one of the many factors associated with increasing stress on the Estuary’s ecosystem; the remaining marsh habitat is extremely important to estuarine biological resources. Existing marshes around the Estuary are still productive habitats; however, they are subject to several factors that degrade habitat quality, including fragmentation of existing tidal marshes, disturbance from recreational activities (hunting, fishing, biking, etc.), point and non-point sources of pollution and introduced species (e.g., red fox, which has increased predation pressures).

The composition of the invertebrate community in tidal marsh habitat is primarily influenced by salinity, the frequency and duration of tidal inundation and the type and density of emergent vegetation. Common invertebrate species in tidal marsh habitats include: the mussel *Ischadium demissum*; the clams *Macoma balthica*, *Tapes japonica*, *Potamocorbula amurensis* and *Mya arenaria*; the isopod *Sphaeroma quoyana*; the amphipods *Corophium spinicorne* and *randidierella japonica*; the snails *Cerithidea californica*, *Assiminea californica* and *Ovatella myosotis*; the polychaete *Capitella capitata*; and the yellow shore crab *Hemigrapsus oregonensis* (SFEP 1991). Of these species, only *Macoma balthica*, (yellow shore crab) and the three snail species are native. As in mudflats, the Asian clam, *Potamocorbula amurensis*, has become the numerically dominant species in many tidal marsh habitats.

Tidal marshes provide critical cover, forage and nursery habitat for adults and juveniles of a number of sportfish and special status fishes (SFEP 1991). The distribution of fish communities in tidal marsh habitat is influenced by the same factors that influence the composition of invertebrate communities. Common fishes include native species arrow goby, topsmelt, Pacific staghorn sculpin and tule perch; and introduced species yellowfin goby, catfish and mosquitofish. Commercially important fish species that rear and forage in these habitats include native Chinook salmon and introduced striped bass. Special status species that utilize tidal marshes include winter-run Chinook salmon, Delta smelt, green sturgeon and tidewater goby.

Tidal marshes also provide a variety of wildlife resting, nesting and escape cover and, most importantly, foraging habitat. These tidal marshes support a diversity of wildlife, including amphibian, reptile, bird and mammal species (SFEP 1992c). In addition to other habitat types, tidal marshes within the Planning Area are very important for migratory birds, providing foraging habitat and roosting sites (SFEP 1992c).

7.2.8.3.6 Tidal Salt Marshes

Tidal salt marshes are found along much of the Estuary's shoreline except in urbanized areas and on rocky shorelines (e.g., Tiburon Peninsula). A typical tidal salt marsh is characterized by a band of cordgrass extending from approximately mean sea level to mean high water with several other vegetation subdivisions by elevation. At mean high water, pickleweed forms an ecotone with the low cordgrass band ("low marsh"). In the middle marsh, the ecotone yields to almost pure stands of pickleweed, which persists to elevations equivalent to the highest tides. At higher elevations, pickleweed is found in combination with peripheral halophytes and forms the high marsh. Above the high marsh, the adjacent upland habitat forms a transition zone that supports plants from the high marsh and the upland plant community. Tidal salt marshes range from a few feet to over a thousand feet in width and, depending on the slope, may exhibit the typical zonal pattern or contain only one or two of the components described above (SFEP 1991).

Salt marshes commonly contain tidal channels or pond connections that distribute water within the marsh plain, circulating estuarine waters during high tides and draining these areas during low tides. Within marsh habitats, these channels are important microhabitats that also serve as nursery areas for fish, foraging areas for shorebirds and resting areas for waterfowl. The presence of channels greatly increases the species and habitat diversity of salt marshes.

Salt marshes provide habitat for a diverse array of special status bird and mammal species, including the salt marsh harvest mouse, the California clapper rail, black rail, salt marsh common yellowthroat, Suisun song sparrow, Alameda song sparrow, San Pablo song sparrow, yellow rail, short-eared owl, salt marsh vagrant shrew, Suisun ornate shrew and San Pablo vole (CNDDB 1995; SFEP 1991; Williams 1986).

7.2.8.3.7 Tidal Brackish Marshes

Tidal brackish marshes occur where the tidal salt water from the Estuary is diluted by freshwater runoff. Like salt marshes, brackish marshes commonly contain tidal channels or pond connections that distribute water within the marsh plain, circulating estuarine waters during high tides and draining these areas during low tides. Within marsh habitats, these channels are important microhabitats that also serve as nursery areas for fish, foraging areas for shorebirds and resting areas for waterfowl. The presence of channels greatly increases the species and habitat diversity of brackish marshes.

The plants of brackish marshes are species of *Scirpus* and *Typha*, which vary with elevation. Brackish tidal marshes can be characterized by three major zones: low marsh dominated by California bulrush; middle marsh with a mixture of cattails and bulrushes; and high marsh with a varied group of halophytes, including saltgrass, brass buttons and Baltic rush. Within the San Francisco Bay area, extensive stands of brackish marsh occur along the Napa and Petaluma rivers and smaller marshes occur at scattered locations within Suisun Marsh (SFEP 1991). Tidal brackish marshes provide habitat for an array of special status species that is similar to those listed above for salt marshes.

7.2.8.3.8 Tidal Freshwater Marshes

Within the San Francisco Bay area, tidal freshwater marsh habitat is limited to streams, creeks and rivers entering the Estuary. These habitats are generally dominated by bulrush, with scattered stands of willow, button-willow and dogwood. Within the Delta portion of the Estuary, freshwater tidal wetlands provide important nesting and foraging habitat for several special status species, namely the tricolored blackbird, double-crested cormorant, western least tern and white-faced ibis. These species may also occur in freshwater habitats at other locations within the San Francisco Bay area, in conjunction with the yellow rail, short-eared owls, saltmarsh common yellowthroat and western pond turtle (SFEP 1991 and 1992c; CDFG and DWR 1993).

Over 90 percent of the freshwater marshes in the Delta region have been converted to cropland. Remaining habitats are affected by a variety of factors, including recreational boating disturbance, agricultural discharges, water exports and introduced species (e.g., brown-headed cowbird and water hyacinth) (SFEP 1992a). These factors have reduced the carrying capacity of regional marsh resources for wildlife, migratory waterfowl and shorebirds.

7.2.8.3.9 Salt Ponds

Salt pond habitat did not exist under pre-settlement conditions within the San Francisco Bay area; rather, it was created by diking and draining tidal marshes and mudflat habitats (LTMS 1994b). Salt pond development began in the mid-1800s, when large-scale conversions of tidal marshes and mudflats were conducted using ditches, pumps and tide gates. The subsequent landscape consisted of large expanses of shallow flat water and salt crusted barren soil. In some cases, subsidence has occurred due to groundwater overdraft (WRA 1994). Salt ponds currently cover a large portion of former tidal marsh habitat in the San Pablo and South Bays, or approximately six percent of all wetlands within the San Francisco Bay area. Currently, there are approximately 9,000 acres of salt ponds in the Napa-Solano area of the North Bay and nearly 27,500 acres in the South Bay (with 11,770 acres within the boundaries of the San Francisco Bay National Wildlife Refuge).

Salt ponds of the San Francisco Bay area support green and blue-green algae and scattered vascular vegetation (wigeon grass). Salinity can range from hypersaline to brackish in areas where inflow from the Estuary occurs. Salt ponds with low to moderate salinity provide valuable foraging, nesting and roosting habitat for migratory and local populations of shorebirds and waterfowl, including terns, gulls, grebes, pelicans, cormorants and herons. In addition, most salt ponds retain the potential for restoration back to tidal marshes (SFEP 1991). The composition of invertebrate communities in salt ponds is influenced primarily by salinity, with the number of species decreasing as salt content increases (SFEI 1991). Common salt pond invertebrates include water boatman (*Corixidae*) and brine shrimp (*Artemia salina*).

As with invertebrates, the number of fish species in salt ponds decreases as salt content increases (SFEI 1991). Because of their high salt content, these habitats are of negligible value to sportfish and special status species. Common fishes in salt ponds with moderate to low salinities include native threespine stickleback, Pacific staghorn sculpin and topsmelt, in addition to introduced rainwater killifish and yellowfin goby. No special status fishes are known to utilize these habitats.

Salt ponds are important foraging and roosting habitats for a wide variety of shorebirds and waterfowl. The creation of salt pond habitat has allowed for several species of ground-nesting shorebirds to become more abundant within the San Francisco Bay area. Further, salt ponds support a variety of special status wildlife, including resident and migratory species. Species observed at San Francisco Bay area salt ponds include the California brackish water snail, Barrow’s goldeneye, western least bittern, longbilled curlew, saltmarsh common yellowthroat, tricolored blackbird and Alameda song sparrow (WRA 1994). South Bay Salt Ponds provide important post-breeding foraging habitat for the endangered California least tern and snowy plover. Other species known to occur at these sites include the California gull, American white pelican, elegant tern and the double-crested cormorant (SFEP 1992c).

7.3 San Francisco Dredging Projects and Associated EFH

Thirteen federal (USACE-dredged) navigation channels and more than 100 non-federal marinas, ports and berthing slips are maintenance dredged within the Estuary. For the most part, the federal dredging projects provide deep-draft navigation through the Estuary and shallow-draft navigation within some tributaries to the Estuary. The non-federal dredging projects are generally located along the shorelines and within the tributaries of the Estuary.

7.3.1 Suisun Bay

With an area of approximately 36 square miles and an average depth of -14 feet MLLW (SFEP 1992a; USGS 2006), Suisun Bay provides navigation access from the Estuary to the inland ports of Sacramento and Stockton through the federally-maintained Sacramento River Deep Water Ship Channel (DWSC) and Stockton DWSC, respectively. In the northern part of Suisun Bay is a small embayment, Grizzly Bay, and the eastern portion contains Honker Bay. Montezuma Slough, Suisun Slough and several smaller sloughs and tributaries flow into Suisun Bay and many of these provide important habitat for several EFH-managed species. Waters from the Sacramento and San Joaquin Rivers flow into Suisun Bay; freshwater flowing from these rivers meet saltwater from the ocean in the vicinity of Suisun Bay.

Suisun Bay is a shallow, brackish water embayment with a floor that is composed predominately of mud (fine silts and clay), crossed by channels scoured by tidal and riverine flows. The surficial sediments around these channels change according to the season. High riverine flows winnow the fine sediments of Suisun Bay and transport them downstream into San Pablo Bay. As a result, the percentage of surficial sediments that are coarse-grained increases from roughly 5 to 35 percent. Eastward flows of saline waters move sediment back upstream (Nichols and Pamatmat 1988).

Water quality within Suisun Bay appears to be more static than in other parts of the Estuary, perhaps due to the proximity from the ocean. Suisun Bay is influenced by the Sacramento and San Joaquin Rivers and is more susceptible to changes in river flow and constituents of concern from these rivers than are other parts of the Estuary. Due to the influx of saline and freshwaters, salinities in Suisun Bay can range from 2 to 20 practical salinity units (PSU); but, tend to range between 2 and 5 PSU.

Benthic species common to Suisun Bay are well adapted to the changing salinities. The Asian clam, *Potamocorbula*, has reached its highest population densities in the Estuary and has caused significant changes in the structure of the benthic community. Other common species found in Suisun Bay include: the mollusks, *Macoma balthica*, *Mya arenaria* and occasionally *Corbicula fluminea* when river flows are high; the amphipods, *Nereis succinea*, *Limnodrilus hoffmeisteri* and occasionally *Ampelisca abdita*; and the polychaete, *Streblospio benedicti* that migrates upstream from more saline waters during periods of unusually low riverine flow (Nichols and Pamatmat 1988).

The largest dredging project located in the Suisun Bay is the 297-acre, -30 feet MLLW federal Suisun Bay Channel. The Suisun Bay Channel traverses the Carquinez Strait and Suisun Bay, from Martinez to the upper portion of the New York Slough, where the Sacramento District maintains the channel. USACE also maintains the 258-acre, -35 feet MLLW Suisun Slough Channel that provides navigation access from Grizzly Bay to the City of Suisun near Fairfield. The Suisun Slough Channel is infrequently dredged and was last dredged in 1991 (see Figure 3.2). Further upstream of Suisun Bay, the western portions of the federally-maintained Sacramento River DWSC and Stockton DWSC are also within the action area.

With a combined area of approximately 50 acres and depths ranging from -6 to -8 feet MLLW, there are five non-federal dredging projects are located within the Suisun Bay with. Other Non-federal dredging projects in Suisun Bay include the approximate 30-acre Pittsburg Marina, 0.3-acre Ryer Island Boat Harbor, 2.3-acre Tosco Refinery and the 3.3-acre Martinez Shore Terminal. Dredging projects located in the tributaries to Suisun Bay include the 12-acre Suisun City Marina, located in Suisun Slough and Montezuma Harbor, located in Montezuma Slough (see Figure 3.2).

The Suisun Bay disposal site (SF-9) is a 500 by 11,200 foot rectangle located along the northern side of the Suisun Bay Channel. This site is currently limited to federal navigation project use for materials that are at least 95 percent sand from the maintenance dredging of the Suisun Bay Channel. USACE and BCDC records indicate recent disposal quantities ranged from a low of 33,000 cubic yards in 1992 and 1993 to a high of 125,000 cubic yards in 1990. The site was not used in 1989 or 1991. The current disposal volume limitation at the Suisun Site is 2.0 million cubic yards per year.

7.3.2 Carquinez Strait, Mare Island Strait and Napa River

The narrow, 12-mile long Carquinez Strait connects Suisun Bay with San Pablo Bay. The Strait is characterized by deep water habitat and a variable salinity regime resulting from fluctuations of freshwater flow from the Delta and tidal exchange from San Pablo Bay. The mean depth of the Strait is -29 feet MLLW (SFEP 1992a). Napa River and Mare Island Strait (Napa River flows into Mare Island Strait) flow into the Carquinez Strait at its western end.

Because Carquinez Strait is a narrow and deep channel, it is scoured by strong tidal currents and riverine flow. The underlying sediment is predominately rock and sand with fine silt and clay forming classic Bay mud in the lower energy areas off the main channel (such as in Southhampton Bay). The deep channel shoreline is characterized by rocky shores and developed waterfront areas, consisting of intertidal riprap, gravel beaches and subtidal fine sand (ENTRIX 1991; Robilliard *et al*. 1989).

Water quality within the Carquinez Strait varies considerably according to season and freshwater flow from the Delta. Salinities can vary substantially, ranging from 8.4 to 20 parts per thousand, with higher salinities during periods of low flow (USGS 2006). There is also a significant salinity gradient with depth at this site that also varies by season.

Water quality the Napa River is impaired by sediment, nutrients, pathogens and sedimentation related to the vast number of agricultural activities in the watershed (USACE and California Coastal Commission 2003). The RWQCB identified the Mare Island Naval Shipyard as a toxic hot spot for arsenic, silver, chromium, copper, mercury, zinc, TBT, PAH, PCB, dieldrin, endrin and toxophene (USACE and California Coastal Commission 2003).

The benthic community in the main channel of Carquinez Strait is characterized by low diversity, dominated by opportunistic species, such as the amphipods *Ampelisca abdida* and *Sinelobus sanfordi*. Salinity of the area west of the Carquinez Strait rarely falls below five parts per thousand; therefore, the benthic community is dominated by salt-tolerant species and is more diverse than the benthic community in the eastern portion of the Strait.

With a total dredged area of approximately 155 acres and depths ranging from -5 to -44 feet MLLW, there are eight non-federal maintenance dredging projects located in Carquinez Strait (50 acres), six in Mare Island Strait (96 acres) and one in the Napa River (8.7 acres). In addition to the non-federal navigation channels, USACE maintains the Suisun Bay Channel, which provides navigation through the Carquinez Strait and Suisun Bay (see Figure 3.3 and 3.4, respectively).

7.3.3 San Pablo Bay Dredging Projects and Disposal Sites

With the exception of two federal (Pinole Shoal and Petaluma River Across the Flats) and two non-federal dredging projects (Pt. San Pablo and San Rafael Rock Quarry), maintenance dredging does not occur in San Pablo Bay. However, several non-federal maintenance dredging projects exist within the tributaries to San Pablo Bay (see Figure 3.5).

The San Pablo Bay disposal site (SF-10) is also located north of the San Pablo Strait. SF-10 is a 1,500- by 3,000-foot rectangle located 0.3 mile northeast of Point San Pedro in San Pablo Bay. USACE records indicate disposal quantities ranged from less than 1,000 cubic yards to a high of nearly 1,000,000 cubic yards in 1987. Use of this site is currently limited to small projects of 100,000 cubic yards or less, no more than 50,000 cubic yards in one month and a total annual disposal volume limitation of 500,000 cubic yards. The San Pablo Bay site is considered dispersive; therefore, material placed there is redistributed throughout the Estuary.

7.3.3.1 Petaluma River

Petaluma River is a large, low gradient tributary to San Pablo Bay and its confluence with the Estuary is located just north of Novato Creek. Five non-federal maintenance dredging projects are located within the Petaluma River. With a total dredged area of approximately 9 acres and 17 acres, respectively, three of the non-federal dredging projects are located near the City of Petaluma, Solano County, and two projects are located near the mouth of the Petaluma River. Authorized depths of these projects range from -2 to -14 feet MLLW. In addition to the non-federal projects, USACE maintains the 354-acre channel portion of the Petaluma River Channel to -8 feet MLLW (see Figure 3.5).

7.3.3.2 Novato Creek

Novato Creek is a tributary to San Pablo Bay, located on the western shore just south of Petaluma River. Novato Creek is a perennial stream that extends approximately 17 miles from its headwaters at Stafford Dam to San Pablo Bay (CCA 2006). The Novato Creek stream system is known to support steelhead and other native fishes. The upper reaches of Novato Creek are impacted by the effects of the Stafford Dam and grazing practices (CCA 2006).

The only dredging project located in Novato Creek is the 28-acre Bel Marin Key Community Services District, which is dredged to -1.8 to -5 feet MLLW approximately every 10 years. Material dredged from Bel Marin Keys is placed upland; therefore, maintenance dredging of the project is not expected to substantially affect EFH or EFH managed species that do not utilize Novato Creek.

7.3.3.3 San Rafael Creek and San Rafael Bay

San Rafael Creek and Bay begins just north of the western span of the Richmond San Rafael Bridge (Point San Quentin) and spans the shoreline to Point San Pedro. San Rafael Bay is characterized by shallow depths, ranging from one to six feet deep, mud flats along the periphery and two islands, West and East Marin Islands, surrounded by shallow mud flats. Approximately 1.6 acres of eelgrass habitat exists near the northern boundary of San Rafael Bay at Point San Pedro.

Seven non-federal navigation projects, totaling approximately 47 acres, are maintained San Rafael Creek and Bay. USACE also maintains the San Rafael Creek navigation channels – Across the Flats, a 13.77-acre project maintained to -8 feet MLLW and the Inner Canal Channel, a 12.26-acre project maintained to -6 feet MLLW. These federal projects are dredged rather infrequently – every seven and four years, respectively (see Figure 3.5).

7.3.4 Central Bay Dredging Projects and Disposal Sites

With a surface area of approximate 65,920 acres (103 square miles), the Central Bay has an average depth of -35 feet MLLW and a mean volume of 2,307,000 acre feet of water (SFEI 1992; USGS 2006). Overall, the Central Bay is characterized by the deepest waters of the Estuary; only 32 percent of the Central Bay is shallower than 16 feet (USGS 2006).

In addition to deeper waters, there are several embayments, tributaries and rock outcrops that provide habitat for EFH-managed species. Embayments within the Central Bay include: Bonitas Cove, Horseshoe Cove, Richardson Bay, Paradise Cove, Corte Madera Bay and the Richmond Harbor Area (including the Sante Fe and Lauritzen Channels). The Central Bay also boasts several islands, including Angel Island (located immediately southwest of Tiburon Peninsula, across from Raccoon Strait), Alcatraz Island (located south of Angel Island), Treasure Island, Yerba Buena Island and Brooks Island (located near the Richmond Inner Harbor). Submerged rocky outcrops within the Central Bay include Harding Rock, Shag Rock and Arch Rock.

Overall, habitat diversity is relatively high because the Central Bay has both marine and estuarine characteristics and has the greatest depth range of any region in the Estuary. The western portion of Central Bay is characterized by relatively deep water, high tidal exchange through the Golden Gate and strong currents. This area is dominated by marine habitat conditions and is bordered by rocky shoreline. The eastern portion of Central Bay is dominated by shallow mudflats. Small embayments off the main water body also contain mudflats, forage and other refuge habitat for several EFH-managed species. Additionally, there are tributaries that provide spawning grounds for EFH-managed anadromous fish species.

The floor of much the Central Bay consists of sand and coarse channel bottom sediments formed from strong currents focused through the Golden Gate and Raccoon Strait. These sand deposits form waves as high as 22 feet that, over time, move with the strong ebb and flood tidal flow through the Golden Gate (Rubin and McCulloch 1979). Characteristics of the surface sediment vary according to seasonal riverine flow, material transport and wave-induced suspension of material in shallow areas during the summer. The eastern shore of the Central Bay is predominately composed of mud (Nichols and Pamatat 1988), the northwestern shore is composed of fine slits and along the southwestern shore sediments are comprised of silts and clays with a higher percentage of sand, especially towards the Pacific Ocean.

Generally, water quality in the Central Bay is better than in other embayments, as this bay is more tidally influenced. Salinity is generally higher due to the proximity to the ocean and turbidity is generally reduced, predominately due to tidal action and the Central Bay's sandy sediment composition. However, turbidity can be seasonally high, due to turbid freshwater input from large local storm events. Concentrations of constituents of concern in the Central Bay are also lower than in other parts of the Estuary (Bay Institute 2003); however, there are areas that exhibit elevated levels of constituents of concern in the water column.

Eelgrass habitat is found only in the shallow areas of the Central Bay where substrate is mud or mixed mud and sand. In 2003, Merkel documented approximately 993 acres of eelgrass habitat within the Central Bay (Merkel 2004) – discussed in the sections below. The second largest eelgrass bed in the Estuary is located in Richardson Bay along the boat moorings near the marinas.

Central Bay benthic habitats are diverse and include large areas of tidal and subtidal mudflats, subtidal shell deposits, sandy shoals, cobbles and exposed rocky outcrops.

Benthic organisms that live in the deeper portions of the Central Bay are typical of those found in sandy sediments along the outer coast (Nichols and Pamatamat 1988). Density and species composition appear to be related to particle size and organic content of the sediments. Polychaetes *Armandia brevis*, *Mediomastus* sp., *Siphones missionensis* and *Glycinde picta*; the amphipod *Foxiphalus obtusidens* and the crab *Cancer gracilis* are commonly encountered (Cohen 2005). Hard-substrate organisms with marine affinities, such as the native bay mussel *Mytilus galloprovincialis*, are found on the rocky outcrops and large numbers of the clam *Tapes japonica* and occasionally *Mya arenaria* are found in the intertidal beds – particularly around the narrow band of rock, cobble and broken concrete rip-rap along the base of dikes, piers and breakwaters (Nichols and Pamatmat 1988).

The Alcatraz disposal site (SF-11) is located in Central Bay. This site is a 2,000-foot diameter circle located approximately 0.3 mile south of Alcatraz Island. Placement of dredged material at this site has occurred since 1994 (LTMS 1994d). Alcatraz was formally designated as a disposal site in 1972 and continues to be the most heavily used dredged material placement site in the Estuary. In the mid-1980s, the site began accumulating significant amounts of dredged material as a result of frequent placement of dredged material. Because of the sediment accumulation, depths were altered from the original 110 feet to 30 feet at its eastern portion. The mound became a threat to navigation and USACE eventually dredged the Alcatraz site. As a result, active management of dredged material placement methods, frequencies and volumes is required to maintain navigable depths at the site. Currently, there is an annual dredged material placement limit of 4 million cubic yards.

With the exception of the large federally-dredged 335-acre San Francisco Harbor Mainship Channel (dredged annually to -55 feet MLLW) and portions of the Richmond Harbor Channel (dredged annually to -20 to -45 feet MLLW), dredging projects are located in the large ports and terminals on the eastern shore of the Central Bay and smaller marinas along the within small embayments, tributaries and along the shorelines.

7.3.4.1 Corte Madera Creek and Bay

Surrounding the shoreline of Corte Madera Bay are shallow depth areas with large spans of mudflats and marsh. The 2003 Merkel survey noted 0.5 acre of eelgrass beds present near Point San Quentin.

The Corte Madera Channel flanks Point San Quentin and provides access to Corte Madera Creek. There are four non-federal maintenance dredging projects located within the footprint of Corte Madera Creek and Bay, comprising approximately 7 acres of surface area. Depths of these navigation projects range from -3 feet MLLW under the dock areas of Greenbrae Marina to -15 feet MLLW within the Larkspur Landing Ferry Terminal footprint (see Figure 3.6).

7.3.4.2 Keil Cove and Paradise Cove

Continuing northeast from Belvedere Cove along the eastern shoreline of the Tiburon Peninsula is Keil Cove. Continuing past Keil Cove, past the eastern most point of the Tiburon Peninsula, Bluff Point, and continuing west along the peninsula is Paradise Cove. According to the 2003 Merkel survey, there are approximately 13.2 acres of eelgrass habitat within Paradise Cove.

There are five non-federal maintenance dredging projects are located in the northern shoreline of Keil Cove. Authorized depths range from -7 to -9 feet MLLW, with a total dredged area of approximately 13 acres (see Figure 3.6).

7.3.4.3 Belvedere Cove

Continuing northeast along the Central Bay's shoreline is Richardson Bay. Richardson Bay's eastern boundary is marked by Peninsula Point, where the shoreline forms the Belvedere Cove embayment. Belvedere Cove continues to flank the shoreline from Belvedere Peninsula, terminating at Point Tiburon. Belvedere Cove is adjacent to the Raccoon Strait. According to Merkel's 2003 eelgrass survey, approximately 21.8 acres of eelgrass beds are present in Belvedere Cove, with 20.4 acres are located near Point Tiburon.

With a total area of approximately 20 acres, five maintenance dredging projects are located within this embayment. Depths of these maintenance projects range from -6 to -13 feet MLLW (see Figure 3.6).

7.3.4.4 Richardson Bay

Following the Central Bay's northern shoreline, past Belvedere Cove is Richardson Bay. Richardson Bay is located between the Marin Peninsula to the west and the Tiburon Peninsula to the east. Nine maintenance dredging projects are located in Richardson Bay; with depths ranging from -8 to -12 feet MLLW and a total area of approximately 91 acres (see Figure 3.6). With approximately 437 acres, Richardson Bay boasts one of the Bay's largest eelgrass beds (Merkel 2004).

7.3.4.5 Horseshoe Cove

Horseshoe Cove is located immediately northwest of the Golden Gate Bridge, just off the southern tip of the Marin Peninsula. The Coast Guard Station, Golden Gate (1.2 acres, -10 to -12 feet MLLW) is the only maintenance dredging project located in Horseshoe Cove (see Figure 3.6).

7.3.4.6 Central Bay - South Western Shore

The southwest shoreline of Central Bay is characterized by a high degree of urbanization, as the shoreline of the Central Bay abuts the City of San Francisco. Two non-federal navigation projects, totaling approximately 360 acres, are located along the southwest shore of the Central Bay – the Port of San Francisco and the San Francisco Marina. With approximately 342 acres dredged to depths ranging from -7 to -50 feet MLLW (a majority of the sites dredged to -35 to -40 feet MLLW), the Port of San Francisco conducts one of the largest non-federal dredging projects in the San Francisco Bay region. The San Francisco Marina dredges 17 acres to depths ranging from -12 to -14 feet MLLW (see Figure 3.6).

7.3.4.7 Central Bay - Eastern Shore

The west span of the Richmond-San Rafael Bridge at Point San Quentin delineates the northwest boundary of the Central Bay. The eastern shore of the Central Bay begins at the eastern span of the Richmond-San Rafael Bridge and terminates at the eastern span of the Oakland Bay Bridge and includes the Richmond Inner Harbor.

Along the northeastern shoreline of the Central Bay are the federal Richmond Harbor navigation channels, comprised of the 550-acre Southampton Shoal, 36.5-acre Outer Harbor at Longwharf turning basin, 459-acre Inner Harbor Channel, 100-acre Approach Channel, 4.5-acre Santa Fe Channel and 7-acre Pt. San Pablo Channel (for a total federally dredged area of 1,158 acres).

With a total area of approximately 309 acres, there are 13 non-federal dredging projects located along the eastern shoreline of the Central Bay. Many of the project areas located within the federally-maintained 1,000 foot long Santa Fe Channel in Richmond, Contra Costa County. Many of the non-federal dredging projects are located in the Santa Fe Channel, including Castrol North American Consumer's Berth, Levin-Richmond Terminal Corporation, Time Oil Terminal, Conoco Philips, Richmond Terminal, Port of Richmond and BP West Coast Products (approximately 141 acres dredged).

The Santa Fe Channel is dredged to allow access for bulk tankers carrying petroleum products and vehicles (see Figure 3.6). Due to the types of use within and around this area, it is not uncommon for sediments to contain higher quantities of petroleum hydrocarbons, volatile solids, PAHs and other constituents of concern.

Habitat types that exist along the eastern shore of Central Bay include approximately 19 and 86.3 acres of eelgrass beds along the North and South Richmond Breakwaters, respectively, 89.6 acres along Point Richmond, 17.7 acres in Brickyard Cove (near Point Richmond), 28.7 acres near the Emeryville breakwater, 21.6 acres within the Emeryville Flats and 2.5 acres near the west toll plaza of the Oakland Bay Bridge.

7.3.5 South Bay Dredging Projects

With an approximate area of 214 square miles and an average depth of -11 feet MLLW (SFEP 1992a), the South Bay is the largest and shallowest bay in the Estuary. Approximately 69 percent of the South Bay is less than 16 feet deep (USGS 2006). USACE maintenance dredges the 226-acre Redwood City Harbor federal navigation channels to -30 foot MLLW. There are twelve non-federal dredging projects along the western shoreline of the South Bay, two in the southern South Bay (south of Dumbarton Bridge), thirteen along the eastern shore of the South Bay, and one on the southern tip of Yerba Buena Island (see Figure 3.7).

The South Bay is more like a lagoon – with a small local watershed and little freshwater input. Salinities remain at near-ocean concentrations during much of the year, although flushing of South Bay waters occurs during periods of high riverine flow. Consequently, the biological resources of the area are adapted to saline conditions.

The extreme southern edge of the South Bay, south of Dumbarton Bridge, has historically been an area where water quality and associated beneficial uses are impacted by sewage treatment facilities and industrial sources. Thus, while nutrient concentrations in other parts of the Estuary vary seasonally, levels in the South Bay are relatively constant. However, water quality parameters differ from the northern reaches of the South Bay to the southern reaches. Areas just south of the Oakland-Bay Bridge are more influenced by tidal action and tend to have increased chlorophyll, salinities and dissolved oxygen and decreased temperatures and suspended sediments.

The South Bay has exhibited some of the highest levels of trace elements in the Estuary (especially mercury, copper and selenium), pesticides (Diazinon) and PAH concentrations between the years 1993 to 1999. All constituents of concern appear to have decreased in concentration, except for selenium, which has increased significantly (Bay Institute 2003). Additionally, in the most southern reaches of the South Bay, near San Jose, Sunnyvale and Coyote Creek, dissolved oxygen concentrations have fallen below levels acceptable for healthy aquatic life (60 to 80 percent saturation) – this could be due to poor tidal action as well (Bay Institute 2003).

Total suspended solids in the South Bay are dynamic in both depth (TSS increases with depth) and from then northern reaches to the south (TSS increases from north to south). South of the Oakland-Bay, total suspended solids tend to be less and water becomes turbid towards the southern portions of the South Bay, measuring from 1.6 to 330 mg/l in the north and south reaches, respectively (SFEI 2006a).

Sediment characteristics of the South Bay averages around 60 to 70 percent silt and clay, with higher concentrations of coarser sediments observed in the early summer (Nichols and Pamatmat 1988). One distinguishing feature of sediments in the South Bay is the high concentrations of shell fragments and remnants of shell beds found in mud along the eastern margin of the embayment. Sediments in the South Bay are resuspended two to five times before final deposition, with the highest resuspension rates occurring during summer months when wind-generated currents move across the embayment. Although it appears that a majority of the Bay is eroding, it appears that the South Bay is overall net depositional (McKee *et al.* 2006).

Because sediments of the South Bay are composed predominately of soft mud and masses of shell fragments remaining from previous commercial oyster industry, benthic populations are dominated by large tube-dwelling polychaete *Asychis elongate*. Other species present include large numbers of small clams (*Gemma gemma* and *Potamocorbula amurensis*), the tube-dwelling amphipod *Ampelisca abdita* and the polychaete *Streblospio benedicti*. The mollusks *Mya arenaria* and *Macoma balthica* (native) and the omnivorous mudsnail *Ilyanassa obsoleta* are also common on the soft sediments of the South Bay. Shell deposits and areas with boulders, broken concrete and cobbles found along the eastern and western margins of central South Bay provide habitat for limpets (*Crepidula* spp.), predatory snails (*Urosalpinx cinerea*), ascidians (*Mogula manhattensis*) and mollusks (*Musculista* and *Tapes japonica*) (Nichols and Pamatmat 1988).

Several different crustaceans are found in the South Bay, including: Bay shrimp (*Crangon nigricauda* and *C. nigromaculata*) and brine shrimp (*Artemia salina*). The introduced green crab (*Carinu maenas*) has also been observed in the South Bay.

Although less abundant in the South Bay than in the Central Bay, eelgrass beds have been documented in the South Bay along the periphery of the east and west shorelines, totaling approximately 402.8 acres near Alameda, Bay Farm and Coyote Point (269.9, 132.3 and 0.6 acres, respectively) (Merkel 2003).

7.3.5.1 South Bay, Yerba Buena Island

Other than the federal The Coast Guard Station, Yerba Buena Island is the only navigation project dredged within the interior of the South Bay. The Yerba Buena Island Coast Guard Station channels and berths are dredged from -10 to 18 feet MLLW (see figure 3.7).

7.3.5.2 South Bay, Western Shore (north of Dumbarton Bridge)

With a combined areas of approximately 208 acres and depths ranging from -8 to -35 feet MLLW, there are eight non-federal dredging projects located along the shore of the South Bay, including portions of the Port of San Francisco, South Beach Marina, San Francisco Drydock, Brisbane Marina at Sierra Point, Oyster Point Marina, Coyote Point Marina, Oyster Cove Marina and Candlestick Point. More than 135 acres of submerged subtidal habitat is dredged along the western shoreline of the South Bay.

7.3.5.3 South Bay, Eastern Shore

With a total dredged area of approximately 158 acres, thirteen non-federal maintenance dredging projects are located along the eastern shore of the South Bay, including: Oakland Harbor (90 acres, -12 to -50 feet MLLW), Schnitzer Steel (2 acres, -37 feet MLLW), Coast Guard Alameda Station (7.1 acres, -29 feet MLLW), Alameda Point Channel (18.2 acres, -32 feet MLLW), Oakland Yacht Club (10 acres, -10 feet MLLW), Ron Valentine Boat Dock (0.01 acre, -4 feet MLLW), Ballena Isle Marina (6.4 acres, -3 to -8 feet MLLW), Ballena Isla Townhomes (6.5 acres, -3 to -8 feet), Hanson Aggregates (0.30 acre, -14 feet), Corona Del Mar Homeowners (0.05 acre, -6 feet), Aeolian Yacht

Club (2.9 acres, -9 feet), Harbor Bay Ferry Channel (20 acres, -7 feet) and San Leandro Marina (20 acres, -7 feet MLLW). Additionally, USACE maintains the approximate 890 acre Oakland Harbor federal navigation channels to -50 feet MLLW and the approximate 58-acre San Leandro (Jack D. Maltester) Channel to -6 to -8 feet MLLW (see Figure 3.7).

7.3.5.4 Southern South Bay, South of Dumbarton Bridge

Although dredging projects do not exist in the southern South Bay waters, there are seven maintenance dredging projects within adjacent lagoons and tributaries to the southern South Bay, including the federal Redwood City Harbor navigation channel (dredged to -30 feet MLLW). The total dredged area south of Dumbarton Bridge encompasses approximately 87 acres (see Figure 3.7).

8.0 Potential Effects to EFH from the Dredging Projects Managed by the San Francisco Bay LTMS

This section describes the potential effects of dredging and dredged material placement activities within the Estuary. Although this document was prepared to analyze the effects of implementation of the SF Bay LTMS on EFH; the SF Bay LTMS would not exist if not for dredging and dredged material disposal in the Bay area. However, compared to pre-LTMS dredging and dredged material disposal practices, the adverse effects on San Francisco Bay resources from these practices are greatly reduced.

Most of the effects of dredging and dredging material placement are temporary and localized and, with the exception of impacts associated with a changed bottom topography (potential changes in local hydrodynamics and in the makeup of the benthic resources present in the dredged area), the impacts end when dredging ends. The most substantial impacts tend to be on water quality – the potential for resuspension of constituents of concern buried in the sediments – and the impacts on biological resources in the dredged and dredged material disposal areas.

NOAA-Fisheries identified the following adverse effects of dredging on EFH: (1) direct removal/burial of organisms; (2) turbidity/siltation effects, including light attenuation from turbidity; (3) contaminant release and uptake, including nutrients, metals, and organics; (4) release of oxygen consuming substances; (5) entrainment; (6) noise disturbances; and (6) alteration to hydrodynamic regimes and physical habitat (NOAA-Fisheries 2005).

This section discusses the impacts on the resources of the Estuary, associated EFH and EFH-managed species, as well as cumulative impacts on EFH and EFH-managed species resulting from dredging, dredged material disposal activities and the implementation of the SF Bay LTMS. This section also discusses dredging and dredged material disposal best management practices (BMPs) already implemented by the SF Bay LTMS that reduce the impacts of dredging and dredged material disposal on the Estuary's resources (e.g., environmental work windows, limited overflow dredging and reduced in-Bay disposal).

Due to the vast differences of the effects generated by in-Bay (disposal at SF-09, SF-10, SF-11 and SF-16) and SF-8 disposal on aquatic resources, compared to SF-DODS, this section only covers the potential effects of disposal at the above listed sites.

8.1 Direct Effects on EFH and EFH-Managed Species

Maintenance dredging can directly affect EFH and EFH-managed species by directly removing individuals and/or bottom substrate and associated benthic communities used by the EFH-managed species. Aquatic dredged material disposal can directly affect EFH and EFH-managed species by directly burying EFH-managed species and EFH.

Mechanical and hydraulic dredges entrain shoaled sediment and many benthic and groundfish species, as well as any eggs or larvae present in the sediment. Hydraulic dredges can entrain EFH-managed fish, eggs and/or larvae in the water column within the immediate vicinity of the hydraulic dredge head; whereas mechanical dredges can scoop up bottom fish, eggs, larvae and benthos within the immediate footprint of the mechanical dredge head.

Aquatic dredged material disposal results in a dense plume of dredged sediment falling through the water column. The descending dredged material plume can strike EFH-managed fish, eggs and larvae that may be present in the surrounding water column. Further, the plum can bury benthic species know to be preyed upon by many EFH-managed species.

Large annual dredging projects (e.g., federal dredging projects, Port of Richmond, Port of San Francisco and Port of Oakland) could result in more frequent direct exposure of dredge equipment and descending sediment plumes to EFH and EFH-managed species, compared to smaller, less frequent dredging projects (e.g., the several small marinas and harbors in the Bay area). However, many of the smaller dredging projects occur along the shallow shorelines of the San Francisco Bay, areas known to be important foraging and breeding grounds for several EFH-managed species.

Direct impacts on EFH and EFH-managed species resulting from dredged material disposal would be limited to the combined 350 acres of submerged land designated as the four in-Bay disposal sites (SF-9, SF-10, SF-11 and SF-16) and the 1,033-acre SF-8 disposal site located just outside the mouth of the Estuary in the Pacific Ocean.

The life stage of EFH-managed species may also affect the level of direct impacts on individuals. For example, larger adult fish may be able to escape entrainment by dredge equipment and potential burial by descending dredged material plumes; whereas juveniles, larvae and eggs may be more susceptible to these impacts.

The SF Bay LTMS has already implemented **BMP 1.0 - *Environmental Work Windows***, **BMP 2.0 - *Lower Hydraulic Dredge Heads***, and **BMP 3.0 - *Reduce in-Bay Disposal*** to reduce the potential direct impacts of dredging and dredged material disposal on EFH and EFH-managed species.

BMP 1.0 - *Environmental Work Windows*. In order to protect threatened, endangered, and special status species and their habitat, the SF Bay LTMS Working Group devised environmental work windows for dredging and dredged material disposal activities within the Estuary. The current environmental work windows limit dredging and dredged material disposal operations in the Estuary to specific times of the year to protect sensitive life stages of Bay-area species protected under California and federal Endangered Species Acts (e.g., salmonids, delta smelt, Dungeness crab, California clapper rail) (see Tables 1.1 and 1.2, *Existing Environmental Work Windows for San Francisco Bay Dredging Projects* and *Existing Environmental Work Windows for Disposal Sites in the San Francisco Bay*). During work windows, maintenance dredging and disposal of dredged material are covered by existing Biological Opinions and do not require additional Endangered Species Act consultation with NOAA-Fisheries and/or the USFWS. Dredging and disposal activities conducted outside the environmental work windows require consultation under the Endangered Species Act with the appropriate resource agency.

Although the environmental work windows were not designed specifically to protect EFH and EFH-managed species, all aquatic organisms benefit from limiting the amount of time dredging and dredged material disposal can occur.

BMP 2.0 - *Lower Hydraulic Dredge Heads*. Prior to turning on hydraulic dredges, the dredge heads must be as close to the sediment surface as practicable. Lowering the hydraulic dredge heads close to the sediments that will be dredged reduces the entrainment field of the dredges.

BMP 3.0 - *Reduce in-Bay Disposal.* One of the goals of the SF Bay LTMS is to reduce in-Bay disposal to no more than twenty percent of all material maintenance dredging in the Estuary. Reducing in-Bay disposal will reduce the amount of time EFH and EFH-managed species are exposed to the descending dredged material plume and associated effects.

With these BMPs in place, it is expected that potential direct impacts on EFH and EFH-managed species ***may affect, but not likely to substantially affect*** EFH and/or EFH managed species.

8.2 Potential Effects on Water Quality and EFH and EFH-Managed Species Resulting from Effects on Water Quality

Water quality variables that can be affected by dredging and dredged material disposal operations include turbidity, suspended solids and other variables that affect light transmittance, dissolved oxygen, nutrients, salinity, temperature, pH and concentrations of trace metals and organic constituents of concern, if they are present in the sediments (United States Navy 1990). These impacts are a result of a direct increase in total suspended solids within the water column.

Adverse effects to water quality results in adverse effects to EFH including: a temporary reduction in migratory corridors within the water column, prey abundance and foraging ability due to increased turbidity and increased resuspension of pollutants. Increased turbidity also has the potential to adversely affect nursery habitat for several larvae fish species; as suspended sediment can to smother larvae or prevent attachment of some larval species onto various surfaces. This section discusses how the adverse effects to water quality generated by dredging activities affects EFH within the Estuary.

8.2.1 Increased Suspended Sediment

During the dredging process, dredging equipment agitates bottom sediments that resuspend in the water column as a result. Aquatic dredged material disposal results in dredged material being disposed of from a barge or hopper dredge; as the sediment falls through the water column, particles are stripped from the descending plume and redistributed in the water column.

Increased suspended solids impact aquatic ecosystems in three ways: (1) physical impacts related to the physical properties of suspended sediments (i.e., reduced light transmission and biological effects); (2) chemical impacts, related to the chemicals associated with suspended solids (including effects to biological receptors); and (3) resettling effects that can smother aquatic habitats and organisms. Resuspended sediments can cause localized changes in ambient water chemistry, pH and dissolved oxygen content. Changes in light transmission can affect primary production by limiting photosynthesis, foraging terrestrial organisms that rely on visual signals for foraging in water and any aquatic organism that uses visual sensory systems (Anchor Environmental, Inc. 2003). Potential effects to physical properties of the action area resulting from increases in suspended sediments are provided in this section.

Potential effects of increased suspended sediment concentrations on EFH-managed species include: reduction in foraging, reduced fecundity, reduced growth, injury and direct toxicity and bioaccumulation, should constituents of concern associated with suspended sediment become bioavailable to individual EFH-managed species (ERDC 2005; O'Conner 1991; Anchor Environmental Inc. 2003). Although the increases in turbidity are transient, they can have several types of longer-term consequences for sensitive biological resources.

The effects of increased suspended sediment on EFH-managed species can vary to some degree, depending on the life stage of the organisms. Early life stages of organisms are more sensitive than adults; as adult fish are mobile and have the ability to avoid dredging activities. Physiological effects may include gill trauma, coughing rates, osmoregulation imbalances and blood chemistry imbalances. Behavior effects include: avoidance and disruptions with territoriality, foraging and predation, and homing and migration (Bash, Berman, and Bolton 2001). Generally, bottom-dwelling fish species are most tolerant to suspended solids, whereas filter feeders are the most sensitive.

8.2.1.1 Resuspension of Sediments Generated During Dredging Activities

Agitation of the bottom sediments by dredging equipment resuspends bottom sediments and thus temporarily increases the turbidity of surface waters. In addition, low-density turbid overflow plumes generated by overflowing hopper dredges or barge/scows during active dredging resuspends sediment within the water column as turbid water is allowed to overflow into the Estuary. Overflow plumes were characterized as narrow swaths of increased TSS concentration above ambient levels. As the plume settles to the bottom of the water column, the swath broadens along the bottom of the channel. Studies have shown that overflow plumes generated by hopper dredges (or barge/scows, when permitted) produces the most sediment resuspension compared to dredge equipment that does not utilize the overflow method (e.g., bucket and clamshell dredges) (USACE 1987).

During overflow dredging, turbidity plumes behave differently depending on the type of material dredged, tidal forces and current velocity within the dredged area (USACE 2002). Overflow turbidity plumes have the potential to move with the current and be resuspended in other areas and habitats within the Estuary. These effects are expected to be temporally and spatially localized, persisting during and shortly after active dredging activities and confined to the general vicinity of active dredging.

Water clarity is a major determinant of the condition and productivity of an aquatic ecosystem; turbidity alters water clarity, thus water quality. The most obvious effect of increased turbidity is the reduction of light penetrating the water column that is available for photosynthesis by planktonic species, free-floating microalgae and aquatic plants. Potential indirect adverse effects of a reduction of photosynthesizing species include: increased nutrient enrichment and decreased dissolved oxygen, all of which reduces water quality. Additionally, suspended sediments have the potential to transport and release constituents of concern into the water column.

USACE's Engineering Research and Development Center (ERDC) conducted several studies to analyze the concentrations and spatial footprint of suspended sediments, including: *Monitoring Hopper Dredge Overflow Plumes in Humboldt Bay, California* (August 2005) and *Characterization of Suspended Sediment Plumes at the Port of Oakland and Port of Redwood City, California* (August 2003 and October 2004, respectively). The Port of Oakland study was conducted using a mechanical clamshell dredge and the Port of Redwood City study was conducted using knockdown dredging practices. The results of these studies are provided below.

Overflow Turbidity Plumes Generated by Hydraulic Hopper Dredges. In the immediate vicinity around a hopper dredge, a well-defined upper plume is generated by the overflow process and a near-bottom plume by draghead resuspension. These two plumes merge into a single plume at some distance behind the dredge. As the distance from the dredge increases, the suspended solids in the plume begin to settle and the plume is limited to the near-bottom waters (USACE 1987).

Plumes for Coarse Grained Material: there are only a small number of dredging projects that dredge sandy material from the Estuary (e.g., Mainship Channel); therefore, this portion of the analysis has limited applicability to this assessment.

A 2005 USACE study of overflow plume turbidity generated from hopper dredging in Humboldt Bay showed that the overflow plume, comprised of 92 percent sandy material, had turbidities of approximately 6 NTUs in waters less than 11.5 feet deep and 12 NTUs in depths of 7.5 and 33 feet (ambient turbidity approximately 2 – 11 NTUs, increasing from the upper water column to the bay floor). The overflow plume behaved as a well-defined vertical feature measuring approximately 50 feet in width. As overflow continued, the plume width increased to approximately 230 to 295 feet (the plume extends behind the dredge as the dredge moves forward) and the plume decayed completely in 15 to 25 minutes following the departure of the dredge to the disposal site (Dickerson, *et al.* 2005).

A 2002 ERDC study of overflow turbidity plumes in Cape Fear River, North Carolina revealed sandy sediment plumes that extend 1,500 feet away from the source during an ebb tide and 1,180 to 2,200 feet down current prior to dissipating (USACE 2002). For the most part, plumes did not infiltrate the side shoals; however, in some instances, they moved along the channel closely hugging the shoal (USACE 2002).

Overflow turbidity plumes generated from dredging areas within the Bay with similar sediment composition (predominately sand) would be expected to behave similarly to the plumes discussed above.

Plume for fine-grained material: studies show that in areas where the sediment composition is finer (clay/silt), overflow plumes generally persist for longer durations and are more horizontally pronounced within the water column. Miller, *et al*. showed that overflow plume suspended sediment concentrations near the surface reached approximately 300 mg/l and persisted for approximately 15 minutes, mid-depth concentrations reached approximately 375 mg/l and persisted for approximately 12 minutes and near-bottom concentrations reached approximately 500 mg/l. The study found that one hour following the completion of overflow dredging operations, levels of suspended materials returned to background conditions and the plume did not disperse beyond the channel boundaries.

The USACE 2005 overflow plume turbidity study in Humboldt Bay, California, further revealed that overflow plumes generated from dredged areas comprised predominately of clay/silt material took longer to decay; plumes persisted for approximately one hour following the departure of the dredge to the disposal site and reached approximately 556 feet long by 556 feet wide. Measured turbidity was approximately 100 NTUs in water less than 11.5 feet deep, 100 NTUs in depths of 25 feet, and 150 NTUs in depths greater than 33 feet (ambient turbidity approximately 5 – 23 NTUs, increasing from the upper water column to the seafloor) (Dickerson, *et al.* 2005). However, the increased turbidity in deeper waters is most likely associated with sediment resuspension as the bay floor is agitated.

Turbidity Plumes Generated by Mechanical Clamshell Dredges. Bucket and clamshell dredges consist of various types of buckets operated from a crane or barge. Resuspension of sediments during bucket dredging is primarily caused by the impact, penetration and withdrawal of the bucket from the bay floor; a secondary cause of resuspension is loss of sediment as the bucket is pulled through the water column. Depending on the effectiveness of the bucket/clamshell dredge, turbidity plumes generated by the use of these dredges can extend approximately 1,000 feet at the surface and 1,500 feet near the bay floor for rather ineffective equipment and remains fairly close to dredging activities for more effective equipment (USACE 1987).

In August 2003, ERDC conducted a study at the Port of Oakland to characterize the suspended sediment generated from clamshell dredging activities. Dredging was conducted using a 12 cubic yard closed (environmental) bucket with material placed in a scow for offsite disposal. The material dredged was predominately silt dredged to depths of -39 to -42 feet MLLW (ERDC 2007).

Prior to dredging activities, the ambient suspended sediment concentrations ranged from 10 to 15 mg/l near the surface and 25 to 50 mg/l near the bottom. During dredging activities, peak concentrations of suspended sediments were approximately 275 mg/l and decayed to ambient concentrations within 1,312 feet (400 meters) from the dredge (ERDC 2007). Although the duration of the suspended sediment plume was not monitored as part of this study, the plume was confined to the lower portion of the water column and did not escape the side slopes of the channel (Clarke 2008, personal communication). Additionally, increased suspended sediment concentrations were largely confined to the lower water column and were driven by weak currents during flood and ebb tides.

Turbidity Plumes Generated by Knockdown Dredging. On October 2004, ERDC conducted a suspended sediment study at the Port of Redwood City, South San Francisco Bay, California, to analyze increased suspended sediment concentrations and footprints generated from knockdown dredging activities. As discussed, knockdown dredging utilizes an I-beam that is dragged behind a vessel to redistribute sediment from high spots or mounds to deeper areas. During this study, approximately 3,000 cubic yards of sandy-silty material was knocked down (ERDC 2007).

Prior to knockdown dredging activities, the ambient suspended sediment conditions ranged from 10 to 60 mg/l near the surface and 30 to 90 mg/l near the bottom. During knockdown dredging, peak suspended sediment concentrations were approximately 600 mg/l following the passage of the beam and decayed to approximately 200 mg/l within 5 to 6 minutes. Additionally, residual plumes ranging from 50 to 100 mg/l persisted between the knockdown dredging cycles. Plumes were temporally variable and spatially consistent. Higher concentrations of suspended sediment were largely confined to the lower water column (ERDC 2007).

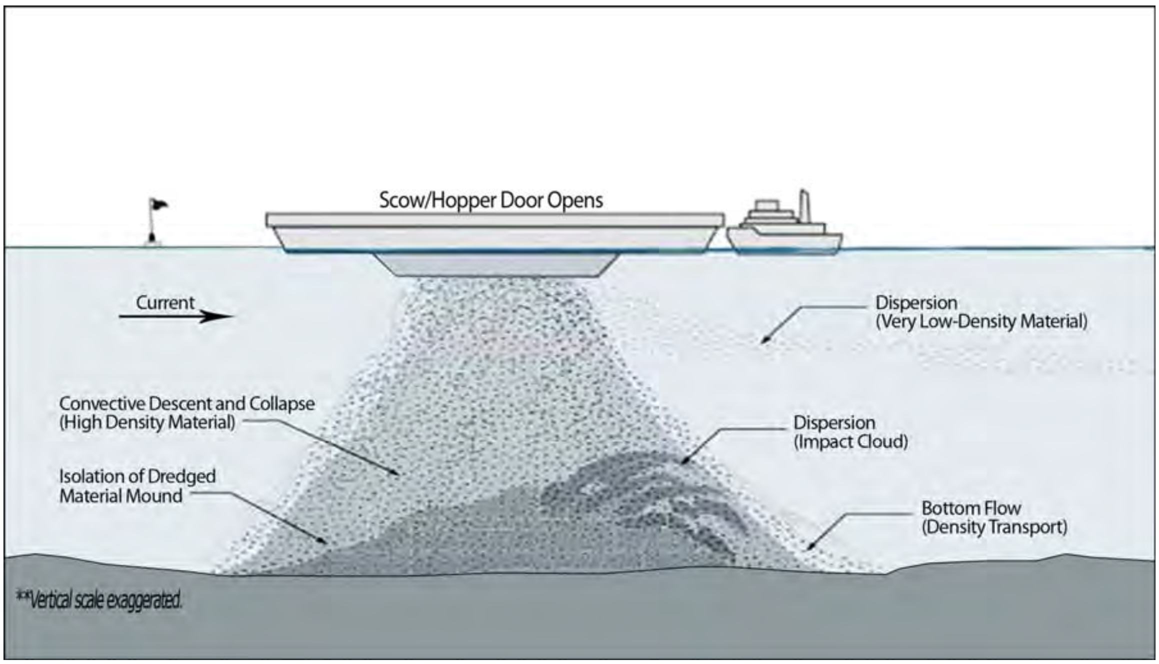
Turbidity Plumes Generated by Hydraulic Cutterhead Dredges. A cutterhead dredge is basically a suction dredge pipe combined with a ‘cutterhead’ used to loosen material that is too consolidated to be removed by suction alone. As the cutterhead rotates, it breaks up consolidated material and effectively guides the material to the suction pipe. The cutting action and turbulence associated with the rotation of the cutterhead resuspends sediments along the bottom of the seafloor and resuspended particles have been recorded at distances of 1,000 feet from the cutterhead (USACE 1987).

8.2.1.2 Resuspension of Sediments during Dredged Material Placement Activities

Dredged material disposal can affect the water column during aquatic disposal and, at times, during habitat restoration along the Estuary's shorelines, and upland habitats outside of EFH during upland dredged material placement.

During aquatic disposal, sediments released from hoppers and barge/scows are injected into the water column at the level of the draft of the vessel and the sediment falls to the floor of the Estuary. Once released into the water column, the dense plume of material falls to the Estuary floor. As shown in Figure 8.1, dredged material falls through the water column in three phases: convective descent, dynamic collapse and passive transport and dispersion. Convective descent and dynamic collapse are considered near-field mixing with short-term dynamics; whereas passive transport and diffusion are far-field mixing events with long-term dynamics subject to background turbulent dispersion and diffusion.

Figure 8.1 Sediment Transport during Aquatic Disposal of Dredge Material



Source: Figure created by USACE 2009.

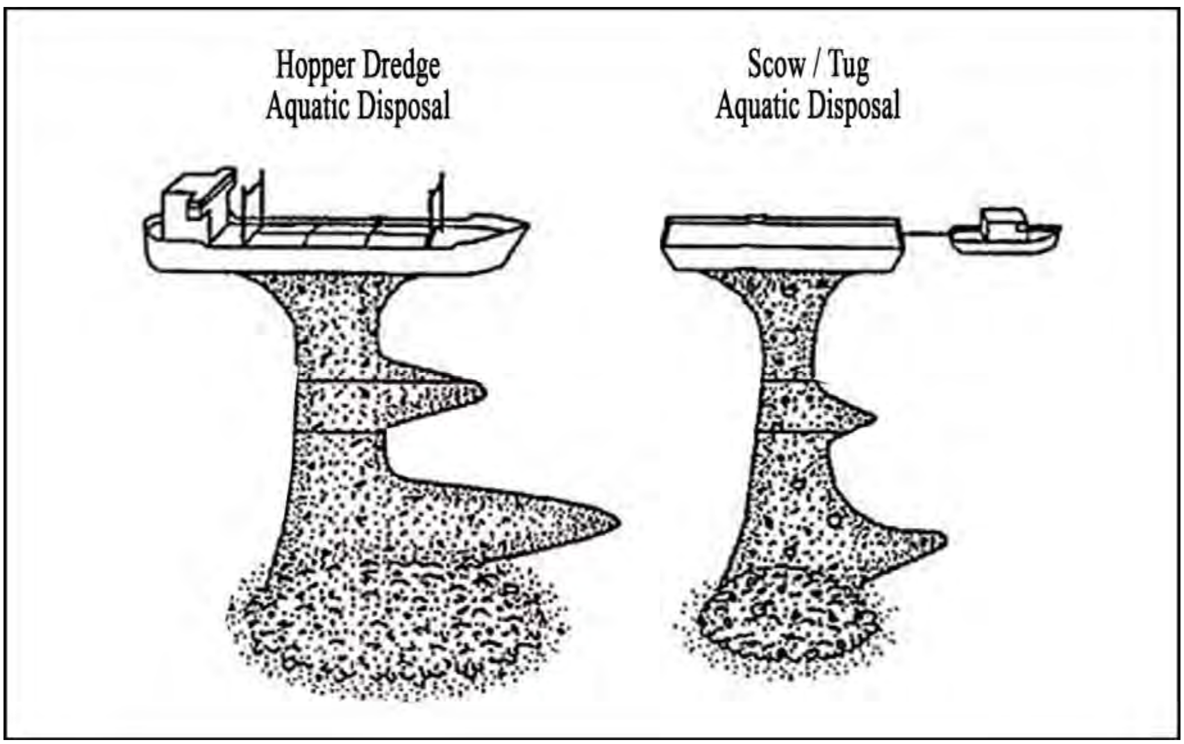
Convective descent describes how dredged material falls through the water column from the point of release until initial contact with the bottom. During this phase, dredged material falls rapidly to the bottom in a high-density sediment plume. Small amounts of dredged material may be stripped from the plume and entrained in the water column as suspended sediments; the remainder of the sediment spreads along the bottom of the disposal site until the momentum is stopped and the sediment settles on the Estuary floor.

Once material makes contact with floor of the disposal site, dynamic collapse takes over and the sediment spreads outward as the vertical momentum of the dredged material is transferred to the horizontal momentum. As the dredged material spreads over the floor of the disposal site, the slurry of material loses energy and settles.

Passive transport describes how material stripped from the descending plume is transported in the water column. The size of the stripped sediment, critical shear stress (shear stress needed to cause a particle to slip in a given direction) and current velocities determine the rate at which the stripped particles will settle out of the water column.

It takes approximately 2 to 5 minutes for a hopper or scow to place dredged material at an aquatic disposal site, depending on the type and volume of sediment. In addition, coarse-grained sediments tend to settle to the Estuary floor quickly, whereas fine-grained sediment can stay suspended in the water column for longer periods, depending on the velocity of currents at the disposal site. Figure 8.2 presents the turbidity plumes associated with the various dredged material disposal methods. Potential adverse effects to EFH resulting from temporary degradation of water quality from disposal of dredged material area expected to be similar to those adverse effects discussed in Section 8.1.2.

Figure 8.2 Dredged Material Aquatic Disposal Suspended Sediment Plumes



Source: Figure recreated from ERDC, USACE 2009.

As discussed, the disposal of dredged material causes a temporary increase in the level of suspended material (turbidity) in site waters. Factors that influence resuspension of sediment during dredged material placement include: grain size class (sands, silts, clays) and the degree to which the sediment type is hard-packed. Most of the material in the descending cloud reaches the substrate, but a small percentage of finer material (approximately 10 percent of sediments dredged from a clamshell dredge) remains in the water column (SAIC 1987). In addition to this material, a more dense cloud of material forms near the bottom after dynamic collapse of the released material. This near-bottom plume of highly concentrated suspended solids spreads horizontally until its momentum has dissipated.

The turbidity plume resulting from aquatic disposal of dredged material typically disperses, and depending on the type of material disposed, water column total suspended sediment levels return to near background levels within 15 to 20 minutes of release (Reilly *et al*. 1992). Observed plumes migrate in the direction of the current at the time of discharge (SAIC 1987). For example, vertical profiles of turbidity plumes at the Alcatraz site monitored in 1976 showed that the maximum increases in suspended solids on site occur at near-bottom depths. At a depth of approximately 3 feet, total suspended solid concentrations rose from roughly 25 mg/l (background) to approximately 275 mg/l at 164 feet from the release point, and then declined again to near-background levels 1,313 feet from the release point. Suspended sediment concentrations at 16 and 30 feet above the Bay floor were much lower, ranging from 25 to 75 mg/l (USACE 1976c).

Levels of turbidity measured downstream of the Carquinez Strait disposal site, on the other hand, were up to 100 times higher in waters close to the bottom than in near-surface waters. Elevated suspended solid concentrations were measured as far as 4,500 feet downstream from the disposal site, but only lasted for approximately 10 minutes (USACE 1976b).

At any unconfined aquatic disposal site, disposal of dredged material is thus expected to cause short-term changes in water column turbidity with each disposal. These changes are primarily limited to near-bottom waters within and immediately adjacent to the disposal site. At disposal frequencies that exceed or approach the time it takes for the near-bottom plumes to disperse or settle, the effect on this water quality parameter is expected to be more severe. In addition, the nature and significance of the impact depends on the characteristics of the embayment; areas and seasons of low turbidity are expected to be affected more than areas or seasons with naturally higher concentrations of turbidity.

The disposal of large quantities of dredged material also has the potential to alter the sediment budget, which in turn, can affect levels of suspended sediment within each embayment. Analysis of turbidity data collected by Johnson Offshore Services demonstrated that substantial changes in turbidity (as measured over a 17-day period with nephelometers at a depth of 15 feet) in the vicinity of the Alcatraz disposal site were related to tidal action. The source of turbidity, however, was speculated to be either tidally transported from other locations, or a result of resuspension of material in and around the region of Alcatraz. The latter explanation was determined to be the more likely (O'Connor 1991).

8.2.1.3 Potential Direct Effects of Suspended Sediment on EFH and EFH-Managed Species

Increased suspended solids have the potential to impair oxygen exchange and increase coughing, both resulting from clogging and/or laceration of gills and decreased dissolved oxygen in the dredged areas. In salmonid species, laboratory studies show that these types of physiological reactions occur in waters with high suspended solid concentrations (i.e., 250 to 1,500 mg/l) and with continuous exposure (i.e., greater than 24 hours) (Servizi and Martens 1992; Bash, Berman and Bolton 2001); however, effects measured in laboratories may be conservative because in the field, individuals have the opportunity to avoid waters with increases suspended solids (Anchor Environmental, Inc. 2003). In many cases, however studies have shown that salmonids avoid turbid waters (Bash, Berman and Bolton 2001; Simenstad *et al.* 1999).

Several EFH-managed groundfish species are better adapted to increased suspended sediments; since the ground of estuaries is naturally more turbid than pelagic waters and they live in or on top of sediments. Pelagic species, on the other hand, are often more mobile than groundfish species and are expected to flee areas where increased suspended sediment concentrations are above their tolerance levels.

The level of potential injury to or death of EFH-managed adult species depends on the proximity of individuals active dredging. Suspended sediments resulting from dredging is expected to be rather localized around immediate dredging activities. Following dredging activities, increased suspended solids are expected to dissipate to background levels.

<u>Potential Effects of Suspended Sediment on Adult EFH-Managed Species</u>

As mentioned above, impacts on adult EFH-managed species resulting from dredging-related increases suspended sediment could include: increased coughing rates, gill laceration, decreased dissolved oxygen consumption, reduced feeding and spawning success. It is anticipated that EFH-protected adult species that come into contact with dredging activities and, therefore, increased suspended sediment loads would seek refuge in other areas not affected by dredging activities. It is anticipated that EFH-managed adult species are rather mobile adult and would flee areas where increased suspended sediment concentrations are not tolerable.

The SF Bay LTMS currently implements **BMPs 1.0 - *Environmental Work Windows***, **3.0 - *Reduce in-Bay Disposal*** and **4.0 - *Limit Overflow Dredging,*** to provide further protection to aquatic resources, including EFH and EFH-managed species, during the dredging process (BMP 1.0 and 3.0 are discussed above in section 8.1 *Direct Impacts on EFH and EFH-Managed Species Resulting from Dredging and Dredged Material Disposal*; BMP 4.0 is discussed below).

BMP 4.0 - *Limit Overflow Dredging*. In the Estuary, overflow is limited to fifteen minutes for dredging fine-grained material and no overflow is allowed when dredging coarse-grained material. Limiting overflow during hydraulic dredging minimizes the potential for negative impacts on water quality resulting from the discharge of highly turbid waters captured in hoppers and scows during the dredging process. The effect of this policy has effectively reduced the hopper/scow capacity for sediments due to the excess water that remains in the hopper/scow during dredging operations. This effect is particularly significant on maintenance dredging projects when the sediment encountered is fine-grained with very high moisture content and the depth of cut being made by the dredge is shallow. Such conditions lead to large volumes of water being entrained during the dredging process and subsequently transferred to the disposal site. The reduction in the sediment volume results in an increase the amount of time it takes to dredge a particular site and in the number of trips to the disposal site. Additionally, suspended sediment and turbidity at the disposal site during disposal is expected to increase due to the increase of fine sediments and entrained water within the hopper/scow. On the other hand, increases in suspended sediment and turbidity at the dredge site are generally decreased with limited overflow dredging.

It is expected that with the current implementation of BMPs 1.0, 3.0 and 4.0, the direct effects of increased suspended solids ***may affect, but not likely to substantially affect*** adult EFH-managed species.

Potential Effect of Suspended Sediment on Egg and Larvae EFH-Managed Species

Eggs and larvae are often the most sensitive life stages of many EFH-managed species and for many species, successful recruitment may be more influenced by the success of larvae than eggs (Connor, Hunt and Werme); however, under natural conditions eggs and larvae of many aquatic species experience very high levels of natural mortality (ERDC 2005). Potential effects to egg and larvae of EFH-managed species may include: decreased gonad maturation, lack of adhesion of eggs to substrate, reduced egg viability, reduced hatching success, smothering of eggs and reduced larval feeding (Conner, Hunt and Werme; Auld and Schubel 1978).

Auld and Schubel (1978) exposed eggs and larvae of six anadromous and estuarine fish species to concentrations of suspended sediments up to 1,000 mg/l (laboratory study). Results indicated that these high concentrations did not affect hatching success of some species (yellow perch, blueback herring, alewife or American shad), but did affect hatching rates of others (white perch and striped bass) (Auld and Schubel 1978).

Studies conducted following the Mount St. Helens eruption exposed Pacific herring larvae to estuarine suspended sediments of ash at concentration up to 8,000 mg/l. Results indicated that feeding was maximized at concentrations between 500 to 1,000 mg/l and decreased at concentrations above 1,000 mg/l (Conner, Hunt and Werme).

Although the above-mentioned studies are not a comprehensive literature review of the potential effects of increased suspended sediment plumes, they do provide an overview of the types of effects that can occur to egg and larvae aquatic species. It is important to point out that individuals will react to increased suspended sediment concentration differently, depending on the species and ambient conditions.

It is expected that potential injury and/or mortality of egg and larvae of EFH-managed species will occur; however, the level of impact is not known. It is anticipated that egg and larvae of EFH-managed species would be able to tolerate the temporary increases in suspended sediment loads, due to the natural high suspended sediment levels in several portions of the Estuary and the ability of several species to survive in concentrations of suspended sediment. Further, the SF Bay LTMS currently implements **BMP 1.0 - *Environmental Work Windows***, **3.0 - *Reduce in-Bay Disposal*** and **4.0 - *Limit Overflow Dredging***; which reduce the exposure of EFH and EFH-managed species to increased suspended sediment concentrations; as such, it is expected that increased suspended sediment concentrations resulting from dredging and dredged material placement ***may affect, but not likely to substantially affect*** egg and larvae of EFH-managed species.

8.2.1.4 Potential Effects of Suspended Sediment on Foraging and Foraging Grounds

During times when maintenance dredging increases the turbidity of the surrounding water column, benthic and planktonic species (prey species for many EFH-managed species) have the potential to be adversely affected as turbidity results in scattering and absorption of light by water molecules. The ability of a particle to scatter light is dependant on the size, shape, relative refractive index of the particle and on the wavelength of the light (Thackston and Palermo 2000). As light is scattered, the ability of several EFH-managed species to forage (i.e., see food particles) would be expected to decrease, since prey detection depends on this factor (Clarke and Wilbur 2000; De Robertis *et al*. 2003). In areas where dredged sediments are composed predominately of sand, potential impacts to prey abundance and foraging ability would not be expected to be substantial. However, in areas where dredged sediments are predominately fines or in areas known to be important feeding habitat (i.e., eelgrass and near shore areas), effects on prey abundance and foraging ability could be more substantial than in areas with coarser-grained sediment.

Reduction in foraging may result if individuals are visual feeders, such as some pelagic species and salmonids. Increased turbidity is known to scatter light within the water column, which can affect optical properties of visual feeders making it more difficult to detect prey. Turbid conditions alter the reaction distances of juvenile salmonids to planktonic prey as a log-linear function of increasing turbidity concentrations (Gregory and Northcote 1993). Other studies, however, found that salmonid foraging rates were actually decreased in clear water and the highest rates occurred in waters with turbidities of 35 to 150 NTU; this may be true for other visual feeders as well (Gregory and Northcote 1993; Gregory 1992).

The SF Bay LTMS currently implements **BMP 1.0 - *Environmental Work Windows***, **3.0 - *Reduce in-Bay Disposal*** and **4.0 - *Limit Overflow Dredging***; BMP 1.0 limits dredging to certain agency pre-approved timeframe and protects sensitive EFH foraging habitat (e.g., dredging in eelgrass beds is prohibited year-round without authorization from USFWS and NOAA-Fisheries) and BMPs 3.0 and 4.0 reduce the amount of suspended sediment that can settle on foraging habitat or impact EFH-managed species food resources. In addition to the above-listed BMPs providing protection for foraging grounds against dredging and dredged material disposal activities, it is expected that EFH-managed species foraging near dredging operations would seek other foraging grounds away from increased suspended sediment concentrations. Based on this assessment, it is expected that effects of the proposed project resulting in a reduced ability to forage ***may affect, but not likely to substantially affect*** EFH-managed species.

8.2.1.5 Potential Effects of Suspended Sediment on Migration and Migratory Corridors

Essential fish habitat features of migration corridors within the Estuary include: safe passage conditions which do not inhibit or delay migration; availability of cover/shelter in the form of water depth; and availability of forage and prey. As discussed above, temporary increases in suspended sediment loads could result in a limited temporal and spatial availability of essential habitat attributes of migratory corridors within the Estuary; these effects would persist only until turbidity levels return to ambient conditions. These adverse effects would be expected to be more substantial in areas where sediments are composed of predominately fines (Suisun Bay, San Pablo Bay, South Bay and the margins of the entire Estuary) and less substantial in areas where sediments are predominately sand. However, there is only limited number of EFH-managed fish that use the Estuary for spawning grounds; further, the acreage of non-impacted waters is much greater than the temporally impacted dredging and dredged material disposal sites.

The SF Bay LTMS currently implements **BMP 1.0 - *Environmental Work Windows***, **3.0 - *Reduce in-Bay Disposal*** and **4.0 - *Limit Overflow Dredging*** to limit the potential effects of dredging and dredged material disposal on migration and migratory corridors; as such, it is expected that increased suspended sediments generated during dredging activities ***may affect, but not likely to substantially affect*** migratory corridors.

8.2.1.6 Potential Effects of Suspended Sediment on Spawning and Spawning Grounds

Although the increases in turbidity are transient, they can have several types of longer-term consequences for sensitive biological resources. Increased turbidity can reduce the survival of herring eggs, which are attached to hard surfaces on Central Bay shorelines, potentially resulting in reduced recruitment and, ultimately, reduced abundance of this important resource in the Estuary. Additionally, increases suspended sediment can reduce the overall spawning success of EFH-managed species that spawn in the Estuary. At certain locations during critical times of the year, increased turbidity can affect the survival of the larval or juvenile stages of sensitive fish species, as well as the feeding and migration of adults.

In the Estuary, dredging between December and February could disrupt the spawning of the Pacific herring and result in mortality of eggs. Depending on the location of dredging, dredging activities could affect the migration of steelhead and Coho and Chinook salmon. Dredging in the Central Bay during summer can affect juvenile Dungeness crabs, for which the Central Bay provides an important nursery habitat. Larval and juvenile fishes and invertebrates are also vulnerable to entrainment by dredging equipment (McGraw and Armstrong 1990; Larson and Moehl; Clark and Wilber 2005).

Most of the EFH-managed species spawn outside of the Estuary and SF-DODS and are not expected to be impacted by dredging activities in the San Francisco Bay area; however, the limited number of species that do spawn in the estuary could be impacted during dredging and dredged material disposal. Further, the SF Bay LTMS currently implements **BMP 1.0 - *Environmental Work Windows***, **3.0 - *Reduce in-Bay Disposal*** and **4.0 - *Limit Overflow Dredging*** to protect all fish species spawning and spawning grounds in the Estuary. As such, it is expected that suspended sediment generated from dredging activities ***may affect, but not likely to substantially affect*** EFH-managed species spawning or spawning grounds.

8.2.1.7 Potential Effects of Suspended Sediment on Nursery Habitat of EFH-Managed Species

Several EFH-managed species that rear in the Estuary could be impacted by increased suspended sediment loads. Increased suspended sediment loads have the potential to smother eggs, should the turbid plumes migrate to nursery areas. Turbid plumes can also impair larval forms of EFH-managed species, as many larval species are free-drifters and would not be able to migrate out of the turbid plume. Depending on the proximity of dredging to nursery habitat; impacts would be expected to range from not substantial to substantial.

Increased turbidity can reduce the survival of herring and other EFH-managed species eggs and, subsequently, affect larval development. Eggs attached to hard surfaces on Central Bay shorelines, potentially resulting in reduced recruitment and, ultimately, reduced abundance of this important resource in the Estuary. At certain locations during critical times of the year, increased turbidity can affect the survival of the larval or juvenile stages of sensitive fish species, as well as the feeding and migration of adults.

During the dredging season, suspended sediment is generated temporally and locally, which can affect nursery habitat; however, the Estuary provides plenty of un-disturbed nursery habitat. In addition, the SF Bay LTMS currently implements **BMP 1.0 - *Environmental Work Windows***, **3.0 - *Reduce in-Bay Disposal*** and **4.0 - *Limit Overflow Dredging***, which help protect nursery habitat in the Estuary from the effects of dredging and dredged material disposal. As such, it is expected that increased suspended sediment generated during dredging and dredged material disposal ***may affect, but not likely to substantially affect*** nursery habitat for EFH-managed species.

8.2.2 Release of Constituents of Concern

Dredging and dredged material disposal may resuspend constituents of concern if they are present in the surface sediments. Metal and organic chemical contamination is widespread in the Estuary's sediment due to river run-off and municipal/industrial discharges. Contaminants of particular concern in various parts of the Estuary include silver, copper, selenium, mercury, cadmium, PCBs, DDT and its metabolites, pesticides, PAHs and tributyltin.

The release of constituents of concern also has the potential to affect phytoplankton, zooplankton and benthic environments; potentially exposing worms, crustaceans and insects to hazardous concentrations of contaminants, which could reduce prey for EFH managed species. Constituents of concern also have the potential to become readily available for absorption and consumption by several EFH-managed species and their prey (NOAA-Fisheries 2005). Once absorbed, many of these constituents of concern can bioaccumulate up the food chain (i.e., methylmercury, selenium, PBCs and PBDEs) (SFEI 2006a).

Most constituents of concern, however, are tightly bound in the sediments and are not easily released during short-term resuspension. Chemical reactions that occur during dredging may change the form of the constituent; thus altering its bioavailability to organisms. These chemical reactions are determined by complex interactions of environmental factors and may either enhance or decrease bioavailability of constituents of concern, particularly of metals.

Constituents of concern can be present in sediments in two forms: adsorbed (bound to sediment particles) or dissolved in sediment pore water. When sediment is dredged, these constituents of concern can be released into the water column in their adsorbed or dissolved form or be transformed into another form. Dissolved forms of metals are considered the most bioavailable form in water and are used to analyze toxicity to aquatic organisms. Organic chemicals, on the other hand, can be absorbed by aquatic organisms in both the dissolved and particulate forms, which can result in direct toxicity and/or bioaccumulation (Anchor Environmental, Inc. 2003).

The primary controlling factors that can result in the release of constituents of concern from sediment particles are the redox potential of the seawater, pH of the seawater and, to a lesser degree, salinity (Pequegnat 1983) ("redox potential" refers to the reduction-oxidation potential, which is a measure of the availability and activity of oxygen to enter into and control chemical reactions). The fine-grained sediment fractions (clay and silt) have the highest affinity for several classes of constituents of concern, such as trace metals and organics, and tend to remain in the water column longer than sand because of their low settling velocities (United States Navy 1990). Oxygen in the seawater could promote oxidation of the organic substances in the suspended materials. This, in turn, can release some dissolved constituents of concern, particularly sulfides into the water column (United States Navy 1990).

The effects resulting from release of constituents of concerns could be more concentrated when dredging in areas where in-situ sediments are already contaminated (i.e., near Carquinez Strait, Port of Oakland and Port of Richmond). Areas known to contain high concentrations of these constituents of concern include: the South Bay, with high levels of mercury, selenium, copper, PBCs and PAHs, in addition to exhibiting less tidal and riverine circulation and finer-grained sediments; Suisun Bay, with high levels of pesticides; and areas along the Richmond-Oakland and San Francisco shorelines are known to have high levels of PAHs, PBDEs and PBCs (SFEI 2006a).

Depending on the location of dredging and the respective contamination of dredged sediments; release of contaminants could pose a substantial adverse effect to EFH and EFH-managed species. However, the USACE and USEPA have developed sediment sampling protocols, as discussed in Section 6.0, and dredging of highly contaminated sediments would be conducted with an environmental bucket to reduce the potential adverse effects of contaminant release. Moreover, highly contaminated sediments would not be disposed of within the Estuary, thus removing contaminants from the system.

8.2.2.1 Resuspension of Trace Metals

Dredging and dredged material disposal has the potential to remobilize metals associated with sediment particles into the water column. The primary factors controlling the degree of mobilization are the oxidation-reduction potential of the sediment, the pH of the sediment pore water and overlying water and the salinity of water near disposal operations. Higher oxygen levels in site water than in the sediment would promote some initial oxidation of substances in dredged material, which would influence the adsorption and absorption of chemical constituents of concern to/from complexes (e.g., with sulfides). The typically higher pH of Central Bay waters compared to dredged material would also promote absorption of constituents of concern. Conversely, higher on-site salinity, which is a less important factor than pH or redox potential, would serve to increase adsorption of contaminants onto sediments (United States Navy 1990).

Studies conducted in the early 1970s found dissolved concentrations of lead, cadmium and copper in disposal plumes were nine, six and four times greater, respectively, than concentrations observed in surrounding Central Bay waters. However, these elevated concentrations lasted less than 1.5 hours (USACE, 1976d). Other studies conducted during the same period indicate that cadmium, copper, lead and zinc can be released into oxygen-rich conditions, increasing water column concentrations by as much as two times (USACE 1977).

In areas where the water is less saline, such as San Pablo and Suisun Bays, adsorption of trace metals to particulates would be expected to be lower as the salinities within these embayments are lower.

The overall impacts of short-term increases of pollutant levels in the water column depend on background concentrations present in the water column, whether water quality objectives are exceeded and the extent of the mixing zone where concentrations are elevated above ambient levels. The highest risk of environmental impact from this phenomenon occurs when dredging or disposal causes increases in water column concentrations above USEPA criteria or state water quality objectives. This is particularly true in cases where water quality within an embayment is already impaired. Within the Estuary, ambient concentrations of some metals are already at or above criteria or objectives. Of particular concern is chromium in Suisun Bay, Carquinez Strait and San Pablo Bay; copper, mercury and nickel in South Bay, San Pablo Bay, Suisun Bay and Carquinez Strait; and lead in San Pablo Bay and Carquinez Strait. At certain times of the year, depending on riverine flows, ambient concentrations of these metals in these embayments have exceeded USEPA criteria (SFEI 1994).

8.2.2.2 Resuspension of Organic Constituents of Concern

Dredging and dredged material disposal has the potential to release organic constituents of concern into the water column depending on the contaminant constituents of the dredged material. However, in-Bay disposal of dredged material is highly regulated by the DMMO; as such, disposal is limited to sediments that are not expected to have contaminant concentrations significantly higher than ambient conditions nor result in severe impacts to species (see Section 6.0 for disposal suitability testing requirements).

Generally, plumes that are generated during dredging and disposal activities are short-lived; as such, potential release of constituents of concern is expected to be short-term as well. Disposal plume studies performed by USACE have shown that levels of chlorinated hydrocarbons increase immediately after disposal, then return to background levels within a short period of time (less than 1.5 hours) (USACE 1976d). As with metals, the potential impact of short-term increases in organic pollutant concentrations in the water column depends on background concentrations.

8.2.2.3 Potential Effects of Releasing Constituents of Concern on EFH-Managed Species

Disturbance of sediments during dredging and dredged material disposal activities could result in releases of constituents of concern (e.g., trace metals and organic compounds) that can become available for uptake by aquatic organisms. Uptake of trace metals and/or organic compounds can lead to direct mortality, reduced fitness, reduced fecundity and bioaccumulation (Anchor Environmental 2003).

Trace metals associated with suspended sediment particles generally become available to biological receptors when they are in their dissolved state. Organic compounds, on the other hand are often less soluble; however, organic compounds are often attached to the surface of finer-grained sediments, which can result in organic compounds becoming more readily bioavailable when ingested by organisms.

Biological effects of exposure of constituents of concern on aquatic organisms are divided into chronic effects (the stressor persists for longer than 96 hours) or acute effects (the stressor persists for less than 96 hours) and lethal effects (the organism dies) or sublethal (the organism experiences some reduced level of fitness but does not die). Often, acute and chronic effects of constituents of concern overlap. Further, some organisms may not experience lethal effects of exposure to constituents of concern; however, they may not fully recover from sublethal effects. The effect on the aquatic organism depends on the concentration and bioavailability of the substance, the duration the substance persists in a bioavailable form and the sensitivity of the organism to the substance (Anchor Environmental 2003).

Bioaccumulation of organic contaminants occurs as biological receptors ingest the compounds and partition them into their carbon structure – generally in their fat cells. Bioaccumulation begins when an organism ingests the constituent of concern, then that organism is ingested by a higher-trophic level organisms. The cycle is repeated until the constituent of concern is biomagnified up the food chain, until they are ingested by humans (Anchor Environmental 2003).

Of particular concern in the Estuary is bioaccumulation of methylmercury. As previously discussed, the dredging process could expose anoxic sediments to oxidized conditions of the surrounding water column; depending on the amount of reactive mercury available and availability of sulfate-reducing bacteria (as well as electron donors, organic carbon content, pH and salinity), mercury could be transformed to bioavailable methylmercury (Marvin-DiPasquali 2008).

As discussed, constituents of concern are often tightly bound to sediment particles and are often not in the bioavailable form required for uptake by EFH-managed species. Further, as Section 6.0 discusses, prior to dredging and dredged material disposal, shoaled material is tested for constituents of concern and potential toxicity to aquatic organisms. Should shoaled sediment have levels of constituents of concern above the ambient concentrations found in the Estuary, the sediment would either not be dredged by the project proponent or the material would be disposed of at an approved upland site outside the Estuary. Further, the SF Bay LTMS has already reduced the threat of exposing EFH-managed species to elevated concentrations of constituents of concern by eliminating unnecessary dredging and reducing in-Bay disposal.

In addition to sediment testing requirements imposed on dredging projects in the SF Bay area, the SF Bay LTMS currently implements **BMP 1.0 - *Environmental Work Windows***, **3.0 - *Reduce in-Bay Disposal*** and **4.0 - *Limit Overflow Dredging***, which help protect the Estuary's aquatic resources from the potential effects of constituents of concern being released to the water column during dredging and dredged material disposal operations. As such, potential effects on EFH-managed species resulting from exposure to increased constituents of concern released during dredging and dredged material disposal ***may affect, but not likely to substantially affect*** EFH-managed fish.

8.2.3 Decreased Dissolved Oxygen

Dredging activities can resuspend in-situ sediments and expose anoxic material to the water column, both of which can temporarily reduce dissolved oxygen concentrations. The disposal of dredged sediment also has the potential to affect levels of dissolved oxygen at each disposal site, particularly in waters near the Estuary floor. The extent of dissolved oxygen reductions depends on the amount of oxygen-demanding substances present in the dredged material and the composition of the material (typically, fine-grained sediments have more oxygen-demanding substance present). Anoxic sediments containing reduced substances, such as hydrogen sulfide, could cause the greatest depression in dissolved oxygen levels on site.

Nutrients found in sediments and the water column that could affect dissolved oxygen concentrations are organic and inorganic forms of nitrogen and phosphorus. Total Organic Carbon (TOC) is organic matter preserved in sediments and dissolved or particulate nutrients that are found in the water column. The amount of nutrients found in an area is a function of the amount of various nutrient sources reaching the water and sediment surface and the rates at which different types of organic matter are degraded by microbial processes. Generally, as sediments are resuspended in the water column, nutrients are resuspended.

As nutrients are exposed to the water column, nutrient enrichment can increase turbidity in the water column by enhancing the growth of phytoplankton, which consumes dissolved oxygen. If this occurs, it is typically a transient phenomenon with minimal local impacts. In areas within the Estuary that are more tidally influenced, nutrients would be diluted and flushed out of the dredging area by tidal currents and freshwater flow; however, in areas where waters are shallower and/or experience less tidal action, nutrients would be expected to remain within the water column longer. Additionally, nutrients have an affinity for fine-grained sediments; at dredge sites where sediments are primarily fine-grained, nutrient enrichment resulting from resuspension of nutrient-rich sediment has the potential to persist for longer periods of time. Effects of nutrients on phytoplankton in the Estuary would generally not be detectable as light would be a limiting factor due to increased turbidity surrounding the dredge (United States Navy 1990).

The effects of dredged material disposal on dissolved oxygen levels in Estuary waters are usually short term, generally limited to the plume associated with each disposal episode, and confined to the disposal area and immediate adjacent waters. However, disposal in areas where dissolved oxygen levels are already depressed and/or disposing at high frequencies could cause more extensive water quality impacts.

Short-term depressions in dissolved oxygen levels were measured in waters immediately adjacent to the Carquinez disposal site during disposal of material from the Mare Island Strait in 1973. Levels of dissolved oxygen near the Bay floor declined from 80 to 85 percent to 20 to 30 percent saturation within several minutes after material was released from the barge, but recovered to ambient levels within 10 minutes (USACE 1976c).

For the most part, potential adverse effects to dissolved oxygen levels would not be expected to be significant unless the overall frequency of disposal at any disposal site approached the amount of time it takes for dissolved oxygen to return to background levels after individual disposal events. Further, the SF Bay LTMS currently implements **BMPs 3.0 - *Reduce in-Bay Disposal*** and **4.0 - *Limit Overflow Dredging***, which reduce the exposure of oxygen-consuming substances to the water column. As such, it is expected that potential effects of dredging and dredged material disposal-related reductions in dissolved oxygen ***may affect, but not likely to substantially affect*** EFH and/or EFH-managed species.

8.2.4 Saltwater Intrusion

In estuaries, salt water intrudes upstream in fresh waters when river water meets sea water; the lighter fresh water rises up and over the denser salt water and sea water flows beneath the out-flowing river water, pushing its way upstream along the bottom.

Depending on the location of the dredging, deepening navigation channels can increase saltwater intrusion into the Delta as the denser saltwater sinks to the bottom of the channel and flows along the bottom of Bay into fresher Delta waters. Saltwater intrusion has the potential to alter the ecosystem as the intruding saltwater is generally oxygen poor and saltier compared to the freshwater. Potential effects of saltwater intrusion include: reduction of dissolved oxygen in bottom waters; alterations of benthic species due to increased salinity and/or decreased dissolved oxygen; impacts to freshwater supplies and impacts to fisheries. Dredging can also increase saltwater intrusion into groundwater aquifers (e.g., the Merritt Sand/Posey formation aquifer in the Oakland Harbor area); with consequent degradation of groundwater quality in shallow aquifers (United States Navy 1990).

However, this EFH analysis covers only maintenance dredging projects within the Estuary; as such, it is important to realize that much of the maintenance dredging that occurs provides the existing environmental conditions of the Estuary. It is unlikely that maintenance dredging would elicit severe saltwater intrusion into the Delta or other freshwater tributaries to the Estuary. New dredging or deepening projects, particularly in the Suisun Bay, have the potential to alter freshwater flow regimes within the Delta and other tributaries.

Because salt water intrusion is not expected to occur as a result of continuing maintenance dredging and dredged material disposal in the Estuary, is ***not likely to substantially affect*** EFH or EFH-managed species.

8.4.5 Potential Effects on pH

Dredging and aquatic dredged material disposal may change the pH of waters near dredging and disposal activities as the material is typically more acidic than the surround estuarine waters. Such an effect, however, is expected to be of extremely short duration and limited to the disposal site area. Therefore, dredging and dredged material disposal is not likely to adversely affect pH of the Estuary's waters.

Regardless of the maintenance dredging projects that occur in the Estuary, pH has remained relatively constant. As such, this impact is ***not likely to substantially affect*** EFH or EFH-managed species.

8.4.6 Un-Ionized Ammonia Disturbance

The magnitude and extent of changes in ammonia levels as a result of dredged material disposal has not been extensively monitored in the Estuary. Short-term changes in this water quality parameter are expected to occur, particularly in conjunction with the near-bottom turbidity plumes, described above. However, oxidative removal of ammonia from the water column generally occurs quite rapidly in well-oxygenated waters such as those of the Estuary (and particularly in the Central, San Pablo and Suisun Bays). As such, dredging and dredging material disposal is not likely to adversely affect water quality by disturbing un-ionized ammonia.

Disturbance to un-ionized ammonia resulting from dredging and dredged material disposal in the San Francisco Bay area is expected to be minimal; as such, this impact is ***not likely to substantially affect*** EFH or EFH-managed species.

8.4.7 Potential Cumulative Effects on Water Quality

Cumulative adverse effects on water quality resulting from dredging and dredged material disposal in the San Francisco Bay area have decreased overall since the implementation of the San Francisco Bay Area, compared to pre-LTMS practices. Specifically, the SF Bay LTMS has limited in-Bay disposal; which has resulted in less depletion of dissolved oxygen in and around the disposal sites, reduced resuspension of sediments and associated turbidity and reduced release of contaminants to the water column in and around the disposal site.

The goal of the SF Bay to further reduce in-Bay disposal and beneficially use dredged material to restore wetlands around the Estuary is expected to result in beneficial effects on water quality; beneficial effects include: overall decrease of contaminated sediments into the Estuary, compared to current levels of in-Bay disposal (SFEI 2003b) and ability of wetland habitat created with dredged material along the Estuary's periphery to absorb and cleanse run-off water that would otherwise go directly into the Estuary. Compared to pre-SF Bay LTMS dredging and dredged material management practices, it is expected that the SF Bay LTMS programs will have a ***beneficial*** effect on water quality and, therefore, EFH and EFH managed species.

8.3 Potential Effects on EFH and EFH-Managed Species resulting from Dredging and Dredging Material Placement Effects on Sediments

Dredging and dredged material disposal physically moves sediment within and from the Estuary's ecosystem. The impacts on sediments at the dredging site include direct removal of sediments, increased post-dredging sedimentation in dredged areas and possible slumping of materials from the side slopes of dredged areas. Dredged material disposal results in sediments being placed at dispersive aquatic disposal sites. These sites are considered dispersive because sediment disposed of at these sites does not remain within site boundaries. Following disposal and settlement on the floor of the disposal site, sediments are continually resuspended by currents and dispersed over a wide area, with the extent of dispersal depending on a number of complex, interrelated factors. Therefore, disposal of dredged material at the various disposal sites has the potential to affect resources over a broader area.

Sediments that are resuspended during dredging and dredged material disposal also have the potential to become increasingly contaminated as they interact with constituents of concern in the water column. Contaminated resuspended sediments have the potential to be carried with the current to other areas of the Estuary. Dredging also results in direct removal of sediments and, therefore, habitat associated with the sediments removed.

Adverse effects to sediments that can result in adverse effects to essential fish habitat; include: direct removal of resting and foraging habitat by dredge equipment; temporary reduction in migratory corridors within the water column as sediments and associated contaminants are resuspended; reduction in prey abundance, as species are directly removed from the system by dredge equipment and/or buried by deposition of turbid plumes. This section discusses how the adverse effects to sediment quality generated by dredging activities affect EFH within the Estuary.

8.3.1 Potential Effects on Sediment Dynamics (Circulation, Currents and Bathymetry)

Preliminary mathematical modeling of dredged material transport and initial deposition following disposal at several locations throughout the Estuary was conducted for the SF Bay LTMS by ERDC (Letter *et al*. 1994). The results of this modeling remain preliminary and substantial model development is still needed before any such results can be used with confidence. ERDC modeling indicates that dredged material initially discharged at existing in-Bay disposal sites may quickly find its way into virtually every major sub-basin of the Estuary. These modeling results are generally consistent with the SF Bay LTMS (1992) figures and are based on empirical information in terms of the heterogeneity of deposition and erosion patterns throughout the Estuary. However, the ERDC model output shows only predicted initial deposition locations and subsequent resuspension. Further transport of the dredged material particles are expected from any initial deposition sites that exhibit erosional characteristics at times.

Because the majority of fine sediment particles are likely to settle and resuspend a number of times in the Estuary, at least a small percentage of the sediment accumulating in navigation channels is likely to include previously dredged material that was discharged at an dispersive in-Bay site. For example, tracer studies in the mid-1970s confirmed that as much as 10 percent of the sediments accumulating in the Mare Island Strait was in fact dredged material re-circulated from the Carquinez disposal site (USACE 1976b).

The continual resuspension of sediments within the Estuary's system also means it can be expected that sediments accumulating in navigation channels may have been exposed to pollutant sources in several locations, far removed from the dredging site. This helps to explain why chemical testing of sediments from some regularly dredged channels can show a fairly high degree of variability from year to year, even when no nearby discharges or spills occurred. It also helps to explain why almost all maintenance dredging projects from throughout the Estuary show at least some degree of elevated (above ambient or "background") concentrations of trace contaminants.

By the same token, particles carrying pollutants may also get diluted with particles from other areas that settle in the same location and have lower concentrations of associated constituents of concern. Thus the sediment from many dredging projects, even when trace pollutants are present, is not contaminated to a degree that causes toxicity or that otherwise represents any significant environmental risk.

Currents and circulation within the Estuary are potentially affected by the placement of dredged material in two ways: first, mounding at an aquatic disposal site may affect the strength or pattern of currents moving through a nearby channel; second, restoring significant areas of land to tidal action through wetland restoration may affect the overall tidal exchange volume (prism) in the Estuary. Mounding is only expected to occur when there is a high level of disposal at one disposal site or one placement environment, as has occurred at the Alcatraz (SF-11) disposal site. Placement of dredged material is otherwise not expected to affect wind-generated waves and currents.

The bathymetry of the Estuary has the potential to be locally affected by the placement of dredged material. The clearest example of this is the formation of a mound at the Alcatraz disposal site in 1982. Since the mounding was discovered, the USACE has limited disposal volumes to minimize mounding. The extent to which mounding occurs depends on the rate at which material is disposed and the rate at which currents scour, resuspend and remove disposed sediment from a site.

Changes to bathymetry can result in substantial impacts to benthic communities, including: burial of organisms, which can result in mortality of some organisms that are prey for many EFH-managed species. Additionally, EFH-managed species within the disposal site may experience injury (e.g., abrasion to body and gills) and/or mortality due to burial, increased turbidity and/or alterations in behavior (such as alterations in migratory paths and impaired feeding).

The SF Bay LTMS currently implements **BMPs 1.0 - *Environmental Work Windows*, 3.0 - *Reduce in-Bay Disposal*** and **4.0 - *Limit Overflow Dredging***, which limit dredging to specific work windows and limit the amount of suspended sediment introduced to the water column during dredging and dredged material disposal; although, the magnitude of this reduction is not measured. It is expected that potential effects of dredging and dredged material disposal circulation, currents and bathymetry will be minimal and not significantly noticed Estuary-wide. As such, it is expected that any impacts on sediment dynamics from dredging and dredged material disposal ***may affect, but is not likely to substantially affect*** EFH or EFH-managed species.

8.3.2 Potential for Accumulation of Constituents of Concern

Recent data show that concentrations of some contaminants, such as selenium, PAHs and PCBs have been accumulating at the disposal sites over time, especially at Alcatraz, which was shown to be a non-dispersive disposal site. The other in-Bay sites are percent dispersive; as such, most sediment is re-dispersed throughout the respective embayment the site is located in. To limit accumulation of contaminants, ongoing disposal and site management at all sites is being conducted to maximize dispersion of sediments and accumulation of contaminants within the area. As previously discussed (see section 6.0), the USACE and USEPA regulate the disposal with the goal of protecting the Bay from release of contaminants during dredging and disposal activities. High levels of contaminated sediments would not be disposed of in-Bay, therefore reducing the potential for accumulation of contaminants.

Any accumulation of constituents of concern may increase the potential for that constituent to bioaccumulate in EFH-managed species. However, as discussed in section 8.2.2.3, *Potential Effects of Releasing Constituents of Concern on EFH-Managed Species*, constituents of concern are often tightly bound to sediment particles and do not become easily bioavailable to aquatic organisms and dredged sediments are tested prior to dredging and dredged material disposal to reduce the risk of contaminated sediments being dredged and disposed of in the Estuary. Implementation of **BMP 3.0 - *Reduce in-Bay Disposal*** further reduces the potential effects of exposure of constituents of concern (e.g., bioaccumulation). As such, this impact ***may affect, but is not likely to substantially affect*** EFH-managed species.

8.3.3 Potential Cumulative Effects on Sediments

Cumulative effects of dredging include changes in bathymetry; however, the maintenance dredging projects that occur in the Estuary somewhat maintain the existing bathymetric character of the Estuary's floor. Should maintenance dredging operations cease or new or deepening projects be approved, significant changes to the Estuary's bathymetry could occur. Disposal of dredged material has the potential to change the bathymetry at the disposal sites. This is most prevalent at the Alcatraz disposal site, which has been adversely affected by cumulative disposal activities, resulting in mounding.

Cumulative changes in bathymetry could alter benthic habitat, benthic species composition and sediment cycling. Over the life of the SF Bay LTMS, continued reduction in in-Bay dredged material disposal could result in small-scale changes in sediment cycling and possible erosion. It is expected that cumulative effect on sediments resulting from the continued implementation of the SF Bay LTMS, including continued dredging and dredged material disposal in the Estuary would maintain the status quo of the Estuary's sediment dynamics, circulation and sedimentation and bathymetry. Should new dredging projects within the Bay arise, potential cumulative impacts to the environment and EFH managed species would be addressed. As such, it is expected that the potential cumulative impacts on sediments resulting from continued implementation of the SF Bay LTMS-managed maintenance dredging projects ***may affect, but is not likely to substantially affect*** EFH or EFH-managed species.

8.4 Potential Effects on Biological Resources

The impacts of dredging and dredged material disposal on biological resources can be short term, resulting from dredging activities, or long term, associated with habitat modification; direct or indirect. Short-term impacts could include local changes in species abundance or diversity during or immediately after dredging. Long-term impacts could include permanent species abundance or diversity changes caused by changes in hydrodynamics or sediment type (United States Navy 1990).

Direct impacts that could be attributable to dredging activities include direct loss of mudflat habitat and temporary turbidity-induced reduction in productivity in eelgrass beds and benthic communities near the dredging site (Nightingale and Simenstad 2001). Indirect effects on organisms include those effects which are not immediately measurable as a consequence of dredging operations. Such effects might, for example, involve population dynamic changes in species caused by the effects of decreased dissolved oxygen or increased release of constituents of concern, and the effects of dredging on its predators, prey or competitors (NOAA-Fisheries 2005; Nightingale and Simenstad 2001). Indirect effects may be manifested over extended periods of time and/or at some distance away from the dredging site. The differentiation between direct and indirect effects is not always clear.

The magnitude of impacts on the surrounding environment at a specific dredging and/or disposal site depends on the overall dredging and dredging material disposal quantities and frequency over the life of the SF Bay LTMS. For the most part, potential effects to aquatic habitats have decreased, compared to pre-SF Bay LTMS conditions, since a major outcome of the SF Bay LTMS to date has been to substantially reduce in-Bay disposal volumes and increase beneficial use of dredged sediment.

The primary aquatic habitats that could potentially be affected by dredging and dredged material disposal are those associated with the benthic community. Other resources such as phytoplankton, zooplankton, pelagic fish and other wildlife also have the potential to be adversely affected by disposal of dredged material.

The biological resources in the action area are all considered part of EFH; as such, potential impacts to EFH and EFH managed species resulting from impacts on the Estuary's biological resources are discussed with each respective resource.

8.4.1 Potential Effects on Phytoplankton and Zooplankton

Dredging and dredged material disposal sediment plumes have the potential to physically alter/cover the coarse sediments and rocky shorelines upon which phytoplankton and zooplankton grow and to affect eelgrass beds. Generally, the increased turbidity plume generated during dredging and disposal of dredged material has the potential to affect planktonic species by limiting the amount of light available (NOAA-Fisheries 2005). However, depending on the dredged disposal quantities and frequency, the effects to planktonic species can be more pronounced if disposal activities occur in such a way that does not provide enough time for turbidity levels to return to ambient conditions and planktonic communities to return to pre-disposal conditions. Adverse effects to planktonic species associated with disposal of dredged material would be more significant in areas where planktonic primary production is greatest, such as the Central and South Bays.

The effects on EFH-managed species resulting from effects on phytoplankton and zooplankton include: temporary increases turbidity that could affect visual feeders and temporary decreases in planktonic food resource for some EFH-managed species. This impact will be temporary, persisting only until the stressor ceases, and spatially limited to the area impacted by dredging and dredged material disposal. As such, it is expected that any impacts on phytoplankton and zooplankton resulting from dredging and dredged material disposal activities ***may affect, but is not likely to substantially affect*** EFH or EFH-managed species. Additionally, implementation of **BMP 1.0 - *Environmental Work Windows*** and **BMP 3.0 - *Reduce in-Bay Disposal*** could further reduce the adverse effects of dredging and dredged material disposal on phytoplankton and zooplankton.

8.4.2 Potential Effects on Benthos

Dredging involves the direct removal of substrate and benthic organisms at the dredging site, resulting in immediate localized effects on the bottom-dwelling species. Besides the destruction of organisms at the dredging site, there is the removal of the existing natural or established community with varying survival of organisms. Aside from the initial physically disruptive effects, a long-term environmental concern is the recovery (repopulation) of bottom areas where dredging has occurred (Hirsch, DiSalvo and Peddicord 1978). Dredging thus opens the area for recolonization on a new substrate that may resemble the original substrate or be completely different in physical characteristics. Recolonization may be by the same organisms or opportunistic species that have environmental requirements flexible enough to allow them to occupy a disturbed site (Reilly *et al.* 1992).

The disposal of dredged material significantly affects the benthos at each disposal site and has the potential to affect the benthos within each embayment. These effects result from burial of habitat and species and changing the composition of the substrate. Organisms that are buried would have to migrate vertically within the newly placed sediment or die (Maurer *et al.* 1986). Although vertical migration is possible, survival is somewhat unlikely to occur since dissolved oxygen is expected to decrease as ammonia and sulfides increase within the top layer of sediment within the disposal site (Maurer *et al.* 1986). These potential effects to benthos are expected to be generally confined to the disposal site and the area immediately surrounding it.

Recolonization of the dredging site can begin quickly, although re-establishment of a more stable benthic community may take several months or years after the dredging operation has ceased (Oliver *et al.* 1977; Conner and Simon 1979). Oliver *et al*. (1977) found that most of the infauna destroyed were located near the center of the dredged area. Communities inhabiting highly variable and easily disrupted environments, such as those found in shallow water, recovered more quickly from dredging operations than communities in less variable environments, such as in deep or offshore waters. Seasonal changes in the environment were considered most important in shallower water where the organisms are more likely to be affected by the changing seasons (Reilly *et al*. 1992).

Oliver *et al*. (1977) noted two phases of succession after a disturbance. In the first phase, opportunistic species, such as some polychaete species, would move into a disturbed area. The second phase involved recruitment of organisms associated with undisturbed areas around the disturbed site. Recovery at the disturbed site depends on the type of environment and the speed and success of adult migration or larval recruitment from adjacent undisturbed areas (Hirsch, Disalvo and Peddicord 1978).

The effects of habitat loss or alteration at the dredge and dredged material disposal sites may extend beyond the boundaries of the dredging operations. However, dredging-induced habitat alterations are minor compared to the large-scale disturbance of benthic habitat in San Francisco Bay from naturally occurring physical forces (Reilly *et al*. 1992). The result of these forces is a state of non-equilibrium in benthic species composition typical of shallow estuaries. Naturally occurring habitat disturbances arise from seasonal and storm-generated waves and from seasonal fluctuations of riverine sediment transport into the Estuary. Human influences on benthic habitat include not only dredging and disposal, but also waste discharges, sediment deposition from hydraulic mining, filling of Bay margins, fresh water diversions, introduction of exotic species and extensive ocean-going vessel traffic. When the disturbance ceases, recolonization of the benthic substrate occurs; however, reestablishment of a more or less stable benthic community can take several months or years (Reilly *et al*. 1992).

As a result of the removal of benthic species, productivity of foraging habitat could be temporarily reduced in dredged areas. In areas subject to dredging on an annual basis (e.g., large federal projects and non-federal ports) and frequent shipping disturbance, benthic communities have little time to recover and, therefore, provide little foraging for species protected under the MSFCMA. Areas where dredging occurs on a less-than-annual basis (e.g., small marinas), dredging may result in loss of benthic habitat that has reestablished during the interval between dredging episodes.

The suspension of sediments during dredging will generally result in localized, temporary increases in suspended sediment loads that are dispersed by currents or otherwise dissipate within a few days, depending on hydrodynamics and sediment characteristics (USACE and Port of Oakland 1998). Where dredging occurs in areas with higher concentrations of constituents of concern in the sediments, the sediments redispersed in the water column, which could result in localized, temporary increases in concentrations of constituents of concern and nutrients. In addition, resuspended sediments could result in a temporary and localized decrease in dissolved oxygen, all of which has the potential to adversely affect fish and benthic invertebrates.

Contamination to and bioaccumulation of benthic species also has the potential to occur during disposal of dredged material. Contaminants bound to sediments that settle after disposal may be in direct contact with benthic species and may be ingested (Engler 1990). Contaminated benthic species may exhibit reduced immune capabilities and fecundity, impair embryonic development and/or experience bioaccumulation of ingested contaminants (Smith *et al.* 1995; Pinto *et al.* 1995). Although these effects would be localized to the disposal area, the effects of contamination may not be temporary, as these effects could result in permanent physiological and/or behavior impairments or could be lethal. Disposal sites that experience disposal of contaminated sediments more frequently would be more adversely affected by repeated disposal of dredged material than those sites that receive uncontaminated disposal.

As discussed in Section 6.0, *Regulation of Dredged Material Disposal*, the DMMO highly regulates disposal of dredged material. When testing and analysis of sediments reveals that concentrations of constituents of concern would pose significant impacts to benthic species, the material is considered unsuitable for aquatic disposal and is either not dredged or disposed of at a rehandling facility or at an approved upland disposal site.

Benthic communities that could be affected by dredging and dredged material disposal may or may not be fully established communities, depending on the frequency of dredging at a specific site. Further, the footprint of dredging and dredged material disposal is small Estuary-wide, compared to the footprint of the entire Estuary and the respective benthos. Following dredging and dredged material disposal, the impacted benthic community could regenerate, to some degree. EFH-managed species that use the disturbed benthic community for habitat or foraging would have to relocate until the dredging stressors are removed or would have to tolerate the stressor. Based on the limited footprint of benthic disturbance, compared to the Estuary's benthos and the ability for EFH-managed species to find other suitable benthic habitat, it is expected that disturbance of benthic communities from dredging activities ***may affect, but is not likely to substantially effect*** EFH or EFH-managed species.

8.4.3 Potential Effects on Eelgrass Bed Habitat

Potential effects to eelgrass beds from dredging and dredged material disposal include: sedimentation of eelgrass beds and direct removal of eelgrass and associated species; alteration and/or covering of the substrate upon which eelgrass grows (coarse sediments and rocky shorelines) and indirectly decreasing eelgrass photosynthesis. Specifically, increased turbidity from dredging, pulsed overflow and dredged material disposal plumes containing resuspended sediments has the potential to reduce water clarity and, therefore, the light reaching eelgrass plants (USFWS, *et. al*. 1984). Additionally, should dredging occur within the immediate proximity of eelgrass beds, eelgrass could be removed by dredge equipment.

The magnitude of potential impacts on eelgrass beds is dependent upon how far dredging and/or disposal plumes disperse from dredging and disposal activities. However, there are only a few dredging projects near eelgrass beds and in-Bay disposal sites are not known to be in close proximity to them.

As discussed, eelgrass is vital habitat for several EFH-managed species. Reduction in eelgrass abundance could reduce primary production, foraging habitat, prey species, refugia and habitat for egg and larvae development for several life stages of EFH-managed species. Additionally, loss of eelgrass habitat could result in increased silt load due to reduction in sediment trapping, and increased erosion of bottom sediments, which could affect other important intertidal and subtidal habitats used by EFH-managed species.

There are only a few maintenance dredging projects located near eelgrass bed habitat (e.g., Richmond Harbor and Richardson Bay dredging projects). Prior to dredging these areas, eelgrass surveys are conducted and site-specific best management practices are put in place (e.g., silt screens to protect eelgrass beds from suspended sediment). Further, SF Bay LTMS has already implemented **BMP 1.0 - *Environmental Work Windows***, which require agency consultation under the Endangered Species Act prior to dredging in eelgrass beds. As such, it is expected that eelgrass beds will be protected during dredging and dredged material disposal and this impact ***may affect, but is not likely to substantially affect*** EFH or EFH-managed species.

8.4.4 Potential Effects on Oyster Bed Habitat

As shown on Figure 7.7, above, oyster beds exist along the periphery of the South Bay and the confluence of the Central and San Pablo Bays; as such, maintenance dredging projects within these areas have the potential to affect oyster bed habitat.

Potential effects to oyster bed habitat are not well studied for the Pacific region; however, literature suggests that increased turbidity and releases of constituents of concern could pose adverse effects on oyster populations. Effects of increased suspended sediment loads and associated release of constituents of concern by active dredging on oysters is dependent on many factors, including the life stage of individual oysters and sensitivities to salinity, dissolved oxygen, temperature and other physical aquatic features (Sherk 1972). Potential effects to oysters resulting from dredging activities include reduced ability of oysters and other filter-feeders to pump water; potential mortality if organisms are buried; and a decrease in egg and larval development, as eggs and juvenile oysters tend to be more sensitive to increased suspended sediment (Sherk 1972 – researching American oysters in Chesapeake Bay). In addition to the potential direct adverse effects of increased suspended sediment loads on oyster habitat, oysters are especially susceptible to bioaccumulation of contaminants; the release of constituents of concern within the water column has the potential to cause increased bioaccumulation of contaminants in oyster species.

Although a limited number of dredging projects in the South Bay have the potential to adversely affect oyster bed habitat, there are no dredged material disposal sites located in the South Bay. As such, dredged material disposal would not result impacts on oyster bed habitat. Based on this analysis, it is expected that impacts on oyster beds resulting from dredging and dredged material disposal ***may affect, but is not likely to substantially affect*** EFH or EFH-managed species.

8.4.5 Removal of EFH-Managed Species' Resting and Foraging Habitat

As dredging removes sediment and associated benthic communities from the Bay's floor, resting and foraging habitat for several EFH-managed species, especially bottom fish, is removed. These potential effects are expected to be localized to the areas being dredged. As discussed in Section 8.1.4.3 below, benthic communities and associated habitat are expected to recolonize in between dredging episodes; depending on the location and frequency of dredging activities. In areas that are dredged annually, the highly disturbed habitat would have less time to recolonize and become viable resting and foraging habitat. As such potential adverse effects to these areas are not expected to be substantial.

Literature suggests that rates of recovery may take from several months for estuarine muds to two or three years for sands and gravels (NOAA-Fisheries 2005). In areas with slow currents, such as San Pablo and the South Bay, recolonization can also take up to five to ten years; whereas, areas with strong currents can recolonize in one to three years (NOAA-Fisheries 2005); thus, substantially reducing benthic foraging habitat in the immediate vicinity of dredging activities. It is expected that EFH-managed species would find other areas to forage where dredging activities are not disturbing benthic feeding grounds. With implementation of **BMP 1.0 - *Environmental Work Windows*** and **BMP 3.0 - *Reduce in-Bay disposal***, these impacts would be further reduced. As such, it is expected that dredging and dredged material disposal-related changes to sediments, sediment dynamics and bathymetry ***may affect, but is not likely to substantially affect*** EFH-managed species foraging habitat.

8.4.6 Potential Cumulative Effects on Biological Resources

This section provides a discussion of the potential resources that could experience cumulative effects of the SF Bay LTMS dredge projects' dredging activities and how these effects could cumulatively impact EFH and EFH-managed species.

8.4.6.1 Potential Cumulative Effects on Benthos

The maintenance dredging sites described in this document are highly disturbed benthic habitat, as dredging and disposal activities continually remove and bury benthic organisms; however, impacted areas generally recolonize rapidly. Although communities can recover rapidly, the communities present in early successional stages may not be the same as the species impacted. Additionally, repeated maintenance dredging of one area and repeated burial of benthic habitat may prevent benthic communities from fully developing, thus resulting in a shift in community structure (Dankers and Zuidema, 1995). However, the SF Bay LTMS currently implement **BMP 1.0 - *Environmental Work Windows*** and **BMP 3.0 - *Reduce in-Bay Disposal***, which will protect benthic communities at dredging and in-Bay disposal sites from the effects of dredging and dredged material disposal and give these species more time to recover. Cumulatively, it is expected that over the life of the SF Bay LTMS, only a few projects would be deepened in the Estuary and the benthos would be similar to existing conditions (depending on invasive species introductions). As such, it is expected that continued implementation of the SF Bay LTMS and continued maintenance dredging and dredged material placement activities ***may affect, but not likely to substantially affect*** EFH or EFH-managed species.

8.4.6.2 Potential Cumulative Effects on Eelgrass Bed Habitat

Dredging activities have the potential to degrade eelgrass habitat due to pulsed overflow turbidity plumes, disposal plumes, turbidity associated with agitating the seafloor, and direct removal of eelgrass plants; however, only the *Essayons* is allowed to overflow during dredging activities. During the life of the LTMS, eelgrass beds could be further degraded because several dredging projects exist along the periphery of the Estuary in close proximity to eelgrass meadows; however, current regulations mitigation of eelgrass removal. Further, some habitat restoration projects, such as the Port of Oakland's MHEA, included eelgrass planting; should eelgrass planting be successful, the SF Bay LTMS could be responsible for additional eelgrass bed habitat in the Estuary. Further, eelgrass monitoring conducted for Richmond Harbor (which is near the Richmond Harbor Training Wall eelgrass bed) failed to show a statistical effect of dredging on eelgrass beds (CH2M Hill 1998).

It is expected that direct removal of eelgrass would not occur while maintaining the existing SF Bay LTMS maintenance dredging projects; however, new deepening projects have the potential to remove eelgrass beds. Dredging and in-Bay disposal of maintenance dredged material can increase suspended sediment loads causing siltation of eelgrass beds and reducing light penetration in the water column. Maintenance and new work dredging projects, as well as other projects that shade or fill the shallow margins of the Estuary could cumulatively affect eelgrass bed habitat or hamper eelgrass bed growth. It is expected that these effects would be exacerbated by new work dredging projects. Mitigation measures that could reduce the potential cumulative adverse effects of new work dredging projects, such as pre- and post- eelgrass bed surveys and silt curtains should be placed on the new work projects during specific EFH consultations. For the maintenance dredging project managed under the SF Bay LTMS, cumulative effects on eelgrass ***may affect, but not likely to substantially affect*** EFH or EFH managed species.

8.4.6.3 Potential Cumulative Effects of Bioaccumulation of Constituents of Concern

Over time, disposal of dredged material has the potential to bioaccumulate contaminants, such as methylmercury, selenium, PCBs, PAHs, and PBDEs up the food chain. The DMMO, however, has set standards that regulate the material that is suitable for in-Bay disposal. Rigorous screening and monitoring is required of sediments prior to dredging and disposal activities and contaminated sediments would be disposed of at upland disposal sites. Further, all following mounding issues at Alcatraz and accumulation of contaminants at the sites, all in-Bay sites are being managed to be dispersive sites.

Implementation of **BMP 3.0 - *Reducing in Bay Disposal*** over the life of the SF Bay LTMS is expected to produce beneficial effects throughout the Estuary as potentially contaminated material would be disposed of outside the Estuary; as such, contaminants would be removed from the Estuary, as the placement of contaminated dredged material, even if slightly contaminated, at upland, ocean or beneficial use sites continues to be implemented under the SF Bay LTMS.

The goals of the SF Bay LTMS (reduce unnecessary dredging, decrease in-Bay disposal and increase beneficial use of dredged material) and the rigorous sediment testing requirements (discussed in Section 6.0) will ensure that EFH-managed species are better protected against the risk of bioaccumulation of constituents of concern. As such, it is expected that potential cumulative effects of bioaccumulation of constituents of concern ***may affect, but is not likely to substantially affect*** EFH-managed species by continued implementation of the SF Bay LTMS.

8.4.6.4 Potential Indirect Effects Related to Invasive Species

Dredging deep-draft navigation channels provides for large, ocean-going vessels to transport goods into and out of the San Francisco Bay. It is well known that ships transporting these goods also transport and discharge ballast water containing exotic species. However, ballast water discharge is not the only method exotic species have entered and successfully established in the Estuary. Exotic species are transported on the hulls and equipment (fishing, anchor, etc.) of several ocean-going vessels, including recreation and fishing vessels and have been brought into the Estuary with commercially and recreationally important species. For the most part, it is difficult to discern the exact method exotic species were brought into the Bay and, even smaller operations can cause significant invasive species populations (CDFG 2008). It is anticipated that approximately four species a year establish as permanent residents in the Bay.

More than 250 non-native species are expected to reside in the San Francisco Bay. Recent introduced species that have caused problems in the Estuary include: the Asian clam, green crab (which feed on clams and Dungeness crab) and the mitten crab (CDFG 2008). Potential effects of introduced species into aquatic ecosystems include: reduced diversity and abundance of native plants and animals (due to competition, predation, parasitism, genetic dilution, introduction of pathogens and smothering and loss of habitat); alteration of native food web and potential declines in productivity; changes in nutrient cycling and energy flow; losses in fisheries production; degradation of water quality and erosion of shorelines and levees.

In January 2008, the State of California Resources Agency Department of Fish and Game established the *California Aquatic Invasive Species Management Plan* (available at: http://groups.ucanr.org/Ballast_Outreach/files/49547.pdf) to address aquatic invasive species, including aquatic invasive species transported into State waters via all known transport vectors. The basic premise of the plan is to prevent invasive species transport into the state, early detection and monitoring, rapid response and eradication, long-term control and management and outreach/education.

It is anticipated that, at times, organisms using the deep-draft federal channels and/or fishing and recreation boats using local marinas and ports may transport exotic species into the Estuary. However, California law mandates that ballast water management for ships arriving from foreign ports exchange ballast water outside the United States Exclusive Economic Zone in order to flush out water that contains organisms from other parts of the world and exchange it with water from the open ocean, as water from the open ocean is expected to contain less organisms that could survive in estuarine environmental (CDFG 2008). Several shipping vessels utilize chemicals to reduce fouling on ship hulls; predominately because fouling organisms slow down vessels, increase fuel consumption and damage the vessel.

Due to the regulations already in place regarding ballast water, the many sources of introduced species that can enter the Estuary, as well as the new invasive species management program, it is not anticipated that invasive species resulting from shipping – as an indirect effect of maintenance dredging – would elicit a significant effects to EFH within the Estuary. As such, it is expected that further introduction of invasive species to the Estuary resulting from continued implementation of the SF Bay LTMS ***may affect, but not likely to substantially affect*** EFH or EFH-managed species.

8.5 Potential Effects of Dredged Material Disposal on Aquatic Resources at SF-DODS

This section provides a summary of the *Ocean Disposal Information: Programmatic EFH Consultation for the LTMS*, dated December 18 2007, as submitted by the USEPA.

Although EFH consultation was not conducted as part of the designation process for SF-DODS, the USEPA's site designation process and regulations (promulgated under the MPRSA and NEPA) independently require evaluation of a variety of factors that minimize the potential effects of disposal on EFH. For example, the MPRSA regulations at 40 C.F.R. Part 228.5 – 228.6, include the following disposal site selection criteria, that directly avoid or minimize impacts on EFH and EFH-managed species:

- Disposal activities must avoid existing fisheries and shellfisheries (228.5(a));
- Temporary water quality perturbations from disposal within the site must be reduced to ambient levels before reaching any marine sanctuary or known geographically limited fishery or shellfishery (228.5(b));
- The size of disposal sites must be minimized in order to be able to monitor for and control any adverse effects (228.5(d));
- Whenever possible, new disposal sites should be beyond the edge of the continental shelf (228.53));
- The location of disposal sites must specifically be considered in relation to breeding, spawning, nursery, feeding or passage areas of living resources in adult or juvenile phases (228.6(a)(2));
- Dispersal and transport from the disposal site be must considered (228.6(a)(6));
- Cumulative effects of other discharges in the area must be considered (228.6(a)(7);
- Interference with recreation, fishing, fish and shellfish culture, areas of special scientific importance and other uses of the ocean must be considered (228.6(a)(8); and
- The potential for development or recruitment of nuisance species must be considered (225.6(a)(11)).

Taken together, the site selection criteria are intended to ensure that the USEPA ocean disposal site designations avoid significant impacts to any important fishery or supporting marine habitat to the maximum extent practicable, even before any dredged material is permitted to be disposed there. Based on consideration of the site selection criteria, the location of the SF-DODS was identified as the environmentally preferred alternative in the EIS/EIR for the designation of SF-DODS as a deep ocean disposal site.

As previously discussed, SF-DODS is the deepest and farthest offshore of any disposal site in the Nation. Unlike many disposal sites in the Nation, it is off the continental shelf and several miles beyond the outer boundaries of the national marine sanctuaries that exist along the Central California Coast. The location of SF-DODS was selected to avoid important fishery areas and geographically unique or otherwise sensitive habitats. In addition, it provides an environmentally superior alternative to placing dredged material at the traditional unconfined aquatic disposal sites within the Bay. As such, SF-DODS is integral to achieving the overall goals of the SF Bay LTMS.

In addition to avoiding impact to aquatic habitats via careful consideration of the best location to designate a deep ocean disposal site, the USEPA's regulations are very strict about when dredged material can be considered for disposal and the quality of any material that is allowed to be disposed of. The USEPA regulations substantially fulfill the United States' implementation of an international treaty, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, also known as the London Convention of 1972. The London Convention, the MPRSA, USEPA's ocean dumping regulations and the USEPA/USACE sediment testing requirements all ensure that dredged material that is potentially toxic, or that may cause significant bioaccumulation of contaminants into the food web, may not be disposed in ocean waters. This protection is in addition to and independent of the avoidance of potential impacts afforded by careful up-front selection of the disposal site itself.

The SF-DODS has been monitored annually since the site was formally opened for dredged material disposal and began receiving material in 1995. This disposal site receives the most intensive monitoring of any disposal site in USEPA Region IX, and it is one of the most actively and intensively monitored sites in the nation. To date, fourteen years of monitoring data have been collected for SF-DODS. The USEPA recently completed a review and synthesis of monitoring; the following discussion summarizes some of the key findings:

Each year, a suite of physical, chemical and biological parameters have been measured on and off site to assess the potential impacts of dredged material disposal operations. Additionally, broader regional biological (including fishery) monitoring has also been conducted. In particular, annual footprint mapping is performed using a sediment vertical profiling camera system and sediment samples are retrieved via boxcore for chemical and biological (infaunal community) analyses.

Footprint mapping has confirmed that significant deposits in any one year have been restricted to within the disposal site boundaries with only very limited exceptions. As expected, based on computer dispersion modeling performed for the SF-DODS EIS/EIR, the deposition of material outside the disposal site boundaries in any one year has generally been less than five centimeters, an annual deposition rate identified in the SF-DODS EIS/EIR as not likely to cause significant physical impacts to most infauna or epifauna present.

Chemical monitoring has confirmed that levels of contaminants in the dredged material actually deposited at the site are consistent with pre-disposal sampling and testing results for dredging projects disposing at SF-DODS. In other words, the pre-disposal sampling and testing programs appears to be representative of the material eventually dredged and disposed there.

Benthic biology samples of the dredged material footprint and reference (ambient) sediments have also been collected annually and archived. These samples were recently analyzed to assess any benthic community changes associated with dredged material disposal operations over the first 10 years of site use. It was determined that no long term adverse impacts have been occurring in the vicinity of the SF-DODS. Further, studies have determined that there is rapid re-colonization and re-establishment of benthic communities that are indistinguishable from other comparable benthic communities in adjacent areas containing ambient undisturbed sediments.

For the first several years of disposal operations at SF-DODS, regional monitoring of water column organisms (principally plankton and juvenile fish) was also conducted seasonally each year. The results of these surveys indicate that variations in distribution and abundance are related to large-scale, region-wide oceanographic conditions unaffected by dredged material disposal operations.

Finally, the USEPA conducted a special third year confirmatory monitoring program to more intensively address some uncertainties from the site designation SF-DODS EIS/EIR. These studies confirmed that the mid- and deep-water currents are of low velocity that would not transport suspended sediment particles great distances and that long-term bioaccumulation was not occurring via water-column exposure to suspended sediment plumes from repeated disposal events, either within the disposal site itself or nearer to the Sanctuary boundary.

In conclusion, the results of several years of intensive monitoring at SF-DODS indicate that the site has performed as predicted in the original site designation SF-DODS EIS/EIR. Actual deposition of dredged material has been consistent with the computer dispersion modeling on which the site designation was based. No significant adverse physical impacts have been identified off site, and no indication of any significant chemical or biological impacts have been found either off site or on site. Regionally, juvenile fish and plankton populations and distribution patterns have not been adversely affected by disposal operations. Additionally, recolonization of benthic communities is rather rapid. In fact, overall, the intensive, multi-year monitoring of SF-DODS has resulted in the collection of an unprecedented amount of new information about the deep ocean benthic environment that has important scientific value far beyond the disposal site management needs of SF-DODS itself.

Because of the site designation process and the extensive monitoring at SF-DODS, the USACE and USEPA believe that continued disposal of dredged material at SF-DODS will have ***no effect*** on EFH or EFH-managed species.

9.0 Conclusion

The Programmatic SF Bay LTMS EIS/EIR and subsequent Management Plan did not explicitly include EFH consultation under the MSFCMA; however, from the inception of the SF Bay LTMS, one of the central goals was to minimize impacts on fisheries and aquatic habitats. Key goals of the SF Bay LTMS include: avoid unnecessary dredging and reduce in-Bay disposal to the maximum extent practicable, both of which directly avoids and minimizes direct and indirect impacts on aquatic habitats and organisms; and beneficially use dredged material to the maximum extent feasible, which actively benefits aquatic habitat and organisms through the creation and/or restoration of tidal wetlands and subtidal habitats around the margins of the Estuary. During its first several years of implementation, the SF Bay LTMS has singularly been successful in achieving their stated goals; which has resulted in significant improvements to the quality and quantity of regional EFH, compared to pre-SF Bay LTMS dredging and dredged material disposal practices.

Most of the projects discussed in the document have been undergoing maintenance dredging for several years and in some instances, longer than 100 years. Due to the longevity of several of these projects, one could assume that maintenance dredging comprises the baseline condition of the Estuary and these areas are highly disturbed. Certainly, if maintenance dredging projects in the Estuary ceased, baseline conditions would drastically change, as would the various ecosystems within the Estuary. Table 9.1 provides a summary of the potential adverse effects (including cumulative) on EFH and EFH-managed species from continued implementation of maintenance dredging and dredged material disposal in the Estuary, the potential best management practices already implemented by the SF Bay LTMS to reduce these effects and the level of significance for each effect. Table 9.1 is followed by a discussion of how the SF Bay LTMS program was designed specifically to reduce the adverse effects of dredging and dredged material disposal on the Estuary's aquatic ecosystem as a whole and improve the San Francisco Bay area by restoring important aquatic habitat (e.g., wetland and subtidal) in the Bay area.

Table 9.1	**Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects**		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	Direct Effects		
8.1 - Direct Effects on EFH and EFH-Managed Species	• Direct removal (entrainment) of EFH and EFH-managed species during dredging.	**BMP 1.0** - Environmental Work Windows. **BMP 2.0** - Lower Hydraulic Dredge Heads. **BMP 2.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
	Water Quality		
8.2.1.3 - Potential Direct Effects of Suspended Sediment on EFH and EFH-Managed Species	***Adults and Juveniles:*** • Impair oxygen exchange rates. • Clogging and laceration of gills. • Increased coughing rates. • Avoidance of turbid areas. • Reduced spawning success. ***Eggs and Larvae:*** • Decreased gonad maturation. • Lack of adhesion of eggs to substrate. • Reduced egg viability. • Reduced hatching success. • Smothering of eggs. • Reduced larval feeding.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.1.4 - Potential Effects of Suspended Sediment on Foraging and Foraging Grounds	• Reduced ability of visual feeders to find food. • Reduced prey abundance (benthos and planktonic organisms) at dredging and	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.

Table 9.1	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	aquatic disposal sites.		
8.2.1.5 - Potential Effects of Suspended Sediment on Migration and Migratory Corridors	• Temporary blockage of safe passage to spawning grounds which cold inhibit or delay migration. • Reduction in cover/shelter during migration. • Reduced ability to feed during migration.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.1.6 - Potential Effects of Suspended Sediment on Spawning and Spawning Grounds	• Reduced egg survival (discussed in impact 8.2.1.3). • Reduce spawning success. • Reduce the quality and/or quantity of spawning ground within the Estuary and dredged tributaries.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.1.7 - Potential Effects of Suspended Sediment on Nursery Habitat of EFH-Managed Species	• Reduce the quality and/or quantity of nursery habitat critical for spawning success.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.2.3 - Potential Effects of Releasing Constituents of Concern on EFH-Managed Species	• Constituents of concern can become bioavailable and directly absorbed by EFH-managed species leading to direct mortality, reduced fitness, reduced fecundity and/or bioaccumulation. • Reduce the quality and/or quantity of	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.

Table 9.1	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	prey (e.g., phytoplankton, zooplankton, benthic organisms and other fish prey).		
8.2.3 - Decreased Dissolved Oxygen	• Exposure of anoxic sediments (which contain oxygen-demanding substances) could temporarily reduce dissolved oxygen levels in dredged and dredged material disposal sites. • Reduced dissolved oxygen has the potential to reduce the fitness of EFH-managed species (should dissolved oxygen levels fall below 5.0 mg/l).	**BMP 3.0 -** Reduce in-Bay Disposal. **BMP 4.0 -** Limit Overflow Dredging.	May affect, but not likely to substantially affect.
8.2.4 - Saltwater Intrusion	• Because the projects managed under the SF Bay LTMS are maintenance dredging projects, saltwater intrusion is not expected to occur with continued implementation of the SF Bay LTMS and maintenance dredging of the projects managed by the LTMS.	No BMPs or MMs proposed.	May affect, but not likely to substantially affect.
8.2.5 - Potential Effects on pH	• Continued implementation of the SF Bay LTMS and maintenance dredging of the projects managed by the LTMS are not expected to affect pH.	No BMPs or MMs proposed.	May affect, but not likely to substantially affect.
8.4.6 - Un-Ionized Ammonia Disturbance	• Continued implementation of the SF Bay LTMS and maintenance dredging of the projects managed by the LTMS	No BMPs or MMs proposed.	May affect, but not likely to substantially affect.

Table 9.1	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	are not expected to affect pH.		
8.4.7 - Potential Cumulative Effects on Water Quality	• Dredging and aquatic dredged material disposal activities are known to temporarily degrade water quality and, generally, these impacts subside once the dredging activities cease. However, the purpose of the SF Bay LTMS is to manage dredging and dredged material disposal activities within the Estuary in such a way to minimize the potential adverse effects on water quality and aquatic resources. Further, BMPs already implemented by the SF Bay LTMS help protect water quality from the adverse effects of dredging and aquatic dredged material disposal.	No BMPs or MMs proposed.	Beneficial
Sediments			
8.3.1 - Potential Effects on Sediment Dynamics (Circulation, Currents and Bathymetry)	• Dredging and dredged material disposal can alter the bathymetry of the Estuary's floor in the immediate surrounding of dredging and dredged material disposal activities. Dredging can affect bathymetry by deepening areas of the Estuary and disposal can	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal. **BMP 4.0** - Limit Overflow Dredging.	May affect, but not likely to substantially affect.

Table 9.1	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	cause temporary mounding at in-Bay disposal sites (in-Bay disposal sites are managed to be dispersive; thus, any mounding is expected to be temporary). • Alterations to bathymetry can alter benthic communities and, therefore, EFH-managed species prey.		
8.3.2 - Potential for Accumulation of Constituents of Concern	• Disposal of dredged sediment has the potential to accumulate constituents of concern at in-Bay dredged material disposal sites. However, all in-Bay disposal sites are managed to be fully dispersive; therefore, it is unlikely that accumulation would occur. • Constituents of concern are often bound tightly to sediment particles and do not easily become dissociated and bioavailable.	**BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.3.3 - Potential for Cumulative Effects on Sediments	• Cumulative changes in bathymetry could alter benthic habitat and species composition. • Continued reduction in in-Bay disposal could result in small-scale changes in sediment cycling and possible erosion over time.	No BMPs or MMs proposed.	May affect, but not likely to substantially affect.

Table 9.1	**Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects**		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	Biological Resources		
8.4.1 - Potential Effects on Phytoplankton and Zooplankton	• Dredging and dredged material sediment plumes can alter habitat in which phytoplankton and zooplankton grow. • Increased turbidity could reduce light penetration required for phytoplankton and zooplankton photosynthesis.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.4.2 - Potential Effects on Benthos	• Direct removal of benthic habitat and organisms during dredging. • Burial of benthic habitat and organisms during dredged material disposal. • Increased suspended sediment concentrations could adversely affect benthic organisms. • Reduced fitness due to potential release of constituents of concern.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.4.3 - Potential Effects on Eelgrass Bed Habitat	• Direct removal of eelgrass beds during dredging. • Siltation of eelgrass beds during dredging and dredged material disposal.	**BMP 1.0** - Environmental Work Windows.	May affect, but not likely to substantially affect.
8.4.4 - Potential Effects on	• Effects related to increased suspended	No BMPs or MMs proposed.	May affect, but not

Table 9.1	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
Oyster Bed Habitat	sediment, including: reduced ability to filter feed, clogging of gills, inability of eggs to adhere to substances and increased tissue concentrations of constituents of concern. Most of these potential effects would occur in the South Bay.		likely to substantially affect.
8.4.5 - Removal of EFH-Managed Species Resting and Foraging Habitat	• Dredging can directly remove foraging habitat and prey species. • Aquatic dredged material disposal could bury foraging habitat. • Dredging and dredged material disposal could reduce the fitness of prey species. • Increased suspended sediment generated by dredging activities could reduce the ability of visual feeders to locate prey.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.4.6.1 - Potential Cumulative Effects on Benthos	• Repeated removal of recolonized benthic communities resulting from repeated maintenance dredging episodes. • Repeated burial of recolonized benthic communities resulting from repeated in-Bay dredged material disposal activities.	**BMP 1.0** - Environmental Work Windows. **BMP 3.0** - Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.

Table 9.1	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	• Additional deepening projects and/or designation of another in-Bay disposal site could exacerbate these effects.		
8.4.6.2 - Potential Cumulative Effects on Eelgrass Bed Habitat	• During the life of the LTMS, eelgrass beds could be further degraded because several dredging projects exist along the periphery of the Estuary in close proximity to eelgrass meadows; however, current regulations mitigation of eelgrass removal. • Dredging and in-Bay disposal of maintenance dredged material can increase suspended sediment loads causing siltation of eelgrass beds and reducing light penetration in the water column. • Maintenance and new work dredging projects, as well as other projects that shade or fill the shallow margins of the Estuary could cumulatively affect eelgrass bed habitat or hamper eelgrass bed growth. It is expected that these effects would be exacerbated by new work dredging projects.	Mitigation measures on new work dredging projects should occur on a case-by-case basis during project-specific EFH consultations.	May affect, but not likely to substantially affect.

Table 9.1	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
8.4.6.3 - Potential Cumulative Effects of Bioaccumulation of Constituents of Concern	• Over time, disposal of dredged material has the potential to bioaccumulate constituents of concern up the food chain. However, rigorous screening and monitoring is required prior to dredging and dredged material disposal.	**BMP 3.0 -** Reduce in-Bay Disposal.	May affect, but not likely to substantially affect.
8.4.6.4 - Potential Indirect Effects Related to Invasive Species	• Deep-draft ocean-going vessels are known to transport invasive species between aquatic environments, generally in ballast waters. California law mandates that ballast water be exchanged outside the EEZ to flush potential invasive organisms. • This SF Bay LTMS EFH Assessment is for maintenance dredging projects only. Maintenance dredging disturbs areas that are continually disturbed due to maintenance dredging and vessel traffic.	No BMPs or MMs proposed.	May affect, but not likely to substantially affect.
8.5 - Potential Effects of Dredged Material Disposal on Aquatic Resources at SF-DODS	• Although EFH consultation was not conducted as part of the designation process for SF-DODS, the USEPA's site designation process and regulations (promulgated under the	No BMPs or MMs proposed.	No effect.

Table 9.1	Overview of Potential Effects on EFH and EFH Managed Species from Continued Implementation of the SF Bay LTMS Dredging Projects		
Impact	**Description**	**Mitigation Measures (MM)/ Best Management Practices (BMP)**	**Significance (with MM or BMPs)**
	MPRSA and NEPA) independently require evaluation of a variety of factors that minimize the potential effects of disposal on EFH.		

Prior to implementation of the SF Bay LTMS, an average of 6.0 million cubic yards of material dredged from the Estuary was placed back in Estuary at four in-Bay disposal sites. The SF Bay LTMS was created as a response to public concerns and perception that open water disposal of dredged material was having an adverse effect on the Estuary's sensitive ecosystem. These perceptions were fueled by several factors: dredging and dredged material disposal were occurring without any particular attention to avoiding sensitive life stages of fish and wildlife; testing requirements for dredged material was minimal, which resulted in potentially contaminated material being disposed of in the Estuary; mounding of disposed sediment occurred at the Alcatraz disposal site (SF-11); and high-turbidity overflow from hydraulic dredging equipment was allowed to occur in the Estuary without restriction.

Since the SF Bay LTMS Management Plan was implemented in 2001, allowable in-Bay disposal has significantly decreased: from pre-LTMS quantities of over 6.0 million cubic yards per year to current quantities of less than 2.0 million cubic yards per year. Additionally, reductions will automatically occur in 2010 and 2013, until the final in-Bay disposal limit of 1.25 million cubic yards per year is reached. The reduction of in-Bay disposal to date is remarkable; but, even more important is the SF Bay LTMS goal to increase beneficial use of dredged material. Beneficial use of dredged material has been a success in restoring several important wetland ecosystems surrounding the Estuary, including Sonoma Baylands, Montezuma Wetlands, and the ongoing Hamilton Wetlands Restoration Project. These three projects alone total approximately 3,000 acres of restored and enhanced habitat that benefits all fish and wildlife species that depend on the Estuary. Further, these restoration sites provide a dredged material beneficial use capacity of approximately 27.5 million cubic yards. Other smaller beneficial use projects are currently being constructed and the SF Bay LTMS continues to look for beneficial use opportunities.

At times, beneficial use is not possible. When this occurs, rather than being disposed of in the Estuary, some dredged material is diverted to the environmentally superior SF-DODS site. Since the 1995 designation of SF-DODS as a deep open ocean aquatic disposal site, approximately 15 million cubic yards of dredged material has been disposed there. This has significantly reduced and eliminated some of the effects of aquatic dredged material disposal on the Estuary's water and sediment quality, as well as direct effects (e.g., burial, abrasion, adhesion of particles to eggs) and indirect effects (e.g., ingestion of constituents of concern, bioaccumulation, reduced fitness) of disposal and subsequent increases in suspended sediment concentrations on aquatic organisms. Moreover, extensive annual monitoring at SF-DODS has indicated that disposal activities do not significantly impact aquatic habitats.

Although there are adverse impacts associated with dredging and dredged material disposal, as presented in Section 8.0 and summarized in Table 9.1, it is clear that the SF Bay LTMS has brought about major improvements in the management of dredging and dredged material disposal in the San Francisco Bay area. As mentioned, these improvements have directly benefited EFH and EFH-managed species, as well as the overall ecosystem of the Estuary. Not only is the SF Bay LTMS directly responsible for improving the management of dredging and dredged material disposal; they are responsible for several other accomplishments that directly and indirectly benefit EFH, EFH-managed species and the Estuary, including:

- Expansion of the Hamilton Wetlands Restoration Project with the Bel Marin Keys "Unit V" property will increase established tidal wetlands restoration capacity to approximately 5,000 acres and 45 million cubic yards of dredged material.
- An Aquatic Transfer Facility is being considered (the Draft Supplement EIS/EIR was released in October 2008) that would allow a much greater percentage of dredged material, from both large and small dredging projects, to be beneficially used at the Hamilton site than would be possible with an hydraulic offloader alone.
- Subtidal aquatic habitat was enhanced in Oakland Middle Harbor through beneficial use of approximately 6 million cubic yards of dredged material.
- The Montezuma Project can accept some contaminated dredged material for capping and, therefore, removes some constituents of concern from the Estuary while also restoring habitat.
- A variety of other small or private beneficial use projects have occurred in the last several years.
- Environmental work windows for dredging and dredged material disposal activities were established to reduce the potential adverse effects on sensitive species. With assistance from NOAA-Fisheries, USFWS and California Department of Fish and Game, advanced planning has significantly reduced the amount of dredging conducted outside of the environmental work windows. In 2008, the inter-agency advanced planning resulted in only 10 percent of all Bay area dredging being conducted outside the environmental work windows.
- Environmental work windows continue to be refined through SF Bay LTMS funded studies, such as the *Juvenile Salmonid Outmigration and Distribution Study in the San Francisco Bay*.
- The SF Bay LTMS has an ongoing program to fund studies that will help increase scientific knowledge about the potential impacts of dredging and dredged material placement. This knowledge will help support regulatory guidance for dredging projects in the Estuary. To date, the SF Bay LTMS has provided over $7 million in funding to support a number of studies, including the following (other studies are ongoing and not yet published):

    - *Assessment of Sediment Resuspension by Vessel Traffic at Richmond Longwharf/Characterization of Sediment Plumes during Knockdown Operations at Redwood City* (February 2005);
    - *Characterization of Suspended Sediment Plumes Associated with Knockdown Operations at Redwood City, CA* (October 2005);
    - *Framework for Assessment of Potential Effects of Dredging on Sensitive Fish Species in San Francisco Bay*; *Mercury Concentrations Bordering the Hamilton Airfield Remediation Site* (October 2002 and September 2003);
    - *Mercury Cycle Studies Associated with the Hamilton Wetland Restoration Project*; *Pre-construction Biogeochemical Analysis of Mercury in Wetlands*

Bordering the Hamilton Airfield Wetlands Restoration Site – Interim Report (September 2005);

- *A Review of Scientific Information on the Effects of Suspended Sediment on Pacific Herring (Clupea pallasie) Reproductive Success – Final Report* (April 2005);
- *Spatial Characterizations of Suspended Sediment Plumes during Dredging Operations through Acoustic Monitoring* (January 2004);
- *White Paper – Potential Impacts of Dredging on Pacific Herring in San Francisco Bay* (May 2005).

Through implementation of the SF Bay LTMS program, the risks to and effects on EFH and EFH-managed species resulting from dredging and dredged material disposal have been significantly reduced. In addition, substantial aquatic habitat restoration and enhancement has occurred throughout the Estuary. Over the life of the SF-Bay LTMS, reducing in-Bay disposal has the potential to improve the Estuary's overall water quality and benthic communities within and around dredging and disposal sites. Furthermore, utilizing dredged material for beneficial use projects has the potential to improve water quality as wetlands constructed or restored around the Estuary and its tributaries would filter pollutants out of the water. Based on the information provided in this document, the SF Bay LTMS agencies believe that the overall benefits of the program to EFH and EFH-manages species far outweigh the potential adverse effects of pre-SF Bay LTMS maintenance dredging and disposal activities, and that these benefits will continue over the coming years.

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Appendix A:

Federal O&M Dredging Locations

Appendix A: Federally-Authorized Dredging Projects within the San Francisco Estuary

San Francisco Harbor

The San Francisco Harbor is located within the Central Bay of San Francisco Bay, in San Francisco County. The Mainship Channel is located five miles west of the Golden Gate Bridge and extends across the arc-shaped, submerged San Francisco Bar in the Gulf of the Farallones. This project was authorized by the Rivers and Harbors Acts of 1927, 1930, 1935, 1965, and 1968. The initial project was placed into operation in 1931; the existing project has operated since 1975.

Navigation Channels within the San Francisco Harbor include the Bar Channel, Islais Creek Shoal, Presidio Shoal, Black Point Shoal, and Alcatraz Shoal, Point Knox Shoal, and the International Airport and Turning Basin (which is currently inactive and has not been dredged since FY 1962). The Bar Channel, measuring approximately 16,000 feet long, 2,000 feet wide, with an authorized depth of -55 MLLW (-57), provides an entrance from the Pacific Ocean to the San Francisco Bay. All deep draft vessels entering the San Francisco Bay must use the Bar Channel to reach the Bay's ports (see Figure 1.0).

Islais Creek Shoal, located just east of Islais Creek in San Francisco California, is 2,000 feet long, 500 feet wide, with an authorized depth of -40 feet MLLW (-42). Presidio Shoal, located just north of the Presidio in San Francisco, Black Point Shoal, located just northeast of the San Francisco Peninsula, and Alcatraz Shoal, located east of Alcatraz Island, vary in length and have an authorized depth of -40 feet MLLW (-42). Point Knox Shoal, located south east of Angel Island, also has a varying length and width; however, the authorized depth is -35 feet MLLW (-37). The inactive International Airport and Turning Basin is approximately 200 to 750 to 2,000 feet long with an authorized depth of -10 feet MLLW (-12

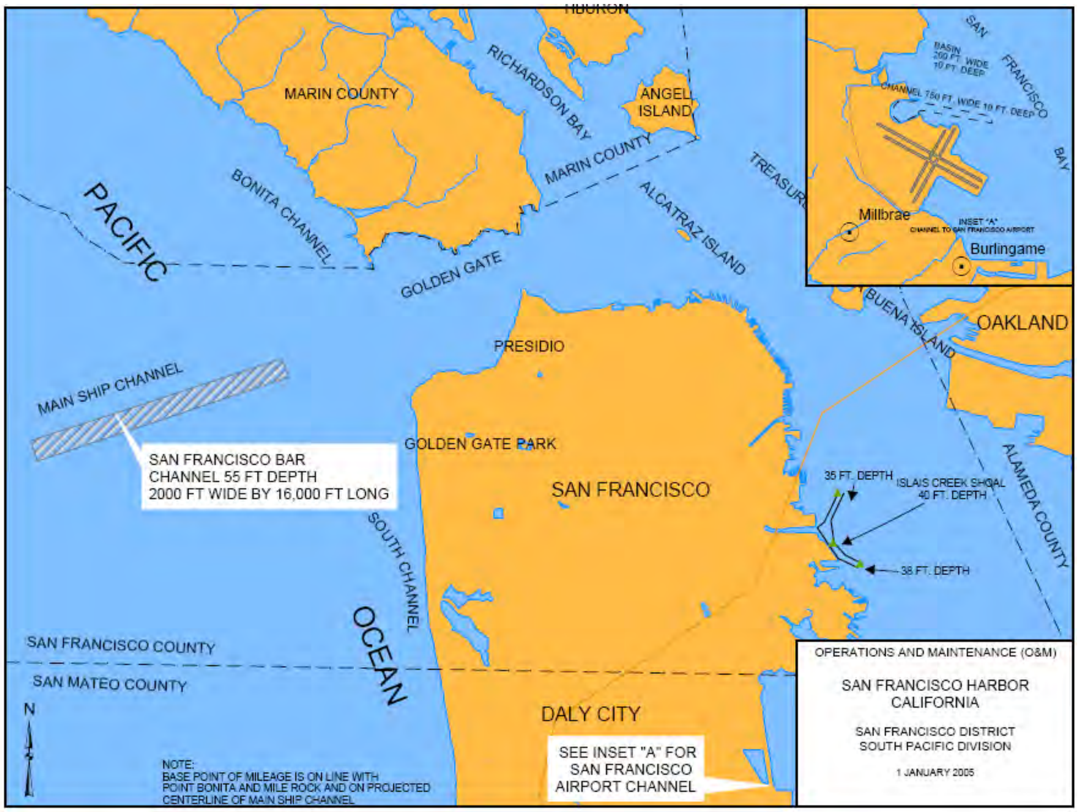
The Bar and Entrance and Mainship Channels are dredged annually by the government hopper dredge, *Essayons*. Historically, disposal of dredged material occurred at SF-8 (San Francisco Bar Channel Disposal Site); during the past two dredging episodes, near-shore disposal has occurred at Ocean Beach, San Francisco for beneficial beach nourishment. Islais Creek Shoal, Presidio Shoal, Black Point Shoal, and Alcatraz Shoal, Point Knox Shoal are infrequently dredged.

Historically areas surrounding Rock Pinnacles, Blossom Rock, and Rincon Reef Rock (all dredged to -40 feet MLLW); as well as Arch Rock, Harding Rock, and Shag Rocks 1 and 2 (all dredged to -35 feet MLLW) were also maintenance dredged as part of the project; however, dredging of these areas was indefinitely deferred and it is highly improbable that dredging will occur again.

The USACE hopper dredge, *Essayons*, is expected to dredge approximately 500,000 cubic yards of material from the San Francisco Harbor annually. Disposal of material dredged from the San Francisco Harbor provides for beach nourishment at Ocean Beach, San Francisco, additional material is generally disposed of at SF-8 disposal site.

The San Francisco Harbor navigation channels provide the only deep water access for the entire San Francisco Bay Area. The channels are considered high-use, deep draft commercial navigation channels vital for Department of Defense facilities and all in-bay ports and considered extremely vital for waterborne commerce and National Security. The project is essential to the local, regional, state, and National economies.

Figure 1.0 San Francisco Harbor Navigation Channels



Napa River

The Napa River Channel is located just north east of the entrance to Carquinez Strait, Solano County, California. The Napa River Cannel was authorized by the Rivers and Harbors Act of 1935 (initially operational in 1937) and 1946 (existing project operational in 1952).

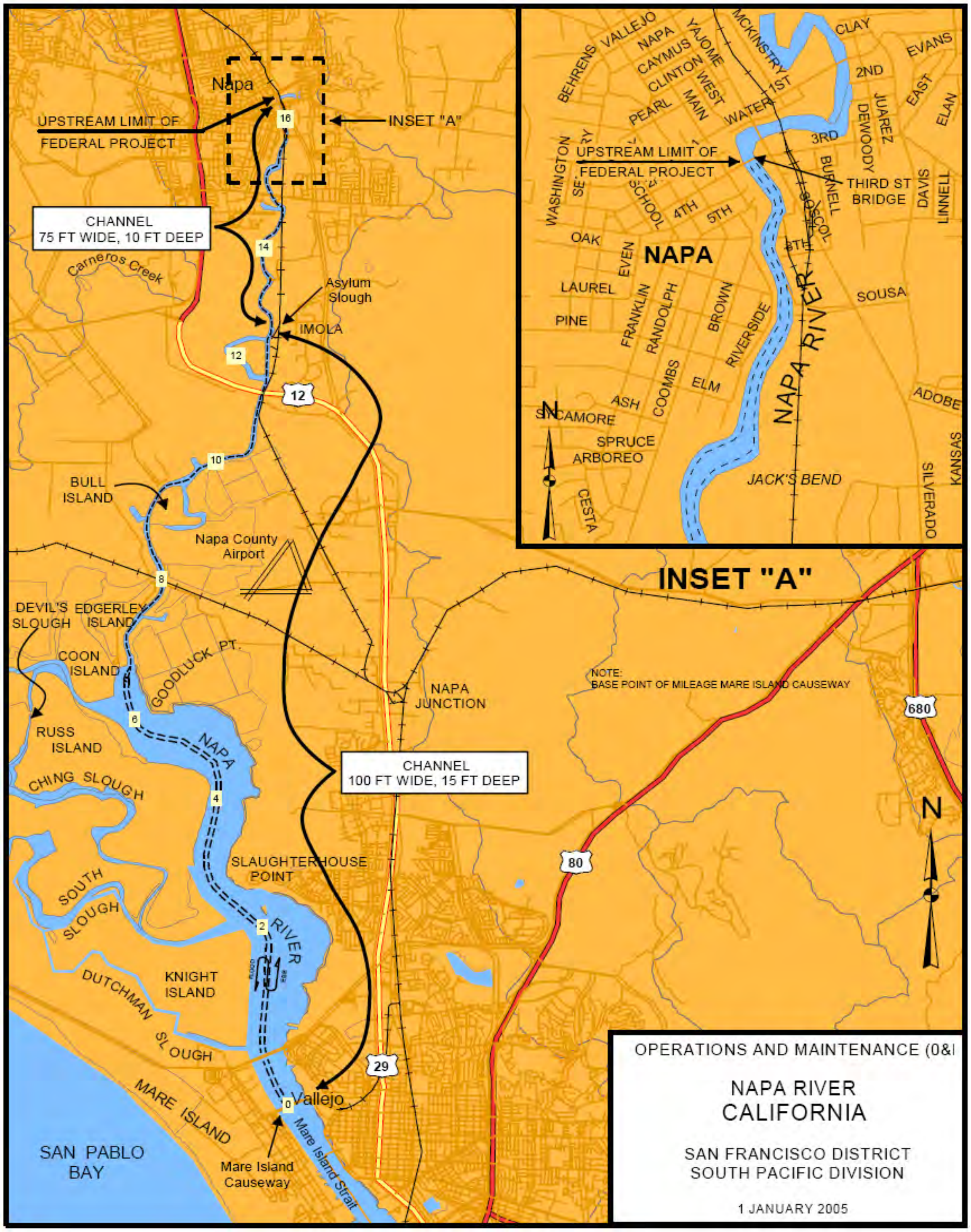
The Napa River Channel is approximately 16 miles long, 100 feet wide, with an authorized depth -15 feet MLLW (-17) from Mare Island Straight Causeway to Asylum Slough and 75 feet wide with an authorized depth of -10 feet MLLW (-12) from Asylum Slough to the head of navigation at the Third Street Bridge in Napa, California (see Figure 2.0). Maintenance dredging is contracted out to the private sector and, generally, a clamshell or a pipeline dredge is utilized. Upland disposal sites are provided by the local sponsor, Napa County Flood Control and Water Conservation District.

Confirmation of site conditions, structural integrity, and available capacity will be confirmed prior to dredging activities.

The channel is on a six-year dredging cycle. The last recorded dredging episode was November 1997. Napa River's Channel is currently overdue for maintenance dredging. Future dredging will be dependant on availability of congressionally approved funding allowance.

The Napa River Channel provides low-usage access for shallow-draft commercial barges transporting diversified commodities and projects and for safe navigation of recreation and fishing vessels. In addition, the upper portion of the navigation channel is part of a critical USACE flood damage reduction project.

Figure 2.0 Napa River Channel



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Petaluma River Channel

The Petaluma River navigation channel was authorized under the Rivers and Harbors Act of 1880 and 1930. The channel was initially placed into operation in 1916 and the existing project became operational in 1933.

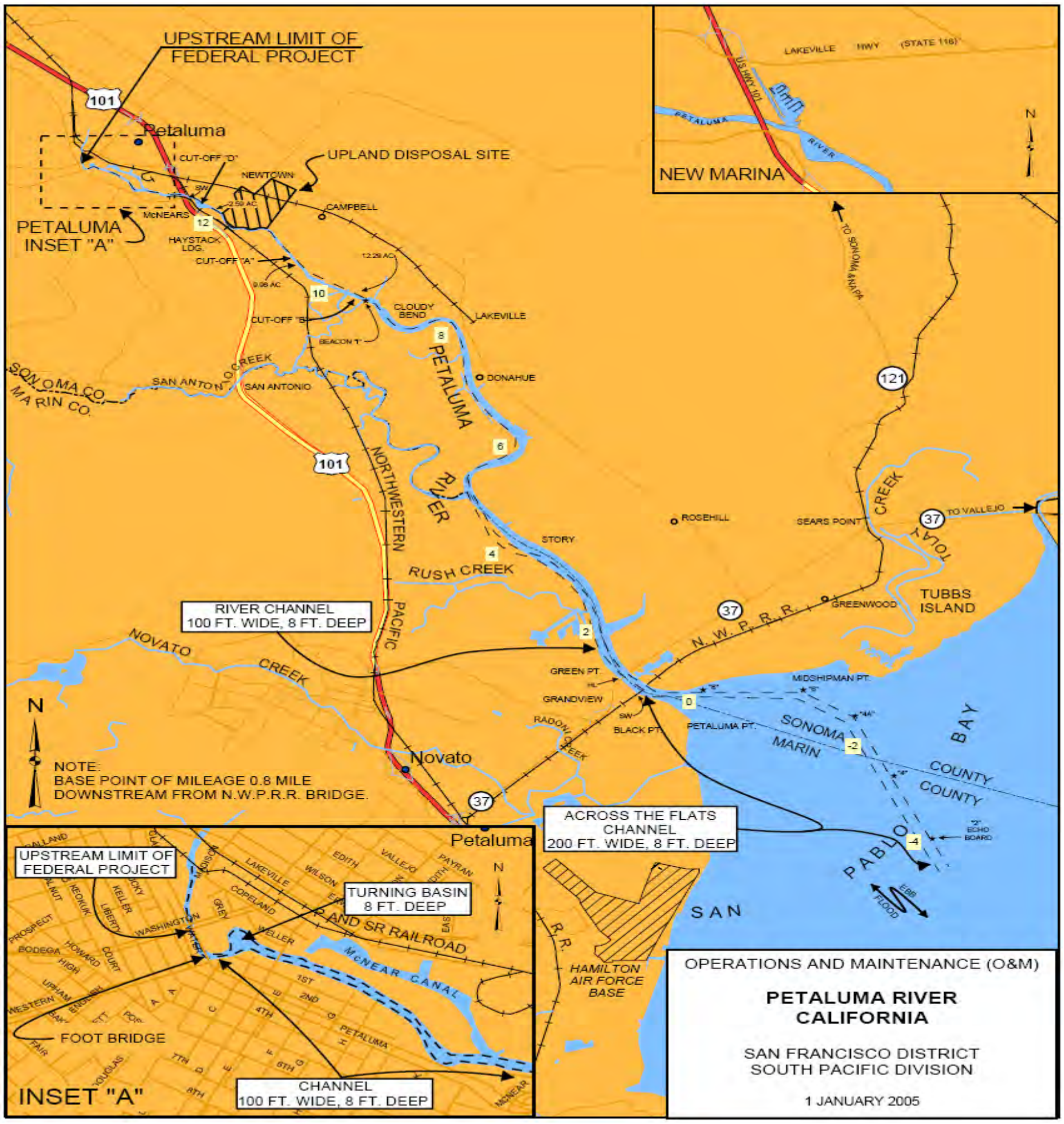
The Petaluma River Channel is comprised of two channels: Across the Flats (ATF) of San Pablo Bay (providing access to the upper River Channel) and the River Channel (see figure 6.5). ATF is approximately 25,500 feet long, 200 feet wide, with an authorized depth of -8 feet MLLW (-10) that terminates at the mouth of the Petaluma River (See Figure 3.0). Historically, disposal of dredged material from this channel occurred at SF-10 (San Pablo Bay); in support of the SF Bay LTMS, future disposal of dredged material from this channel is expected to be utilized for beneficial reuse for wetlands creation in conjunction with the Hamilton Airfield restoration effort. Maintenance dredging is generally conducted by private sector clamshell, pipeline, or small hopper dredge.

The River Channel extends from the mouth of the Petaluma River to Western Avenue (Petaluma, California) for approximately 77,000 feet with a width of 100 feet wide and a depth of -8 feet MLLW (-10) (includes a turning basin that spans 300 to 400 feet wide); the River Channel continues from Western Avenue to Washington Street for 1,700 feet. This Channel is approximately 50 feet wide with a project depth of -4 feet MLLW (-6), which is no longer maintained. Disposal of dredged material from the upper portion of the Petaluma River Channel occurs at an approved, sponsor-provided upland site. Confirmation of the site conditions, structural integrity, and capacity will be confirmed prior to the commencement of dredging activities. Dredging is predominately conducted by private sector clamshell or pipeline dredge.

The ATF section of the channel is dredged every three years and was last dredged in FY 1998; the River Channel is maintenance dredged every four years. Future dredging will be dependant on availability of congressionally approved work allowance funding. Currently, both channels are overdue for maintenance dredging.

The Petaluma River federal navigation channels provide low-usage access for shallow-draft commercial barges transporting diversified commodities and products and for the safe passage of recreational and fishing vessels.

Figure 3.0 Petaluma River Channel



San Rafael Creek

The San Rafael Creek navigation project was authorized under the Rivers and Harbors Act of 1919. The initial and existing project was operational in 1928.

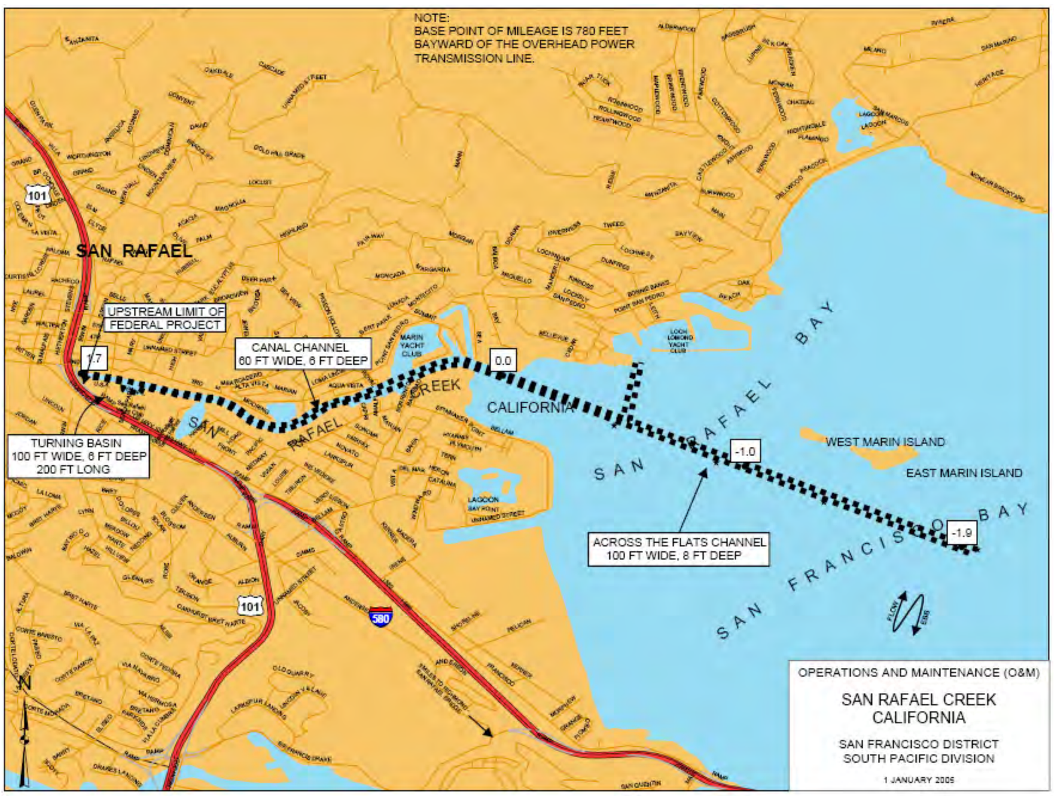
San Rafael Creek is located north of San Francisco Bay in Marin County, California. This Federal navigation project includes: the Across the Flats Channel, which is 10,000 feet long, 60 feet wide, with an authorized depth of -8 feet MLLW (-10). The channel continues up the San Rafael Creek as the Inner Canal Channel, measuring 8,900 feet long, 60 feet wide, with an authorized depth of -6 feet MLLW (-8). The channel terminates at a Turning Basin which measures 200 feet long, 100 feet wide, with an authorized depth of -6 feet MLLW (-8) (see Figure 4.0).

The Across the Flats Channel is dredged every seven years and was last dredged in FY 1995; the Inner Canal Channel and the Turning Basin are dredged every four years and were last dredged in FY 2003. Historically, dredged material from these channels was disposed of at SF-11 (Alcatraz) disposal site.

Disposal of material dredged from the Inner Canal Channel occurs at SF-11. Maintenance dredging is conducted by private sector clamshell dredges. Disposal of dredged material from the Across the Flats portion of San Rafael Creek also occurs at SF-11. Maintenance dredging is conducted by either a private sector clamshell dredge or small hopper dredge.

The San Rafael Creek federal navigation project provides low-use access for shallow-draft commercial barges transporting diversified commodities and products and for safe passage of recreational vessels. In addition, it supports waterborne operations for police, fire, flood, and search and rescue.

Figure 4.0 San Rafael Creek Channel



<u>Pinole Shoal/Mare Island Strait</u>

The Pinole Shoal and Mare Island Strait Channels are located in the southern San Pablo Bay, Contra Costa County, California. The Pinole Shoal and Mare Island Strait Channels were authorized under the Rivers and Harbors Acts of 1902, 1911, 1917, 1938, 1945, 1965, 1968, and Section 117. The project was initially operational in 1917 and the existing project in 1982.

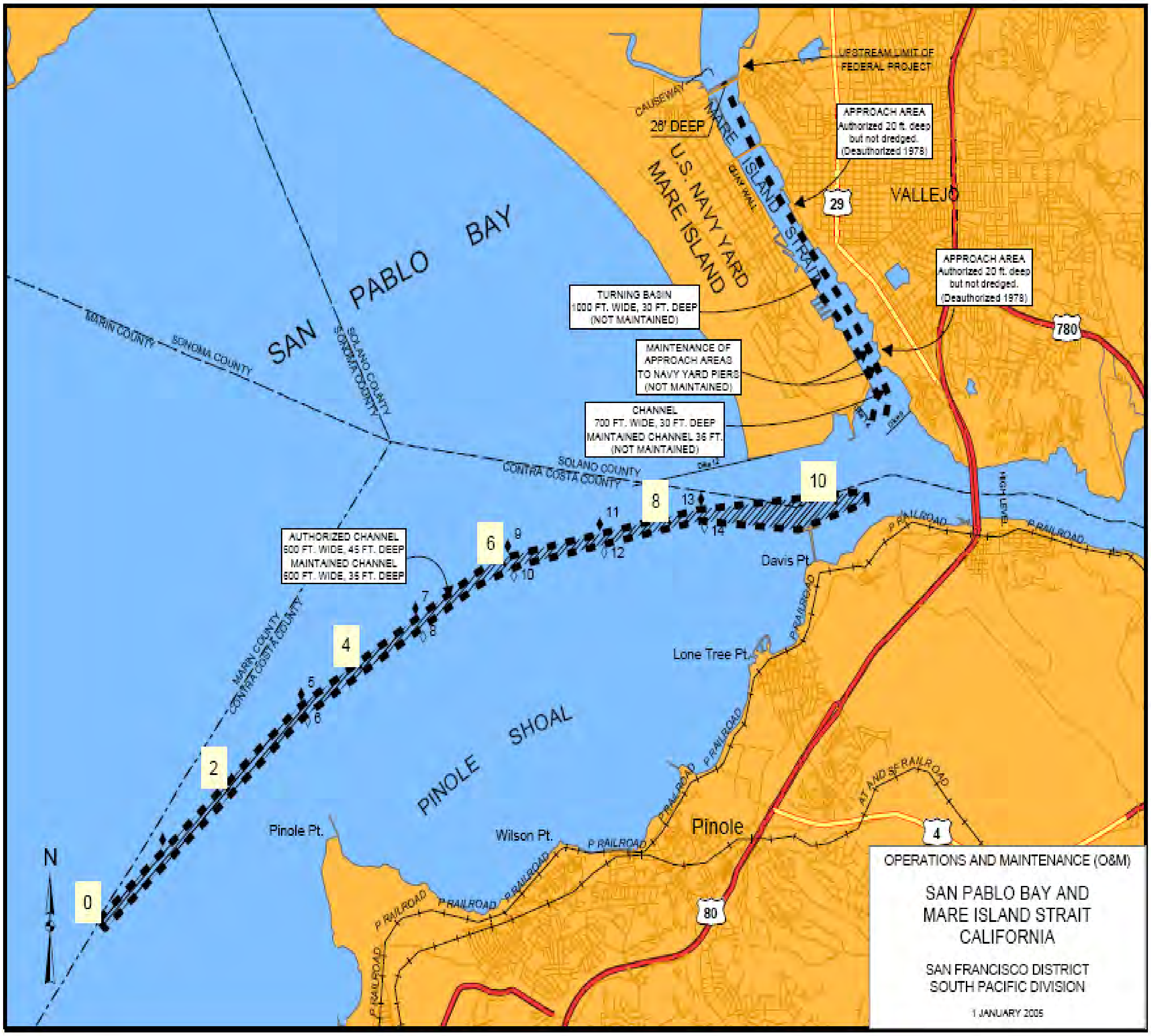
The project is comprised of two channels, the Pinole Shoal and Mare Island Strait Channels (see Figure 5.0). The Pinole Shoal Channel is approximately 11 miles long (58,000 feet), 600 feet wide, with an authorized depth of -35 feet MLLW (-37). The channel is located in San Pablo Bay, traverses the Pinole Shoal, and includes a turning basin adjacent to the Oleum Pier at the mouth of the Carquinez Strait. Historically, disposal of dredged material from this channel occurred at the SF-10 in-Bay aquatic disposal site.

The Mare Island Strait Channel, located between Mare Island and the City of Vallejo, is 17,000 feet long, 600 feet wide, flaring to approximately 1,000 feet wide from the former dike number six to within 75 feet south of the causeway between Mare Island and the City of Vallejo, with an authorized depth of -30 feet MLLW (-32). Historically, disposal of dredged material occurred at the SF-9 in-Bay disposal site. Currently, SF-9 remains the only viable site for disposal of dredged material; unless Hamilton Wetland Restoration Project or another beneficial reuse site becomes available.

Pinole Shoal Channel is on a two-year dredging cycle and was last dredged in FY 2005. Mare Island Strait is dredged rather infrequently and was last dredged in FY 1994. Currently, maintenance dredging of Mare Island Strait is deferred indefinitely since the closure of the United States Naval Shipyard; however, the project has congressional interest and may be revived.

The Pinole Shoal Channel provides safe deep-draft commercial and military navigation to critical oil refineries, the Concord Naval Weapons Station, and the ports of Sacramento and Stockton. It is considered a high-use deep water channel essential to National security, waterborne commerce, and regional and statewide economics. When in use, the Mare Island Strait supports commercial shipyard and scrap metal recycling facilities and provides the only waterway access to the Napa River.

Figure 5.0 Pinole Shoal/Mare Island Strait Channels



Suisun Bay Channel

Suisun Bay's navigation channels were authorized under the Rivers and Harbors Acts of 1927, 1930, 1935, and 1960. The portion of the Main Channel between Martinez and Avon was deepened to -35 feet MLLW under Section 107 of the Rivers and Harbors Act of 1960 and the portion of the channel between Avon and New York Slough was deepened to -35 feet MLLW under San Francisco Bay to Stockton Ship Channel.

The Suisun Bay Channel traverses Suisun Bay from the Carquinez Strait in Martinez to Pittsburg approximately 30 miles northeast of the City of San Francisco (part of the San Francisco Bay to Stockton Ship Channel). The channel then veers south east and continues as the New York Slough Channel, where the USACE, San Francisco District's jurisdiction ends; from this point on, the Sacramento District is responsible for maintenance dredging from the end of the New York Slough eastward to Antioch and on to Stockton.

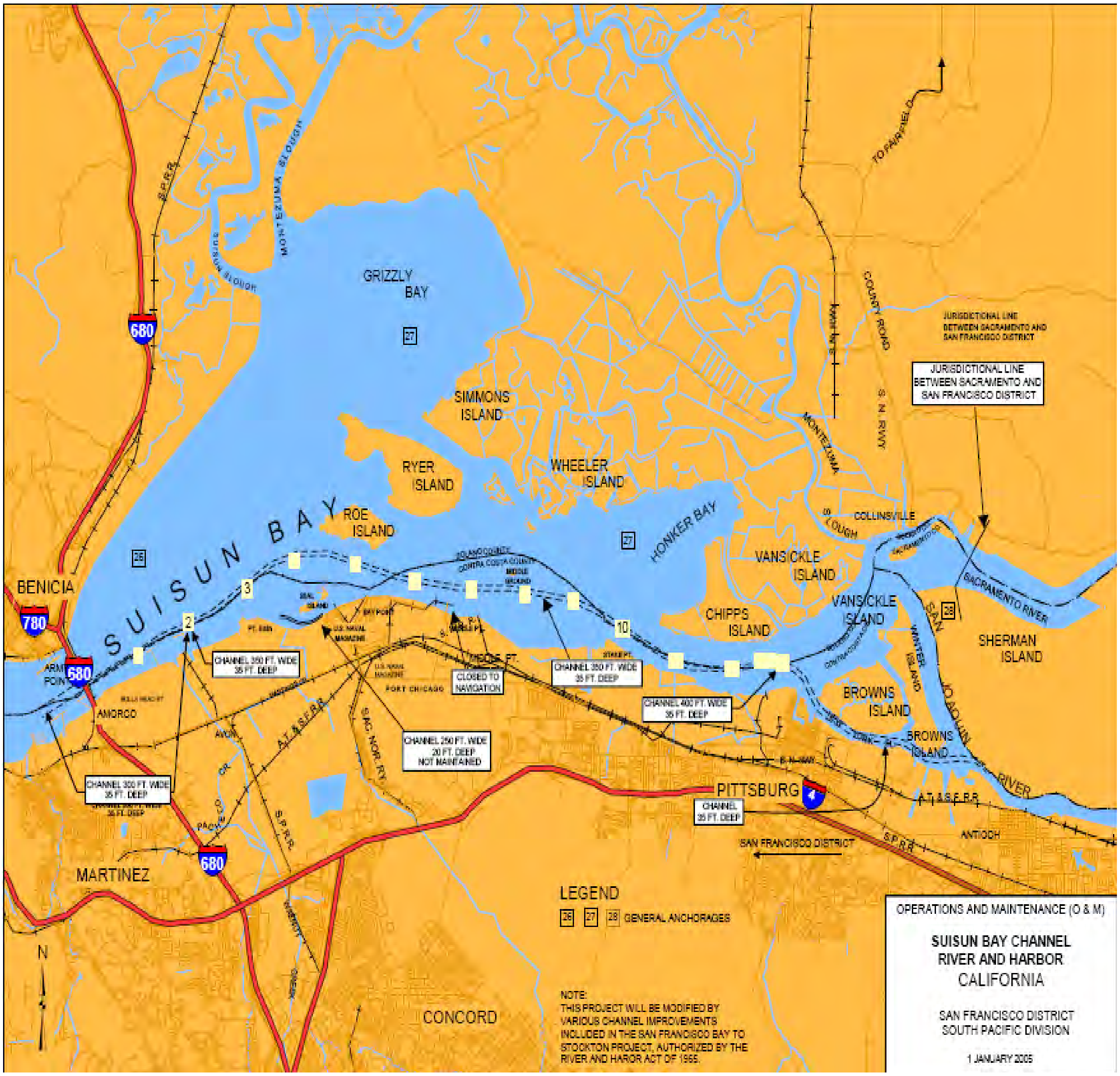
The length of the Suisun Bay and New York Slough Channels is approximately 17 miles long and 300 feet wide with an authorized depth of -35 feet MLLW (-37). The South Seal Island Channel, located along the coastline of Suisun Bay between the Main Channel at Point Edith and to the Main Channel at Chicago Point (mile 6), is approximately 5,600 feet long, 250 feet wide, with an authorized depth of -20 feet MLLW (-22) (see Figure 6.0).

The Main Channel is dredged annually and the New York Slough Channel is dredged on a four-year cycle (last dredged in FY 2005). Maintenance dredging of the South Seal Island Channel is deferred indefinitely and was last dredged in FY 1972. Without adequate dredging of the Main Channel and the New York Slough Channels, oil tankers may run aground, potentially causing regional economic and ecological damage.

Maintenance dredging is conducted by either a private sector clamshell dredge or a government or private sector hopper dredging. In the case a clamshell dredge is utilized, disposal may occur at an upland disposal site; if a hopper dredge is used, disposal generally occurs at SF-16 (Suisun Bay Disposal Site); unless beneficial reuse sties are identified in the Delta Long Term Management Strategy.

The Suisun Bay federal navigation project provides safe deep-draft navigation for military and commercial traffic of foreign and domestic merchant vessels serving major industries, oil refineries, Department of Defense facilities, and the deep water ports of Sacramento and Stockton.

Figure 6.0 Suisun Bay Channel



Suisun Slough Channel

The Suisun Bay Channels are located in Suisun Bay, approximately 30 miles northeast of San Francisco, in the Counties of Contra Costa and Solano, California. The Suisun Slough Channel was authorized by the Rivers and Harbors Acts of 1910, 1913, and 1937. The project was initially placed into operation in 1929 and the existing project has operated since 1947.

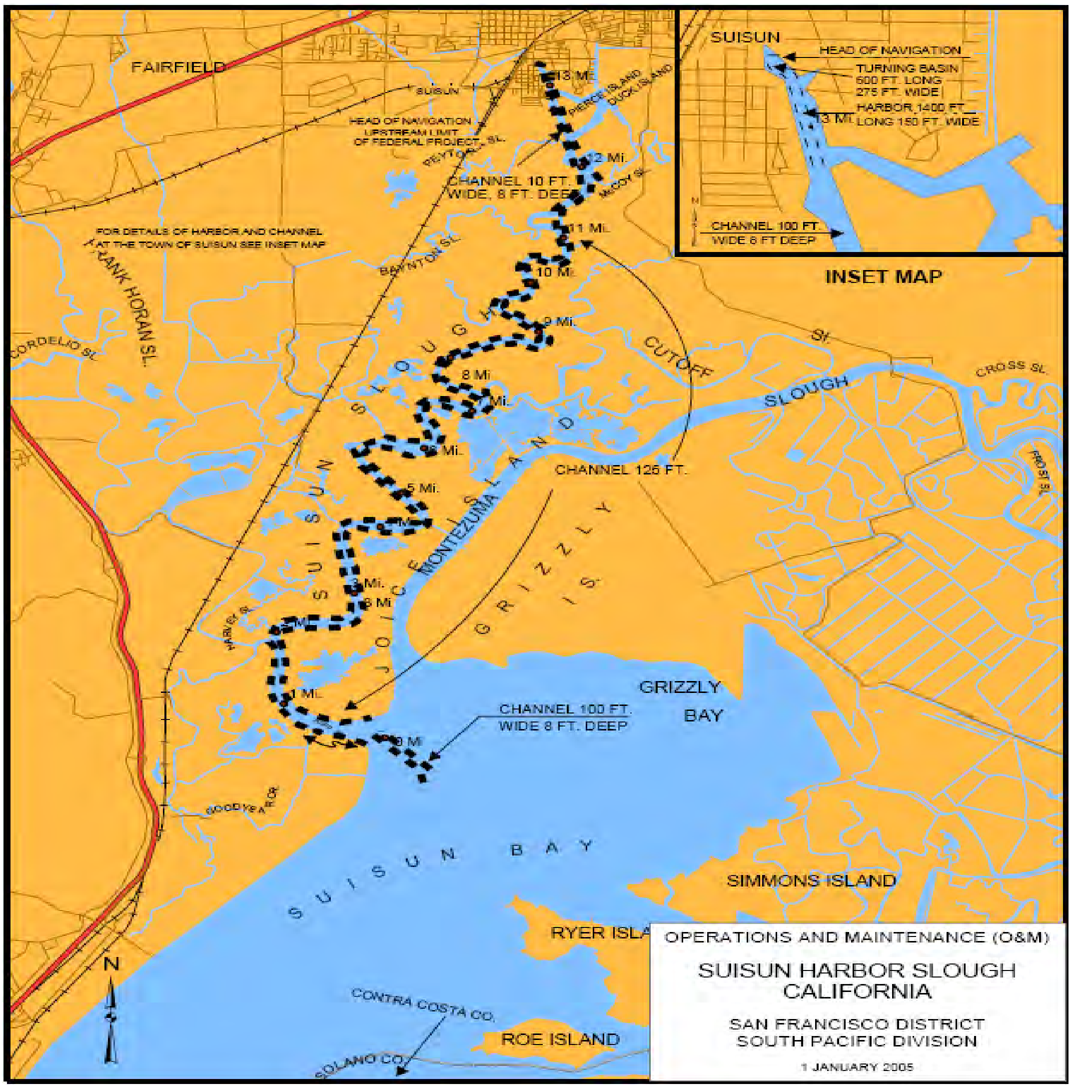
The Suisun Slough Channel is approximately 13 miles long, 200 feet wide at the entrance and 100 to 125 feet wide for the remainder of the channel, with an authorized depth of -8 feet MLLW (-10). The Channel is approximately 30 miles northeast of the City of San

Francisco and connects the City of Suisun near Fairfield, California to Grizzly Bay and Suisun Bay (see Figure 7.0).

The Suisun Slough Channel is dredged infrequently, and was last dredged in FY 1991; historically, it was dredged on an eight-year cycle. Maintenance dredging is generally conducted by a private sector pipeline dredge. The City of Suisun is responsible for providing a suitable upland disposal site to accommodate any future dredging.

The Suisun Bay Channel is an integral part of the San Francisco Bay to Stockton project, providing deep draft access to the Pacific Ocean from the inland ports of Stockton and Sacramento. The channel supports marine and commercial facilities, sport fishing, and recreation.

Figure 7.0 Suisun Slough Channel



Oakland Harbor

Oakland Harbor's federal navigation channels were authorized by the Rivers and Harbors Act of 1974, 1910, 1922, 1927, 1928, 1945, and WRDA of 1986. Oakland Harbor was initially placed into operation in 1931; however, the -42 MLLW project was operational in 1975, and the -50 foot MLLW project is currently under construction. The -50 foot MLLW project began construction in September 2001 and is expected to be operational sometime during the March to June 2009 timeframe. The Port of Oakland is the local sponsor for this project.

The Oakland Harbor is comprised of four separate channels (see Figure 8.0). The Outer and Inner Channels as well as the Turning Basin are dredged on an annual basis. The Outer Harbor is approximately 9,000 feet long, spans from 600 to 800 feet wide, with an authorized depth of -50 feet MLLW (-52) (after the Oakland Harbor deepening project is complete and the project is officially considered an operations and maintenance project, rather than new work). The Inner Harbor (including the Turning Basin) is approximately 37,000 feet long and from the entrance to Government Island is approximately 600 to 800 feet wide. The Inner Harbor Channel continues from this point forking around Government Island forming the 300 foot wide North Channel above the island and the 500 foot wide channel below the island. Just east of Government Island the channels combine to form a 1,200 foot long, 500 feet wide turning basin that continues into a 275 foot wide channel. The North Channel and the Turning Basin east of Government Island are no longer dredged as dredging was deferred indefinitely.

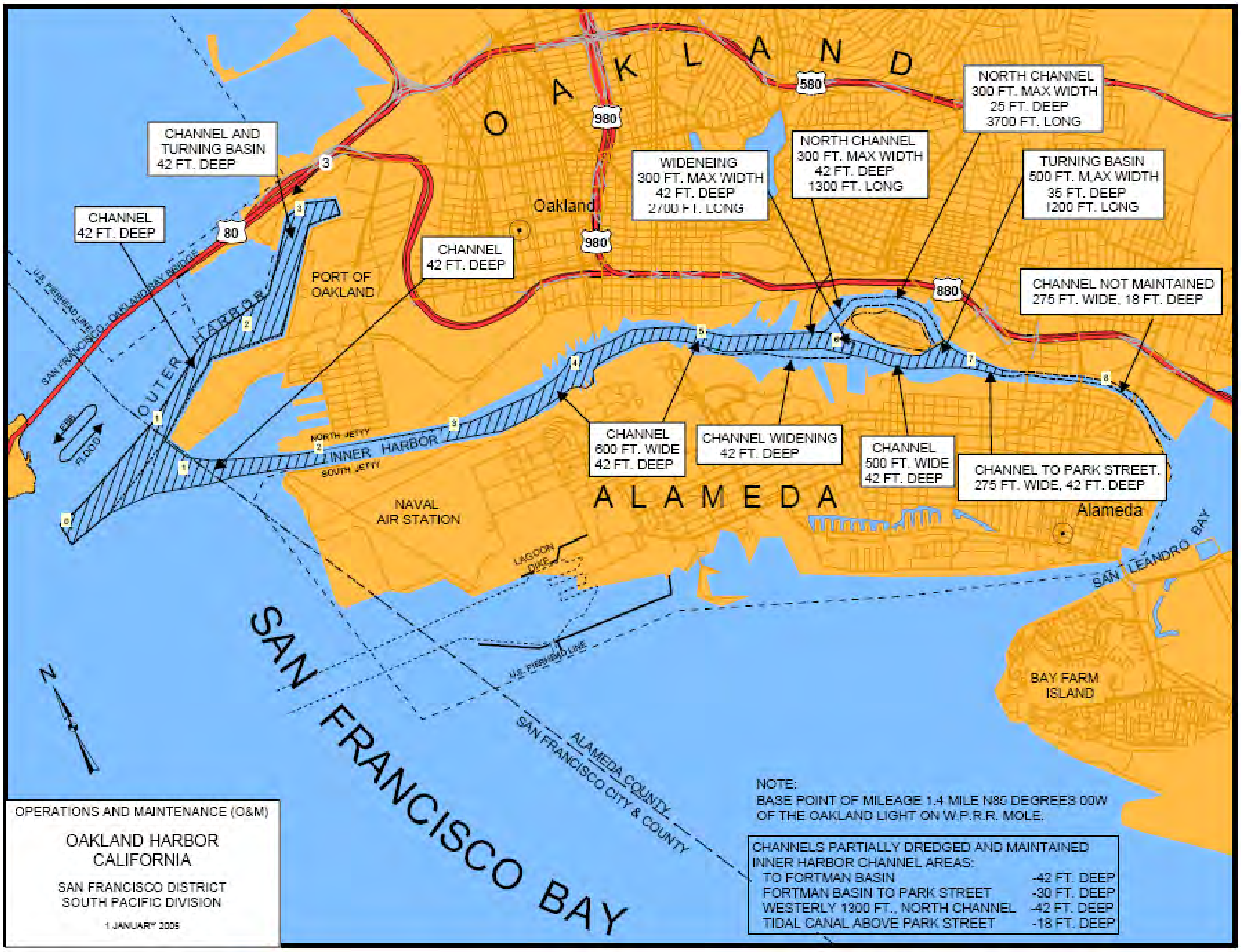
Historically, the disposal site for the material dredged from Oakland Harbor's federal navigation channels was SF-11; however, following the -42 foot MLLW deepening project, San Francisco Deep Ocean Disposal Site (SF-DODS; Ocean Site Designation at 40 CFR 228.12(b)(70)(iv)) became the primary disposal site.

The first material dredged from the -50 foot MLLW deepening project was taken to Middle Harbor Enhancement Area and material that did not qualify for wetland cover application was disposed of at a land fill in Contra Costa County. In fiscal year 2006, dredged material was taken to the Montezuma Restoration Project and the Middle Harbor Enhancement Area. The dredging portion of the deepening project is expected to be complete in 2009 with a total of 11.8 million cubic yards requiring disposal/placement. Operations and maintenance material requiring dredging will be dredged in conjunction with the deepening project in fiscal year 2007.

While the Oakland Deepening Project is in construction, operations and maintenance dredging will be limited to areas that have been deepened and have shoaled sufficiently to require maintenance to restore project depths. Approximately 300,000 cubic yards of material is expected to be dredged at Oakland Inner and Outer Harbor. If available, material dredged in fiscal years 2007, 2008, and 2009, and any future dredging episodes will be reused of at Hamilton Wetland Restoration Site. The alternative disposal site to Hamilton is SF-DODS. Maintenance dredging is generally conducted by a private sector clamshell dredge; however, with close-haul aquatic disposal, a government hopper dredge can be utilized.

Oakland Harbor is a major container port supporting commercial traffic of foreign and domestic deep-draft merchant vessels serving Department of Defense facilities and major industries. The Harbor is the second largest harbor on the West Coast and the fifth largest container port in the Nation. Oakland Harbor's federal navigation channels are a high-usage, deep water navigation channels essential to National Security and the regional and statewide economies. The project is specifically mandated for deep ocean disposal.

Figure 8.0 Oakland Harbor Navigation Channels



San Leandro Marina (Jack D. Maltester Channel)

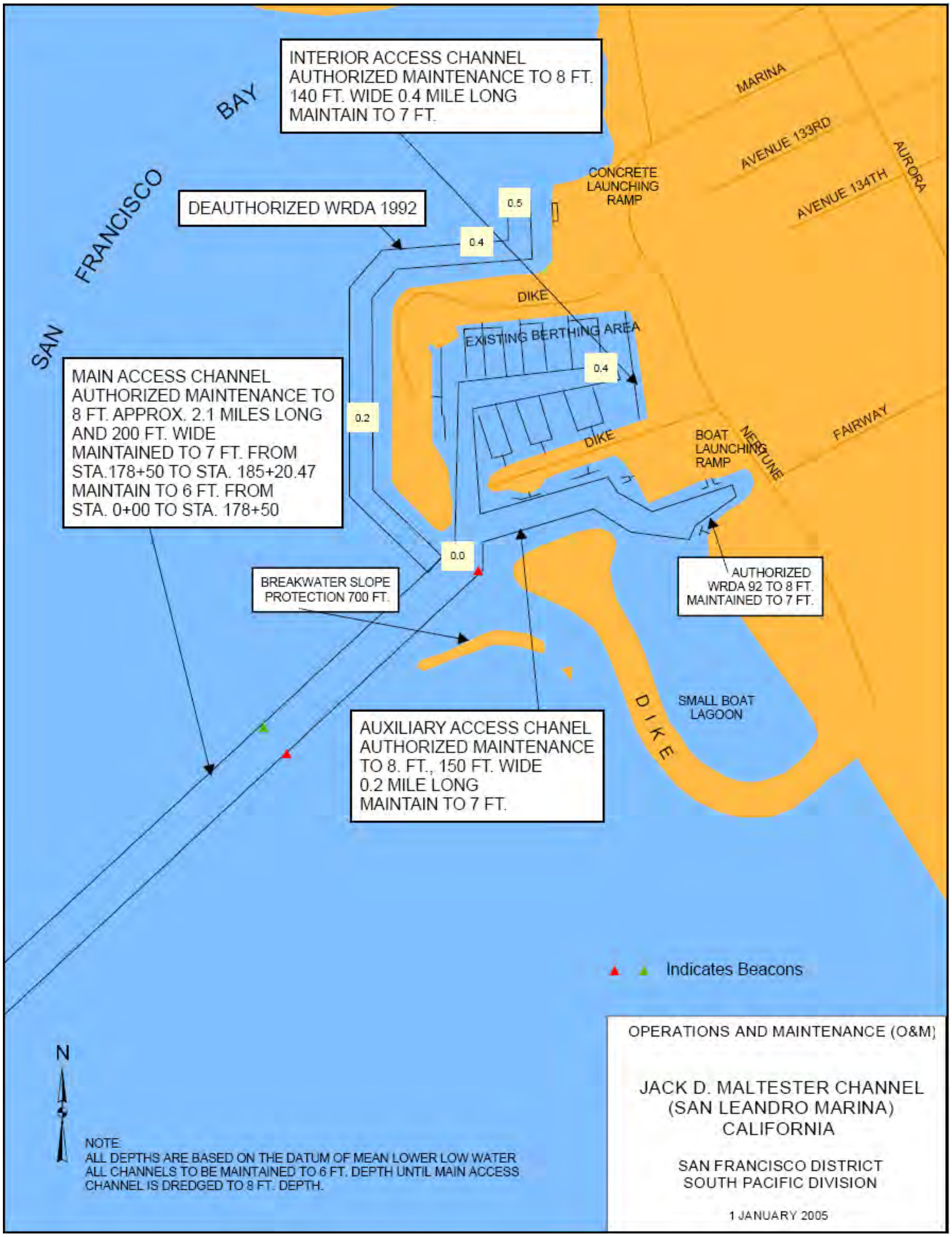
The San Leandro Marina is located in the eastern portion of the South San Francisco Bay. San Leandro Marina's federal navigation channels were first authorized by the Rivers and Harbors Act of 1965 (the project changed via WRDA 1986 [PL 99-662] and WRDA 1992). The Northern Auxiliary Channel was deauthorized under WRDA 92 and is no longer in use.

Federal navigation channels located in San Leandro Marina includes: the Main Access Channel, measuring approximately 2.1 miles long, 200 feet wide, with an authorized depth of -8 feet MLLW (-10) (this channel is maintained to -6 feet MLLW); the Interior Access Channel, measuring approximately 0.4 mile long, 140 feet wide, with an authorized depth of -8 feet MLLW (-10) (maintained to -7 feet MLLW); and the Eastern Auxiliary Channel, measuring approximately 0.2 mile long, 150 feet wide, with an authorized depth of -8 MLLW (-10) (maintained to -7 feet MLLW). Included in this project is the area adjacent to and just south east of the Auxiliary Channel connecting the Channel to the Boat Launching Area (see Figure 9.0).

Dredging of the San Leandro Marina Channels is on a four-year maintenance cycle and the last dredging episode took place in fiscal year 2001. The Local Sponsor, City of San Leandro is responsible for providing a suitable upland disposal site. Confirmation of site conditions, structural integrity, and capacity will be confirmed prior to commencement of dredging activities. Breakwater repairs were last performed over eight years ago; the last inspection occurred in fiscal year 2004 and indicated the breakwater structure is in good condition.

The San Leandro Marina federal navigation channels provide low-use access for shallow –draft commercial vessels as well as sport fishing and recreational vessels. Additionally, these channels support Oakland Airport waterborne operations for police, fire, and safety and rescue.

Figure 9.0 *San Leandro Marina (Jack D. Maltester Channel)*



Redwood City Harbor

The Port of Redwood City is located 18 nautical miles south of San Francisco on the western shoreline of the South San Francisco Bay. Redwood City's federal navigation channels were authorized by the Rivers and Harbors Acts of 1910, 1930, 1935, 1945, and 1950. Initially they were placed into operation in 1948 with the existing project operating since 1962.

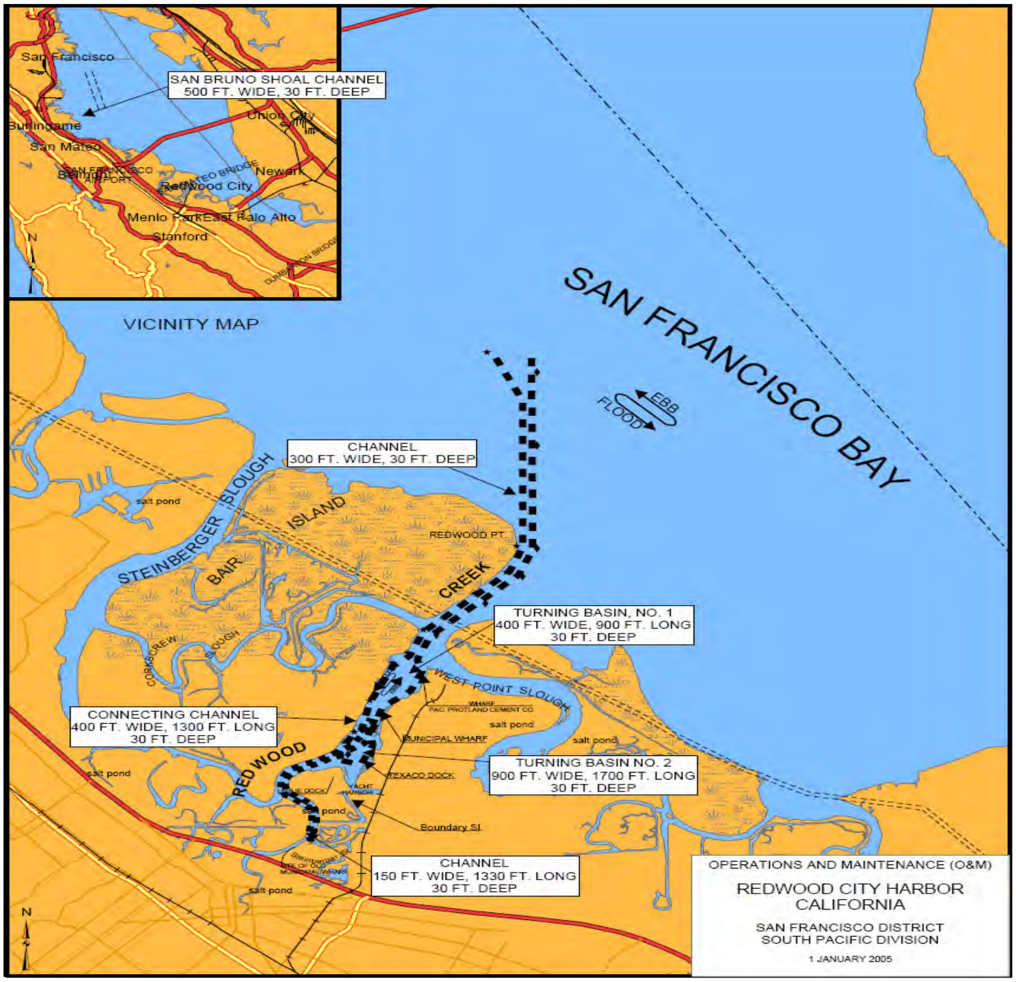
The Entrance Channel, measuring approximately 13,900 feet long, 300 to 350 feet wide, with an authorized depth of -30 feet MLLW (-32), provides a conduit from the San Francisco Bay to the Confluence of the West Point Slough and Redwood Creek. The Outer Turning Basin is approximately 2,200 feet long, 400 to 900 feet wide, with an authorized depth of -30 feet MLLW (-32). The Connecting Channel is 1,300 feet long, 400 feet wide, with an authorized depth of -30 feet MLLW (-32). The Inner Turning Basin, measuring 1,700 foot long and 400 to 900 foot wide turning basin, exists at the southeastern most point of the Connecting Channel. The Connecting Channel provides navigation from the Entrance Channel and Outer Turning Basin to the Inner Turning Basin, which is approximately 2,200 feet long, 400 to 900 feet wide, with an authorized depth of -30 feet MLLW (-32). A shallow-draft Slough Channel continues up Redwood Creek to Redwood City; this channel measures 7,000 feet long, 150 feet wide, with an authorized depth of -5 feet MLLW (-7). A separate channel, the San Bruno Channel, located miles from the Entrance Channel, is approximately 1,800 feet long, 510 feet wide with an authorized depth of -30 feet MLLW (-32) (see Figure 10.0).

The Entrance Channel, Outer Turning Basin, Connecting Channel, and Inner Turning Basin are dredged every two years, with the last dredging episode occurring in FY 2005. The Inner Turning Basin, Inner Channel, and San Bruno Channel are dredged annually; the San Bruno Channel is dredged infrequently (1987, 1960, and 2005); and maintenance dredging of the Slough Channel is deferred indefinitely.

Historically, approximately 240,000 to 975,000 cubic yards of sediment has been dredged from Redwood City Harbor every three years. Disposal of dredged material has occurred at the SF-11 site. To comply with the goals of the SF Bay LTMS, the USACE is partnering with the United States Fish and Wildlife Service (USFWS) to facilitate the restoration of the Bair Island wetlands, potentially utilizing dredged material from the Redwood City navigation channels starting fiscal year 2009; dredged material may also be used for the Hamilton Wetland Restoration Project in 2009.

Redwood City's port is a regionally critical port that provides safe deep-draft navigation for commercial bulk carrier waterborne commerce for concrete and construction industries. Redwood City's federal navigation channels are considered a moderately high-use deep water project vital to the local and regional economies.

Figure 10.0 Redwood City Harbor Navigation Channel



Reach 1: Sacramento River Deep Water Ship Channel and the Stockton Deep Water Ship Channel

The western portions of Reach 1 of both the Sacramento River Deep Water Ship Channel (DWSC) and the Stockton DWSC are located in the Sacramento/San Joaquin Delta, west of Chipps Island. The Sacramento River DWSC is dredged to -30 feet MLLW and provides navigation access to the Port of West Sacramento. The Stockton DWSC is dredged to -35 feet and provides access to the Port of Stockton.

Appendix B:

Federal O&M Dredged Material Quantities

Appendix B: Federal O&M Dredged Material Quantities													
Dredge Location	**Historic Disposal Site**	**Dredging Volume (Fiscal Year)**											
		1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Richmond Inner Harbor	SF-11/SF-10	346,024	269,800	376,100									
Richmond Outer Harbor													
South Hampton Shoal	SF-11					138,040	129,409	31,300	59,994	82,346	166,321	311,542	
Outer Harbor at Longwharf	SF-11				145,293	54,966	186,044	183,505	91,991				
Inner Harbor	SF-11					496,437	245,426		108,000	59,539		634,491	
	SF-DODS							598,140					
San Francisco Harbor Main Ship Channel (Bar)	SF-8				666,652	78,013	268,491	378,153	232,893	115,097		85,460	200,312
	Ocean Beach									290,252		235,929	
Napa River		195,046		140,000									
Petaluma River Channel	Petaluma CDF							37,500					
	SF-10		148,842										
San Rafael Creek													
	SF-11		191,829				9,200						
	SF-10						20,475						
	Winter Island							44,450					

Appendix B: Federal O&M Dredged Material Quantities

Dredge Location	Historic Disposal Site	Dredging Volume (Fiscal Year)											
		1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Pinole Shoal/ Mare Island Strait	SF-10/ SF-11	256,846	66,986	349,167		347,949		225,571	93,658	3,500	380,300	136,806	
Pinole Shoal	HWRP												21,000
Suisun Bay Channel/ New York Slough	SF-16		104,942		59,421	125,493	510,009	75,610	293,612	216,000	103,175	201,600	128,700
Oakland Harbor	SF-11	213,982	222,317										
	SF-DODS				381,290	46,400	259,211		165,000	192,000			
	SF-DODS					21,100	223,200	68,314	187,400		208,200	808,500*	
	Hamilton											105,300*	
	Berth 10-POO							43,777	53,700	694,200			
	MHEA							165,730	123,200			1,207,000*	
	SF-11								60,000				
San Leandro Marina (Jack D. Maltester Channel)	Upland						52,154	129,394					
	San Leandro												
Redwood City Harbor	SF-11			115,658	430,705		495,043	78,260	69,374	30,714		508,175	
	SF-10											2,519	

*Oakland -50 Foot Navigation Improvement Project.

Appendix C:

Non-Federal O&M Dredged Material Quantities

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
1	**USS Posco**	Winter Island											2,700	
2	**Pittsburg Marina**	Winter Island						18,620	93,604					
3	**Ryer Island Boat Harbor**	SF-9						3,850						
4	**Montezuma Harbor**	Upland					2,450							
5	**Suisun City Marina**	Pierce Island							129,759					38,729
6	**City of Suisun Pierce Island Boat Ramp**	Pierce Island					14,000							
7	**Tosco Refinery**	SF-9												
8	**Martinez Shore Terminal**	SF-11				7,073				5,000				
9	**Valero Refinery Company - Benicia Crude Dock - Crude Wharf Tug Mooring Area**	SF-9	36,600	34,600	39,380	32,375	46,100	21,300	64,400	27,900	36,800	21,700	20,000	32,490
		SF-11								20,400	27,900	13,320	42,580	24,580
10	**Benicia Port Terminal**	SF-9	37,590			15,050		17,400	38,329	49,100	39,485	39,892		16,500

Appendix C: Private Dredge Bin Volumes, San Francisco Bay

No.	Location	Disposal Site	Volume											
			1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	(Amports)													
11	**Shell Terminal**													
12	**Martinez Marina**	Upland							53,544					33,486
13	**Benicia Marina**	SF-9	15,560	14,080	29,457		13,950	59,950	28,650	13,780	7,500	20,250	4,775	18,000
		SF-11									1,000			
14	**Glen Cove Marina**	Winter Island								4,950				
		SF-9	14,520		18,232								513	
15	**C&H Sugar**	SF-9												
16	**Conoco Philips, Rodeo Terminal**	SF-8											6,670	
		SF-9	89,556		84,709				51,197		32,758	53,982	14,400	17,054
		SF-10								12,464				
17	**Napa Valley Marina**	Upland								10,000	20,789	13,941		
18	**Vallejo Marina**	SF-9					10,125	92,455	95,975	34,750				
19	**Vallejo Yacht Club**	SF-9	1,500				500	31,375			500			27,675

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
20	**Vallejo Ferry Terminal**	SF-9					39,785			28,800				7,000
21	**Mare Island Shipyard**	SF-9												
		HWRP												
22	**Kiewit Pacific Company**	Upland						22,000						
23	**U.S. Army Reserve Center, Mare Island**	SF-9						34,115				50,014		
24	**Petaluma River Turning Basin**	Upland			14,000							73,835		
25	**Shamrock Materials**	Upland												
26	**Petaluma Marina**	Upland, Petaluma								36,900	36,500	5,308		
27	**Black Point Boat Launch Ramp**	SF-10					300	240					144	
28	**Port Sonoma Marina**	Upland		320,000		30,475	94,177	31,851		12,051	72,475	78,089		61,478
29	**Bel Marin Keys Community Services**	Upland							48,355		39,548			
		HWRP										79,500	135,757	

Appendix C: Private Dredge Bin Volumes, San Francisco Bay

No.	Location	Disposal Site	Volume											
			1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	District	Sonoma Baylands											7,574	
30	**Gallinas Creek**	SF-10												
		SF-11												
		Upland												
31	**San Rafael Rock Quarry**	SF-10			51,000					10,000				
32	**Point San Pablo Yacht Club**	SF-10										10,650		
33	**Loch Lomond Marina**	SF-10	32,560	34,810	40,370	250		53,525						
		SF-11							15,325					
34	**Marina Vista Canal & Homeowners Association**	SF-10					17,275						4,400	
35	**Marin Yacht Club**	SF-10	3,475			21,270	25,125	3,225		14,250			11,600	
36	**San Rafael Creek & Residential Berths**	SF-10	7,950				1,525		6,600	16,900			4,025	3,875
		SF-11	750						425	60,575				14,550
37	**Lowrie Yacht Harbor**	SF-10	18,925						12,025					5,100

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
38	**High Tide Boat Sales**	SF-10									1,450			
39	**San Rafael Yacht Harbor**	SF-10											4,200	3,700
40	**Larkspur Landing Ferry Terminal**	SF-10						23,552						
		SF-11	9,425			91,660	191,731	470,697		22,350	11,350	520,450		
41	**Larkspur Marina**	SF-11												
42	**Larkspur Sea Scout Base**	SF-10							725					
43	**Marin Rowing Association**	SF-10												
		SF-11			2,000							450		2,250
44	**Greenbrae Marina Neighborhood**	SF-10								64,800				
45	**Paradise Cay Yacht Club**	SF-11								7,200	9,000	32,400	34,550	6,550
46	**Paradise Cay Homeowners Association**	SF-11	11,700		300	11,200	24,250		27,200	7,200		33,600		
47	**Timmers Landing**	SF-11				200								
48	**Corinthian Yacht Club**	SF-11		20,315							3,845	22,300		
49	**Bellevue**	SF-11											6,900	

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
	Channel (Belvedere Cove)													
50	**Johnson Property**	SF-11			200									
51	**Belvedere Land Company**	SF-11												
52	**San Francisco Yacht Club**	SF-11	43,132	9,593	4,100									
53	**Strawberry Recreation District**	SF-11	6,950								105,450	21,600	5,600	
54	**Kappas Marina**	SF-11			23,740	840								
55	**Clipper Yacht Harbor**	SF-11		500	500					47,324	23,300	6,400	16,725	
56	**Arques Shipyard and Marina**	SF-11								11,040	6,000			
57	**Marina Plaza Harbor**	SF-11								14,000				
58	**Schoonmaker Point Marina**	SF-11						5,050	14,400					
59	**Galilee Harbor**	SF-11			5,235		500							
60	**Sausalito Marina Properties**	SF-11												

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
61	**Sausalito Yacht Club**	SF-11	1,100											
62	**Coast Guard Station, Golden Gate**													
63	**San Francisco Marina (includes Golden Gate Yacht Club and St. Francis Yacht Club)**	Ocean Beach Pilot					13,113	13,833						
		Montezuma Slough		10,000							500			
		SF-11	12,403	28,225	24,650									
64	**Port of San Francisco (encompasses the southwest shoreline of Central Bay and the northwest shoreline of South Bay)**	SF-11	95,000	117,256	273,180	427,200	186,675	59,800	219,200	13,600	110,600	71,575		260,900
		Berth 94			18,454	900		40,300		2,400	2,400	72,475		6,000
		Winter Island				22,825		65,690	89,900				8,400	
		SF-DODS								68,000		124,560	87,900	57,000
		SF-8									40,000			
65	**Chevron, Richmond Longwharf**	SF-9						61,369						
		SF-11	298,710		192,178	68,379	107,900	248,200	105,900	71,000	10,600	172,750	145,150	104,400

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
		SF-10	26,300								13,400			
		Winter Island									12,650			
66	**Richmond Yacht Club**	SF-11									27,100			14,800
67	**Brickyard Cove Homeowners Association**													
68	**Castrol North American Consumer's Berth**													
69	**Levin-Richmond Terminal Corporation**	POR Parking Lot					10,120							
70	**Time Oil Terminal**													
71	**Conoco Philips, Richmond Terminal**	SF-9									32,758			
72	**Port of Richmond**	SF-11		22,093										
		SF-DODS											24,600	

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
73	**BP, Richmond Terminal**	SF-11								21,400				
		Winter Island								23,500				
74	**Berkeley Marina**													
75	**Emery Cove Yacht Harbor**	SF-11						82,486						28,862
76	**City of Emeryville Marina**	SF-11							20,430	34,850				21,700
77	**Emery Cove Marina**	SF-11	36,075					85,000						
78	**Coast Guard Station, Yerba Buena Island**	SF-11					31,851							
79	**South Beach Yacht Club**	SF-11												
80	**San Francisco Dry Dock**	SF-11		143,750	178,400					66,600			42,000	80,455
		SF-DODS												21,336
81	**Brisbane Marina at Sierra Point**	SF-11				112,241	80,625							
82	**Oyster Cove Marina**													
83	**Oyster Point Marina**	SF-11			15,303	51,825				56,400			76,800	

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
84	**Candlestick Point**	SF-11	50,700	300	6,525									
85	**Coyote Point Marina**	SF-11							55,200	85,845		24,225		
86	**Foster City Lagoon**	Upland, Foster City							66,606	46,944				
87	**Redwood Shores Lagoon**	Upland												
88	**RMC Lonestar Cement Marina Terminal**	SF-11				64,298								
89	**Port of Redwood City**	SF-11		44,850						40,800				
		Upland		4,665										
90	**Redwood City Marina**													
91	**Alvisio Marina Boat Ramp**													
92	**City of Sunnyvale Boat Ramp**	Upland											52	
93	**Port of**	SF-11	154,374	42,929	249,046	62,093	29,290	79,800		191,800	18,050	142,300	131,100	80,375

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
	Oakland	Upland, Berth 10			10,481			2,400		22,809				
		NSC				1,862,574								
		MHEA					399,194			94,037	7,900			
		Upland, Berth 40					725,737							
		Berth 40					725,737							
		SF-8									121,303		50,500	
		SF-DODS									100,063		21,600	
94	**Schnitzer Steel**	SF-11	481			1,751						9,655		
95	**Oakland Yacht Club**	SF-11									225			
96	**Coast Guard, Alameda Station**													
97	**Alameda Point Channel**	SF-11								14,177	89,900	146,300		356,070
98	**Ron Valentine Boat Dock**													
99	**Ballena Isla Marina**	Upland						27,129						
		SF-11								6,000				

Appendix C: Private Dredge Bin Volumes, San Francisco Bay														
No.	**Location**	**Disposal Site**	**Volume**											
			1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
100	**Ballena Isla Townhomes**								11,325					
101	**Hanson Aggregates**													
102	**Corona Del Mar Homeowners Association**	SF-11							450					
103	**Aeolian Yacht Club**	SF-11		18,605									18,100	
104	**Harbor Bay Ferry Channel**													
105	**San Leandro Marina**	Upland					9,901							
		SF-11		26,170										

Appendix D:

Disposal History: Per Disposal Site, Per Month

Appendix D: Aquatic Disposal Sites for the Placement of Dredged Material (Volumes in Cubic Yards)

Fiscal Year 1997												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	0	115,870	364,905	0	0	0	0
SF-9	52,590	89,556	2,600	10,450	9,575	530	5,710	1,500	19,000	0	0	3,815
SF-10	0	0	0	6,300	7,040	6,940	5,825	287,276	7,425	15,020	9,530	700
SF-11	185,317	478,569	154,023	97,197	481	95,764	258,713	141,732	201,030	156,122	108,980	136,860
SF-16	218,502	61,434	5,045	0	0	0	0	0	0	0	0	0
SF-DODS	7,587	69,323	161,376	119,392	210,775	259,898	251,243	214,738	202,759	233,922	266,613	328,288

Fiscal Year 1998												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	0	160,541	233,247	0	393,788		
SF-9	0	9,054	1,400	0	0	14,800	325	1,350	4,480	258	20,157	92,015
SF-10	0	910	1,400	4,000	2,675	4,750	68,136	1,850	0	5,025	9,935	5,425
SF-11	162,378	51,253	41,525	22,220	3,350	8,250	273,745	85,905	111,641	62,680	103,750	300,257
SF-16	0	0	0	7,135	0	0	104,942	0	0	112,077		
SF-DODS	334,389	387,333	561,385	459,925	101,121	303,799	365,597	327,960	213,079	284,100	64,569	0

Fiscal Year 1999												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	0	0	103,795	164,281	268,076		
SF-9	900	6,230	3,120	9,000	19,455	5,375	6,250	8,875	3,900	24,000	0	0
SF-10	116,074	40,018	4,525	0	250	10,725	5,470	3,650	172,295	138,596	97,776	0
SF-11	529,960	411,024	120,056	331,097	143,352	71,016	111,291	196,182	234,538	12,113	79,777	113,089
SF-16	0	0	0	0	0	0	0	0	0	0	0	0
SF-DODS	0	0	0	0	0	0	0	0	0	0	0	5,400

Fiscal Year 2000												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	0	534,882	131,770	0	0	0	0
SF-9	0	0	743	0	0	33,487	32,828	1,110	721	1,966	0	0
SF-10	250	0	0	0	0	0	0	0	2,225	11,750	7,875	1,420
SF-11	240,283	223,825	151,433	10,378	59,480	18,646	90,188	68,331	82,548	29,515	14,850	87,095
SF-16	0	0	0	0	0	0	0	20,964	0	0	0	0
SF-DODS	66,550	123,139	114,100	140,800	3,000	0	0	99,530	163,240	0	0	0

Fiscal Year 2001												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	0	78,013	0	0	0	0	0
SF-9	14,500	0	500	0	0	9,600	0	10,800	0	0	18,190	56,343
SF-10	1,300	0	300	0	0	289,773	58,176	0	0	10,050	22,850	9,500
SF-11	118,563	270,318	21,150	9,675	11,575	61,075	163,371	1,805	7,725	1,425	29,590	249,971
SF-16	0	400	33,200	0	0	0	105,779	0	0	0	0	24,571
SF-DODS	0	0	0	0	0	0	0	0	3,500	189,440	218,170	125,627

Fiscal Year 2002												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	214,699	53,792	0	0	0	0	0
SF-9	115,244	62,600	5,000	0	0	0	18,031	0	813	15,251	68,994	34,066
SF-10	3,225	240	0	0	0	0	0	0	14,500	16,150	12,225	10650
SF-11	484,048	447,070	89,374	13,000	10825	31,496	370,477	58,715	7,100	26,350	93,900	185,222
SF-16	0	0	0	0	0	0	0	0	417,623	0	0	0
SF-DODS	123,200	74,400	0	0	0	0	0	0	13,484	92,879	124,922	185,222

Fiscal Year 2003												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	**	**	0	378,153	0	0	0
SF-9	32,275	27,750	2,850	0	445	**	**	124	78,138	1,559	28,829	46,050
SF-10	32,652	17,225	0	0	0	**	**	0	0	95,300	269	0
SF-11	156,044	227,234	51,868	20,219	20,431	**	**	54,558	308,413	130,770	4,063	56,262
SF-16	92,386	0	0	0	0	**	**	0	134,612	19,000	18,103	55,786
SF-DODS	141,232	211,727	46,257	3,800	0	**	**	90,000	130,400	166,049	156,267	163,400
**No data provided (months skipped in logs).												

Fiscal Year 2004												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	0	0	221,529	11,364	0	0	0
SF-9	64,662	58,063	0	560	1,141	0	0	0	0	13,500	0	0
SF-10	4,994	18,058	372	0	0	0	0	0	108,808	10,700	2,250	7,200
SF-11	168,641	176,026	52,583	32,099	26,460	36,803	58,386	120,692	192,274	23,085	80,520	122,781
SF-16	0	0	0	0	0	0	0	0	0	93,000	18,000	0
SF-DODS	147,400	124,000	0	0	0	0	68,000	0	0	0	93,000	30,000

Fiscal Year 2005												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	0	0	115,097	0	0	5,473	29,660
SF-9	0	28,180	0	0	0	0	0	0	45,592	7,566	10,000	0
SF-10	26,550	24,750	4,050	0	0	0	0	0	0	0	1,450	0
SF-11	110,721	52,021	4,197	1,941	15,157	1,638	14,000	15,850	189,310	69,325	36,600	55,250
SF-16	78,000	27,000	0	0	0	0	0	0	0	0	0	0
SF-DODS	150,000	0	0	0	0	20,800	19,200	0	34,774	45,552	19,737	28,360
****Port of Oakland Deepening Project**				403,400	248,200	274,035	411,971	551,213	489,116	577,674	829,895	403,829

Fiscal Year 2006												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8	0	0	0	0	0	0	0	60,420	0	0	0	0
SF-9	50,014	20,000	250	0	0	0	0	0	0	65,182	0	10,500
SF-10	30,300	4,500	8,400	0	0	0	0	0	0	0	231,900	103,700
SF-11	181,550	121,050	550	0	0	0	84,895	0	281,221	256,118	144,662	166,675
SF-16	207,050	11,650	0	0	0	0	0	0	0	0	0	0
SF-DODS	221,480	243,200	86,160	0	0	36,000	40,560	21,000	0	0	0	77,320
****Port of Oakland Deepening Project**												

Fiscal Year 2007												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8						28,000	18,000		4,500	91,615		
SF-9		4,775								23,900	513	10,500
SF-10	3,850	4,375							234,929	20,029	12,000	4,000
SF-11	63,425	281,150	18,600		19,720		9,860	13,000	210,229	43,304	18,300	22,500
SF-16	88,800											112,800
SF-DODS	99,600	28,500	16,800				87,500	189,600	60,600	80,700	7,200	46,500
****Port of Oakland Deepening Project**												

Fiscal Year 2008												
Site	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
SF-8								56,093	144,219			6,445
SF-9	35,975	29,305	15,250							22,900		14,809
SF-10	500	1,700							2,250	1,500		
SF-11	240,777	264,383	36,160			8,550	9,720	14,220	30,143	99,712	174,600	125,337
SF-16			152,100									
SF-DODS		45,300	11,700							21,336		
****Port of Oakland Deepening Project**												

**Disposal volumes taken from United States Army Corps of Engineers *Fiscal Year Annual Reports* for fiscal years 1997 through 2004 and from DMMO's raw dredged material disposal data (in bin volumes) for fiscal years 2005 though 2007.

Appendix E:

Sediment Sampling Results for Federal and Non-Federal O&M Dredging Projects

Appendix E: Sediments of Non-Federal O&M Dredging Locations					
Location	**Sediment Type**				**Sediment/Permit Comments**
	Gravel	**Sand**	**Silt**	**Clay**	
Coast Guard Station, Golden Gate	10.7	88.4	0.5	0.4	
Marin Plaza Harbor	0.3	4.1	42.8	52.8	
Schoonmaker Plaza	0.1 - 0.2	3.4 - 6.1	38.3 - 49.9	43.7 - 58.3	
Galilee Harbor					
Kappas Marina	0.1 – 0.4	1.2 – 1.6	43.0 – 47.4	51.1 – 55.3	
Strawberry Recreation District					
Clipper Yacht Harbor	1.4	2	67.1	32.1	2006: 150,000 over 10 years
Arques Shipyard and Marina	0.7	1.6 - 8.1	52.3 - 55.0	38.9 - 42.7	Site AR-2 had significantly elevated heavy metals, TRPH, PAHs, and PCBs. High leves of organic tin AR-2 showed high mortality in amphipod tests and was not suitable for SF-11 disposal. 2004 Permit: 23,000 cy initial: 52,000 over life.
Greenbrae Marina					
Larkspur Landing Ferry Terminal					
Turning Basin	0	0	33.9 – 35.7	64.9 – 66.8	
Berths 1, 2, 3, 4	0.0 – 1.5	0.3 – 1.6	39.7 – 49.0	50.4 – 58.9	
Ferry Channel					
Larkspur Sea Scouts Base					
Marina Rowing Association	0.2 – 0.6	2.2 – 4.8	37.2 – 46.3	48.6 – 60.1	

Appendix E: Sediments of Non-Federal O&M Dredging Locations					
Location	**Sediment Type**				**Sediment/Permit Comments**
	Gravel	**Sand**	**Silt**	**Clay**	
Paradise Cay Homeowners Association	0	0.8	45.7	53.5	150,000 cy - 10 years Expires June 30, 2016 3 year cycle??? Different dates on permits indicate differing areas.
Paradise Cay Yacht Harbor (Pullman Building Co.)	0 - 1.33	0.57 - 1.80	35.2 - 46.3	53.1 - 61.7	2004: 50,000 initial; 84,000 10 years
Timmers Landing					
Corinthian Yacht Club	0.0 – 0.2	8.0 – 9.0	54.2 – 60.0	29.8 – 37.6	
San Francisco Yacht Club	--	4	54	41	
Kahn Dock 27, Belvedere					
Jackson Property	--	2.8	54.4	42.1	
Port of San Francisco					Permit issued Nov 2003 for 4.8 million cubic yards over 10 years. Dredging limited to June 1 to November 30
Fisherman's Wharf West Approach	0.51	16.71	29.8	53.01	Port of San Francisco Dredging Support Program Sediment Characterization: Fisherman's Wharf Sampling and Analysis Results Report (Anchor Environmental CA, L.P., October 2005). Composites from FW-DU2B, FW-DU3A, FW-DU3B not suitable for unconfined disposal at SF-11 due to PAH concentrations.

Appendix E: Sediments of Non-Federal O&M Dredging Locations					
Location	**Sediment Type**				**Sediment/Permit Comments**
	Gravel	**Sand**	**Silt**	**Clay**	
Hyde Street Marina	0.02	14.6 – 72.3	12.6 – 30.5	14.8 – 56.1	
Pier 45 East	0.03	0.03	14.7 – 40.7	60.3 – 86.7	
Pier 39	0.04	0.04	34.7 – 37.9	62.1 – 65.4	
Pier 38 North	0.05	8.0 – 8.8	41.6 – 42	49.2 – 50	
Pier 35 West	0 – 0.18[6]	11.72 – 98.87	2.5 – 55.15	2.65 – 35.6	Permit expires nov. 30, 2010; historic high concentrations of PAHs, range 12,058 to 112,910 ug/kg.
Pier 35 East					Conc. PAHs range from 1,890 to 64,553 ug/kg (Berths 35 East and West Sediment Characterization for Open Ocean Disposal; Epidodic Samplig and Analysis Pland and Tier I Evalutation (Anchor Environmental, L.L.C., October 2005).
					Port of San Francisco Dredging Support Program: Sediment Characterization: Berths 35 East and West Sampling and Analysis Results Report (Anchor Environmental CA, L.P., February, 2006
					35 DUE1, E2, E3, W1 Suitable for SF-DODS; 35DUW2 Not suitable.
					Increased PAHs due to creosote pilings.
Pier 33W					
Pier 30 – 32					
Pier 29					
Pier 27	0.1	3.02 - 28.79	51.38 - 68.48	19.11 - 28.5	Port of San Francisco Dredging Support Program: Sediment Characterization: Berth 27, USACE Permit #27549S, Biological Assessment (Anchor Environmental L.L.C., March 2006)

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Location	**Sediment Type**				**Sediment/Permit Comments**
	Gravel	**Sand**	**Silt**	**Clay**	
					Port of San Francisco Dredging Support Program: Sediment Characterization, Berth 27: Sampling and Analysis Results Report (Anchor Environmental CA, L.P. (March 2006)
					Port of San Francisco Dredging Support Program: San Francisco Deep Ocean Disposal Site Tier I Evaluation for Berth 27 Dredged Material (Anchor Environmental CA, L.P., March 2006)
					DU-5 and DU-6 exhibited higher concentrations of PAHs, suitable for SF-DODS disposal; all other at SF-11
Piers 80 – 94 Approach	--	4.50 - 10.98	64.19 - 75.56	18.56 - 25.98	Port of San Francisco Dredging Support Proram: Sediment Characterizaton: Berths 80A, B, C, D, 92 and Islais Creek Channel and Approach: Sampling and Analysis Results Report (Anchor Environmental, L.L.P., October 2005).
Pier 80B					One area, ICI-DU@ (Berth 92/Islais Creek Channel) not suitable for aquatic disposal
San Francisco Marina		21 - 88			
Coast Guard, Yerba Buena Island	0	0	26.5 – 29.2	21.0 – 53.5	
Richmond Longwharf, Chevron Products					
Point San Pablo Yacht Harbor			99		
Time Oil Terminal					

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	Gravel	**Sand**	**Silt**	**Clay**	
BP Richmond Terminal					
Castrol North American Consumer's Berth					
Levin-Richmond Terminal	2.6	59.5	0	19.6	
	7	9.5	0.7	22.3	
	32.9	6.8	85.4	56.6	
	62	22.5	14.1	2	
Port of Richmond	0	8	49	43	
Conoco Philips Richmond Terminal					
Aeolian Yacht Club	0.1 - 0.7	6.0 - 17.4	36.1 - 39.3	46.5 - 54.0	Mercury concentrations over double the SF Bay ambient conditions in one site.
Berkeley Marina					
Richmond Yacht Club	0	0.7 - 1.0	33.8 - 36.3	63.0 - 65.2	2004: 19,000 cy initial; 28,000 cy over life.
Aeolian Yacht Club	0.1 - 0.7	6.0 - 17.4	36.1 - 39.3	46.5 - 54.0	Mercury concentrations over double the SF Bay ambient conditions in one site. Feb 2006, DMMO decision that Tier I is NOT appropriate.
Emery Cove Marina					
Emery Cove Yacht Harbor	12.0 – 18.6		30.4 – 43.5	37.9 – 56.9	
Emeryville City Marina	3.7 – 4.4	15.0 – 20.6	25.3 – 28.3	50.5 – 52.2	
Coyote Point Marina					2006 permit: up to 60,800 cy
Entrance Channel					Ag slightly above SF Bay ambient
Basin 1	0	3.2	58.2	38.1	PCB 1254 slightly above SF Bay ambient

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	Gravel	**Sand**	**Silt**	**Clay**	
Basin 2	0.1	2.3	54.7	42.4	Organotins above SF-11 2002 levels
Approach Channel	21.8	7.1	41.2	38.7	USACE permit (2006): up to 300,000 cy - 10 years (2006, 199,200 remain
Marina Vista Homeowners Assoc.	0.6	6.2	33.5	59.8	
San Rafael Creek	0 – 0.1	1.0 – 1.8	29.4 – 32.2	66.0 – 69.6	
San Rafael Creek, Residential Berths					
City of San Rafael Yacht Harbor	0.15 - 0.56	2.91 - 19.1	37.1 - 41.1	44.1 - 59.2	Mercury levels roughly double ambient bay levels and above currently-proposed TMDL target limits. Copper, lead, zinc, PCB Aroclors, and total Butyltinsand PAHs were above SF-10 reference site levels.
San Rafael Rock Quarry			42	37 - 47	
Marin Yacht Club			31	68	
Loch Lomond Marina					
Bel Marin Keys Community Services Dist.	0.11 - 0.95	0.57 - 1.14	33.6 - 35.7	63.3 - 65.2	Boron and Cadmium present in higher levels; however, reuse placement approved.
Black Point Boat Launch Ramp					
Petaluma Turning Basin					
Shamrock Materials					
Port Sonoma Marina					
Napa Valley Marina					
United States Army					

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	Gravel	**Sand**	**Silt**	**Clay**	
Reserve Center					
Vallejo Ferry Terminal	2.2	6.1	36.6	55.1	
City of Vallejo Marina					
Vallejo Yacht Club					
Kiewit Pacific Company	0.0 – 15.8	2.1 – 35.7	32.2 – 41.0	30.8 – 56.8	
Valero Refinery Company - Benicia Crude Dock**	0	4.7 – 5.8	41.2 – 48.4	53.0 – 46.9	
Glen Cove Marina	0.0 – 0.8	1.9 – 9.4	34.7 – 36.9	52.9 – 63.3	
Benica Port Terminal (Amports)	0	4.4	34.1	62.4	
Benicia Marina	0.2 – 3.6	0.6 – 86.6	3.9 – 41.3	5.8 – 65.7	
ConocoPhillips Refinery Company Marine Term.					
Martinez Marina	0	0.1 – 0.3	15.7 – 23.5	46.7 – 84.2	
Martinez Shore Terminal	0.4	71.9	11.9	16.9	
C&H Sugar Company					Not often dredged as Carquinez Strait currents scour area.
PG&E					
Pittsburg Power Plant					1997 Permit: initial (1997-98) 43,000 cy (10,000 cy every other year start 2000)
Contra Costa Power Plant					1997: initial 2,182 (2,000 cy every other year)
Suisun City Marina	0	3.8 – 9.3	36.5 – 47.5	46.2 – 59.2	
Montezuma Harbor					

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	Gravel	**Sand**	**Silt**	**Clay**	
Ryer Island Boat Harbor (Venoco)	0.07	5.6	54	41.7	Slight elevated concentrations: 4,4-DDT, 20methylnapthalen, acenaphthylene, cadmium, chromium, and nickel. Dredge Sediment Sampling Report, Ryer Island Boat Harbor Dredging Report, Suisun Bay, California (Entrix, Inc., April 17, 2001) Sediment LSP toxicity with Mytilus edulis significant toxicity from comp sample.
Jerico Towing, Inc. (Sand Mining)					
Pittsburg Marina	0.0 – 0.5	1.3 – 28.0	38.7 – 49.2	33.2 – 49.5	
Port of Oakland					
Alameda Point Navigation Channel	0 - 0.1	0.52 - 12.7	35.8 - 44.3	44.7 - 63.7	Permit: 149,000 initial: 442,000 over 10 years. Uses Knockdown every three years of permit
Schnitzer Steel	0	7	67	26	
Ballena Isla Marina	0.1 – 1.7	2.0 – 11.8	34.4 – 39.6	53.6 – 58.3	
Ron Valentine Boat Dock					
San Leandro Marina					
Sunnyvale Boat Ramp					
RMC Lonestar Cement Marina Terminal					
Port of Redwood City			29	63 - 71	

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Location	**Sediment Type**				**Sediment/Permit Comments**
	Gravel	**Sand**	**Silt**	**Clay**	
Foster City Lagoon					
Oyster Point Marina					
Oyster Cove Marina	0	1 – 6	33 – 44	55 – 60	
Brisbane Marina at Sierra Point	0.0 – 1.0	1.3 – 4.6	33.7 – 51.9	41. – 63.2	1999 Permit: 224,000 cubic yards. Low to moderate PAHs, 783 - 1,321 ug/kg, moderate levels of metals compared to reference site, minimal toxicity in bivalve larvae.
San Francisco Drydock					
Drydock 1	0.0 – 0.1	0.8 – 2.9	33.6 – 44.9	52.1 – 64.2	
Drydock 2	0.02	13.3 – 13.5	68.5 – 68.7	18.32	
*Data taken from USACE and BCDC Regulatory Permit files.					