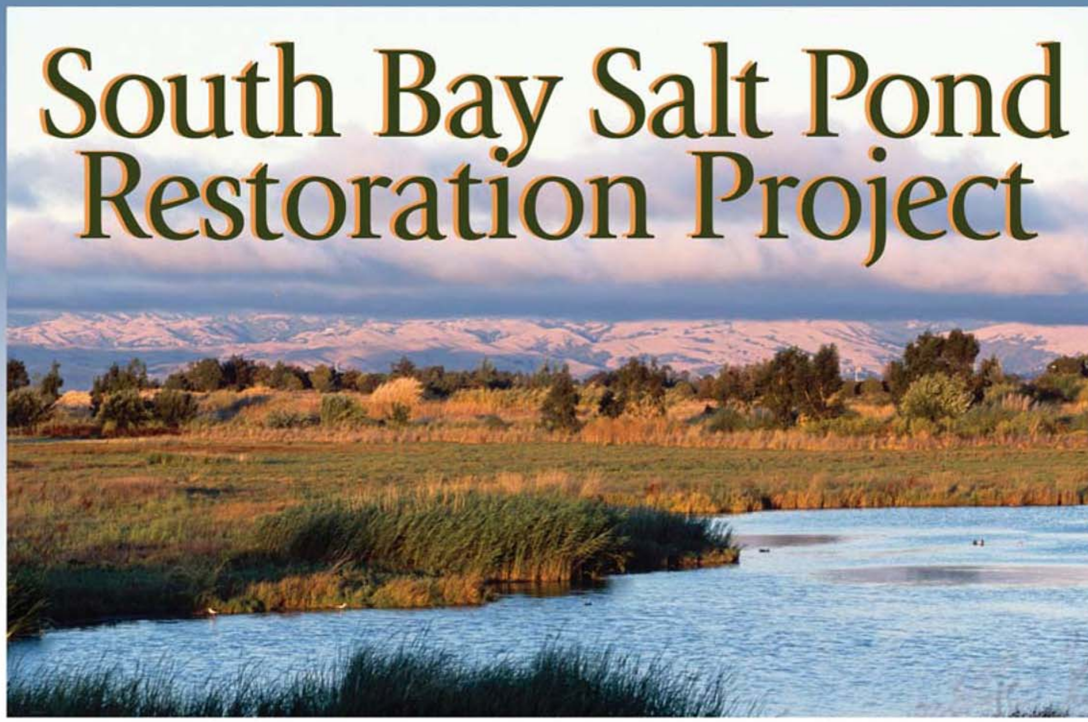

Flood Management and Infrastructure Existing Conditions Report

Submitted to:
California State Coastal Conservancy
U.S. Fish & Wildlife Service
California Department of Fish and Game

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ABBREVIATIONS & ACRONYMS

44CFR	Title 44 of the Code of Federal Regulations
ACFCC	Alameda Creek Flood Control Channel
ACFCWCD	Alameda County Flood Control and Water Conservation District
ALERT	Automated Local Evaluation in Real Time
BFE	Base Flood Elevation
CDFC	California Department of Fish and Game
DFIRM	Digital Flood Insurance Rate Map
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GIS	Geographical Information System
HET	Highest Estimated Tide
ISP	Initial Stewardship Plan
LGRFPP	Lower Guadalupe River Flood Protection Project
LOMR	Letter of Map Revision
MHHW	Mean Higher High Water
MHW	Mean High Water
MLLW	Mean Lower Low Water
MLW	Mean Low Water
MSL	Mean Sea Level
MTL	Mean Tide Level
NAVD88	North American Vertical Datum of 1988
NASA	National Aeronautics and Space Administration
NFIP	National Flood Insurance Program
NGS	National Geodetic Survey
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
OAC	Old Alameda Creek
PAFB	Palo Alto Flood Basin
RWQCB	Regional Water Quality Control Board
SBSP	South Bay Salt Pond
SCVWD	Santa Clara Valley Water District
SFCJPA	San Francisquito Creek Joint Powers Authority
SFHA	Special Flood Hazard Area
SPF	Standard Project Flood
SPRR	Southern Pacific Railroad
UPRR	Union Pacific Railroad
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

1. EXECUTIVE SUMMARY

Understanding the existing conditions within the South Bay Salt Pond (SBSP) Restoration Project is a key element in restoration planning. Before the expected response to proposed restoration and management actions can be described, it is first necessary to detail the pre-project environment setting. This Flood Management and Infrastructure Existing Conditions Report is one of five reports that describe the pre-project environmental setting for the SBSP. This document, along with the companion reports for Biology and Habitats, Hydrodynamics and Sediment Transport, Water and Sediment Quality, and Public Access and Recreation, will be used as a baseline for developing restoration alternatives. The SBSP Restoration Project must provide at least the same level of protection from flood hazards that currently exists in the project area. Therefore, it is essential to understand existing flood management activities and infrastructure, and the level of flood protection they provide, when planning for restoration and management of the South Bay Salt Ponds.

This report describes the current flood hazard management setting based on information from scientific literature, recent San Francisco Bay and South San Francisco Bay (South Bay) reports, data collected by local and government agencies, and previous SBSP project reports.

Local water districts and municipalities currently provide the majority of the flood management services in the project area. The federal government also contributes technically and financially to flood protection projects with federal jurisdiction and interest. The Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers (USACE) have developed flood maps for the South Bay region, including delineation of the 100-year floodplain. The SBSP Restoration area currently lies within the 100-year coastal floodplain. The USACE has aided in implementation of many of the previous South Bay flood protection projects.

Flood hazards in the project area result primarily from coastal flooding (tides, storm surge and wind wave action) and fluvial flows (rainfall/runoff) from the adjacent watersheds to the Bay. Coastal flooding normally results from exceptionally high astronomical tides, increased by storm surge, El Nino climatic events and wind wave action. Near shore flooding often results from the joint occurrence of coastal flooding conditions and large rainstorm events that produce significant fluvial discharges. Fluvial discharges include the contribution from both primary drainages (rivers and major streams) and secondary drainages (including small creeks, culverts and storm water outfalls). Though not the focus of this report, flooding can also be caused by tsunamis and backed up storm drains. Tsunamis have historically been considered subordinate in risk to wind waves, although this is an area of active research and update by Federal Agencies such as the National Oceanic and Atmospheric Administration (NOAA) and FEMA. Local flooding can occur when storm drain discharges are impeded by high Bay water levels. There are many storm drain facilities throughout the project area under several jurisdictions.

Multiple rivers, streams, creeks, and flood control channels provide flow conveyance from upland rainfall runoff sources into the South Bay restoration areas. The primary channels that discharge to the salt ponds include the Alameda Creek Flood Control Channel, Old Alameda Creek and Mt. Eden Creek (minimal freshwater flow) within the Eden Landing Pond Complex; Mud Slough, Coyote Creek, Artesian Slough, Alviso Slough, Guadalupe Slough, Stevens Creek, Mountain View Slough and Charleston Slough within the Alviso Pond Complex; and Ravenswood and Flood Sloughs in the Ravenswood Complex. Publicly maintained flood protection levees provide some level of flood protection in portions of the project area by providing a physical barrier to contain high water from the creeks in the lower watershed areas, including flows through the SBSP project area.

Coastal flood hazards result from extreme tides, with water levels further raised by storm surge and waves. Planning for coastal floods must accommodate existing flood hazards, but also recognize evolving conditions including sea level rise and local subsidence. The South Bay has elevated tides relative to the ocean and the rest of the Bay. The maximum tide levels generally increase with distance southward, although the tidal levels in the numerous tributary sloughs are not well quantified. Historical sea level rise has been about 0.5 ft/century. This has resulted in increased tidal elevations and increased tide ranges in the South Bay, due to the hydrodynamic response in the South Bay. The global eustatic sea level rise is predicted to rise by 0.5 ft in the next 50 years and 1.3 ft in the next 100 years (IPCC 2001). Historically, land subsidence resulting from groundwater extraction has been a major contributor to flood hazards in the Alviso area. Recent data indicate that subsidence due to groundwater extraction has been largely arrested.

Prior studies have presumed that the storm surge (an increase in water levels above tidal elevations resulting from low barometric pressure and on-shore winds) in the South Bay is about the same as that measured at the San Francisco tide gauge (at the Presidio). This has not been verified by in-Bay studies. Recent El Nino events (1983-4 and 1997-8) have caused an increase of Bay water levels averaging about one foot over the entire winter, with peak increases on the order of 2 to 3 feet during storms. Wind waves can exceed 5-feet in exposed areas of the Bay during extreme wind events with recurrence on the order of 100 years. This level of wind wave action can erode and overtop most of the existing salt pond levees.

Nevertheless, the salt ponds have been very effective dissipaters of incident wind wave action and act as large reservoirs to store overtopped waters. With frequent maintenance of the non-engineered levee systems, the salt ponds have historically formed an effective ad-hoc flood protection system. However, there is no formal assessment of the flood management effectiveness of the existing system and hence the actual performance under design conditions is uncertain.

Prior studies (U.S. Army Corps of Engineers 1988; 1989) concluded that the coastal flood risk depends largely on the level of levee damages during a flood event. The range of coastal flooding predicted varies by location, with major flooding predicted in the developed areas inland of the Alviso Ponds, less but locally significant flooding in the vicinity of the Ravenswood Ponds and areas to the south, and minimal coastal flooding near the Eden Landing Ponds and areas to the south. Fluvial flood risks have been significantly reduced in the Alviso region due to planned or recently constructed flood projects along the major channels. The primary fluvial flood issue in the Eden Landing region is the Alameda Creek Flood Control Channel due to significant conveyance losses as a result of channel sedimentation. However, the channel still has the capacity to convey most major floods. Alameda County is actively pursuing measures to restore the channel to expanded capacity to meet their operations and maintenance agreement with the USACE who funded and constructed the original flood control project. Fluvial flooding in the Ravenswood region is largely due the inability of local drainage runoff to reach the Bay. Flows are restricted as a result of insufficient channel capacity along the Bayfront Canal. Expansion of channel capacity and potential off-channel storage options are being investigated to reduce the fluvial flood risk.

2. INTRODUCTION

2.1 Goals and Report Organization

This document describes the existing conditions for Flood Management and Infrastructure for the South Bay Salt Pond (SBSP) Restoration Project. A map of the project vicinity is provided in Figure 1. The goals of the project include the restoration and enhancement of a mosaic of wetlands, creating a valuable ecosystem, while maintaining or improving existing levels of flood protection. The project will also provide public access, wildlife-oriented recreation, and educational opportunities. To accomplish the restoration goals, it is necessary to understand the existing environment, including the existing natural features, salt pond infrastructure, and flood management structures.

This report is one volume in a set of five existing conditions reports. Additional volumes include:
- Biology and Habitats
- Water and Sediment Quality
- Hydrodynamics and Sediment Dynamics
- Public Access and Recreation

Additional companion documents include the Data Summary Report (PWA and others 2004a), the Initial Opportunities and Constraints Summary Report (PWA and others 2004c), and the Mercury Technical Memorandum (Brown and Caldwell 2004).

Existing flood management in the South Bay relies upon both the salt pond facilities adjacent to the Bay and additional flood specific measures to minimize property loss/damage or compromise of infrastructure function. One of the objectives of the restoration project is to maintain at least the same level of flood protection as currently exists, such that frequency of flooding does not increase as a result of the restoration process[1]. As described in the Alternative Development Framework (PWA and others 2004b), the Project Objectives include:

Objective 2: Maintain or improve existing levels of flood protection in the South Bay area.
Objective 6: Protect the services provided by existing infrastructure (e.g., power lines, railroads, wastewater treatment plants)

This report describes the existing hydrologic conditions and flood hazards within the vicinity of the salt ponds, extending inland to the upstream boundary of coastal flooding effects. Existing flood protection and flood management practices identified in this report will guide design recommendations in later stages of the restoration process in support of Project Objectives 2 and 6.

Following this introduction, which includes an overview of flooding processes, this report includes the following sections:

[1] In zones where flooding is not desired. For example, excludes habitat areas.

Section 3 Flood Management. This section presents the existing conditions for regional flood management issues and practices in the South Bay, such as floodplain delineation methodologies and the potential effects of sea level rise. This section also describes the existing conditions for the project setting in the South Bay, including background on major waterways through the restoration area and existing or planned flood control projects.

Section 4 Levees and Other Infrastructure. This section addresses the existing infrastructure, including fluvial and salt pond levees that have been constructed in the project area.

Sections 5 and 6 provide a summary of bibliographic references and a list of report preparers, respectively.

2.2 General Flooding Processes

Flooding in near-shore areas adjacent to the SBSP project sites results from a combination of fluvial (rainfall-runoff) discharges and coastal flooding (U.S. Army Corps of Engineers 1988; U.S. Army Corps of Engineers 1989). Fluvial discharges include the contribution from primary drainages (rivers and major streams) and secondary drainages (including small creeks, culverts, and pump station or gravity storm water outfalls). Coastal flooding results from exceptionally high astronomical tides, increased by storm surge and wind wave action. Storm surge refers to the increased elevation of water levels due to meteorological conditions, such as elevated water due to low barometric pressure, "setup" of the water surface due to on-shore winds, and climatic effects such as the high-water levels that occur during El Niño conditions. Overtopping of levees resulting from wind-wave induced erosion and wave run-up (the maximum vertical elevation above still water) can exacerbate coastal flooding. Near shore flooding often occurs when coastal flooding conditions and large rainstorm events coincide. These two effects are often correlated, since large winter rainstorms may also cause conditions producing storm surge. During these combination events, the elevation of the tide may inundate upland zones directly, or may prevent rainfall runoff from draining to the Bay, resulting in localized inland flooding.

The watersheds bordering the SBSP release stormwater into the Bay through a network of rivers, streams, creeks, and flood control channels. Flooding has been documented in every watershed draining to the Bay. Flooding is typically caused by the inadequate stormwater capacity of the receiving waterway despite efforts to increase channel capacity through levee construction. Channels not meeting the capacity of the expected runoff eventually fail from overtopped levees or its limited capacity to accept more drainage from the basin resulting in back-ups throughout the storm drainage system. Excessive ponding may occur in topographic depressions due to inadequate or compromised drainage facilities, when subjected to severe storm conditions (Tudor Engineering Company 1973; U.S. Army Corps of Engineers 1988)

For coastal flood hazards, potential maximum floodwater elevations depend on local site characteristics as well as regional differences in the flood-generating processes. For example, the steepness of the nearshore profile is an important site characteristic affecting wave runup processes. Another important regional consideration is that the maximum tidal elevations increase with distance going south in the Bay, producing higher tides in the Alviso ponds than in the Eden Landing and Ravenswood complexes. This phenomenon results from the shape of the South Bay in conjunction with the tide characteristics. While storm surge has been considered as a uniform increase above the astronomic tide, variations with location and event, and wind setup are likely to vary regionally as well as locally. Thus, the total water level (tide, storm surge and wave runup) may be expected to vary appreciably between each pond complex. In addition, wave-induced erosion potential varies with both Bay fetch (maximum length for wind wave generation) conditions as well as wind conditions, resulting in elevated erosion potential along the Alameda County shore of the South Bay. The outboard salt pond levees currently provide a beneficial, though generally unquantified, level of coastal flood control for the bayshore communities.

In addition to fluvial and coastal flooding, the frequency, depth and duration of the tides adjacent to flood protection levees may result in high groundwater elevations. Seepage through and underneath the levees may increase the groundwater table and decrease the sediment storage volume available for infiltration. This form of flooding is of particular concern in topographically low-lying areas where ponded surface water is a flood hazard.

3. FLOOD MANAGEMENT

3.1 Regional Setting

Local Flood Control Districts and municipalities presently provide most of the South Bay flood management activities, and a majority of flood protection projects are initiated and funded by the Flood Control Districts. The County and regional Districts with jurisdiction within the Restoration Project include the Santa Clara Valley Water District (Alviso Pond Complex), Alameda County Flood Control and Water Conservation District (Eden Landing Pond Complex) and the County of San Mateo Public Works Department (Ravenswood Complex). In addition, many of the cities in the area are also involved in flood protection activities though studies of coastal flood potential and protection have been limited to a few projects. The ad hoc flood protection provided by the salt ponds had been continuously maintained by Cargill as part of salt production activities.

Prior assessment of coastal flood risks have been accomplished primarily by Federal Agencies (the Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers (USACE)), with cooperation / input from local flood control districts. The USACE coastal studies were completed in the 1980s. FEMA provides flood mapping through the area, and is gradually updating their estimation of coastal flood risks by revising the National Flood Insurance Program publications for communities along the South Bay. The effective date, for FEMA publications, range from the early 1980s to the year 2000 depending on the affected community. Both agencies are in the process of updating their prior assessments of flood risk. USACE is considering an update to their 1988 San Francisco Bay Shoreline Study. FEMA is actively modernizing their Flood Insurance Rate Maps (FIRMs) into digitally available and technically improved flood studies. But because most effective FEMA and USACE documents are dated the current flood risk due to coastal processes may not be accurate in all areas.

While local agencies generally provide for local flood management activities, the federal government is involved in several aspects of flood hazard identification and reduction. FEMA maps flood-prone areas (referred to as SFHA or Special Flood Hazard Areas), and the USACE conducts studies on flood hazards and often participates in flood-management projects with the local agencies. The USACE has taken a Federal interest in several local flood protection projects, such as the San Francisco Bay Shoreline, Alameda Creek and Lower Guadalupe River. On a national level, the federal government has determined that the 100-year flood (flood with a one-percent chance of occurring during any given year) represents the level of flood hazard to be mapped, to provide subsidized insurance for, and provides the level of protection to which most flood control projects are designed. These flood zones may represent flooding from fluvial, coastal, or combined fluvial-coastal flood processes.

FEMA was created in 1979 to administer the National Flood Insurance Program (NFIP). One key role of the agency is to develop standards for fluvial and coastal floodplain delineation. Flood insurance premiums are assigned with reference to flood zones, determined according to FEMA standards, and found on FIRMs. Additional responsibilities of the County Water Districts include participation in the FEMA flood management program and payment of flood insurance premiums by property owners. In communities along the Bay, FEMA has developed Flood Hazard Factors to assign risk to the potential flooding areas. Flood Hazard Factors are used to set actuarial insurance premium rate tables.

Existing floodplain maps/flood zone delineations can be updated via the Letter of Map Revision (LOMR) process, or as part of FEMA's ongoing program to modernize flood maps. FEMA is currently proposing to conduct a flood re-mapping project of San Francisco Bay coastal flood hazards. The project would entail surveying, base mapping, flood hazard analysis and hazard zone mapping, resulting in updated Flood Insurance Studies (FISs) and Digital Flood Insurance Rate Maps (DFIRMs). (Existing paper flood maps based on prior studies and LOMRs are presently being converted to DFIRMs.) In coastal zones, FEMA requires estimates of the 100-year high water elevation, based on a number of factors including maximum tidal elevation, storm surge, waves, etc. The South Bay flood re-mapping project is anticipated to include coastal flood sources (high Bay water levels and wind wave action), and terrestrial flood sources within the coastal region (fluvial and overland / storm drainage), defined by the coastal flood plain. The salt ponds and associated existing pond levees provide limited protection against coastal flooding by sheltering inland areas from direct wave attack and providing storage for flood waters that overtop the levees. The shallow water depths in the ponds also limit wind wave development within the ponds. The existing salt pond levees do not meet FEMA flood protection criteria, but have been effective in the past due to frequent maintenance by Cargill. Many of the berms and levees associated with the salt ponds would require improvement, or replacement, if they were to provide the level of flood protection required for FEMA flood protection standards. Levee enhancement could be achieved by retrofitting of existing levees or by the construction of new levees, combined with an ongoing maintenance program. Retrofitting or constructing levees certified by FEMA may result in a change to the SFHA, relieve a community from current levels of flood risk, and reduce the individual cost for mandatory flood insurance.

To correspond to FEMA's standards the levee system must meet engineering standards set forth in Title 44 of the Code of Federal Regulations (44CFR), Section 65.10 of the NFIP regulations, including: a minimum of 3.0 feet of freeboard above the Base Flood Elevation (BFE) or at least one foot above the calculated total water level (including wave runup); geotechnical analyses to demonstrate that the levee foundations and embankments will remain stable during the base flood; and an operation and maintenance plan to ensure the continued flood protection capacity of the levee system in the future. Historically there are differences between FEMA and USACE levee certification methods, though a recent agreement allows the USACE to certify levees that meet FEMA criteria and certify levees that do not meet FEMA criteria when risked-based analysis has been performed. The analysis must demonstrate that with lesser freeboard adequate levee protection is maintained. For coastal levee analyses, particular emphasis must be placed on wave forces, overtopping, and erosion potential. In such cases exceptions to the FEMA freeboard criteria can be requested per 44CFR providing the crest is at least two feet above the stillwater surge elevation, which includes wave runup. The USACE minimum freeboard criterion for coastal levees is one foot above stillwater tide elevation or one foot above the wave runup elevation.

The USACE approach to coastal levees in the Bay was summarized by Moffatt & Nichol as: "The design crest elevations for the levees and other protective structures considered in this study were based on four components: "still-water" tide elevations; tidal flood elevations; wave run-up elevations; and freeboard.

An allowance for overbuild above the design crest elevations of levees was made to compensate for post-construction settlement." Freeboard requirements for outboard levees exposed to wind-induced waves, is one foot of freeboard above the wave runup elevation. For inboard levees or levees not exposed to wave runup the crest elevation requires one foot of freeboard above the still-water tide elevation. Wave effects were not estimated for inboard levees due to the presence of the outboard levees although the USACE has acknowledged that the inboard levees may overtop should the outboard levees fail (Moffatt & Nichol Engineers 2005)

FEMA FIRM Panels for communities along the South Bay typically show the coastal flood limits extending to the topographic elevation of the estimated BFE with no extenuated consideration for the existing levees (U.S. Army Corps of Engineers 1988). A review of the FEMA Guidelines and Specification for Coastal Flood Studies indicates that the failed condition of a coastal structure and or eroded shore (called Event Based Erosion) can be considered in a Flood Study, and hence an updated study may re-assess the presumed failed condition (Federal Emergency Management Agency 2003) Guidelines and specifications for the Pacific Coast are presently being updated and should be available in 2005.

For fluvial systems, FEMA determines BFE by using Mean Higher High Water (MHHW) as the downstream tidal water surface elevation (tidal boundary), coupled with a 10-, 50-, 100-, or 500-year flood discharge for the upstream flow conditions. In order to provide a national standard without regional discrimination, the 100-year flood profile has been adopted by FEMA as the base flood for delineation of the 100-year floodplain and for purposes of flood management measures (Federal Emergency Management Agency 1988). The stillwater flood elevation is defined by FEMA as the projected elevation that floodwaters would assume in the absence of waves resulting from wind or seismic effects.

FEMA delineation of the coastal floodplain in the South Bay is based on the conservative assumption that the salt pond levees (which do not meet standard FEMA flood protection stability criteria) would provide a reduction of wave action but would not prevent inundation from high Bay water levels. Hence, the coastal floodplain subject to the NFIP, which affects development and insurance requirements, is based on a projection of the 100-year BFE onto the surrounding landscape. The USACE (1988) used a somewhat less conservative approach to delineate a *potential* 100-yr tidal floodplain for San Francisco Bay utilizing a tidal stage versus frequency study at several locations in the Bay, and estimating the degree of levee erosion and overtopping. The maximum extent of tidal flooding was determined using the contour of the computed 100-year tidal elevations on 1:6000 scale photo-topographic maps. This contour represented the inland boundary of the tidal floodplain that would result if the levees in the study area failed during the tidal event and all areas behind the levees flooded to the elevation of the tide (U.S. Army Corps of Engineers 1988). This estimate was provided to FEMA for their use in mapping the flood plain limits. Figure 2 illustrates the FEMA 100-year combined fluvial and coastal floodplain in addition to the 100-year extent of coastal flooding computed in the 1988 USACE study, are similar. The actual extent of inundation in a 100-year coastal flood would likely be less, owing to the flood protection afforded by the existing salt ponds, as historically maintained by Cargill. This was analyzed by the USACE in the same study, but estimating the extent of levee erosion and failure. The estimated flood plain using this approach is much smaller than shown in the FEMA maps, in particular in Alviso

In the SBSP area the floodplain can be defined utilizing multiple methods (USACE or FEMA methodologies) and considering multiple mechanisms of flooding. These differing methods may result in substantially different floodplain limits (U.S. Army Corps of Engineers 1988). Within the San Francisco Bay Shoreline Studies (1988; 1989; 1992), the USACE analyzed the hydraulics of wave runup, and associated overtopping and erosion of levees. The extent of coastal flooding, incorporating levee-based wave attenuation, is depicted in Figure 2 for several locations in the Alviso pond complex. Within these locations, the USACE floodplain, including levee attenuation effects, covers a much smaller area than the more conservative estimate provided in the same Corps study for use by FEMA (described above). The USACE floodplain analysis assumed that the salt pond levees would be maintained to preserve existing flood protection benefits. This assumption is an important consideration during the interim and restoration project phases. The USACE Shoreline Studies will be re-evaluated and updated as part of the USACE SBSP Feasibility Study. It is possible that any updated FEMA FIS, based on new guidelines for the Pacific Coast (in development), may also include an updated assessment of levee performance during flood events.

3.1.1 Coastal Flooding Processes

Coastal flood elevations can be determined by examining extreme water levels and wave conditions. The USACE reports from 1988 and 1989 reported both “worst-case” scenarios and “most likely” conditions in defining potential tidal floodplains in the South Bay. The “worst-case” scenario ignored any type of physical barrier that could reduce the extent of potential flooding and only considered extreme high tides. The “most likely” condition evaluated the probability of waves generated by winds of various speeds, durations, and directions occurring simultaneously with various extreme Bay water levels (tides and storm surge). Combinations of winds and tides were selected to define the 10, 50, 100, and 500-year forcing events from which wave runup and overtopping were predicted. Overtopping and erosion of the salt pond levees were also considered in the “most likely” condition.

Astronomical tides in the South Bay are mixed semidiurnal consisting of two tides of unequal range that occur each day. On an annual basis, the tides in the South Bay show strong spring-neap variability with the greatest spring tides typically occurring in July and December and the smallest neap tides occurring in April and October. As the tides propagate from the Pacific Ocean into the San Francisco Bay, in the form of shallow water waves, the tide amplitudes and phases are modified by bathymetry, reflections from the shores, the earth’s rotation and bottom friction. The enclosed nature of the South Bay creates a mix of progressive wave and standing wave behavior, wherein the wave is reflected back upon itself (Walters and others 1985). The addition of the reflected wave to the original wave increases the tidal amplitude. Amplification causes the tidal range in the South Bay to increase southward, from approximately 7.8 feet at the Presidio, to 8.5 feet at the Dumbarton Bridge, to 9.01 at Coyote Creek (National Oceanic & Atmospheric Administration)

Storm surges result from atmospheric disturbances characterized by low pressures and high winds and produce a short-term rise in water elevation. The timing of storm events with respect to the phase of the astronomical tides is critical in defining the water surface elevation. When a storm coincides with a spring high tide, the resulting increase in water elevation can be significantly larger than just the storm surge alone. In addition to storm surge, an El Nino event can produce a substantial difference in still water level along the Pacific Coast and within estuaries. The significant El Niños of 1982-83 and 1997-98 raised water levels along the Pacific Coast by 1 to 2 feet in some areas and persisted for several months (Komar and Allan 2004). Water level data collected at the Presidio tide station in San Francisco show the water was elevated an average of 0.7 foot during the 1997-98 winter months (Philip Williams & Associates Ltd 2002). Figure 3 shows the predicted and measured tidal elevations at the Redwood City NOS station and illustrates the extreme storm surge during the 1997-98 El Nino. On February 6, 1998, the difference between the measured water levels and the predicted astronomic tide was about 2 feet.

The 100-year tidal elevations for various tidal gauge locations in the South Bay were calculated by the USACE (U.S. Army Corps of Engineers 1984). The 100-year water levels relied on the Presidio tide data for storm surge estimates due to a lack of comparable data in other locations. The adopted annual peak tide-frequency curve included 129 years of tidal records from the period 1855 through 1983. Tidal data for this study included the effects of astronomical tides, barometric pressure fluctuations, and wind setup. A consistent rise in 20-year mean tidal elevations throughout the 129-year period was reported and, as a result, the computed tide-frequency curve was adjusted upward 0.53 foot to account for this increasing trend (U.S. Army Corps of Engineers 1984). The adopted 100-year tidal elevations for the South Bay are shown in Figure 4. The profile of elevations is slightly irregular and broken due to the fact that most of the extreme tidal elevations were predictions rather than observations. Figure 5 shows the adopted 100-year tidal elevations superimposed on a map of the South Bay.

Most of the waves in the South San Francisco Bay are locally generated wind-waves as opposed to swell propagating from the open ocean. The wind direction over the South Bay is typically from the west to northwest in the late spring, summer, and early fall with more variable conditions in winter (Cheng and Gartner 1985). Extreme high winds can arrive from other directions, in particular southerly winds that precede frontal passage and north and northeast winds that can occur during strong thermal gradients in the fall and winter. Local wind-wave characteristics such as wave height and wave period in the South Bay are estimated using empirical equations in simplified form or with the aid of two-dimensional computer models. In addition to wind characteristics, the fetch over which the waves are generated is considered in terms of length, depth and shape. The local still water level at the shoreline is elevated due to both wave setup and wave runup. Wave setup is a primarily a function of the height of breaking waves and wave runup mostly depends on wave height, wavelength, and the slope of the levee or embankment.

In combining the water level fluctuations from the astronomical tides and storm surge with the increases in water level elevation due to wave setup and wave runup, a total increase in the water level elevation relative to the still water level can be defined. Wave overtopping occurs when the total water elevation exceeds the crest elevation of the embankment or levee.

Another possible flood source is a tsunami, most likely generated by seismic activity in the Pacific Ocean propagating into the Bay through the Golden Gate. This scenario has been investigated previously with the aid of a numerical model of long wave propagation (Garcia and Houston 1975). The results indicated that the Bay was susceptible to inundation by tsunamis. The 100-year runup due to Tsunami waves was estimated to be between 4.0 and 4.5 feet above mean sea level in the South Bay. The timing relative to the tide was considered an important factor, and it was considered unlikely that a tsunami would occur during an extreme high tide. The total water level during a tsunami is expected to be less than the water level caused by wind wave action, for a given recurrence probability level. Also, the recurrence of tsunamis is so infrequent that they probably do not measurably affect extreme Bay water level statistics. Hence, it has been largely presumed that coastal flood risk in the Bay is controlled by wind wave action and not tsunamis (U.S. Army Corps of Engineers 1984).

It should be noted that tsunamis and the associated risk of coastal flooding is an area of renewed research. In particular, there is concern that massive tsunamis could be generated at subduction faults and landslides near developed shores causing locally massive damages with short notices. Until NOAA and others complete ongoing studies, it is not clear how to assess the risks associated with tsunami action in the South Bay. For example, it is not known how well the existing levee system would withstand a tsunami event likely to occur within a 100 to 500 year time frame.

In determining the amount of overtopping for each levee, it is important to consider the amount or condition of the structure and the damage that occurs to it during a storm (event based erosion). A two-step approach to estimating levee degradation was adopted for the earlier studies by the USACE (U.S. Army Corps of Engineers 1988; U.S. Army Corps of Engineers 1989). The first step assigned an erodibility index to each levee segment. The erodibility index was derived from analyzing the crest width, steepness of inboard slope, and type of material for each levee. For overtopping events, reductions in crest elevations were then correlated with the erodibility index. The second step involved a water level analysis of tide and wind events with various frequencies of occurrence. For levee segments protected from wave action, the still water level was used and for levees exposed to wave action, the wave runup elevation was used. These studies showed that significant erosion of levees occurred when the still water level exceeded the minimum levee elevation by 1.0 foot or the wave runup exceeds the minimum levee elevation by 2.0 feet (U.S. Army Corps of Engineers 1988; U.S. Army Corps of Engineers 1989).

The USACE studies found that the salt ponds formed an effective flood barrier for many inboard locations, due to the dissipation of Bay wind waves by the levees and the capacity of the ponds to store overtopped waters. The flood protection performance was considered dependent on the active maintenance of the un-engineered and sub-standard levees. Even with the extensive pond systems as coastal protection buffers, coastal flooding was predicted to occur during extreme events in some locations, as described in the following sections.

Sea Level Rise

The rise in sea level relative to land depends on global eustatic sea level rise and vertical land movements. If the land experiences uplift, the relative rate of sea level rise will be less than the eustatic sea level rise; if the land subsides, the relative sea level rise will be greater than eustatic sea level rise.

The mean sea level trend at the Presidio, San Francisco between 1906 and 1999 is 0.70 feet per century (NOAA 2004). This estimate is based on monthly mean sea level data with the averaged seasonal cycle removed. The rate of sea level rise at the Presidio is considered to be equivalent to eustatic sea level rise at the Bay boundary because the land at the Presidio is stable (Moffatt and Nichol Engineers 1988). While rates of sea level rise have been relatively constant over the past couple of centuries, the rate is expected to increase because of global warming. Global eustatic sea level is predicted to rise by 0.5 feet in the next 50 years and 1.3 feet in the next 100 years (based on mid-range estimates from IPCC (2001)

Local land subsidence has occurred in the Santa Clara Valley due to groundwater withdrawals, leaving parts of Alviso at a very low elevation relative to the adjacent sea level. Rates of land subsidence measured at San Jose between 1934 and 1967 exceeded 0.024 ft/year (approximately 8 ft in 34 years; (Poland and Ireland 1988). The rate of groundwater withdrawals has since been reduced and the aquifers artificially recharged. Both activities are expected to reduce or arrest local land subsidence in the Santa Clara Valley due to groundwater withdrawals. Regional subsidence occurs in the South Bay region due to tectonic activity at a rate on the order of a few inches/century (Moffatt and Nichol Engineers 1988).

Recent estimates of vertical land movements in the South Bay have shown small amounts of subsidence and seasonal uplift. USGS satellite data showed that uplift occurred throughout much of the southern Santa Clara Valley from 1992 to 1997 at a rate of approximately 0.01 feet/year (Galloway and Jones 2000). For the Palo Alto shoreline, the data showed stable land conditions. A small amount of subsidence occurred along the Hayward shoreline at a rate of approximately 0.005 feet/year. Benchmark re-survey data around Alviso between 1987 and 2001 (Santa Clara Valley Water District 2002) shows some agreement with the USGS satellite data based on a spot check. Overall, these recent data indicate that the extreme subsidence due to ground water extraction is no longer occurring. The future rate of vertical land motion has not been estimated. It may not be appropriate to extrapolate rates observed in recent data over many years for planning purposes as they are based on only short measurement periods using new techniques.

National Geodetic Survey (NGS) tidal benchmark re-leveling data typically provide the best estimate of local vertical land movements for planning purposes. However, these data are not presently available for the South Bay. Typically, NGS tidal benchmarks were established in the South Bay during the mid-1930s and the last published re-leveling data are from the mid-1960s. These data show subsidence due to groundwater withdrawals. Updated re-leveling data will provide long-term records for project areas and may be available from NGS or surveying contractors in the near future. Figure 6 shows an example of long-term subsidence trends in San Jose that indicates subsidence has been arrested. This trend should be confirmed with NGS tidal benchmarks.

Moffat & Nichol (1988) estimated the projected relative sea level rise rate by adding the rate of eustatic sea level rise for the Bay to an estimate of local vertical land motion (typically subsidence). Land subsidence was calculated based on re-leveling of NGS tidal benchmarks between the mid-1930's and mid-1960's. Since recent re-leveling data were lacking at the time of the study, the high historic rates were adopted. The historic rates reflected significant land subsidence in the South Bay due to groundwater withdrawals. A method similar to that used in Moffat & Nichol (1988) should be used with updated benchmark re-leveling data and the most recent projections of global sea level rise (i.e. IPCC) to estimate local rates of projected relative sea level rise for planning purposes.

Updated re-leveling data of NGS tidal benchmarks will also provide accurate conversions between published tidal datums (i.e. mean lower low water [MLLW]) and vertical land datums (i.e. North American Vertical Datum of 1988 [NAVD88]). These conversions are critical to project planning and are currently not available. NGS or surveying contractors may provide updated conversions from tidal to land datums in the near future.

NOAA recently updated tidal datums based on the most recent tidal epoch (1983-2001), which is a 19-year period that tide levels (i.e. MLLW, mean sea level (MSL), mean higher high water (MHHW)) are averaged over. Comparison of tidal datums with the 1960-1978 tidal epoch provides an estimate of the change in mean sea level and other tidal datums relative to the land elevation over a period of 23 years. These estimates may not be representative of long-term trends because they are based on only two periods of time and the variability in tidal datums over time may be on the order of the estimated differences. However, these estimates are based on the most recent data and may indicate recent shifts in sea level rise trends. The difference in datums is listed in Table 1 along with the difference at the Presidio, San Francisco. The equivalent rate of increase in mean sea level rise and other tidal datums is shown in Table 2.

The comparison of tidal datums indicates that the tidal range in the South Bay is increasing, except in Coyote Creek at the extreme south end of the Bay. As a result, MHHW may be increasing faster than MSL. It will be important to consider the potential increase in MHHW above MSL for planning purposes, as coastal flooding occurs at high tide water levels.

In summary the observations indicate that the relative increase in mean sea level in the South Bay may be less than at the Presidio over the last 23 years. However, this varies around the South Bay with an increase of 0.14 feet at Redwood Creek compared with 0.11 feet at San Mateo, Dumbarton Bridge, Palo Alto, and Coyote Creek. The difference in tidal datums may be due to tectonic uplift offsetting the eustatic sea level rise further south in the Bay. The actual rates of relative sea level rise may vary appreciably from these estimates, given the size and rate of changes relative to measurement capabilities and measurement time frame. The rate used for planning purposes should be selected based on consideration of the sensitivity of the project to higher or lower rates, as well as other available data.

Table 1 Relative sea level/tidal datum rise in the South Bay based on update to NOAA Tidal Benchmarks from 1960-1978 to 1983-2001 tidal epoch

Station ID: Station Name:	9414290 The Presidio, SF	9414458 San Mateo Bridge, West Side	9414523 Redwood City, Wharf 5	9414509 Dumbarton Bridge	9414525 Palo Alto Yacht Harbor	9414575 Coyote Creek, Alviso Slough
MHHW (ft)	0.21	0.16	0.20	0.20	0.19	0.15
MHW (ft)	0.20	0.15	0.20	0.18	0.17	0.17
MTL (ft)	0.20	0.11	0.16	0.12	0.12	0.15
MSL (ft)	0.19	0.11	0.14	0.11		0.11
MLW (ft)	0.20	0.02	0.13	0.07	0.08	0.14
MLLW (ft)	0.20	0.05	0.10	0.06	0.06	0.15
Diurnal Tide Range (ft)	0.01	0.11	0.11	0.14	0.12	0.003
Mean Tide Range (ft)	0.00	0.13	0.07	0.11	0.09	0.03

Table 2 Rate of relative sea level/tidal datum rise in the South Bay from 1960-1978 to 1983-2001

	Presidio	San Mateo	Redwood City	Dumbarton	Palo Alto	Coyote Creek
MHHW (ft/cy)	0.91	0.69	0.89	0.86	0.81	0.67
MHW (ft/cy)	0.88	0.64	0.86	0.77	0.74	0.72
MTL (ft/cy)	0.88	0.47	0.70	0.54	0.52	0.64
MSL (ft/cy)	0.82		0.60	0.47		
MLW (ft/cy)	0.89	0.08	0.55	0.30	0.34	0.60
MLLW (ft/cy)	0.87	0.22	0.42	0.24	0.27	0.66
Diurnal Tide Range (ft/cy)	0.04	0.48	0.47	0.61	0.54	0.01
Mean Tide Range (ft/cy)	-0.01	0.56	0.31	0.47	0.39	0.12

	Presidio	San Mateo	Redwood City	Dumbarton	Palo Alto	Coyote Creek
Relative change in MSL	+	+	+	+	+	+
Change in diurnal tidal range	(+)	+	+	+	+	(+)
Change in diurnal inequality[1]	+	-	+	+	+	-

3.1.2 Fluvial Flooding Processes

Fluvial discharges result from rainfall runoff conveyed to the Bay by natural or constructed channels. In the South Bay, fluvial flooding along these channels often results from the constriction of flows to a relatively narrow corridor, usually by levees, to protect the adjacent developed areas (upstream) or the salt ponds (downstream). During large rainstorms, high runoff flows are constricted by the channel levees, resulting in higher water surface elevations and overtopping of the levees and inundation of the near channel areas at some flow rate.

From a flood management perspective, there are two potential solution approaches to reduce fluvial flooding: increase channel flow conveyance or increase flood storage capacity (detention).

Increased conveyance results from channel modifications to accommodate a higher flow rate within the channel corridor. This can be achieved by increasing the width or depth of the channel, (thereby providing additional cross-sectional area for flow) or in some cases, reducing the channel roughness to increase flow velocity and conveyance. Channel width is usually constrained by adjacent development. Increased depth can be obtained in some cases by excavation, or by raising the height of the channel levees. Modifications to the channel cross-section may change over time due to either erosion (increases conveyance but destabilizes the channel) or sedimentation (decreases conveyance). The cross-sectional area of a stable channel is generally in equilibrium with the amount of water and sediment conveyed on a regular basis. While channel dredging may temporarily provide additional flow area, subsequent sediment deposition will gradually reduce the channel conveyance back to an equilibrium configuration. This is a common problem for most of the fluvial channels in the SBSP area. As a result of the low channel slope in the baylands (resulting in low flow velocities and the potential for sediment deposition) sedimentation has reduced the channel depth and width over time, resulting in reduced conveyance and increased flood hazards. One approach to permanently increasing channel cross-section for these tidally-channels is to increase the amount of daily tidal flow (referred to as tidal prism) in the channels by connecting adjacent or restored tidal wetlands to the channel. The increased tidal flow can provide ongoing scour of existing channels and result in augmented channel conveyance without repeated dredging costs and impacts.

Providing temporary detention storage of floodwater can also reduce flooding impacts by reducing the flow rate in the channels further downstream. Although this has typically been accomplished with reservoirs or basins in the upper watershed, it is a viable approach in the baylands area as well. Off-channel detention storage can reduce in-channel water surface elevations, which is an important consideration during very high tides. One approach to providing off channel storage would be to route channel discharge through the restored salt ponds. This could result in a decrease to downstream water levels and reduce upstream water levels and flood hazards.

Two examples of flood mitigation currently being considered for waterways through the pond complexes are the Santa Clara Valley Water District (SCVWD) off-channel detention storage project at Alviso Slough ((Schaaf & Wheeler 2004) and the Alameda County study to expand flood conveyance and temporary storage capacity in the lower reaches of the Alameda County Flood Control Channel (URS, (2004a). In the analyses, culverts or weirs between the channel and the ponds would be created to divert flood events into the salt ponds for flood control purposes. The alternatives being considered have the potential to increase the tidal prism resulting in scour of the channel and increased conveyance of flood flows. An expected result is a decrease in downstream water levels within the channel. The lower water surface (and associated flood reduction benefits) would extend for some distance upstream from the Bay to reduce the flood hazards to along the drainage-way corridor.

3.2 Project Setting

The South Bay Salt Ponds Restoration Project includes three geographically distinct salt pond complexes (refer back to Figure 1):

- The Eden Landing Complex, located immediately south of the San Mateo Bridge.
- The Alviso Complex, located at the southern end of the South Bay, near Alviso.
- The Ravenswood Complex, located at the western connection of the Dumbarton Bridge.

The combination of existing salt ponds, the surrounding levees, and existing adjacent marshplains comprise the project area. The USACE Shoreline Studies (1988; 1989; 1992) provide a historical record of coastal flooding events in the South Bay. According to the study, levee failures are not the most likely mode of flooding. Rather, the combination of moderate to high tides, coincident with high fluvial runoff, is the cause of many South Bay flooding events. The influx of Bay water into tidal sloughs at high tide reduces the channel capacity and increases channel water levels upstream. Changes to the salt ponds would affect flood protection to residences and businesses in these areas. These areas represent a constraint on the restoration design as well as providing an opportunity to improve flood protection.

Major fluvial runoff events occur during the rainy winter and spring seasons. During the summer months and dry years, there is little rainfall-runoff inflow to the South Bay, and most freshwater inflow results from the municipal wastewater treatment plants (Cheng and Gartner 1985). Wastewater effluent flows from the treatment plants represent a significant effect on South Bay salinity, but not directly on the magnitude of winter flood flows. Seasonal and annual variability in streamflow can range over an order of magnitude at a given stream (Life Science 2003).

A number of studies and some measured data are available on water levels or flood hydrographs for channels in the vicinity of the restoration areas. The Santa Clara Valley Water District, the City of Palo Alto, and the USGS collect river stage and flow for the South Bay tributaries. While most of these measurement sites are upstream of the restoration project, they provide useful data for predicting peak flood flows in the lower reaches. The USGS maintains gauging stations on Coyote Creek, Guadalupe River, Alameda Creek, the Alameda Flood Control Channel and most stations contain historical records dating back to the 1950s. The City of Palo Alto maintains flow gauges and water level sensors on Adobe Creek.

Tudor and others (1973) documented the 100-yr design flows for nine of the major drainages located between San Francisquito Creek and Coyote Creek; however, these flow rates may underestimate the current 100-yr flow rates due to the extensive development that has occurred in Santa Clara County since the 1970s. Moffatt & Nichol (2005) provide detailed descriptions of the primary drainages and sloughs, including physical parameters, estimated peak flow rates and records of fluvial flooding history. FEMA publishes FIS data with peak flow discharge rates for most major waterways draining to the Bay. FIS data for the communities that border the Bay are aging and may not represent existing conditions. The peak flow rates published in the effective FIS are re-printed in this report for each drainage-way, in each watershed, hydrologically connected to the Bay and influenced by its tides.

3.2.1 Eden Landing Pond Complex (Baumberg)

The 4,800-acre Eden Landing Pond Complex is located between Highway 92 (the San Mateo Bridge) and the Alameda County Flood Control Channel within Alameda County (Figure 1). The California Department of Fish and Game (CDFG) owns and manages the Eden Land Complex. Mt. Eden Creek and Alameda Creek divide the 23-pond complex into three sub-groups of ponds. West of the outboard levees is a wide mud flat and tidal marsh. Several hundred acres of extant tidal marsh known as the Whale's Tail Marsh front the San Francisco Bay near the center of the complex. The cities of Hayward, Union City, and Fremont are adjacent to the pond complex on the inland side.

The CDFG is in the process of restoring a portion of the Eden Landing Ecological Reserve on the northeast boundary of the SBSP restoration site. In support of the reserve and to protect recent development in the Eden Shores Community, additional flood protection is being created for the residential and commercial inland developments. The CDFG are building a flood protection levee around the ecological reserve and high ground was created for the recent residential development.

Eden Landing Coastal Flooding

Predictions for extreme tide events and tidal benchmark data for stations near the Eden Landing Pond Complex are shown in Table 3. The Highest Estimated Tide (HET) and the 10, 100, and 500-year Estimated Tides are from the USACE (U.S. Army Corps of Engineers 1984). Tidal benchmark data are from NOS. The newly released data from NOS for the 1983-2001 tidal epoch shows an increase in water levels and tidal ranges. It should be noted that the USACE high water level estimates were developed from the 1960-1978 tidal epoch and have not been updated to account for sea level rise. Also, the available tidal elevation data are relatively sparse in the South Bay. Presently, complete correlation of tidal datums in the South Bay to the North American Vertical Datum (NAVD 88) is not available and many of the tide gauges were operational for only short periods of time. Revisions are currently underway by the USGS and NOAA to correlate NGVD 29 and NAVD 88 for the SBSP project sites.

The Eden Landing Pond Complex is exposed to persistently elevated wind wave action due to the westerly and northwesterly winds crossing the Bay. Consequently, the outboard levees and exposed marshes are prone to erosion. The USGS collected wave data between the Dumbarton and San Mateo Bridges in 1993 and 1994, and URS also collected wave data within the South Bay for the San Francisco Airport Runway Reconfiguration Study (URS 2002c). The USGS and URS data are summarized in Table 4. Although these wave data are useful, the measurements do not represent extreme events for the South Bay.

Analysis of wind data from the San Francisco Airport between 1948 and 1995 shows approximate 100-year wind speeds of 67, 78, and 90 mph for the W, NW, and N directions, respectively. Using wind wave hindcast equations and methods from the Shore Protection Manual (U. S. Army Corps of Engineers 1984) for the South Bay in the vicinity of the Eden Landing Pond Complex, these extreme wind events could potentially produce 6 to 8 foot waves. As a consequence, waves of this size could cause significant overtopping and erosion of the outboard levees. Flood protection measures in the Eden Landing Complex have consisted of reinforcing outboard levees with riprap. Portions of outboard levees in the Eden Landing Pond Complex have been reinforced with riprap and are reported to be in serviceable condition (Moffatt & Nichol Engineers 2004). Effective stillwater elevations published in FEMA FISs for communities contiguous to the Eden Landing Complex and the Bay are shown in Table 5.

The USACE flood studies completed in the 1980's found little risk of coastal flood damage in the vicinity of Eden Landing due to lack of developed areas and the presumption that the levees would be maintained to facilitate salt production (U.S. Army Corps of Engineers 1988). Where salt ponds are currently being re-opened to tidal action, the restoration team is constructing a new inboard levee between the restoration zone and developed areas to the east. It is unclear whether this levee meets FEMA criteria to remove these areas from the designated floodplain.

Table 3 Eden Landing Tidal Benchmarks

	ID # 941 4458 San Mateo Bridge (West End)	ID # 941 4637 San Mateo Bridge (East End)
Tidal Epoch	1983-2001	1960-1978
500-year Estimated Tide (USACE)	11.0	11.0
100-year Estimated Tide (USACE)	10.7	10.7
10-year Estimated Tide (USACE)	10.2	10.2
HET (USACE)	10.8	10.7
Highest Observed Water Level	10.7	9.2
Mean Higher High Water (MHHW)	7.7	7.7
Mean High Water (MHW)	7.1	7.1
Mean Tide Level (MTL)	4.1	4.1
National Geodetic Vertical Datum 1929 (NGVD)	3.6	3.7
Mean Low Water (MLW)	1.2	1.2
Mean Lower Low Water (MLLW)	0.0	0.0
Lowest Observed Water Level	-2.9	-1.8

Note: Elevations are in reference to ft above MLLW
Source: NOS and USACE, 1984

Table 4 Wave Heights and Periods in the South Bay

Data Source	Time Period	Range of Significant Wave Heights (ft)	Range of Wave Periods (s)
USGS	December 1993	0.33—1.8	2—5
USGS	March 1994	0.66—2.6	1—2.5
URS-2	Winter—Fall	0.07—3.0	1.9—10.7
URS-3	Winter—Fall	0.07—2.3	2.0—10.2

Sources: USGS and URS Measured Wave Data in South Bay (URS 2002c)

Table 5 San Francisco Bay Stillwater Elevations in Eden Landing Complex (ft NGVD)

Eden Landing Complex	FIS	Recurrence Interval (Year)				
Adjacent Community	Effective Date	10	50	100	500	Location
Alameda County, Unincorporated	2/9/2000			7.1	7.4	At City of Hayward, North Corporate Limits
Hayward[1]	2/9/2000	6.0	6.3	6.5	6.7	North Corporate Limits to West Jackson St
Hayward[1]	2/9/2000	6.6	6.9	7.0	7.2	West Jackson St to South Corporate Limits
Union City	2/9/2000			7.2	7.5	At Union City
Fremont	2/9/2000			7.0		At Mouth of ACFCC to Thornton Road
Fremont	2/9/2000			8.0		From Thornton Rd to Coyote Creek Railroad Crossing
Fremont	2/9/2000			9.0		From Coyote Creek Railroad Crossing east to Corporate limits

Source stated in FIS: USACOE SF District, San Francisco Bay Tidal Stage vs. Frequency Study, October 1985

[1] Format for establishing the 100-year and 500-year flood elevations described in FIS

Eden Landing Fluvial Flooding

The pond complex is within the Alameda Creek Watershed. Alameda County Flood Control and Water Conservation District (ACFCWCD) has jurisdiction over the watershed and all drainage-ways leading to the Eden Landing Pond Complex. The USGS has operated a stream gauge (11179000) at the Alameda Creek exit from Niles Canyon for 111 years. The size of the watershed at the gauge station is 633 square miles.

Table 6 below summarizes all Eden Landing hydrologic connections to the Bay and their tidally influenced tributaries. Further details on the fluvial channels are provided in the following sections.

Table 6 Eden Landing Hydrologic Connections

Hydrologic Connection	**Watershed**	Tributary	**Recurrence Interval**				Notes
Tributary	Community	(sq-mi)	10-year	50-year	100-year	500-year	
Mt. Eden Creek	**Alameda Creek**	-					4
Old Alameda Creek	**Alameda Creek**	-					
Line A (Zone 3A)	Hayward	21.6			2,815	2,885	1
Ward Creek-Line B (Zone 3A)	Alameda Unincorporated	8.9	1,640	2,800	3,460	5,100	
Line D (Zone 3A)	Hayward	5.5			1,610	1,620	1
North Creek	Hayward	-					
Alameda Creek Flood Control Channel	**Alameda Creek**	700.0	14,600	27,000	29,000	52,000	3
Dry Creek	Union City	9.5	750	1,500	1,800	2,740	

Source: (Moffatt & Nichol Engineers 2003)
Notes: 1-Capacity Restrictions Flows Adjusted for Spill 2-Capacity Restrictions Flows not adjusted 3- 2-year = 3,810 cfs 4- Freshwater Input Negligible

Alameda Creek Watershed

The Alameda Creek watershed is the largest drainage in the southern San Francisco Bay region, encompassing almost 700 square miles and stretching from Mt. Diablo in the north to Mt. Hamilton in the south, and east to Altamont Pass. The watershed includes remote wildlands, urbanizing areas such as Livermore, Pleasanton, Dublin, and San Ramon, and the urbanized Tri-City area of Fremont, Union City, and Newark on the San Francisco Bay Plain. Most of the watershed is undeveloped rangeland or public lands and parks. A smaller portion is used to grow crops. Although more than 200,000 people live within the watershed boundary, only about seven percent of the total acreage is used for residential, commercial, and industrial purposes.

The following sections describe the major Alameda Creek Watershed waterways (Coyote Hills Slough, Old Alameda Creek, and Mt. Eden Creek) that drain to the Eden Landing Pond Complex. The descriptions start from the north and move sequentially south.

Mt. Eden Creek

The Mount Eden Creek tributary drains a small area south of Highway 92 in the City of Hayward. The slough only receives flood flows from one local pump station and is not considered a source of flood hazards.

The CDFG is sponsoring the Mount Eden Creek and Old Alameda Creek restoration efforts to restore and enhance tidal marsh habitat outside of the northeast corner of the Eden Landing Complex. As part of the restoration project, tidal sloughs are currently under construction in the Eden Landing Complex using the Cargill dredge. When this restoration project is complete, Mount Eden Creek and North Creek will connect the restoration project in the northeast corner of the Eden Landing Ecological Rreserve to the San Francisco Bay. North Creek will connect directly to Old Alameda Creek approximately 1.2 miles from the Bay and Mount Eden Creek will enter the Bay approximately 1.2 miles north of the mouth of Old Alameda Creek. The SBSP Restoration Project will coordinate with the CDFG restoration project to ensure that the projects are mutually beneficial.

Old Alameda Creek

Alameda Creek is currently diverted into the Alameda County Flood Control Channel. Prior to the diversion, it followed the alignment of what is now known as Old Alameda Creek (also referred to by FEMA as Alameda Creek Line A (Zone 3A)) in the coastal plains. Old Alameda Creek (OAC) is a tidal slough that now drains an area of about 22 square miles. The channel and one of its tributaries, Ward Creek, continue to carry urban runoff from southern Hayward and the Alvarado district of Union City, although the total freshwater input is minimal. The creek was constructed in 1955 by excavating two earth channels widely apart and using the excavated material to construct the outside levees. Old Alameda Creek is now comprised of levees along both sides through the salt pond complex and two distinct channels (a narrow northern channel and a wider southern channel) divided by a vegetated bar that is only submerged at higher high water during strong (spring) tides. The center island was originally to be removed when the watershed became fully developed but the excavation was never completed. A small amount of water level elevation data is available for Old Alameda Creek, which indicates that high water elevations measured about 1.2 miles from the mouth of Old Alameda Creek are as high are as 6 feet NGVD and low water is typically near the bed elevation of –1.6 feet NGVD.

On the landward side of the salt pond complex, 3.4 miles upstream of the Bay, a large gated structure was designed to prevent tidal waters from extending further upstream. This consists of twenty 4-ft diameter culverts with flap gates on the downstream side (the gates allow upstream runoff to enter the lower reaches/Bay, but the flap closes when tidal water levels exceed the upstream water level). The structure reduces the effective conveyance of OAC during high flow events, but limits tidal flows upstream. Some leakage occurs through the gates. The current channel capacity is estimated at the 15-year flood, roughly 4,000 cfs. Just downstream of this structure, the Potrero pump discharges pumped flows collected from areas to the south and east.

Flood profiles were prepared by FEMA and published in the FIS for tributaries to Old Alameda Creek. The OAC 100-year water surface profile establishes the boundary conditions for these connecting drainage-ways and changes to the FEMA designated BFEs may have an impact on the tributary’s ability to discharge into the receiving waterway. All tributaries are located upstream from the tidal gates. Each channel is described with its FEMA designation. Line A-2 (Zone 3A) confluence with OAC is at the SPRR crossing. The Ward Creek - Line B (Zone 3A) and Line D (Zone 3A) confluence with Alameda Creek Line A (Zone 3A) is located just upstream of Interstate 880.

Alameda County Flood Control Channel

The Alameda Creek Flood Control Channel (ACFCC) (also known as Coyote Hills Slough) is the primary flood control channel for the Alameda Creek Watershed by way of Alameda Creek. The twelve-mile long lower flood channel from the west end of Niles Canyon to the terminus at San Francisco Bay was designed by the USACE and constructed between 1965 and 1975 following damaging floods in 1955 and 1958. The flood control project included construction of a marsh restoration area and interior detention ponds. The channel provides flood protection for the metropolitan areas of Union City, Fremont, and Newark, preventing inundation of nearby agricultural areas, railroads and highways. The lower four miles of this channel crosses the Eden Landing Pond Complex. The peak discharge of the 1955 flood was estimated at 21,000 cfs near Niles District. Extreme runoff from storms in 1986 (16,400 cfs) and 1995 (15,000 cfs) did not result in flooding. The ACFCC is enclosed with levees for most its length and is tidally influenced in the vicinity of the salt pond restoration area. The SBSP restoration project presents a major opportunity for the restoration of an estuarine channel such as the ACFCC.

The USACE flood control project originally provided protection from the “Standard Project Flood” (SPF = 52,000 cfs) or an extreme flood with a recurrence interval of 200- to 500-years. The maximum current capacity is 29,000 cfs (a 100-yr recurrence interval) due to significant levels of sedimentation since the project was constructed. Sediment has been removed from the channel several times since construction was completed. The most recent project (1998-2001) removed 367,000 cubic yards of sediment over four years at a cost of over $3 million. In 2003, the ACFCWCD retained Watershed Sciences to evaluate existing sedimentation data and to develop a fluvial sediment source and sediment budget methodology. A first year progress report has been completed (Alameda County Public Works, Ralph Johnson, personal communication).

The ACFCC bottom dimension ranges from 400 feet near its mouth to 120 feet at the upstream end where the channel transitions to a natural stream. The bottom rises about 75 feet as it crosses the Bay plain, with the lower 7 miles being relatively flat and the upper 5 miles relatively steep. The deepest part of the channel has a bottom elevation of approximately –4.7 feet NGVD near the mouth of ACFCC and slopes gently up with distance upstream. The portion of ACFCC that adjoins the salt ponds is tidal with high tide elevation slightly lower than the high tide elevation at San Mateo Bridge and low tide elevation considerably higher than low tide elevation at San Mateo Bridge. Therefore the tidal range in ACFCC is quite substantial though less than the tidal range in nearby portions of the South San Francisco Bay. Depths in the channel of ACFCC typically range from 6.6 to 10.0 feet at high water while at low water depths can be less than 3 feet in the deepest part of ACFCC. In addition, ACFCC contains a large inter-tidal area that is only covered with water near high water and is drained during ebb tides. Therefore a large portion of the water volume that is present in ACFCC at high water drains into the Bay during ebb tides. Salinity generally varies from Bay salinity at the mouth of ACFCC to freshwater arriving from Alameda Creek.

The ACFCC is currently owned and maintained by the ACFCWCD. An operations and maintenance agreement between the ACFCWCD and the USACE requires the ACFCWCD to restore the channel flow capacity to the original SPF protection level. Approximately 1 million cubic yards of sediment has accumulated in this 4-mile reach. Initial cost estimates to excavate the deposited sediment were approximately $30 million. URS (2002a; 2002b) analyzed the ACFCC to determine a preferred flood management approach to restore channel capacity. In the most recent 2004, Phase 2 Study (2004a), URS identified and evaluated three initial concepts for ACFCC levee reconfiguration. The concepts include breaching the channel levee and allowing the excess flows to be conveyed through the restored salt ponds along the north side of the channel downstream of Ardenwood Blvd. The URS report also recommends breaching OAC through both the north and south levees to provide a reduction in maximum water levels during floods on OAC. In addition, a 700 ft long "spillway" would be created in a levee notch just downstream of Ardenwood Blvd to provide the most upstream location of water surface reduction. This would discharge into a salt pond currently owned by Cargill. The excavation of the levee breaches and major slough channels in the former salt ponds would generate about 300,000 cubic-yards of dredge material that could be used elsewhere in the project. A new inboard levee approximately two miles long may be needed to protect the existing homes east of the Eden Landing Complex. The projected lower water surfaces and associated flood reduction benefits are expected to extend approximately four miles upstream from the Bay (2002a; 2002b). SBSP Restoration Project efforts in the Eden Landing Complex will be closely linked with potential levee reconfiguration efforts for the ACFCC.

Pond bottoms in the Eden Landing Complex are currently at relatively high topographic elevations compared with the Bay. Hydrologic modeling conducted for the Initial Stewardship Plan (ISP) (Life Science 2003) indicates that the 2C system (ponds 6, 5, 6C, 4C, 3C, 5C, 1C, and 2C) will have average water depths about 0.1 to 1 foot higher than existing conditions, although some of those ponds (1C and 5C) will still be seasonal. The remaining ponds will have average water depths about 0.5 to 2 feet lower than existing conditions. Average water depths in the Eden Landing Complex will range from zero to about 2.5 feet in summer, and about one to 2.5 feet in winter. Hydrologic modeling results indicate that water levels will vary by about 0.5 feet due to weather and tides. Water levels under the ISP are therefore likely to expose the pond bottom for some portion of the year.

URS used MIKE 11 and MIKE 21 hydraulic models to calculate 1-D and 2-D flow properties of OAC and ACFCC and the MIKE FLOOD program for hydrodynamic modeling to study in detail the selected alternative (Option D) from Phase I of the Flood Control Feasibility Study (2002a; 2002b). The model results, predicting tidal influence to the site, showed that it is feasible to restore the ACFCC flood control capacity by increasing the tidal flows (URS 2004b)

3.2.2 Alviso Pond Complex

The Alviso Pond Complex is located at the far end of the South San Francisco Bay (Figure 1). There are 24 salt ponds in the complex totaling 7,500 acres. The US Fish and Wildlife Service owns the Alviso Ponds. The western limit of the Alviso Complex is bound by the Charleston Slough in Santa Clara County. The complex overlaps the border between Santa Clara County and Alameda County. The Alameda County ponds are north of Coyote Creek and divided by Mud Slough. As a result of land subsidence, flood hazards in the Alviso area are the highest in all of the SBSP project areas.

Alviso Coastal Flooding

Predictions for extreme tide events and tidal benchmark data for stations near the Alviso Pond Complex are shown in Table 7. Tidal floodplain elevations presented in Table 8 are derived from the tidal epochs of 1960-1978 and 1983-2001.

The 1988 Shoreline Study by the USACE analyzed tidal flooding for two separate reaches that front the Alviso Pond Complex. One coastal reach extends from Coyote Creek to Alviso Slough/Guadalupe River and another extends from Calabazas Creek to Stevens Creek (U.S. Army Corps of Engineers 1988). Other reaches that front the Alviso Pond Complex were eliminated for the 1988 Shoreline Study as a result of a preliminary flooding analysis. The study was based on the presumption that the levees and ponds would be maintained by Cargill for salt production, and therefore be maintained as an informal (ad hoc) coastal flood protection system.

Due to overtopping of the outboard salt pond levees near Alviso Slough and lower Coyote Creek (downstream of Artesian Slough), tidal flooding can occur in Alviso and surrounding areas (U.S. Army Corps of Engineers 1988). The capacity of the salt ponds in this area will limit flooding to undeveloped areas except during the most extreme tide and wind events. Effective stillwater elevations published in FEMA FISs for communities contiguous to the Alviso Complex and the Bay are shown in Table 9. For the 100-year event, the 1988 Shoreline Study estimated that Alviso could incur up to 6 feet of flooding and that most of the flooding would be limited to the area north of Highway 237.

Table 7 Alviso Complex Tidal Benchmarks

	ID # 941 4548 Guadalupe Slough	ID # 941 4575 Coyote Creek	ID # 941 4551 Gold Street Bridge
Tidal Epoch	1960-1978	1983-2001	1983-2001
500-year Estimated Tide (USACE)	--	12.7	12.6
100-year Estimated Tide (USACE)	--	12.4	12.3
10-year Estimated Tide (USACE)	--	11.8	11.8
HET (USACE)	11.9	12.5	12.4
Highest Observed Water Level	10.3	10.8	11.0
Mean Higher High Water (MHHW)	8.6	9.0	9.3
Mean High Water (MHW)	8.0	8.4	8.7
Mean Tide Level (MTL)	4.6	4.8	4.9
Mean Low Water (MLW)	1.1	1.2	1.1
Mean Lower Low Water (MLLW)	0.0	0.0	0.0
Lowest Observed Water Level	-0.7	-1.8	-1.2

Note: Elevations are in reference to ft above MLLW, Source: NOS and USACE, 1984

Table 8 Estimated Tidal Floodplain Elevations for Alviso

Tidal Flood Event	Elevation (feet, NGVD)
50 year	2.7
100 year	4.5
500 year	6.8

Source: (U.S. Army Corps of Engineers 1988)

Table 9 San Francisco Bay Stillwater Elevations Near Alviso Complex (ft NGVD)

	FIS	Recurrence Interval (Years)				
Adjacent Community	Effective Date	10	50	100	500	Location
Fremont	2/9/2000			8.0		From Thornton Road (84) to Coyote Creek Railroad Crossing
Fremont	2/9/2000			9.0		From Coyote Creek Railroad Crossing east to corporate limits
Santa Clara County, Unincorporated	8/17/1998			8.1		At Confluence of Coyote Creek and Guadalupe Slough
San Jose	8/17/1998			8.6		At Crossing of Railroad and Alviso Slough
Milpitas	6/22/1998			8.6		At Milpitas
Sunnyvale	12/19/1997			8.0		At Sunnyvale
Mountain View	6/19/1997	7.5		8.0	8.3	At Mountain View
Palo Alto	6/2/1999	7.2		7.7	8.0	At Palo Alto
Palo Alto	6/2/1999	7.3		7.8	8.1	Mayfield Slough at Embarcadero Slough

Source stated in FIS: (U.S. Army Corps of Engineers 1984)

Due to overtopping of the outboard salt pond levees along Reach 19, tidal flooding can occur in the locations of the Sunnyvale sewage treatment ponds, the northern portions of the NASA Ames Research Center, Moffett Field Naval Air Station, the Lockheed Missiles and Space Company Plant, and the industrial park area north of Java Drive and west of East Sunnyvale Channel. Within Reach 17, the capacity of the existing salt ponds will limit tidal flooding to undeveloped areas, the sewage treatment ponds, streets, and parking lots during all but the most extreme tide and wind events (U.S. Army Corps of Engineers 1988).

Alviso Fluvial Flooding

The Alviso Complex is located at the base of four distinct watersheds: Coyote Watershed; Guadalupe Watershed; West Valley Watershed; and Lower Peninsula Watershed. North of Coyote Creek in Alameda County, the ACFCWCD has jurisdiction over the connecting waterways. The Alameda County Public Works Department (Flood Planning and Design Division) is responsible for watershed planning, major maintenance, and new construction of the western Alameda County Flood Control System. The Santa Clara Valley Water District (SCVWD) provides flood management services throughout Santa Clara County, which includes much of the Alviso complex. The SCVWD has conducted flood hazard studies along all of the major drainages that enter the Alviso complex, and constructed flood protection projects along the upstream and lower sections of many of these waterways. Specific District staff are knowledgeable about individual streams and watersheds and have provided background for much of the information in this report. In addition to these flood management studies and projects, the SCVWD operates and maintains the Automated Local Evaluation in Real Time (ALERT) system to monitor a variety of hydrologic data including rainfall, stream flow, and reservoir levels within their jurisdiction. This data provides the basis for much of the flood project design work.

A UNET model was prepared as part of a Final Reconnaissance Report (Northwest Hydraulic Consultants 2002)) to study the extent of flood risk under varying boundary conditions. UNET has the capability to simulate complicated interconnected channel/pond networks and unsteady flow. Twenty modeling scenarios were analyzed for combinations of hypothetical flood measures and situations that included: various inflows; 10-year and 100-year tides; prevention of flows into Alviso, and protecting Cargill ponds A5 to A8. The sensitivity analysis results provided maximum flood depths within the Alviso pond complex and within Alviso. A UNET Model was also used in the NHC report to simulate the study alternatives which included, dredging Alviso Slough, raising the Alviso Slough Levees, raising Guadalupe and Alviso Slough Levees, split flow over the weir at Pond A8, and marsh accretion of the Knapp Tract (Pond A6). Results of the alternatives UNET analysis also provided maximum water depths for the Alviso Ponds and the Alviso community.

Land subsidence in the Santa Clara Valley has been observed since the early 1900s and has been linked to extensive groundwater withdrawals up until the mid-sixties. The maximum subsidence occurred in San Jose to about 8 feet. At the mouth of Alviso Slough the ground has subsided nearly 3 feet. Ground subsidence has contributed to a change in the bed slope of sloughs in the Alviso Complex. Groundwater recharge efforts have made a significant change to the subsidence trends experienced in the early 1900s although the current rate of subsidence is still being monitored.

The salt pond levees were constructed as part of the salt manufacturing process but were built up to offset subsidence and reduce the potential for flooding from contiguous sloughs, creeks, and the Bay tide. Bay mud was typically used to construct the levees although subsequent improvements may have required other various materials used for fill. The levees have not been engineered and most do not meet the stringent FEMA requirements for flood protection.

Construction of the levees decreased the volume of Bay water entering the sloughs and reduced the tidal exchange through the channels. Sediment deposition occurred as the slow moving currents deposited clay and silt from the outboard mud flats that were carried into the sloughs with the tide. SCVWD dredged Alviso Slough in 1963 to realign the channel and to restore storm water conveyance. Marsh accretion followed as vegetation began to grow on bench margins between the low-flow channel and the levees. Levees were sequentially raised to increase channel conveyance and offset the marsh accumulation in the slough.

The following sections describe the major watersheds (Coyote, Guadalupe, West Valley, and Lower Peninsula) that drain to the Alviso Complex. Each slough channel in the Alviso Complex and all waterways draining into the complex are described below. The descriptions start on the east side and move sequentially west.

Table 10 includes all Alviso Pond Complex hydrologic connections to the Bay and their tidally influenced tributaries. Recurrence interval flood peaks are from the FEMA FIS Reports for each community. The FEMA discharge numbers may include historic levee overtopping and therefore may underestimate peak flows which are now contained within the channel due to recent flood protection projects.

Schaaf and Wheeler have conducted hydrologic modeling to predict water elevations under the ISP and compared those elevations to pre-ISP conditions. On average, water elevations in the Alviso ponds will be within about one foot of pre-ISP average elevations. Water in these ponds will be one to three feet deep on average throughout the year under the ISP conditions. Actual water depths within the individual ponds and pond systems will depend on the management operations. ISP pond management operations will be integrated into the Salt Pond Restoration Project.

SCVWD is developing watershed stewardship plans for West Valley, Lower Peninsula, and Guadalupe areas. These plans will be integrated into the Salt Pond Restoration Project to account flow discharge and sediment movement from the upstream watersheds and also to develop continuous habitat corridors.

Coyote Watershed

Coyote Creek is the largest drainage-way to pass through the Alviso Complex, with a watershed of 322 square miles. Located on the west side of Diablo Mountain range, the tributary drains all of Milpitas, and portions of San Jose and Morgan Hill. The center of the Coyote Creek channel, within the Alviso Complex, is coincident with the boundary between Alameda County and Santa Clara County. During winter and spring a substantial amount of fresh water is delivered to the Bay from the Coyote Creek watershed. The creek also receives a freshwater influx from the San Jose-Santa Clara Water Pollution Control Plant. Therefore, the lower Coyote Creek is less saline than might be expected from typical tidal interaction.

Several sloughs, channels, and creeks near the Alviso Complex are tied to the Bay through Coyote Creek including: Mud Slough, Lower Penitencia Creek, Fremont Flood Control Channel, Artesian Slough, Alviso Slough, and the Coyote Creek bypass channel. The water surface elevations in Coyote Creek, influenced by Bay tides, sets the downstream boundary condition for many of these tributaries

Table 10 Alviso Pond Complex Hydrologic Connections

Hydrologic Connection	**Watershed**	Tributary	Recurrence Interval				Notes
Tributary	Community	(sq-mi)	10-year	50-year	100-year	500-year	
Mud Slough	**Coyote**						
Laguna Crk	Fremont	25.0			3,100	3,290	1
Agua Caliente Crk	Fremont	2.6			940	975	1
Artesian Slough	**Coyote**						
SJ/SCWPCP	San Jose			186	250		7
Coyote Slough	**Coyote**						
Coyote Creek	Coyote	315.0	7,300	10,500	12,800	15,000	6
Lower Penitencia	Milpitas/San Jose	27.7	1,750			3,500	1
Alviso Slough	**Guadalupe**				20,000		2
Guadalupe River	SJ/Unincorporated	170.0	7,500	12,000	13,000	17,000	1
Guadalupe Slough	**West Valley**	81.0					
San Thomas Aquino Crk	San Jose	45.0	2,840	4,350	4,920	6,650	5
Calabazas Creek	Sunnyvale/Unincorporated	20.8	3,600	4,100	4,600	5,800	2
Sunnyvale East	Sunnyvale	6.1			1,100		
Sunnyvale West	Sunnyvale	2.9			360		
Whisman Slough	**Lower Peninsula**						
Stevens Creek	Mountain View	36.4	3,030	5,550		5,950	4
Permanente Creek Diversion	Mountain View/Unincorporated	8.9	1,230	1,280	1,390	1,550	3
Mountain View Slough	**Lower Peninsula**						
Permanente Creek	Mountain View/Unincorporated	17.0	1,390			1,400	3
Charleston Slough	**Lower Peninsula**						
Palo Alto Flood Basin	Palo Alto						
Matadero Canal	Palo Alto	13.6	1,640			1,775	1
Barron Creek	Palo Alto	3.1	320			430	1
Adobe Creek	Palo Alto	13.5	1,660			1,780	1

1 Capacity Restrictions-Flows Adjusted for Spills

2 Capacity Restrictions-Flows not adjusted

3 High flows diverted to Stevens Creek

4 Flow Reduction due to capacity restriction (2,350 on FIS)

5 Flow at Williams Road (Basin=17 sq-mi)

6 Downstream of Confluence w/ Berryessa

7 Dry season Q=186cfs; Winter Q=250cfs

8 Flood Channel - Basin & Flowrate not determined

Source: FEMA FIS Reports for each community

Mud Slough

At the western end of Alviso Complex, Mud Slough forks from Coyote Creek and, bordering Alviso Ponds A21, A20 and A19 (the Island Ponds), continues landward to connect with the Warm Springs marsh restoration area. Mud Slough is a shallow tidal slough, which receives minimal freshwater input during all seasons from Laguna Creek (Arroyo Del Agua Caliente Creek – Zone 6 Line F). The slough channel dimensions have expanded over the past 18 years as a result of the increased tidal prism at Warm Springs Marsh. There are no major flood management issues associated with Mud Slough.

The Laguna Creek watershed is 25 square miles and includes City of Fremont. The Laguna Creek 100-year water surface profile is published in the FEMA FIS for City of Fremont. The water surface profile is influenced by San Francisco Bay tides at its mouth. The backwater effects propagate up to the mouth of Arroyo Del Agua Caliente and Agua Caliente Creeks where fluvial flooding has historically been a result of inadequate conveyance capacity. As discussed below, flooding from this area may extend down to Coyote Slough.

Coyote Slough

Coyote Slough begins at Calaveras Point. The slough confluence with Coyote Creek is at the southern tip of the San Francisco Bay. Flooding along Coyote Creek occurred in 1982 with 1,700 people evacuated and an estimated 360 homes and 40 businesses sustaining damage in excess of $6 million. A major channel remediation project included levee setbacks and excavation of an overflow channel to improve the inadequate and unstable levees constructed by farmers with land along lower Coyote Creek. The project extended for seven miles from Coyote Slough to Montague Expressway and removed a majority of the area west of I-880 from the FEMA SFHA after the improvements were completed. The project also involved extensive environmental mitigation designed in compliance with the Endangered Species Act. Reach 1 of the project included construction of an engineered levee on Bay mud across part of Pond A18. The severed portion of the pond adjacent to Coyote Creek was then breached and opened to tidal action. This levee may provide a model for flood protection levees in the South Bay. The project has averted potential damages caused by flooding during record runoff in 1997 and 1998. However, SCVWD staff are concerned that the flood protection project is not adequate to the east (Alameda County jurisdiction) where overflows from Coyote Creek could enter behind the current protection works and cause flooding.

The bottom elevation of the main channel of Coyote Creek ranges from -3 to -13 feet NGVD29. The tidal range in Coyote Creek, reported as 7.3 feet at NOAA Station 9414575 (National Oceanic & Atmospheric Administration), is particularly large. The creek width varies from about 300 feet at the UPRR Bridge widening to 1600 feet downstream of the Alviso Slough confluence. Coyote Creek stream flow and water level gauges are operated by the USGS.

Artesian Slough

Artesian Slough borders Alviso Ponds A16-18 and is a tributary to Coyote Creek. Fluvial flood hazards are not a significant concern. The discharge from the City of San Jose / Santa Clara municipal wastewater treatment plant enters the upstream end of Artesian Slough with a RWQCB-permitted dry season flow of 120 million gallons per day (mgd) (186 cfs). In winter discharges average 160 mgd, though flows in recent years have been less. The treated effluent has supported a brackish marsh habitat in lieu of the native saltwater marsh requiring San Jose to mitigate for the impacts. The SBSP restoration project will be coordinated with the City's wetland mitigation strategy.

Guadalupe Watershed

The Lower Guadalupe River reach receives runoff from a highly urbanized region comprising a steep upper watershed, an urban residential and light commercial zone (the Upper Guadalupe River), and a significantly developed and encroaching downtown commercial zone. Storm drainage from these areas and from storm water pump flows within the project area is also discharged into the Lower Guadalupe River, adding to the runoff volume.

Alviso Slough

The Alviso Slough extends from the Coyote Slough to the UPRR Bridge crossing in Alviso. The slough is the major Bay connection for the Guadalupe River and the 170 square miles of land south of the Alviso Pond Complex. The Slough is tidal from the Bay upstream to Montague Expressway (approximately 18,373 ft upstream) (Santa Clara Valley Water District 2001). The tidal reach of the Guadalupe Slough is a depositional environment characterized by low channel slopes and low energy conditions.

Many floods have occurred, historically, along the Guadalupe River. Major flooding on the Guadalupe occurred in 1911, 1941, 1945, 1952, 1958, 1963 , 1967 and 1995 (Santa Clara Valley Water District 2001). As development in the Guadalupe Watershed continued to increase runoff, structural methods were initiated to provide flood protection for the town. A $12.8 million bond initiative was approved by SCVWD in 1963 to provide flood protection on the Guadalupe River. In the Lower Guadalupe, construction consisted of channel modifications, bank stabilization and levee construction. The levees were improved in the 1980s and 1990s along with construction of a floodwall. Under existing flood protection, flooding in the community of Alviso does not occur from the Guadalupe River, but rather, from insufficient internal drainage backing up in zones of low elevation.

Alviso has subsided by as much as 6 ft between 1934 and 1967, greatly increasing flood hazards. Subsidence has mostly slowed, and may be arrested, as a result of groundwater management and recharge. The community of Alviso continues to be very active, working with the SCVWD to develop flood protection measures due to multiple, ongoing flooding threats including overflow from Coyote Creek, excessive floodwaters from the low-lying area east of Alviso, or through Rincon de Los Esteros

(Northwest Hydraulic Consultants 2002). Recent and ongoing flood mitigation activities are expected to provide significantly reduced flood risk to this system.

As established and reviewed by the USACE in 2000, the Guadalupe River 100-year design storm is 18,300 at the UPRR Bridge. Under existing conditions, the channel does not have the capacity to carry the design storm to the Bay (Santa Clara Valley Water District 2001). At around 6,800 cfs, the channel begins to overflow into the adjacent levee at Pond A8W. The existing left bank (looking downstream) levee (adjacent to Pond A8) has recently been reconfigured as part of the Lower Guadalupe River Flood Protection Project (LGRFPP), to act as a weir, allowing high flows in the Guadalupe river to exit Alviso slough into the pond. Flood waters will be held in the ponds and then pumped out (or conveyed via culverts with flap gates) over a period of time (about 1 month). The SCVWD estimates that, downstream of the weir, the Alviso Slough channel has a capacity of approximately 11,000 cfs.

The Lower LGRFPP was constructed by the SCVWD on the Guadalupe River between Interstate 880 and the community of Alviso and on Alviso Slough from the UPRR Bridge to the terminus of Alviso Slough. The focus of the LGRFPP was primarily to address the Guadalupe River contribution to flood conditions in the area. In addition to the Pond A8 engineered weir, project work included: construction of floodwalls or raising levees along the river banks; replacement of the HWY 237 eastbound bridge (bridge construction began in 2003); modification of 19 storm drain outfalls; improvement and construction of maintenance roads and under-crossings; improvement of the west perimeter levee around Alviso and construction of grade-control weirs (gradual drops in the stream elevation). Operation of the LGRFPP could result in changes to river geomorphology in the sub-reaches downstream of Interstate 880. Post-project monitoring is planned and will focus on channel incision and sediment deposition.

The downtown San Jose, Guadalupe River Project, located upstream of the LGRFPP, was completed in December 2004. The downtown channel improvements increased the carrying capacity of the Guadalupe River to the level of the 100-year design flood. The river now has the potential to deliver base flood flows to the lower reach, which did not, previously, have the ability to convey the expected design flood event.

A potential future phase of channel capacity enhancement has been investigated by the SCVWD (Schaaf & Wheeler 2004). Proposed culverts connecting the channel to the adjacent ponds would increase the tidal prism within Alviso Slough, resulting in channel scour and, ultimately, improved conveyance of flood flows. The predicted initial response, before scour, is muted tidal action (decreased tidal amplitude) within the slough. The elevation of low tide is anticipated to increase in the short-term with channel scouring occurring in the long-term, enhancing the channel conveyance.

West Valley Watershed

The West Valley Watershed is 85 square miles and managed by the SCVWD. Several communities are within the drainage area, including Sunnyvale, Cupertino, San Jose, Santa Clara, and Saratoga among others. The Guadalupe Slough is the primary conveyance from the watershed to the Bay. Historically the Guadalupe River drained through Guadalupe Slough to the Bay. The river was diverted to Alviso Slough in the early 1900s during construction of the salt ponds and as a convenience for navigation.

Guadalupe Slough

The Guadalupe Slough receives flow from Calabazas Creek, San Thomas Aquino Creek, Sunnyvale East and West Channels, and Moffett Channel. The Guadalupe Slough extends from the Bay to the confluence of San Thomas Aquino and Calabazas Creeks. The slough conveyance capacity is estimated at 6,500 cfs, which is less than the 10-year discharge from the basin (Northwest Hydraulic Consultants 2002). The slough continues to lose capacity as the salt marsh vegetation and sediment deposits accumulate in the channel.

The San Thomas Aquino Creek tributary watershed area is 45 square miles. The creek joins Guadalupe Slough immediately north of Highway 237. The most recent FEMA FIRM for City of Santa Clara depicts spill from the main channel at Tasman Road. The split flow is then approximated along the Southern Pacific Railroad (SPRR) to a small marshland at the confluence of Guadalupe River and Alviso Slough. Two LOMRs were approved by FEMA that removed the split flow conditions from San Thomas Aquino Creek to the SPRR. The 100-year flow is expected to remain in the channel to Guadalupe Slough.

Calabazas Creek near the Alviso Complex is located at the eastern edge of the City of Sunnyvale and western edge of the City of Santa Clara. Calabazas Creek drains an area of 21 square miles. The FIS starting water surface elevation for Calabazas Creek is based on the mean higher high water of 4.7 feet NGVD at the San Francisco Bay. The creek was constructed along its current alignment in the middle 1950s. In December 1955 debris blocked the channel under the SPRR bridge and caused the creek to overflow and during a January 1968 storm Calabazas Creek overflowed at the Kifer Road Bridge causing flooding conditions along several thoroughfares. The SCVWD Calabazas Creek Flood Control Project in the mid to late nineties increased the Calabazas Creek capacity to the 100-year event, reduced bank erosion, and provided for long-term riparian habitat improvement. The creek is concrete lined from Lawrence Expressway down to the Bayshore Freeway.

Flooding in the City of Sunnyvale has occurred after four significant rainfall events since 1950 in 1955, 1958, 1963, and 1968. The frequencies of these floods were not determined. Sunnyvale East and West Channels were constructed in the early 1960s to convey the 10-year flood event from the tributary storm drain system. The East Sunnyvale Channel basin is seven square miles, and the West Sunnyvale basin is eight square miles. Lower portions of the creek are subject to the backwater effects of the San Francisco Bay. SCVWD staff indicate that the tidal influence extends upstream near Highway 237. In fact, the Sunnyvale FIRM shows the area of inundation of the SFHA up to and beyond the highway. There are currently no Federal flood-control facilities on the streams in the City of Sunnyvale. Upstream of the highway the levees along the Sunnyvale East Channel do not meet FEMA criteria for flood protection. The FIRM delineates the probable area impacted by levee failure as Zone AE. SCVWD will in the next few years begin the planning phase to augment the Sunnyvale East and West Channels to minimize or eliminate the impacts of the 1% chance floodplain due to fluvial flooding. One of the key aspects of this study will be to improve the channel conveyance of the East and West channels around Pond A4. The current alignment was built to accommodate the pre-existing Pond A4 (owned by others at the time) and requires several hydraulically inefficient sharp turns.

The City of Sunnyvale is also served by independent storm-drainage systems that intercept significant drainage areas and prevent flows from entering Sunnyvale East and West Channels. These flows are pumped directly into Guadalupe Slough. The Sunnyvale municipal wastewater treatment plant discharges (approximately 14-15 mgd) into Moffett Channel/Sunnyvale West Channel providing the primary source of freshwater during the summer and fall (Life Science 2004).

Lower Peninsula Watershed

The Lower Peninsula Watershed is nearly 100 square miles and includes Los Altos Hills, Palo Alto, Mountain View, Los Altos, and Cupertino. The drainage-ways from the tributary join sloughs in the Alviso Complex before reaching the South San Francisco Bay. The sloughs include: Mountain View, Outer Charleston, Inner Charleston, and Mayfield. Matadero, Barron and Adobe Creeks drain into the Palo Alto Flood Basin (PAFB) which discharges to the Bay via flap gates. Additionally, Devils Slough and Jagel Slough are two small sloughs identified within the Alviso Complex. These two sloughs are estimated to be completely tidal and no information regarding fresh water input to these sloughs could be identified. Devils Slough extends to the Moffett Field Naval Air Station.

Stevens Creek

Stevens Creek flows northerly from the City of Mountain View. The channel becomes Whisman Slough as it enters the salt pond complex bounded by levees, to its mouth near Long Point at the San Francisco Bay. Much of the creek as it crosses Mountain View is channelized and artificial materials are used for bank stabilization and flood control. The Stevens Creek tributary is 27 square-miles and also receives (at times) overflow from Permanente Creek via a diversion. Stevens Creek watershed, in its upper zone, is permeable undeveloped forest or rangeland. This watershed has the highest percentage of legally protected area. The lower zone is typical of Westside watersheds, with high-density residential use predominating; commercial and public developments are interspersed. Contiguous commercial development is also prevalent along State Highway 82. Industrial development is concentrated in the downstream area near U.S. Highway 101. Fresh water flows from the basin are negligible in the summer and more prominent in the winter.

PWA has obtained the Stevens Creek hydraulic computer model based on 1982 as-built conditions and updated in September 1991 and February 1993 (model obtained from the SCVWD). The steady flow model shows a fairly consistent decrease in flow as drainage area increases. This is relative to the capacity of the channel and not the estimated peak flow of the contributing upstream basin. The Stevens creek channel does not currently have 100-year event capacity (SCVWD, personal communication).

Permanente Creek (Mountain View Slough)

Permanente Creek is located in the Lower Peninsula Watershed. The tributary area encompasses 28 square miles and includes portions of the cities of Los Altos, Mountain View, Cupertino, and Los Altos Hills. Mountain View Slough extends to Shoreline Regional Park, a 750-acre park with paved trails, a golf course, a lake and the historic structures. As with other neighboring communities in the Bayshore Area, the shoreline area of the City of Mountain View depends on the extensive levee system for its protection from tidal flooding. The Shoreline Regional Park also offers additional prevention of tidal flooding. The major tributary to Permanente Creek is Hale Creek.

The Permanente Creek tributary (17 square miles) has had a history of recurring floods in Los Altos and Mountain View. Major flooding occurred in 1862, 1911, 1940, 1950, 1952, 1955, 1958, 1963, 1968, 1983, 1995 and 1998. In December 1955, the so-called “Christmas Storm” inundated approximately 770 acres in the lower reaches of Permanente Creek. Homes, businesses and agricultural land in Mountain View and Los Altos sustained losses. Bridges and culverts in Mountain View were extensively damaged. In 1958, flooding occurred along both the upper and lower reaches of Permanente Creek. In response to these floods, SCVWD and other agencies have, at various times, improved several sections of the creeks. The major portion of channel lining and the construction of the Permanente Diversion (to Stevens Creek) were conducted in the 1960s, and there was significant follow-up work in the 1980s. Other flood control improvements for Permanente Creek included: flood protection, erosion control, structural repair, sediment reduction, and habitat restoration. The planning and design phases of the projects were sponsored by the SCVWDs’ Lower Peninsula Watershed Management Division and are included as part of the SCVWDs’ Capital Improvement Plan. Currently, Permanente Creek does not have 100-year capacity throughout the channel. The SCVWD began work on additional Permanente Creek projects in 2001 and expect to complete the planning and design phases by June 2008. The projects will consist of channel improvements and flow reduction alternatives (such as detention). Construction will be performed between 2009 and 2015. The Clean Safe Creeks Program will fund construction.

A portion of the higher flows from the upper Permanente tributary is directed to Stevens Creek through the Permanente Diversion, located three-quarters of a mile north of Foothill Expressway. Low flows are intended to remain in the Permanente Creek. The diversion currently reroutes nearly all flows to Stevens Creek. The beds of Permanente and Stevens Creeks contain gravel lenses that penetrate the underground clay layers allowing runoff to percolate down into the water supply.

Palo Alto Flood Basin

The PAFB is located in a wetland east of Bayshore Drive Freeway and was constructed in 1956. The stored floodwaters from Matadero, Barron and Adobe Creeks are discharged into the San Francisco Bay during low tide periods. The flood basin has a total storage capacity of 3,000 acre-feet below an elevation of 3.2 feet NGVD.

The Adobe Creek tributary is roughly 11 square miles. Adobe Creek channel improvements are currently in the planning phase at SCVWD. The project, near the Alviso Complex, will provide protection from a 1 percent-chance flood event upstream of El Camino Real (the Creek already has 100-year flood protection downstream of El Camino). The completed project will provide additional flood protection for residents and businesses in Palo Alto, Los Altos and Los Altos Hills. The project scope includes replacing the Burke Road Bridge and O’Keefe Lane Bridge, and repairing two creek bank erosion sites. The planning study and the Environmental Impact Report for the project were completed in 1999. Project design began in August 2001.

SCVWD has just completed improvement projects on Matadero Creek. The intent of the projects was to eliminate the annual, 1% chance flood. The project included the installation of an overflow channel, related levee adjustments, wetland and riparian mitigation areas, the installation of a floodwall around part of the Municipal Services Center, and landscaping. The bottom width of the 1200 feet long, flood control overflow channel consists of approximately 30 feet of concrete and 25 feet of earthen channel. The channel improvements, downstream of Hwy 101, will eliminate the risk of flooding in Matadero and Barron Creeks between Middlefield Road and San Francisco Bay. While the project provides protection for a 1% (100-year) fluvial flood event, it will not effect tidal flooding which affects the channel area from the Bay to approximately Middlefield Road. (City of Palo Alto 2003).

Charleston Slough

Charleston Slough is also located in the Lower Peninsula Watershed. The Charleston Slough reaches the Bay through Mayfield Slough. The Charleston Slough splits into an Inner and Outer reach. The levee between the two sloughs was breached to provide tidal marsh habitat between the Outer Charleston Slough and adjacent Alviso Complex. The sloughs are primarily tidally influenced because storm water flows from Adobe, Barron, and Matadero Creeks are redirected into the PAFB.

3.2.3 Ravenswood Pond Complex

The Ravenswood Complex (also referred to as the West Bay Pond Complex) is in San Mateo County immediately inside of a narrow mudflat and tidal marsh along the west Bay between Menlo Park and Redwood City (Figure 1). There are seven salt ponds in the complex covering 1,500 acres. The U.S. Fish and Wildlife Service owns the Ravenswood Ponds. Highway 84 (the Dumbarton Bridge) and the Ravenswood Slough divide the ponds into three sub-groups. Bair Island is located north of the pond complex , the Moseley Tract, located on the bayside of Ravenswood Complex, is owned by the City of San Jose and is planned for tidal marsh restoration.

Flooding occurs in winter or early spring when large frontal storms coincide with extreme high tides. The most severe potential flood risks in this area would result from tidal flooding associated with salt pond levee failure. The perimeter levee of the salt ponds is a few tenths of a foot less than the high tide and overtops. Short duration of the crest will would limit the shallow flooding provided the levees do not fail. Tidal flooding has recently occurred along Bayfront Canal and Ravenswood Slough in 1973, 1982, 1983, and 1986.

Ravenswood Coastal Flood Hazards

Predictions for extreme tide events and tidal benchmark data for stations near the Ravenswood Pond Complex are shown in Table 11. The Highest Estimated Tide (HET) and the 10, 100, and 500-year

Estimated Tides are from the USACE (U.S. Army Corps of Engineers 1984) Tidal benchmark data are from NOS and data presented in Table 11 are derived from the tidal epochs of 1960-1978 and 1983-2001.

The 1989 Shoreline Study by the USACE analyzed tidal flooding for two separate reaches that front the Ravenswood Pond Complex. Reach number 24 extends from San Francisquito Creek to Willow Road - only the northern most area of this reach fronts the Ravenswood Pond Complex. Reach 25 extends from Willow Road to Flood Slough fronting most of the Ravenswood Pond Complex.

Levees on the east side of the Ravenswood Pond complex are protected from wave overtopping and are only subjected to tidal overtopping (U.S. Army Corps of Engineers 1989). The USACE study was based on the presumption that outboard levees were maintained as barriers to open Bay waves, and that water depths in the ponds were low enough to limit local wind wave generation. Since the levees on the northern side of the Ravenswood Pond Complex are exposed to local wind waves from the north, a detailed analysis of wave runup was completed for Reach 25 in the 1989 Shoreline Study. Computations for 10, 50, 100, and 500-year events were made for the velocity of the wind, deepwater wave height, wave period, runup elevations, and floodplain elevations and are shown in Table 12. The fetch length used in the calculations was 15 miles with a depth of 15 feet (U.S. Army Corps of Engineers 1989).

The San Mateo County, FEMA FIRMs and FISs provide information on the regulated extent of flooding in the area and the primary cause of flooding in the area. The FIRM Panels show the Ravenswood Complex fully encompassed in Zones AE or V1 that extend past Highway 84. BFEs are mostly constant throughout the complex at 7 ft NGVD (8 ft at Pond SF2). The existing levees in the Ravenswood Complex do not meet FEMA standards for flood protection. As a result, the major urban areas included in the tidal flood zone include the Bohannon Industrial Park between Hwy 84 and US 100 and the Belle Haven neighborhood in Menlo Park. Actual tidal flooding has occurred along the frontage road to the Dunbarton Bridge adjacent to Pond SF2. This is related to overflows from the Moseley Tract, just north of the Bridge. The USACE has no defined Coastal Flood Limit delineated at the Ravenswood Complex. Effective stillwater elevations published in FEMA FISs for communities contiguous to the Ravenswood Complex and the Bay are shown in Table 13.

Ravenswood Fluvial Flooding

The Ravenswood Complex is within the San Francisquito watershed. Ravenswood Slough is the largest tidal slough located within the Ravenswood Pond Complex. No major drainage-ways flow directly to the Ravenswood Complex therefore the slough receives localized runoff from the adjacent terrain. Runoff consists, primarily, of stormwater flows from the east side of Redwood City. Stormwater runoff reaches the Ravenswood Slough via multiple tributaries: Atherton Creek, Bayfront Canal, Flood Slough and Westpoint Slough. The area tributary to these channels includes portions of Redwood City, Menlo Park, East Palo Alto, and an unincorporated area of San Mateo County along Highway 101.

Table 11 Ravenswood Pond Complex Tidal Benchmarks

	ID # 941 4501 Redwood Creek	ID # 941 4507 Westpoint Slough	ID # 941 4509 Dumbarton Bridge
Tidal Epoch	1960-1978	1960-1978	1983-2001
500-year Estimated Tide (USACE)	11.2	11.4	11.8
100-year Estimated Tide (USACE)	11.0	11.1	11.5
10-year Estimated Tide (USACE)	10.5	10.6	11.0
HET (USACE)	11.0	11.2	11.6
Highest Observed Water Level	9.6	--	10.2
Mean Higher High Water (MHHW)	8.0	8.0	8.5
Mean High Water (MHW)	7.4	7.4	7.9
Mean Tide Level (MTL)	4.3	4.3	4.5
National Geodetic Vertical Datum 1929 (NGVD)	3.9	--	4.1
Mean Low Water (MLW)	1.2	1.2	1.2
Mean Lower Low Water (MLLW)	0.0	0.0	0.0
Lowest Observed Water Level	-2.1	--	-2.2

Note: Elevations are in reference to ft above MLLW

Source: NOS and USACE, 1984

Table 12 Wind, Wave, Runup and Floodplain Computations for the Ravenswood Pond Complex

Parameter	10-Year	50-Year	100-Year	500-Year
Wind speed (mph)	27	32	34	37
Deepwater wave height (ft)	1.8	2.1	2.5	2.3
Wave period (s)	2.7	2.8	2.9	2.9
Runup elevation (ft, NGVD)	8.3	8.5	8.7	8.7
Floodplain elevation (ft, NGVD)	7.0	7.1	7.1	7.4

Source: (U.S. Army Corps of Engineers 1989)

Table 13 San Francisco Bay Stillwater Elevations Near Ravenswood Pond Complex (ft NGVD)

	FIS	Recurrence Interval (Year)				
Adjacent Community	Effective Date	10	50	100	500	Location
San Mateo County, Unincorporated[1]	8/5/1986	7.0	7.3	7.4	7.7	Near San Francisquito Creek
San Mateo County, Unincorporated[1]	8/5/1986	6.7	7.0	7.1	7.4	Near Marsh Road and Bayshore Freeway Interchange
East Palo Alto[1]	8/23/1999			7.6		Near San Francisquito Creek
Redwood [2]	11/17/1981	6.3	6.6	6.7	7.0	At Redwood Shores
Redwood [2]	11/17/1981	6.5	6.8	6.9	7.2	At Redwood Creek

Source Stated in FIS:

1 (U.S. Army Corps of Engineers 1984)

2 (U.S. Department of Commerce Coast and Geodetic Survey 1972)

The major fluvial flood problems in this area have resulted from the inability to convey local drainage into the Bay during periods of concurrent high tide. In Redwood City, local runoff is conveyed to the Bayfront Canal, which conveys flow south to Flood Slough (which is tidal). During high tides, the water backs up in the Bayfront Canal, and causes local flooding. The City is pursuing possible options to discharge excess runoff into the adjacent salt ponds, either north or south of Flood Slough (the ponds south of Flood Slough are part of the Ravenswood Complex). Table 14 provides flooding detail for all Ravenswood Pond Complex hydrologic connections to the Bay and their tidally influenced tributaries.

Atherton Creek drains a narrow oval-shaped basin. From Whiskey Hill Road in Woodside, the creek flows northwesterly through Atherton, Redwood City, and Menlo Park to Flood Slough. The basin development is nearly full (in 1981) ranging from medium density residential in the hills to high density residential, commercial, and industrial near the Bay (Federal Emergancy Management Agency 1981) In January of 1973, Atherton Creek overflowed due to a 100-year tide occurring concurrent with a 5-year storm. Inadequate storm drain capacity resulted in local ponding as high as 4 feet deep.

The San Francisquito Creek Joint Powers Authority (SFCJPA) was created in 1999 to develop solutions to flooding problems and provide for a coordinated approach to planning in the San Francisquito Creek Watershed. The SFCJPA members include the cities of Palo Alto, East Palo Alto, Menlo Park and the Santa Clara Valley Water and San Mateo County Flood Control Districts. The San Mateo County Flood Control District is a countywide special district that was created by State legislation in order to provide a mechanism to finance flood control projects in the cities and counties within their jurisdiction. However, it includes only two zones, and does not have staff or funding comparable to the two other major districts in the study (SCVWD and Alameda County). Thus, in the Ravenswood area, flood hazards are primarily dealt with by the local cities: Redwood City, Menlo Park and East Palo Alto.

The ISP documentation (Life Science 2003) describes simulated circulation hydraulics for the Ravenswood Complex. These results indicate that the ponds will continue to be operated as continuous circulation ponds with water depths of at least one foot. Some ponds may be converted to muted tidal action. The ISP changes will not negatively impact the overall drainage to the Ravenswood Complex.

Table 14 Ravenswood Pond Complex Hydrologic Connections

Hydrologic Connection	**Watershed**	Tributary	Recurrence Interval				Notes
Tributary	Community	(sq-mi)	10-year	50-year	100-year	500-year	
Ravenswood Slough	**San Francisquito**						
Westpoint Slough	Redwood City	-					1
Flood Slough	Redwood City	-					2
Bayfront Canal	Redwood City	-					2
Atherton Creek	Redwood City	5.0	350	350	350	350	3
San Francisquito Overflow	East/Palo Alto	-			1,080		4

Source: (Moffatt & Nichol Engineers 2003)

Notes

1 Freshwater Input Negligible

2 Receives Stormwater pumped into canal

3 Capacity at Upstream Box Culvert

4 San Francisquito does not have capacity for the 100-year

4. LEVEES AND INFRASTRUCTURE

4.1 Regional Flood Protection

There are approximately 150 total miles of levees (internal and external) located within the restoration area (Siegel and Bachand 2002) (Figure 7). The outboard levees (i.e., bayfront and slough/creek levees adjacent to tidal waters) were built to enclose evaporation ponds on former tidal marshes and mudflats and to protect the salt ponds from Bay inundation. These levees are typically constructed with Bay mud dredged from adjacent borrow ditches or pond areas which received little or no compaction. Bay mud fill has been added to these levees in the past to compensate for inboard land subsidence, and they have been periodically maintained by former owners to compensate for levee erosion and settlement resulting from consolidation and/or displacement of the compressible levee-fill material and weak underlying Bay mud deposits. The Bay mud used to construct the levees is typically made up of weak clays and silts. The material was excavated from within the ponds and side cast to form the levees and was not well compacted during construction. These soils are highly compressible and continue to settle and deform. In general the levees are typically low to moderate in height, have fairly flat slopes and are stable. Some dikes in the restoration area were constructed from imported soil, riprap, broken concrete and other predominantly inorganic debris. The dikes typically have steeper slopes than levees constructed of Bay mud. Some levees are protected with riprap on the bayward side (Figure 8). Generally, the salt pond levees were not designed, constructed, or maintained following a well-defined standard and may require retrofit to provide an adequate level of inland flood protection.

The inboard (or shoreline) levees (i.e., pond levees constructed inland along the old Bay margin) are predominantly former salt pond levees that offer the last line of defense against flooding of low-lying, inland areas. These inboard levees separate the individual salt ponds from each other and are typically smaller than the outboard levees. Some have been modified or raised to improve flood protection but, as with the outboard levees, have not been constructed to a well-defined standard. Bay mud constitutes the basic construction material, but in some instances along readily accessible alignments, imported fill and various types of concrete rubble also have been used. Bay mud deposits also underlie these levees; however, the muds are generally thinner than the Bay mud underlying the outboard levees. It is possible that some of these levees are not situated on any Bay mud but instead on stronger, less-compressible alluvial soils (i.e., generally sands, silts, and clays).

Levee construction methods, levee materials, and subsurface conditions are further detailed in reports by Tudor Engineering Company (1973), the USACE (1988), and Moffatt & Nichol (2004). The general condition of the Alviso and Ravenswood levee networks were assessed by Moffatt and Nichol (2004) Within the reconnaissance study, current levee physical parameters (such as length, slope, width, vegetation) were recorded. A potential “perimeter levee” was identified as an urban flood protection and engineering requirements for the levee were evaluated. Table 15 provides a summary of existing minimum and maximum levee elevations along the line of urban flood protection, as evaluated by Moffatt & Nichol (2004).

Table 15 Existing Inboard Levee Elevations at Alviso and Ravenswood

Inboard Levee Description	Minimum Elevation (ft, NGVD)	Maximum Elevation (ft, NGVD)	Pond Complex
Southwest levee of Charleston Slough near Coast Casey Forebay	7.58	8.12	Alviso
South levee of Pond A1 near Coast Casey Forebay	8.55	17.23	Alviso
South levee of Pond A2W near Mountain View Tidal Marsh	1.09	3.98	Alviso
South levee of Pond A2E near Moffett Field	0.62	4.29	Alviso
Southwest levee of Pond B2 near Moffett Field	1.09	3.07	Alviso
South levee of Pond A3W near golf course	1.04	4.85	Alviso
South levee of Salt Pond located south of Sunnyvale Treatment Ponds	0.18	1.59	Alviso
South levee of Pond A4 near Sunnyvale recycling facility	6.47	10.57	Alviso
South levee of Guadalupe Slough near Pond A8S	9.5	12.71	Alviso
Southeast and southwest levees of New Chicago Marsh	-1.65	10.08	Alviso
West levee of Alviso Slough near Alviso	13.92	14.85	Alviso
East, North, and West levees of Pond A22	5.97	12.33	Alviso
South levee of Pond S5 near Highway 101	5.11	7.71	Ravenswood
South and East levees of Pond R3 near Sun Microsystems	4.89	8.64	Ravenswood
Southeast levees of Pond R2 near Highway 84	5.54	9.86	Ravenswood
Northwest levees of Pond SF2 near Highway 84	5.27	8.65	Ravenswood

Source: (Moffatt & Nichol Engineers 2004)

Proposed and completed levee maintenance is documented in Cargill's annual "maintenance work plan" and "completed maintenance" reports, respectively. The reports include information about regular levee maintenance as well as special projects, on an annual basis. Estimated maintenance costs were provided to the FWS at the time of land transfer (Table 16). These costs represent rough estimates only and should be used merely to establish general maintenance guidelines. For example, Alviso ponds A9-15 were maintained in December 2004, ahead of schedule. The Eden Landing pond complex levees will be maintained next (Marge Kohler, USFWS, personal communication, Dec 2004).

Many of the salt pond levees were not constructed according to USACE flood protection standards however, the levees do provide a measure of flood protection (U.S. Army Corps of Engineers 1988): Levee failure is infrequent during storm events; and the frequency of tidal inundation in developed areas along the Bay is reduced due to the ponds.

Table 16 Estimated Levee Maintenance Costs

	Maintenance Frequency	Due	Duration	Cost[1]	Annual Allocation	Method
Eden Landing	7 years		9 months	$480,000	$69,000[1]	
Ravenswood	7 years		9 months	$480,000	$69,000[1]	
Alviso					$206,000[1]	
A1 – A8	7 years	June 2006	9 months	$480,000		Mallard
A9 – A15	5 years	Feb 2007	9 months	$480,000		Mallard
AB1	3 years	Oct 2004	1 month	$53,000		Mallard
A16 – A17	10 years	Sept 2005	2 months	$106,000		Mallard
A16 – A17	10 years	Sept2015[2]	8 months	$240,000		Land-Based

Notes:

[1]- This does not include provisions for major storm damage.

[2]-Assuming that A16 and 17 will no longer be accessible by the Mallard after the Island Ponds are breached.

Source: Cargill Staff Estimates Feb 13, 2002 – Supplied by Marge Kohler, USFWS (Dec 2004)

The existing salt ponds act as temporary storage during coastal flooding conditions, as depicted in Figure 9. As the ponds fill, waves may overtop internal levees in a sequence, moving shoreward. Under current conditions, the crest of some levees may not be high enough to prevent overtopping. The existing levee material may erode when overtopped, reducing the flood protection capabilities. The continuing integrity of the salt pond levees as a flood protection mechanism is dependent on levee maintenance. The levees would require significant modifications to satisfy USACE standards.

Existing levels of flood protection must be maintained post-restoration, although the levees themselves are not specifically required to be maintained. If tidal action is introduced to the salt ponds, either through restoration or passively through deterioration of the levees, the effectiveness of the salt pond complexes as flood protection elements could be substantially reduced. Removal, or breaching, of the bayside levees will transfer the primary flood protection to internal or inland salt pond levees in those areas where adjacent development/facilities are not sufficiently elevated above the potential flood zone.

4.2 Project Setting

The identification of existing infrastructure in the SBSP Restoration Project area is essential for restoration planning. Infrastructure immediately adjacent to and within the boundaries of the SBSP Restoration Project was identified using several sources for Geographical Information Systems (GIS) information (PWA and others 2004d). The base map was assembled with a large amount of GIS infrastructure data provided from the Bay Area Open Space Council. The Cargill Salt Company also provided useful GIS information used to prepare the existing infrastructure mapping. Comprehensive lists of infrastructure facilities are also provided in studies by Stuart Siegel and Philip Bachand (2002) and Moffatt and Nichol Engineers (2005). The San Francisco Estuary Institute has provided a large amount of GIS data including aerial photographs (San Francisco Estuary Institute 2004). The accuracy of the collected infrastructure GIS data is unknown at this time.

Existing infrastructure within the project area is extensive and diverse. Figure 10 through Figure 12 shows the general location of all known existing infrastructure in the vicinity of the restoration project. Infrastructure may include:

PG&E electrical transmission lines. Above ground towers require vehicular (heavy equipment) access for routine inspections, repairs and for emergency maintenance. Daytime inspections may be completed with the aid of a helicopter, however nighttime site visits require ground access. PG&E access to the levees is restricted during sensitive breeding seasons; permits are required. PG&E levee access points (Figure 10 through Figure 12) need to be preserved during and after restoration, as they are the key locations used for wire restringing.

If water levels are increased at the base of line footings (as a function of pond management or tidal inundation), the tower footings may need to be raised to provide appropriate clearance beneath the wires. Currently, the line clearance ranges from 25 to 40 ft, however if the adjacent waterways are deemed to be navigable, wire clearance must be increased to at least 40 ft. Typically, towers can be raised between 5 and 10 ten feet above their original height. Height increases above 10 feet often require construction of a new tower. The lines in Alviso ponds A22 and A23 are attached to wooden poles, which have a lifespan of approximately 10 years. Access is required for periodic repair and replacement.

Below ground transmission lines require a minimum depth of cover. The requirements will vary depending on whether the current towers/boardwalks were designed to accommodate the water level fluctuations that will be recommended in the restoration plan.

PG&E natural gas pipelines. Pipelines may lie at elevations that would block tidal exchange. A minimum depth of cover must be maintained on the pipelines and the lines require vehicular access.

Existing Cargill facilities. Cargill has a number of pipelines and pumping facilities that they use in their ongoing operations. While completing their responsibilities, such as reducing pond salinities to an acceptable level, some facilities will be kept in use during the restoration process

Sewer force mains and outfall pipes. The East Bay Dischargers Authority, the South Bayside System Authority, the Union Sanitation District, the Cities of Palo Alto, Sunnyvale, San Jose and Santa Clara manage sewer mains. The mains and outfalls may interfere with tidal exchange. The infrastructure requires minimum depths of cover and vehicular access. Discharge from the outfalls may affect water quality in localized areas.

Roads. The existing road network may interfere with tidal exchange by limiting areas of tidal circulation. For example, the Dumbarton Bridge/Hwy 84 bisects the Ravenswood Pond Complex and limits the extent of potential circulation in the complex. The final restoration configuration will require access for long-term maintenance of the proposed restoration facilities (levees, water control structures, etc).

Railways. Existing and proposed railways may interfere with, or block, tidal exchange. Introduction of an altered hydrologic regime may require additional protection to prevent possible inundation of the tracks, or increased settlement problems. Potential changes in channel velocities and channel elevations may result in scour of railroad bridge foundations. Existing railways are located within the Alviso Complex.

Storm drain systems. Drainage systems include pipelines, outfall pipes and pump stations. Local Cities, Counties and Flood Control Districts own this infrastructure. The current locations of the storm drain systems may interfere with tidal exchange and may affect water quality in localized areas. In addition, the restoration project must be designed to accommodate the functions provided by these systems. This may include protecting these facilities or relocating them, and providing access for maintenance. Storm drain systems are found within, and adjacent to, each of the pond complexes.

The existing hydraulic infrastructure within the salt ponds is an important component to the restoration process. Culverts, operable gates and flapgates, levee gaps or cuts, siphons, pumps and weirs are used in water management techniques to move water in and out of various ponds and the Bay. Existing infrastructure provides the connections between ponds to be utilized in the establishment of tidal circulation and in managing ponds during the restoration effort.

The Initial Stewardship Implementation Plan (Life Science 2003) promotes circulation of water through the South Bay salt ponds to minimize any effects on potential existing wildlife habitat, pond water quality and salinity levels during the planning and implementation of the long-term salt pond restoration program. The project described in the ISP includes the installation of water control structures, operation of ponds, and maintaining structures and levees. Some control structures are designed to allow the ability to close off all flow, allow inflow only, or allow outflow only, offering the management ability to reverse direction of inflow and outflows when necessary. The existing infrastructure used as water control facilities and the infrastructure proposed in the ISP are shown in Figure 10 through Figure 12, along the with direction of flow circulation. The ISP also summarizes the existing pond water surface elevations and predicts conditions under the plan. The ISP pond operations are based on hydraulic modeling data of the individual pond systems and may be modified by adaptive management based on results of wildlife and water quality monitoring data.

Pond systems may require variations in operations between seasons. Water transfers will be supplemented using pumps that are controlled manually, based on measured pond salinities. The amount of pumping depends on the Bay salinity, gravity inflow rates and the net evaporation from the ponds. Proper implementation of the ISP requires active management to monitor salinities and modify the infrastructure operation between seasons as necessary.

The potential risk of failure or service degradation associated with restoration alternatives will be evaluated for individual structures during the Project Alternative Development. The evaluation will be based on the comparison of restoration-induced physical changes, such as scour or sedimentation, water inundation, increased environmental loads (wave action, hydrostatic pressure), direct construction impacts, and increased risk of vandalism from additional public access. Changes in maintenance access may occur, post-restoration, due to physical conditions (i.e., tidal flooding, lowering of levees), and changes in the timing or methods of access that could result from sensitive species regulations applicable after restoration.

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6. LIST OF PREPARERS

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Source files for this report are located at PWA:
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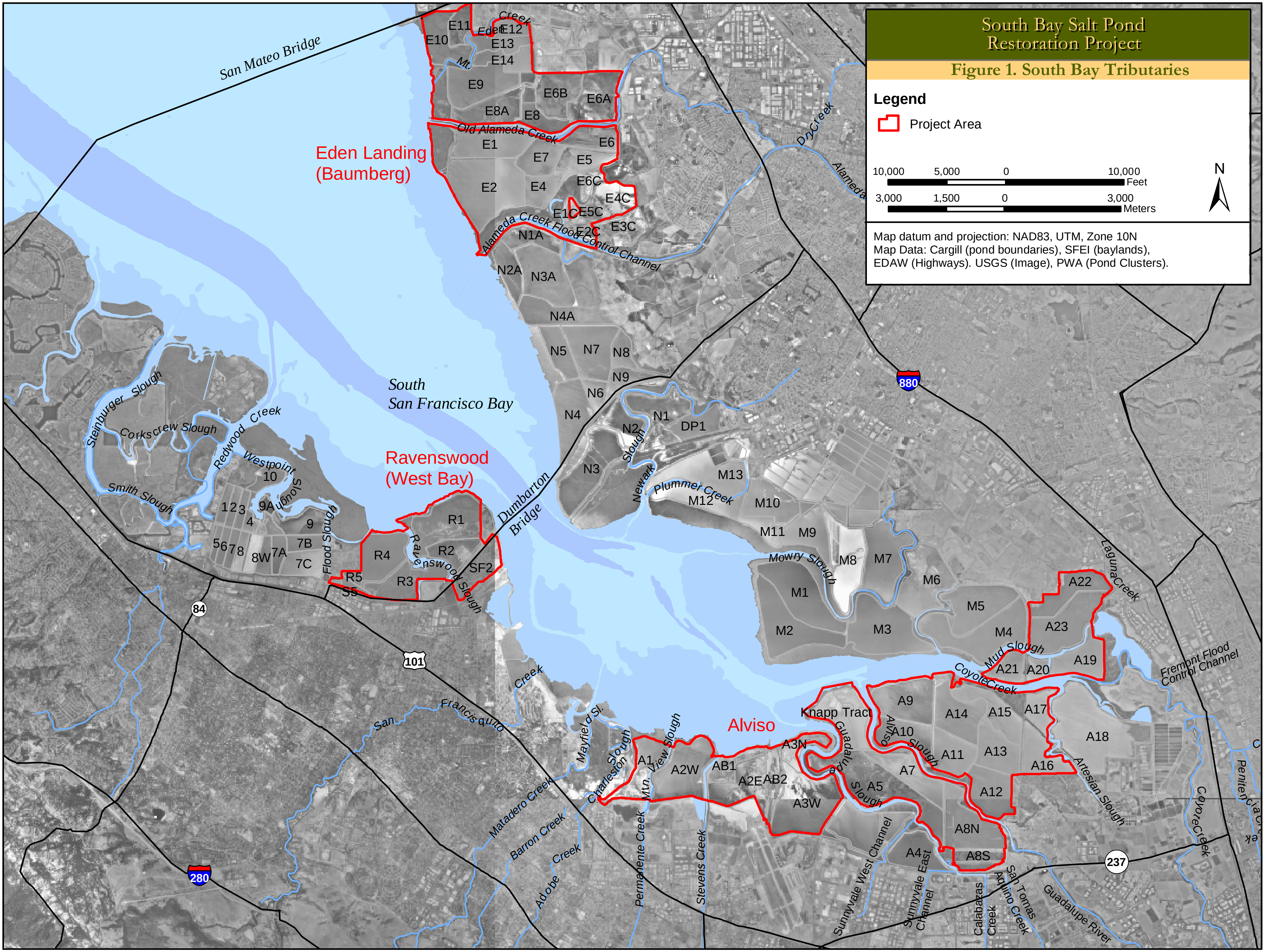
South Bay Salt Pond Restoration Project
Figure 1. South Bay Tributaries
Legend
Project Area
10,000 5,000 0 10,000 Feet
3,000 1,500 0 3,000 Meters
N
Map datum and projection: NAD83, UTM, Zone 10N
Map Data: Cargill (pond boundaries), SFEI (baylands), EDAW (Highways). USGS (Image), PWA (Pond Clusters).
Eden Landing (Baumberg)
Ravenswood (West Bay)
Alviso
South San Francisco Bay
San Mateo Bridge
Dumbarton Bridge
Old Alameda Creek
Alameda Creek Flood Control Channel
Dry Creek
Alameda
Steinburger Slough
Corkscrew Slough
Redwood Creek
Westpoint Slough
Smith Slough
Flood Slough
Ravenswood Slough
Newark Slough
Plummer Creek
Mowry Slough
Mud Slough
Coyote Creek
Laguna Creek
Fremont Flood Control Channel
Knapp Tract
Alviso Slough
Guadalupe Slough
Artesian Slough
Mayfield Sl.
Charleston Slough
Mtn. View Slough
San Francisquito Creek
Matadero Creek
Barron Creek
Adobe Creek
Permanente Creek
Stevens Creek
Sunnyvale West Channel
Sunnyvale East Channel
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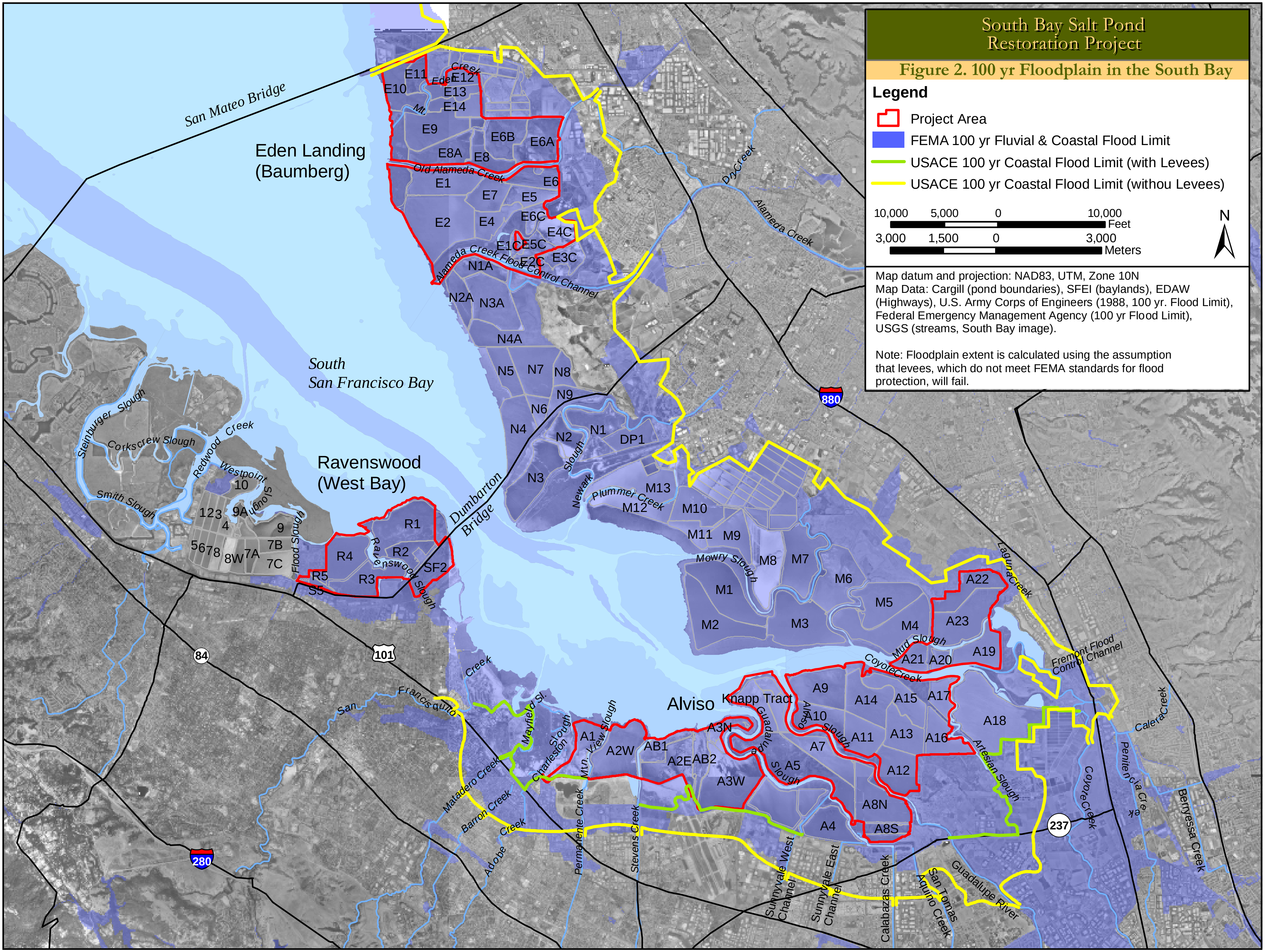
San Tomas Aquino Creek
Guadalupe River
Coyote Creek
Penitencia Creek
84
101
280
880
237
March 28, 2005



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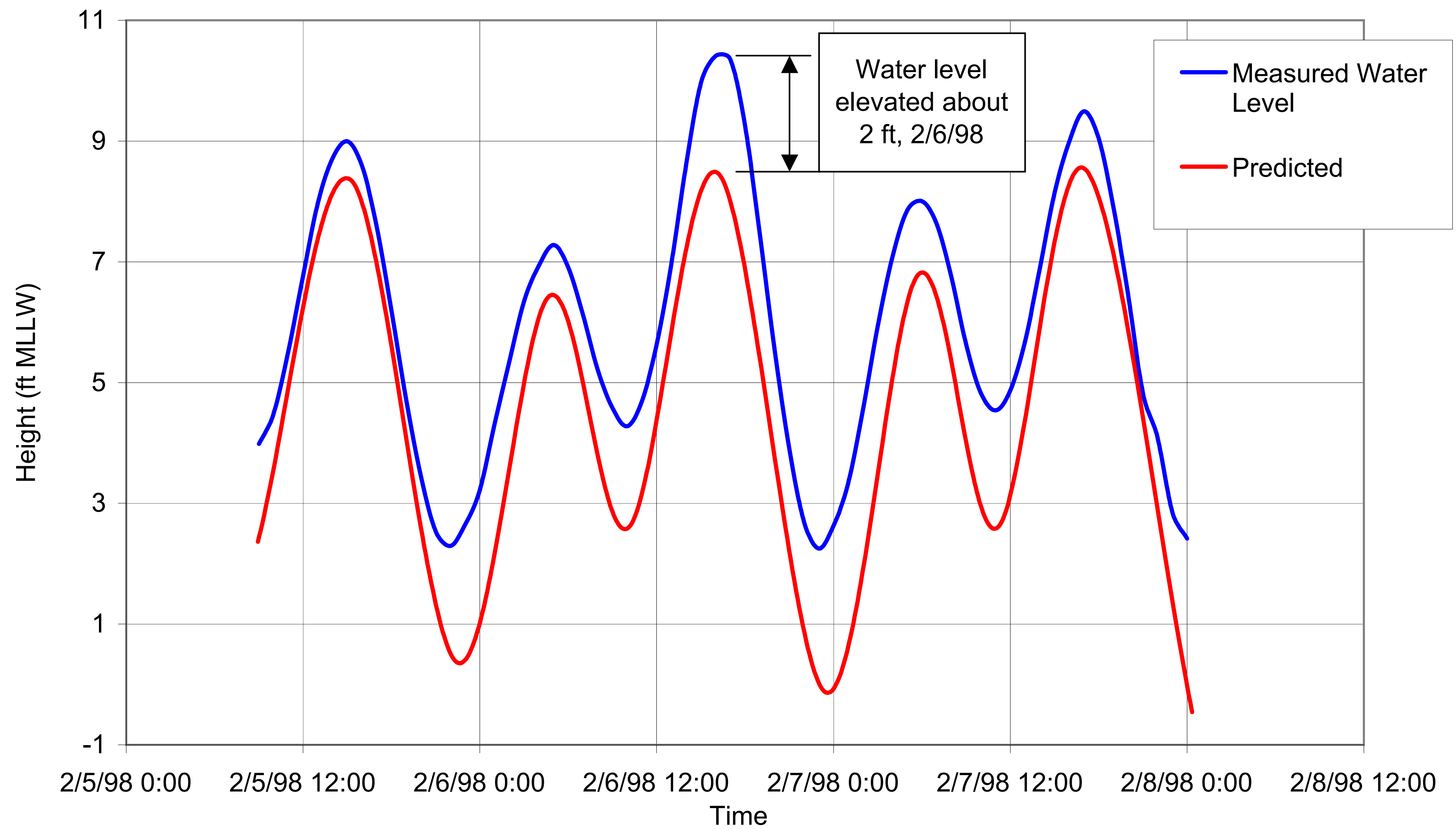


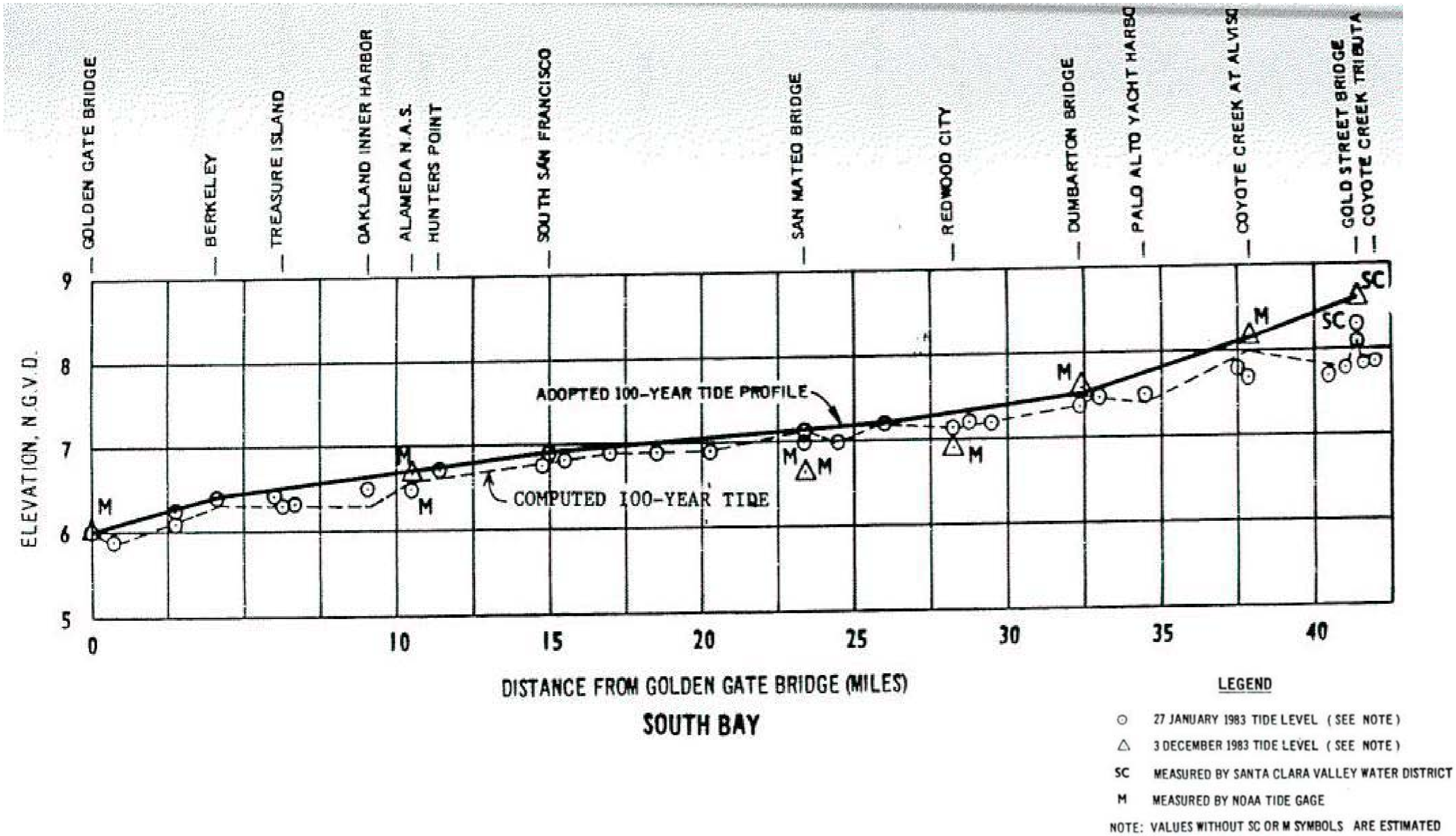
Source: CO-OPS Verified Hourly Height Water Level

figure 3

South Bay Salt Ponds Restoration Project

Predicted and Measured Tidal Elevations at Redwood City, CA

PWA REF 1750.04



Source: USACE (1984)

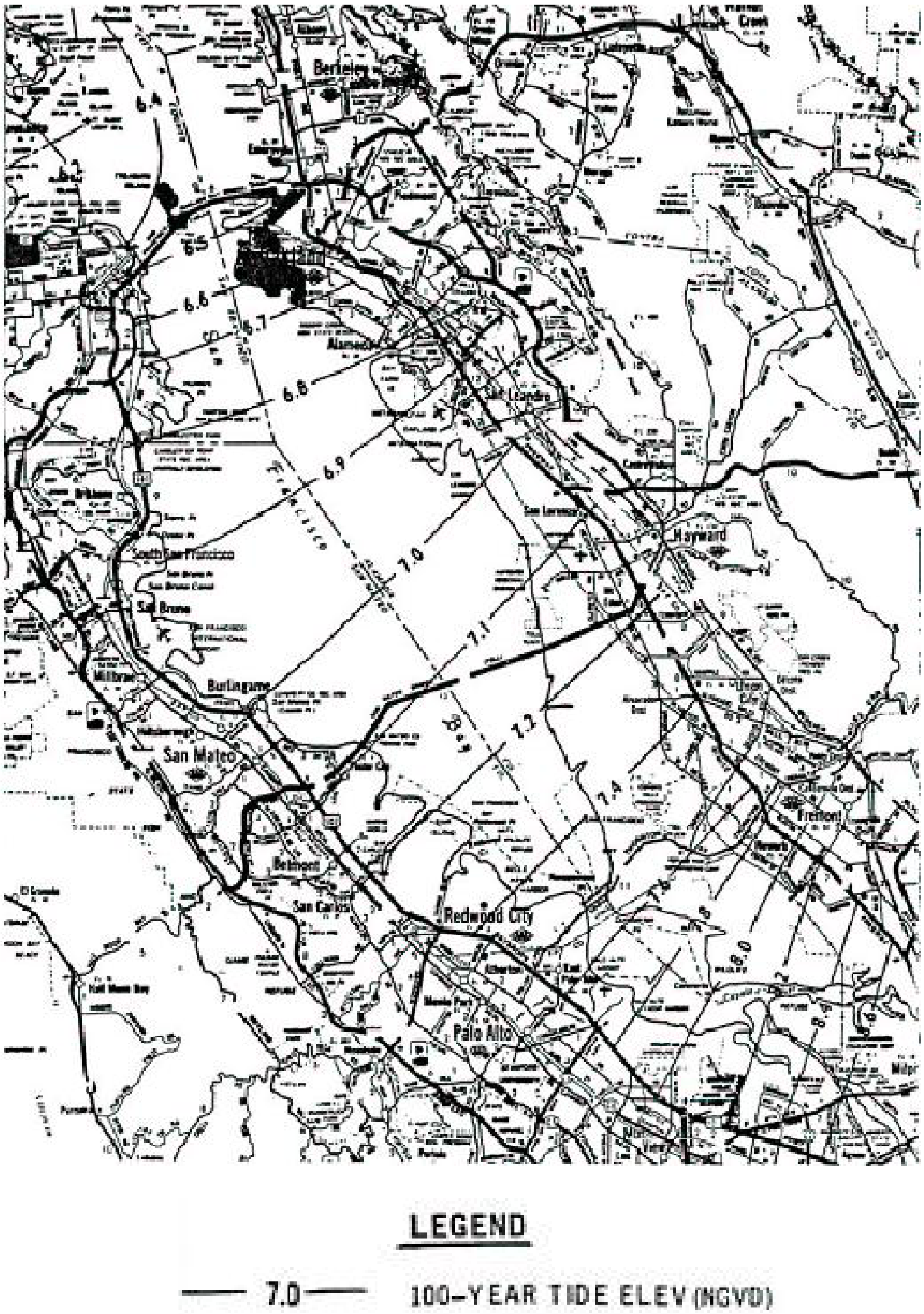
Figure 4

South Bay Salt Pond Restoration

100-Year South Bay Tidal Elevation Profile

PWA Ref# 1750.04

PWA



Source: Moffatt & Nichol (2004)

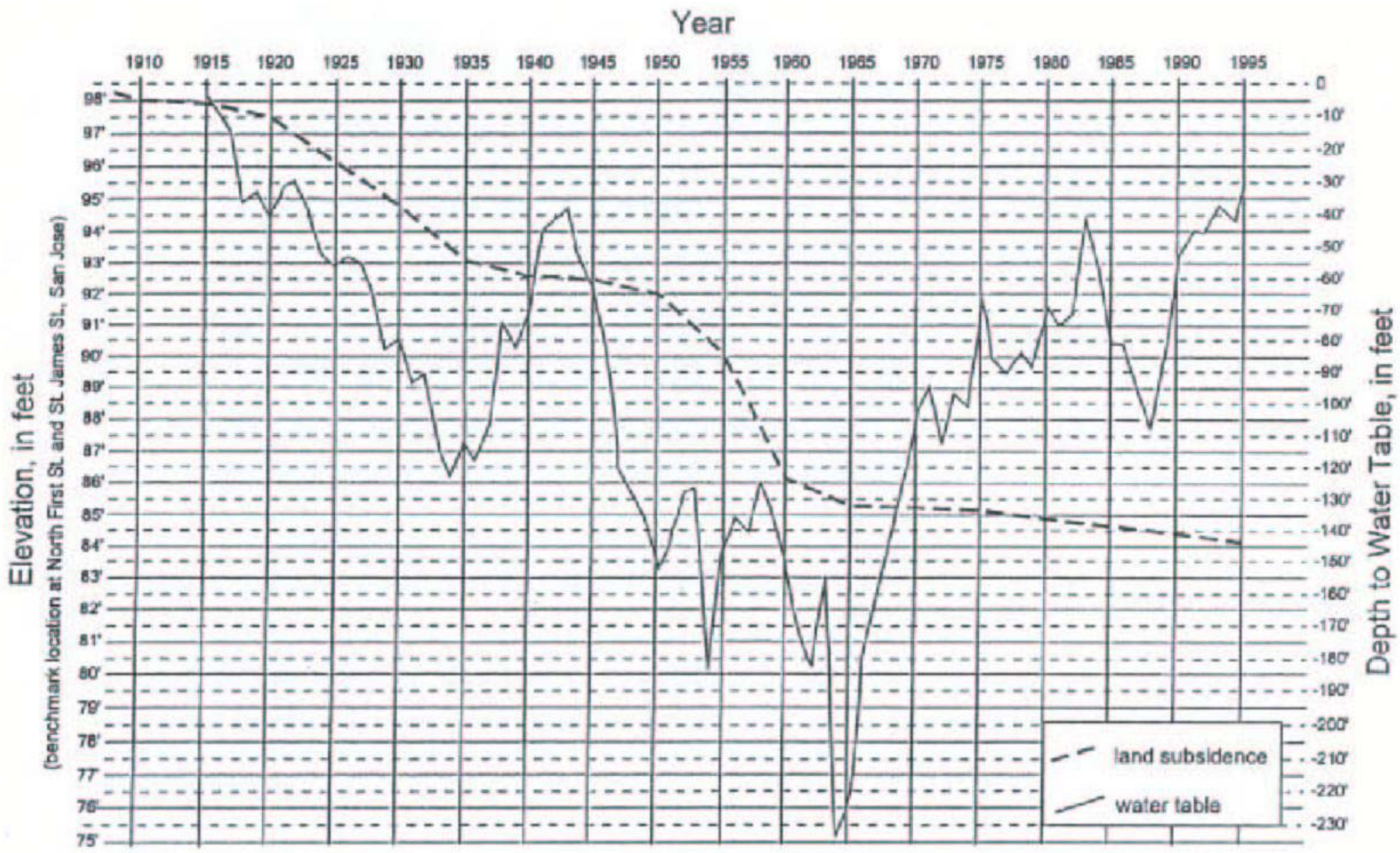
F i g u r e 5

South Bay Salt Pond Restoration

Plan View of 100-Year South Bay Tidal Elevations

PWA Ref# 1750.04

PWA



Source: Moffatt & Nichol (March 2004), SCVWD (2002)

Figure 6

South Bay Salt Pond Restoration Project

Long Term Subsidence Trends in San Jose, CA

PWA Ref# 1750.04

Source: PWA photo

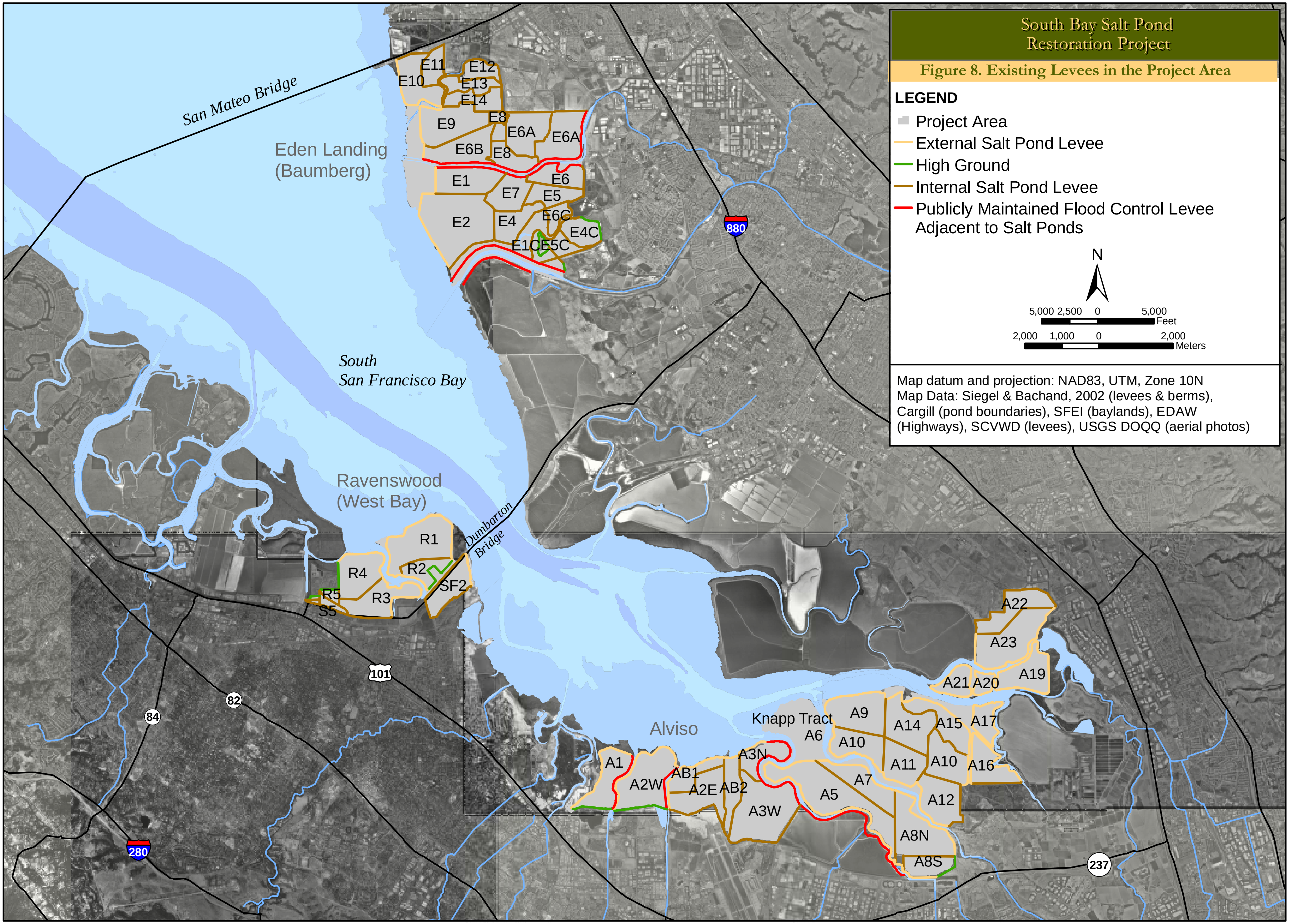
figure 7

South Bay Salt Pond Restoration Project

Reinforced Outboard Levee at Eden Landing

PWA Ref 1750.04

PWA



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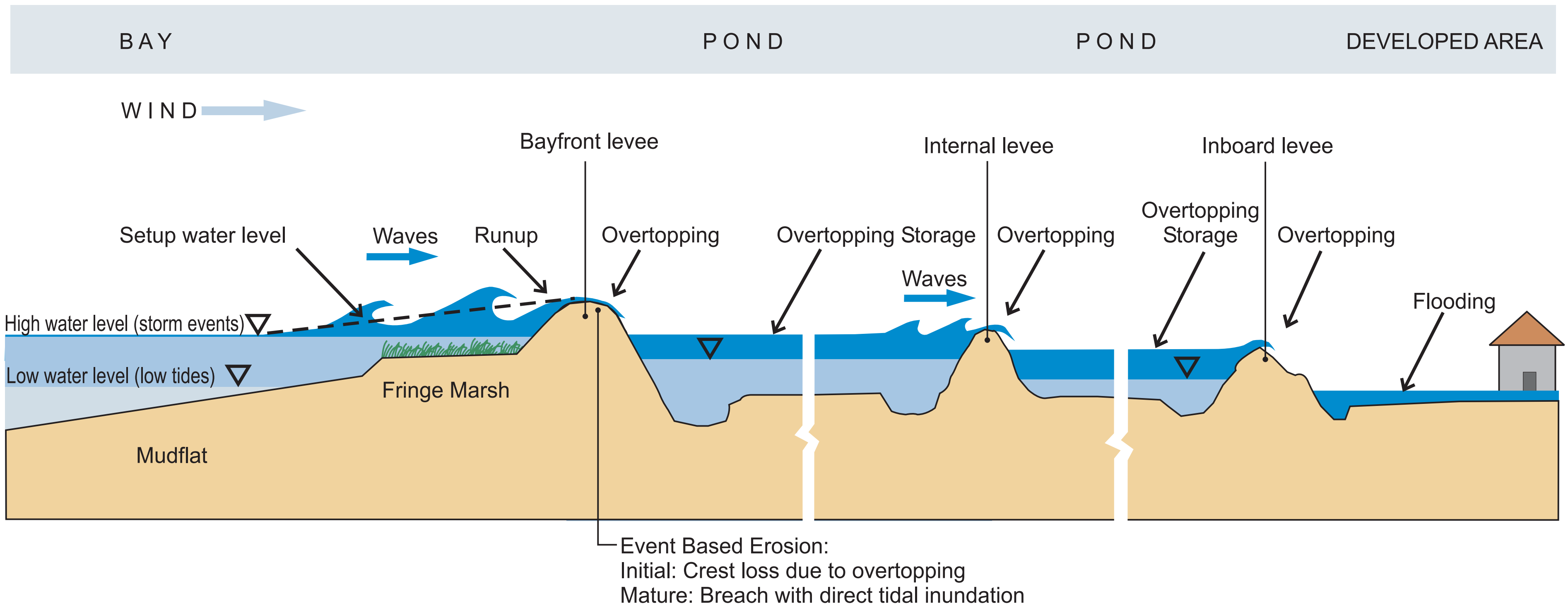

figure 9

South Bay Salt Pond Restoration Project

Conceptual Coastal Flooding
Existing Conditions

PWA

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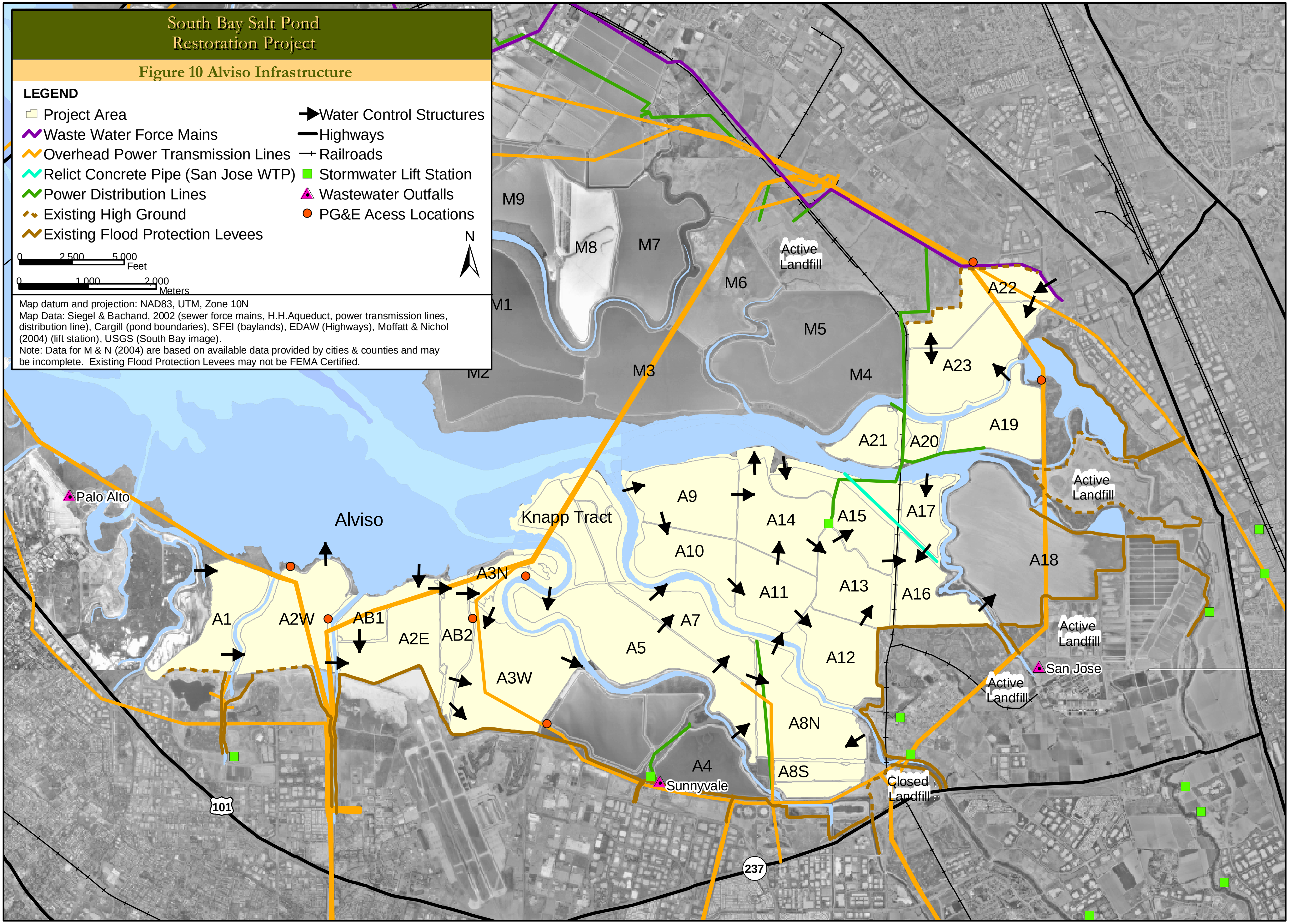

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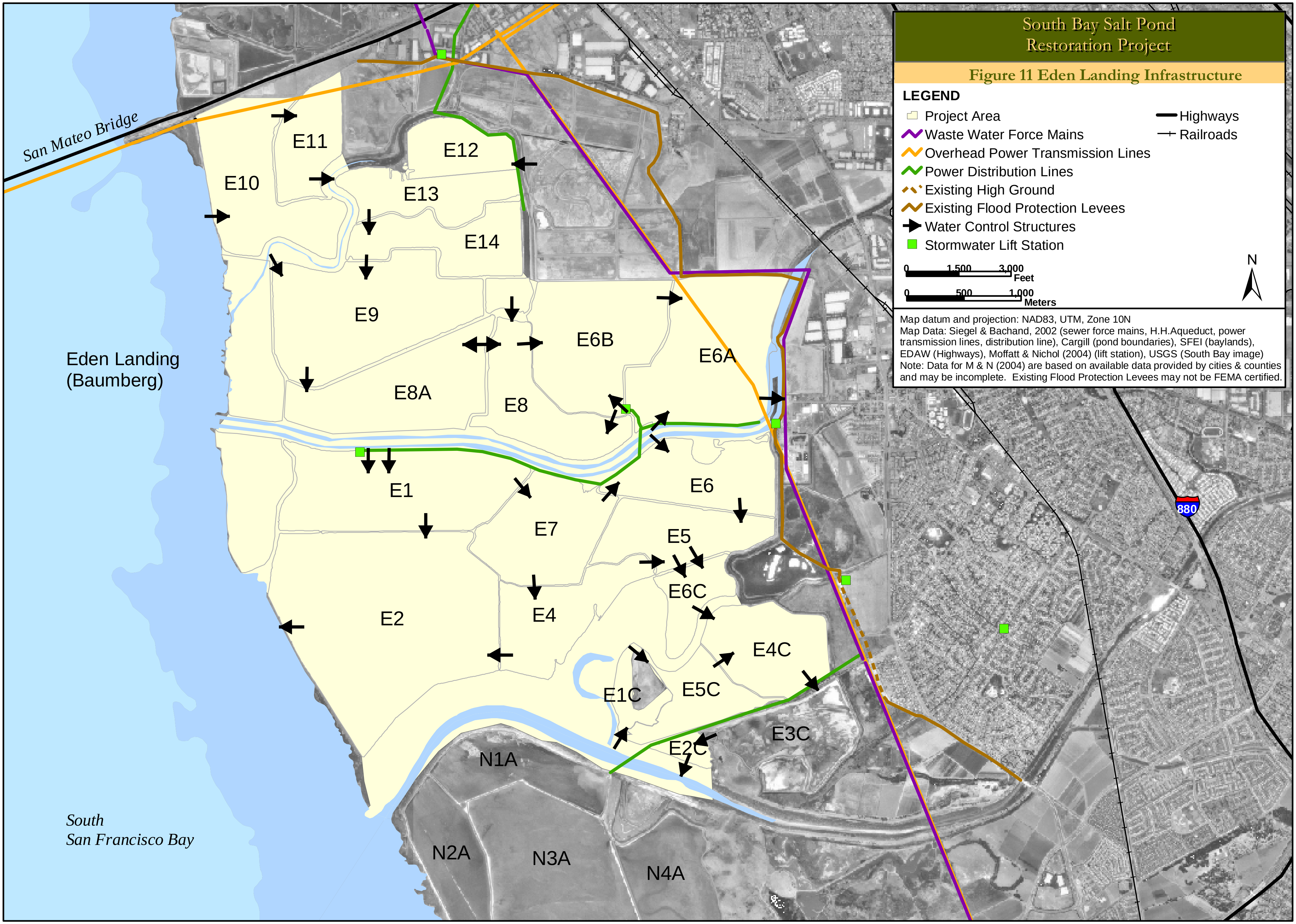

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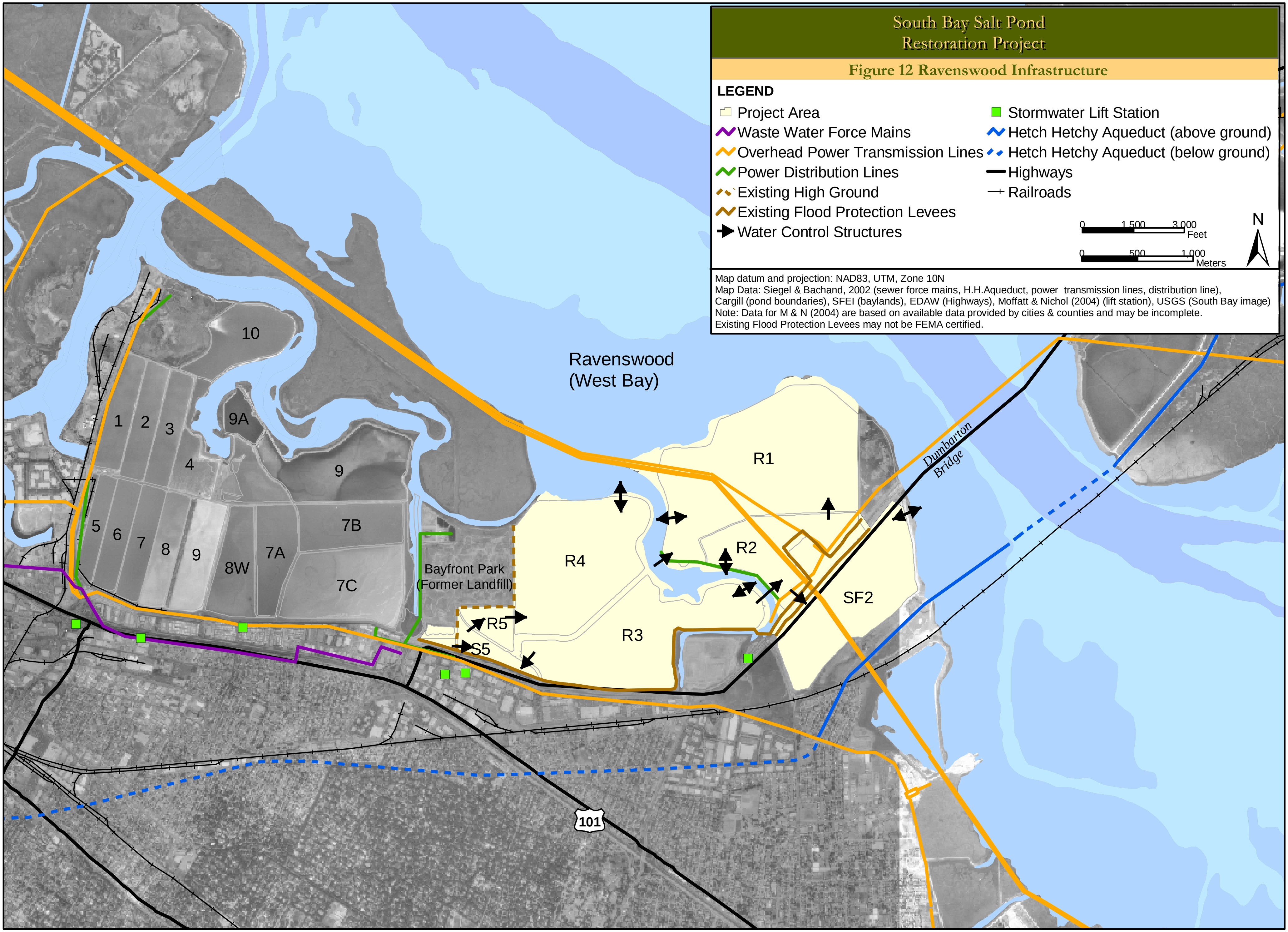

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